UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

ATAS XII

Advanced Technology Assessment System

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES

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FOREWORD

The Advanced Technology Assessment[1] (ATAS) has, in the past, analysed the implications of new developments in areas ranging from biotechnology, new materials, energy and information technology to new approaches to science and technology cooperation. In doing so, it has mainly followed a traditional approach to technology assessment (TA), which involves anticipating and evaluating the intended and unintended consequences of technological developments. In line with its objectives, ATAS has examined both the problems arising from technologies and the opportunities and constraints emerging for different societies in accessing, producing and using new technologies. TA is thus a tool to accompany or even guide technological change. ATAS has contributed to this process in particular by helping developing countries to build their own TA mechanisms. With the changing paradigms and practices of international technology cooperation, the focus of ATAS has shifted towards a more integrated and broader approach.

With this issue, ATAS returns to a topic it has dealt with before, namely environmentally sound technologies (ESTs), but with a particular purpose: understanding the role that publicly funded research and publicly owned technologies can play in the transfer and diffusion of ESTs worldwide, with particular attention to developing countries. In keeping with previous bulletins, ATAS XII is policy-oriented, i.e. it tries to be a decision-making tool in order to help policy makers and regulators.

The objectives of the study that led to ATAS XII were the examination of the legal regimes and policies governing publicly funded research on ESTs and the commercialization of their results, together with issues of ownership structure, as well as a review of policies related to the generation, use, transfer and diffusion of these technologies. The study had also to make suggestions for the improvement of the currently ineffective diffusion system.

ATAS XII is the result of a cooperative effort between the United Nations Conference on Trade and Development (UNCTAD), the Department of Economic and Social Affairs and the United Nations Environment Programme (UNEP). It draws on eleven case studies, and many experts were involved in both the studies and the review meeting. The publication benefited from the generous and greatly appreciated support of the Republic of Korea.

The concept of technology in this study includes knowledge embodied in machinery and equipment, and knowledge codified in patents and blueprints, as well as tacit knowledge, including the special routines, practices and know-how to manage production processes. “Diffusion” of technology refers to the wider utilization of technology, while “transfer” of technology refers to technology transmission to another party. International debate differentiated sometimes between “transfer” and “commercialization” of technology. Transfer was seen as a direct and preferential provision of technology, whereas

[1] ATAS was launched by the United Nations in 1984 with the purpose of “initiating arrangements for the early identification and assessment of new scientific and technological developments which may adversely affect the development process as well as those which may have specific and potential importance for that process and for strengthening the scientific and technological capacities of the developing countries”. Starting out as a pilot project, ATAS was transformed into a regular programme of the United Nations in 1989 by the United Nations General Assembly. In 1993, UNCTAD was designated as the secretariat for this programme.

“commercialization” involved sale orlicensing by the owner to the buyer. “Environmentally sound technologies” refers to “clean” technologies that are low in impact on the environment in terms of pollution and/or high in energy efficiency compared with other technologies currently in use. Publicly funded ESTs are understood as those that are generated from research and development (R&D) activities sponsored by the public sector.

The results of the study presented in ATAS XII indicate that even though many Governments have made public policy statements in support of the need to share ESTs with developing countries and countries with economies in transition, the extent and pace of ESTs transfer are still inadequate. New policy initiatives are required, while existing mechanisms need to be strengthened in order to accelerate the transfer of publicly funded ESTs to users in those countries. A number of recommendations have been made to that end in several parts of this publication.

Rubens Ricupero
Geneva, October 2000 Secretary-General of UNCTAD

PREFACE

By the 1990s, there was widespread recognition of the role that technological change could play in ensuring a sustainable development path for all nations. New and environmentally sound technologies (ESTs) were also seen as critical elements in the competitiveness of firms and by extension of countries in the global economy. Incentives on both the demand and supply sides appeared to augur well for the widespread adoption of ESTs.

Agenda 21, adopted at the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, devoted a whole chapter (chapter 34) to the “transfer of environmentally sound technologies, cooperation and capacity-building”. Hope was high that an accelerated transfer and diffusion of ESTs to the developing world would take place. There was reason for this optimism given widespread political articulation, if not willingness, to join forces in halting global environmental destruction while at the same time meeting the development aspirations of the developing countries. Thus, in his book *Earth in the Balance*, published in the year of the Rio Conference, then-Senator Al Gore called for a “strategic environmental initiative” in which technology cooperation would play a crucial role. Leading industrialists came together in the *World Business Council for Sustainable Development*. In the book *Changing Course,* published by the Council’s Chairman Stephan Schmidtheiny, examples were provided of the initiatives already under way in the private sector to transfer ESTs. Reflecting this optimistic spirit, the former United Nations Centre for Science and Technology for Development dedicated a previous issue of the *ATAS Bulletin* (ATAS Bulletin No. 7) to the topic of environmentally sound technology for sustainable development.

Yet, the momentum of "Rio" was quickly lost and hopes for an accelerated transfer and diffusion of ESTs remained largely unfulfilled despite the extensive acceptance that resource-efficient and cleaner technologies will benefit all. While the speed with which new technologies are being generated and the pace at which they are being diffused within and across national boundaries has accelerated in recent years, as the example of information technology shows, the same cannot be said for ESTs. Many factors account for the slow pace at which ESTs are being transferred to developing countries. In some cases intellectual property rights and the economic interests of large corporations have played a role, notably in the case of substitutes for CFCs.

The public sector has also failed in its responsibilities to transfer and diffuse ESTs to the developing world. As some studies show, much of the publicly funded research and development (R&D) never leaves the laboratory in which it is developed. Conscious of their obligation to ensure the public's access to knowledge produced with public funding and their zeal to commercialize publicly funded ESTs, most governments have equated transfer of technology with commercialization. Consequently, they consider that their mandate under Agenda 21 is fulfilled if the results of publicly funded R&D are transferred to private domestic firms whether or not such technology is subsequently commercialized and diffused. These firms, moreover, have neither the financial interest in upgrading and adapting ESTs for markets where demand and the ability to pay is low, nor have they the networks in developing countries through which to identify potential users prepared or able to undertake these upfront expenditures. Therefore, innovative incentive systems will need to be put in place to ensure that publicly funded R&D in ESTs reaches users. New funding mechanisms and bridging institutions will also be needed to identify potential users and to speed the transfer and diffusion of publicly funded research on ESTs to them.

Another issue concerns the benefits derived from the production of ESTs by publicly funded institutions. Current practice in the United States, for example, ensures that gains from research in public sector institutions and universities is shared between the institution, the researcher and a firm that brings a product or technology to the market. Public sector institutions must also protect the public's access to knowledge produced with public funding. One way to ensure this would be to have public institutions and international organizations share in the intellectual property rights resulting from publicly funded R&D. Another way would be to create new alliances or linkages between research institutes where the publicly funded R&D on ESTs was being carried out and R&D institutions in other countries where there may be local user-firms (three-way partnerships). There is thus considerable room for a new and more proactive role for Governments to play in developing new mechanisms for the transfer and diffusion of ESTs resulting from publicly funded R&D. The studies in this volume provide a wealth of insight and information that can contribute to this goal.

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The original project was carried out by a team led by Lynn K. Mytelka comprising Pedro Roffe, Taffere Tesfachew and Dieter Koenig, with the assistance of Jean Parry. The *ATAS Bulletin* was prepared by a team led by Helen Argalias comprising Mongi Hamdi, Dieter Koenig, Jean-Claude Mporamazina and Gerardo Gúnera-Lazzaroni as technical editor, with the assistance of Deborah Wolde-Berhan and Monica Conteh. The cover page was designed by Diego Oyarzún-Reyes. It was desktop-published by María Teresa Sánchez.

PART I

INTRODUCTION: ENVIRONMENTALLY SOUND TECHNOLOGIES AN OVERVIEW

INVIRONMENTALLY SOUND TECHNOLOGIES - AN OVERVIEW

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Environment and a prosperous economy do not have to be opposites. On the contrary, environment is a prerequisite for the sustainability of the economy. Therefore, innovation in the area of environmentally sound technologies (ESTs) plays a crucial role with regard to the development of societies. Many governments have realized this. As a result, publicly funded support for the development of EST has grown over the years along with a common understanding of the important role of ESTs in the innovation process. In searching for innovative strategies in the area of ESTs, UNCTAD has undertaken in 1997 a project to examine the potential role of different mechanisms and tools for facilitating the transfer and diffusion of publicly funded technologies, for example through public-private research consortia and other new forms of public-private partnerships in the area of technology. The objective was to identify efficient and cost-effective measures for accelerating the adoption of ESTs by firms world-wide.

In 1997-1998, UNCTAD, in cooperation with the Department of Economic and Social Affairs of the United Nations (DESA) and the United Nations Environment Programme (UNEP),[1] carried out a project on *"The role of publicly funded research and publicly owned technologies in the transfer and diffusion of environmentally sound technologies"*. The objective of this project was to take stock of the role, scope and relative importance of publicly funded research in the generation of ESTs, to review existing policies based on technology-related provisions under *Agenda 21*, including legal and institutional issues, and to suggest possible policy options and initiatives likely to accelerate the transfer and diffusion of ESTs.

The project was a direct response to recommendations of the Commission on Sustainable Development (CSD) at its fifth session, which had concluded that "the Government's control and influence over the technological knowledge produced in publicly funded research and development institutions open up a potential for the generation of publicly owned technologies that could be made accessible to developing countries, and could be an important means for Governments to catalyse private sector technology transfer."

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[1] Represented by the UNEP Industry and Environment Programme (UNEP-IE) and the UNEP International Environmental Technology Centre (UNEP-IETC).

Research carried out under the project included nine country case studies (Brazil, Canada, the Czech Republic, Germany, India, Japan, the Republic of Korea, the United Kingdom and the United States). Furthermore, two additional studies - on the United States and the MERCOSUR countries - focused on legal regimes and institutional issues dealing with the transfer and commercialization of ESTs. In an attempt to gain a better understanding of the role of supporting institutions and their partnerships with businesses in the generation of ESTs, a review of publicly funded research and development (R&D) in universities was also prepared, using as an example leading universities in the United States. This volume contains a selection of these studies along with additional material.

The empirical research under the case studies was guided by specific questions. To what extent do governments fund R&D on ESTs? Here we were looking for empirical data. What happened to the results of this research? Were they taken up by the private sector and successfully commercialized or were they transferred and diffused in different ways? And, if neither, what were the impediments? Our assumption was that public research could compensate or have a complementary role in sectors where "normal" private sector transfer and diffusion of ESTs had proved inadequate to meet the needs of developing countries.

The results of the case studies, as well as a synthesis report, were evaluated at a review meeting involving the three cooperating agencies, other international organizations (the Organization for Economic Cooperation and Development, and the European Union), selected experts, and several authors of case studies (Paris, 11-12 December 1997). A final review meeting took place in Kyongju, Republic of Korea (4-6 February 1998), with the participation of experts and representatives of several CSD Member States. The results of this meeting were presented to the sixth session of the CSD (April 1998). At that session, the CSD decided to recommend a number of measures and studies that could be undertaken by governments and international organizations in order to accelerate the transfer and diffusion of ESTs. Several of these explicitly called for further follow-up action by United Nations bodies and agencies, including UNCTAD.

When the project started, no systematic effort had been made to explore the potential that publicly funded technologies could offer in the area of ESTs. Thus, the potential of such technologies as an element in the transfer and diffusion of ESTs and the identification of appropriate mechanisms posed a number of questions, which required further analysis. First, it was not known to what extent publicly funded technology included ESTs likely to meet the specific ecological needs of countries, particularly developing countries. Second, it was not clear under what conditions such technologies could be successfully adopted. Third, there were no readily available mechanisms through which publicly funded technology could be transferred to developing countries. Furthermore, legal issues ranging from proprietary questions to those arising from the Agreement on Trade-Related Aspects of Intellectual Property Rights (the TRIPS Agreement) needed to be addressed.

A systematic effort to examine the role of publicly funded research and technologies owned by public institutions in the transfer and diffusion of ESTs required a thorough analysis of the economic, institutional and legal issues surrounding their effective use and transfer.

Thus, it was also necessary to study possible strategies for using the potential of publicly funded technologies effectively. New mechanisms needed to be considered to promote cooperation in the area of transfer and diffusion of ESTs. In this respect, the study also explored to what extent such new mechanisms could be mobilized in making publicly funded technologies available to firms and institutions in developing countries and economies in transition. Some new bilateral and multilateral programmes and pilot projects encourage cooperation between firms, particularly small and medium-sized enterprises (SMEs) from developed and developing countries, in the domain of ESTs. These efforts attempt to increase technology cooperation and partnerships through joint ventures, licensing, shared technology development and the creation of information clearing houses and "match making" services needed to make both suppliers and potential technology recipients aware of opportunities in the area of ESTs. Tripartite arrangements involving the collaboration by R&D institutes from developed countries with developing countries' R&D institutes and firms have also been proposed.

At the outset of the project, it was assumed that developing country awareness of the potential of partnerships and other arrangements would be an important factor in ensuring the appropriate diffusion and dissemination of ESTs adapted to their needs and requirements. Another important factor, so it was assumed, would be the identification of meso institutions able to function as interlocutors in a global process of informational exchange and technology capacity-building with regard to the availability, adaptability and use of ESTs in developing countries. However, while working on this study we found that it was also necessary to examine what was happening in the private sector at the same time and how the two domains could be better linked in accelerating the transfer and diffusion of ESTs. For this reason we added an additional study, written by Joerg Meyer-Stamer of the Institute for Peace and Development, University of Duisburg, Germany, complementing the material with both conceptual and practical insights.

I. MAIN ISSUES AND ACTORS IN THE FIELD OF PUBLICLY FUNDED TECHNOLOGIES

The overall objective of the studies was to *examine the potential of publicly funded technologies in the area of ESTs*, including economic, institutional and legal issues. To this end, a number of elements served as "terms of reference" for the work carried out by the team of staff from UNCTAD and cooperating agencies, as well as the consultants.

As a first step the authors examined, at the country level, the issues at stake with respect to publicly funded technologies, particularly ESTs, and their commercialization on the basis of case studies and aggregate data. Thus, within the context of the country case studies we carried out surveys of institutions, programmes and funds at the national level, dealing with publicly

funded ESTs and the approaches chosen. The objective was to determine to what extent publicly funded ESTs would be effectively "available" in terms of technology transfer and diffusion. On the basis of the practical experiences of these initiatives we examined the factors affecting the more widespread availability and use of ESTs developed with public funding, and possible ways of promoting those technologies.

With regard to specific legal issues, we aimed at identifying the stock of available ESTs falling into the following categories:

- ESTs in the public domain;
- ESTs which are subject to private decisions;
- ESTs whose transfer is not subject to private decisions.

Also, the authors undertook comparative surveys of the legal regime of a selected number of developed and developing countries (United States, MERCOSUR) governing ownership of R&D results from publicly funded research institutions. In this context we looked at arrangements relating to the protection and exploitation of R&D results, including the rights of inventors vis-à-vis publicly funded research institutions, the assignment of ownership, shared ownership arrangements, and the preferential rights of inventors regarding the use of patents that result from their research. We also looked at policies relating to the dissemination, use and commercialization of R&D results and including the legal mechanisms and instruments used in facilitating the transfer and diffusion of ESTs for the development of prototypes, and ownership and contractual issues relating thereto.

Finally, on the basis of the results and empirical evidence from the case studies, we have gone a step further and developed a set of ideas about how the transfer and diffusion of ESTs could be accelerated, particularly in countries not easily able to buy into the range of commercially available technologies.[2] It is hoped that these ideas will, in turn, stimulate the adoption of measures at the international level and bring new life to the sometimes frustratingly slow process of implementing the recommendations of chapter 34 of Agenda 21.

The background report provides illustrations of existing policies, structures and mechanisms that should be further examined with regard to their potential relevance in accelerating the transfer and diffusion of ESTs. One common trend in the transfer and commercialization of ESTs reflected by several case studies is in collaborative efforts sought through networks, partnerships, and alliances. Several countries refer to the importance of public-private partnership involving a broad range of actors, including universities and R&D institutions, government entities and private companies. While most such initiatives are designed for technology transfer and commercialization at the national level, a few have been developed for international cooperation that includes developing countries.

II. SESSION I

[2] For details see the concluding section.

RELEVANCE OF PUBLICLY FUNDED R&D IN THE GENERATION AND DIFFUSION OF ESTs

Four country case studies (the Republic of Korea, the Czech Republic, Germany and India) were presented as examples of the experience with publicly funded R&D in the area of ESTs. A special study covering the role of universities – as supporting institutions – was also presented.

The study of the Republic of Korea emphasized the importance of a broad concept of technology transfer involving the transfer of all knowledge and know-how required for using a technology. A significant number of R&D programmes are currently being carried out with public support in both the public and the private sectors, and some are relevant to ESTs. The research results are owned by the financing institutions, sometimes jointly with the investor. The research institutions are encouraged to transfer their results to the private sector. Loans are available to help the private sector improve its technology capabilities to respond to environmental regulations. It is difficult to differentiate between the treatment of ESTs and other technologies.

The study of the Czech Republic highlighted the changes that have taken place in the R&D system in recent years. Initially, the system was exclusively State-driven and all R&D was publicly funded. Thus R&D was often not demand-driven, but supply-driven. The recent radical changes have resulted in the introduction of new policies, laws and institutions. Many R&D programmes are now targeting specific products and applications. While ESTs are not distinctly identified as a special category for public R&D funding, it is expected that most new publicly funded technologies will be environmentally-friendly. Public support could involve a variety of measures, including the provision of subsidies and soft loans. Particular emphasis in the area of ESTs is on abatement technologies, cleaner production technologies and the recovery and conversion of former military installations for civilian use.

The study of Germany identified explicit government policy behind funding for EST-related R&D. Germany perceives ESTs as technologies that are crucial for maintaining competitiveness and entering new markets. Considerable public funding is provided for EST-related R&D. At the same time, public R&D funds are becoming more and more market-oriented. However, technology cooperation with developing countries in this area is also an explicit government goal and considerable funding is being provided for this purpose.

The Indian study showed that public funding is a major source of R&D activities in India. There is an extensive network of public R&D institutions. However, until the late 1980s there were few linkages between those institutions and the private sector. Since the early 1990s, the Government has been trying to promote such linkages. Very often they are still subject to ad hoc decisions rather than to clear mechanisms. At present there are no legal restrictions on cooperation with foreign partners, public or private. While there is no explicit policy to give priority to the funding of ESTs, and empirical analysis gave evidence that often R&D containing

EST-related element does receive some priority in terms of funding.

The special study on the role of universities focused on four universities in the United States in an illustrative fashion. The United States legal system provides for joint ownership of patents by researchers and their institutions. This was considered by policy makers as an incentive for the R&D community to actively pursue the commercialization of technologies. Only in the area of defence-related technology does the United States Government maintain some form of public ownership. Since the end of the cold war, attempts have been made to commercialize some of these technologies. Discussion of the Bayh-Dole Act affirmed the need for "significant manufacturing" in the United States as an impediment but not an insurmountable barrier to the transfer of ESTs since there are commercialization mechanisms for EST partnerships, joint ventures and cost-sharing with other countries.

The discussion following the above presentations centred on issues of technology transfer. Some of the existing models were described, such as the European Union's PHARE programmes for cooperation with economies in transition. The discussion also included references to possible finance mechanisms, such as the establishment of revolving funds for the transfer of technology. The creation of new institutions for the transfer and diffusion of ESTs was not welcomed by all participants as some felt that existing arrangements should be strengthened.

"Team building" and partnership were also mentioned as ways of accelerating the transfer and diffusion of ESTs. A need for pilot projects was expressed. The expert from France noted that a number of successful examples of transfer of ESTs from France had been undertaken and case studies were currently being prepared.

III. SESSION II
EXAMPLES OF TECHNOLOGY COOPERATION TO PROMOTE THE COMMERCIALIZATION AND DIFFUSION OF ESTs IN DEVELOPING COUNTRIES

Three presentations were made under this item on the following topics: the United Kingdom's Technology Partnership Initiative (TPI) and the Department for International Development (DFID); the United States' experience; and the lessons in technology transfer under the Montreal Protocol.

TPI is a governmental initiative aimed at enabling successful international partnership. Its mission is to link companies and organizations in industrializing and developing countries with United Kingdom companies and other organizations which provide both technologies and services, as well as the information and advice they need in order to deal with their environmental problems. To that end, TPI has developed a global network through which it provides information, free of charge, on nearly 1,000 United Kingdom suppliers for environmental goods and services. TPI also works with international organizations. A brief summary was also presented of relevant DFID contributions to technology transfer, including through bilateral programmes and research projects, funding of non-governmental organizations (NGOs) and

contributions to multilateral institutions.

The presentation of the United States case study noted there are 735 laboratories in the United States with about US$ 65 billion in annual-government supported R&D. In addition, about 3,000 universities have research programmes of varying size. The driving factor for the Government to fund research on ESTs was the need for American companies to comply with environmental regulations rather than to increase their competitiveness. It was noted that business in the United States of America is generally risk-adverse, especially with regard to investing in environmental protection. Environmental regulations were seen by companies as an impediment to business operations. Interaction between government and industry is important in the process of technology transfer and dissemination. The essential role of the government is to provide incentives to industry and to use appropriate economic instruments to encourage EST application and diffusion. Governments also should fund demonstration and pilot projects, particularly to encourage international technology transfer. A brief statement was also made describing the operations of the United States-Asia Environmental Partnership Initiative (US-AEP) as an example of an international partnership that promotes the transfer and diffusion of ESTs.

The presentation on the Montreal Protocol highlighted the fact that the damaging effects of ozone depleting-substances (ODS) have become a driving force for the development of technology. Most of the funds provided under the Protocol were spent through investment projects involving the transfer of ESTs. Globally agreed targets to phase out ODS have resulted in technology cooperation partnership between developed and developing countries based on equality rather than dependence, and that has created a sense of commitment among the partners. It was noted that the provision of unbiased information through a clearing-house has accelerated the changeover process. One issue that still needs to be addressed is the phase-out of chloroflurocarbon (CFC) production in developing countries. Some of the participants felt that the process established under the Montreal Protocol followed a donor-driven agenda; however, there was general acceptance among the participants that the Montreal Protocol was one of the most successful environmental agreements.

In summing up the discussion, the Chairman highlighted the following points:

- There is no clear and commonly accepted definition of ESTs.
- There are no rules or guidelines for promotion of the transfer and diffusion of the results of publicly sponsored research.
- There are a large number of bilateral and multilateral technology cooperation initiatives for the promotion of ESTs involving partners from developed and developing countries. Some of these are supply-driven; others are more in the form of partnerships.
- There is considerable room for accelerating the transfer and diffusion of publicly sponsored ESTs through the elimination of all kinds of policy and institutional barriers.
- Special attention must be given to the needs and conditions of SMEs.
- Publicly sponsored ESTs should be included in framework agreements for technical cooperation between developed and developing countries.

- R&D institutions in developing countries need to be supported and partnerships with their counterparts in developed countries need to be encouraged.
- Measures for the compensation of R&D expenditures should be considered as an incentive

for encouraging the commercialization of technology.
- The possibility of establishing revolving funds should be explored.
- Technology demonstrations should be supported as a useful means of promoting technology dissemination and proven viability.
- Possible legal impediments to the transfer and diffusion of ESTs in terms of existing laws governing the commercialization of publicly funded technologies were mentioned. However, opinions on the validity of assumptions about such impediments were divided.

IV. SESSION III
POLICIES AND INSTITUTIONAL FRAMEWORK TO FACILITATE THE WIDER DIFFUSION OF PUBLICLY FUNDED ESTs.

The following presentations were made under this item: issues related to the role that governments might play in facilitating the transfer and diffusion of publicly funded R&D on ESTs; a summary of the findings of the MERCOSUR case study; and examples of technology cooperation and partnership: Environment Canada.

The first presentation highlighted the fact that despite the progress that has been made since the Rio Conference to promote the transfer of ESTs to developing countries in accordance with paragraph 34.18 of chapter 34 of Agenda 21, little attention has been paid to promoting the transfer of ESTs resulting from publicly funded research. In view of the considerable amount of public R&D on the development of ESTs, new avenues have to be explored to accelerate the transfer of publicly funded ESTs to developing countries. The presentation also pointed out that the question of transferring publicly funded technologies should be regarded not only as a North-South issue, but also as an issue relevant to all countries engaging in public R&D support for ESTs development. It raised a number of questions. Have governments introduced any new policy measures to implement the commitment of transferring publicly funded ESTs? Are the policy objectives of public R&D funding, for example, to support domestic industrial competitiveness, compatible with the commitment to transfer publicly funded ESTs? Are there any legal or institutional restrictions on, and obstacles to, the transfer of publicly funded ESTs? Are there new kinds of incentives that could be introduced to stimulate governments to transfer publicly funded ESTs (for example, reflecting the R&D costs for publicly funded ESTs that are transferred, in official development assistance (ODA) statistics, or establishing multilateral mechanisms through which governments could pool, exchange and share publicly funded ESTs)?

The findings of the MERCOSUR study show that the appropriation of the results of publicly funded R&D activities is not subject to any specific legal regime. Indeed, since the liberalization reforms in 1980s, there has been a major shift in the commercialization and transfer of technologies in the MERCOSUR member countries. There are no legal and institutional restrictions on the transfer of technologies resulting from publicly funded R&D institutions which are generating revenues through the commercialization of technologies in collaboration with industry. The present legal and institutional framework, therefore, does not pose difficulties for the transfer of ESTs.

The Environment Canada presentation focused on the advancement of ESTs, nationally and internationally. The topics covered included overall policy framework, Cooperation among federal departments, bridging the gap between knowledge and results, technology partnerships, technology R&D, demonstration and evaluation, as well as programmes on outreach, information products and services. Particular attention is paid to technological capacity building. Environment Canada also supports the transfer of technology to developing countries through its contributions to multilateral funds, as well as through the International Environmental Management Initiative and bilateral and multilateral memoranda of understanding (MOUs) which strengthen environmental cooperation.

The deliberations that followed these presentations highlighted the need for closer examination of the role that technical cooperation and ODA can play in facilitating the transfer of ESTs. Several experts noted the need to develop the capacity to assess and select appropriate ESTs and maintain developing countries' technological capacity. Thus, it was felt that one way in which ODA can assist in the effective transfer of ESTs is by enabling countries to develop technology assessment and auditing capability. In some cases, the adjustments required to make enterprises environmentally sound or to enable them to adapt ESTs are minor. Environmental auditing services for companies could help in this respect.

It was stressed that there are many ESTs in the public domain that remain under used or unutilised. To make these technologies easily accessible to developing countries, a number of measures may have to be taken. First, for example, information on available ESTs could be systematically compiled and made available. This could be done by networking existing databases. Second, incentive measures could be introduced to encourage suppliers to make the technologies available to users, to assess user needs and to stimulate the adaptation of ESTs by users.

V. MAIN FINDINGS AND SUGGESTIONS FOR NEW POLICY INITIATIVES

Many governments explicitly refer in their public policy statements to the need to share ESTs with the developing world. It appears, however, that the extent to which ESTs are being transferred to developing countries and countries with economies in transition, and the pace at which that is occurring, are inadequate. Therefore, new policy initiatives may be required and support structures may need to be strengthened in order to accelerate the transfer of publicly funded ESTs to users in these countries. It is suggested that the CSD include this issue in its future work on technology transfer.

There is considerable room for governments to play a role in supporting and promoting new transfer and diffusion mechanisms for ESTs that are the result of publicly funded R&D. These mechanisms could collectively constitute a framework within which the necessary identification, assessment, adaptation and post-transfer follow-up can take place. This would ensure that transfer of ESTs is effective by building technological capacity in both local firms and research and technology institutions and promoting the interactivity between these actors that is needed in order to stimulate and sustain a process of innovation.

More specifically, the experts suggested the following for further considerations:

A. Policies for the generation of publicly funded R&D on ESTs

1. Strengthen linkages between the generators of ESTs, for example the R&D institutions, and downstream players, such as industry and other users (e.g. establish eco-funds as a possible mechanism for joint funding arrangements and EST exchanges through conferences and seminars where both generators and users of EST, can meet and learn).
2. Support the development of a sustainable development business "culture" through, for example, national cleaner production centres and centres for innovation and enterprise development, or their equivalents.
3. Develop national environmental policy frameworks for the stimulation and application of ESTs, including the establishment of an appropriate legal framework, regulatory policies, environmental goals, user analyses, focused and targeted R&D activities/priorities, incentives and rewards, and government procurement policies.
4. Promote innovations in all types of ESTs, including non-proprietary technologies, and strengthen design capacities in developing countries through reward systems such as utility models (petit patents).
5. Develop joint R&D activities in order to strengthen capacity-building and training.
6. Encourage the sharing of the results of collaborative R&D activities, including joint patenting.

B. Policies for the transfer and diffusion of ESTs

7. Create incentives for the transfer and diffusion of ESTs to developing countries, including tax incentives, tariff reductions for EST related imports, and intellectual property protection in exchange for technology transfer.
8. Provide support to business, including feasibility studies on market opportunities and commercial viability of ESTs, fiscal incentives such as lower taxes or tax holidays; export promotion programmes such as trade missions targeted towards ESTs, and support in developing business plans.
9. Reduce risks to the environmental industry through various types of financing, such as grants, venture capital investments underwritten by governments and loan guarantee schemes.

10. Formulate appropriate EST transfer arrangements, including equity and non-equity arrangements. Additional studies are needed.
11. Encourage pilot and demonstration projects in the area of ESTs.
12. Develop innovative mechanisms for the sharing and exchange of EST, such as bilateral

and multilateral MOUs, EST pooling/banks and other initiatives. These require further study.

13. Promote the transfer of uncommercialized publicly funded R&D results to enhance capacity-building in developing countries, as well as the use of these results.
14. Consider the incorporation of publicly funded ESTs into technology transfer and funding arrangements under multilateral environmental agreements (MEAs).
15. Include in public funding mechanisms for ESTs a financial provision for diffusion activities.
16. Strengthen partnerships between development cooperation agencies and public R&D institutions and technology transfer facilities.

C. Cross-cutting policies

17. Build and strengthen interfaces between existing information networks to facilitate access to information on ESTs by developing countries.
18. Encourage technology needs assessments to identify demands for ESTs as a market demand search approach.
19. Develop and inventory best practices in commercializing and diffusing publicly funded ESTs.
20. Governments are encouraged to review their policies, including legal and institutional policies, with a view to eliminating impediments to the transfer of publicly funded ESTs to developing countries, and to take appropriate steps in that direction.

ANNEX

THE ROLE OF PUBLICLY FUNDED R&D

Selected documents:

Historical Trends in Protection of Technology in Developed Countries and Their Relevance for Developing Countries. Study prepared by Dr. Alberto Bercovitz-Rodriguez at the request of the UNCTAD secretariat. Geneva, 1990.

The Implementation of Laws and Regulations on Transfer of Technology: The Experience of The Republic of Korea. Geneva, 1990.

The Role of R&D Institutes in Contributing to Technological Innovation: A Synthesis Report. Report by the UNCTAD secretariat. Geneva, 1990.

The Use of Patents for the Protection of Technological Innovation: A Case Study of Selected Swedish Firms. UNCTAD, Geneva, 1990.

The Implementation of Laws and Regulations on Transfer of Technology: The Experience of Brazil. Study prepared by Arthur Cardozo at the request of the UNCTAD secretariat. Geneva, 1990.

Technology Indicators and Developing Countries. Study by the UNCTAD secretariat. Geneva, 1991.

Utilization and Commercialization of UN System-funded R&D Results: Case Study of India. Report by the UNCTAD secretariat in cooperation with Rajiv Kumar. Geneva, 1991.

From Technological Competence-building to Competitiveness: Challenges for Publicly funded R&D in India: A Case Study of the National Chemical Laboratory, Pune. Report by the UNCTAD secretariat, Geneva, 1993.

R&D Collaboration Agreements among Enterprises: A Legal and Contractual Analysis. Report by the UNCTAD secretariat, Geneva, 1993.

Report of the Workshop on the Transfer and Development of Environmentally Sound Technologies (ESTs). UNCTAD and the Government of Norway. United Nations publication, Sales No. E.94.II.D.1, Geneva, and Oslo, 1993.

Universidad y Empresa en un Nuevo Escenario Competitivo. Report by the UNCTAD secretariat, Geneva, 1994.

La Vinculación Universidad-Empresa en la Bibliografia Latinoamericana. Report by the UNCTAD secretariat, Geneva, 1994.
Veena Jha and Ana-Paola Teixeira. “Are environmentally sound technologies the emperor’s new clothes?” UNCTAD Discussion Paper No. 89, Geneva, 1994

Final Report of the Ad Hoc Working Group on the Interrelationship between Investment and *Technology Transfer to the Trade and Development Board. UNCTAD, Geneva, 1994.*

Do Environmental Imperatives present Novel Problems and Opportunities for the International Transfer of Technology. Roman Study, by Andrew Barnett in collaboration with the UNCTAD secretariat. United Nations publication, Sales No. E.95.II.D.11, New York and Geneva, 1995.

Strengthening of Linkages between the National Research and Development Systems and Industrial Sectors. Report by the UNCTAD secretariat to the second session of the Commission on Science and Technology for Development, Geneva, 2 March 1995.

Scientific and Technological Aspects of the Conversion of Military Capacities for Civilian Use and Sustainable Development. Report by the UNCTAD secretariat to the second session of the Commission on Science and Technology for Development, Geneva, 3 March 1995.

Technological Capacity-building and Technology Partnership: Field Findings, Country Experiences and Programmes. Papers prepared for the Workshop on Selected Cooperation Aspects for Technological Capacity-building in Developing Countries, held in Geneva on 10 and 11 April 1995, with the sponsorship of the Technology Partnership Initiative (TPI), the Department of Trade and Industry (DTI) and the Overseas Development Administration (ODA), United Kingdom, and the Division for Science and Technology, UNCTAD. United Nations publication, Sales No. 95.II.D.6.

Report of the Workshop on Selected Cooperation Aspects for Technological Capacity-Building in Developing Countries. Geneva, 10-11 April 1995. Sponsored by the Technology Partnership Initiative (TPI), the Department of Trade and Industry (DTI) and the Overseas Development Administration (ODA), United Kingdom, and the Division for Science and Technology, UNCTAD.

Exchanging Experiences of Technology Partnership: The Helsinki Meeting of Experts. Papers prepared for the Meeting of Experts on Technology Partnership for Capacity-building and Competitiveness. Helsinki, Finland, 10-12 April 1996. United Nations publication, Sales No. E.96.II.D.8.

Fostering Technological Dynamism: Evolution of Thought on Technological Development Process and Competitiveness. A Literature Review. UNCTAD, New York and Geneva, 1996.

The TRIPS Agreement and Developing Countries. Geneva 1996, United Nations publication, Sales No. E.96.II.D.10.

Promoting the Transfer and Use of Environmentally Sound technology: A Review of Policies. United Nations publication, Sales No. E.96.II.D.4, New York and Geneva, 1997.

Scientific and Technological Aspects of Sustainable Energy Systems. Note by the UNCTAD secretariat to the third session of the Commission on Science and Technology for Development, May 1997.

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES

SYNTHESIS REPORT

Background document for the International Expert Meeting on the Role of Publicly Funded Research and Publicly Owned Technologies in the Transfer and Diffusion of Environmentally Sound Technologies, Kyongju, Republic of Korea, 4-6 February 1999

Prepared by the UNCTAD Secretariat in co-operation with the United Nations Environment Programme (UNEP) and the Division for Sustainable Development, Department for Economic and Social Affairs (DESA) of the United Nations

I. INTRODUCTION

A. Background

The objective of this study, prepared with the generous support of the Republic of Korea, is to take stock of the role, scope and relative importance of publicly funded research and development (R&D) in the generation of environmentally sound technologies (ESTs). In this context, the study explores the feasibility of implementing relevant provisions under Agenda 21, reviews existing policies, including legal and institutional issues, and suggests possible policy options and initiatives. Its findings were discussed at the International Expert Meeting on the Role of Publicly Funded Research and Publicly Owned Technologies in the Transfer and Diffusion of Environmentally Sound Technologies, organized by the Government of the Republic of Korea, and held in Kyongju from 4 to 6 February 1998. The results of this meeting were made available to the sixth session of the Commission on Sustainable Development (CSD), held in New York in April 1998.

The study was a cooperative effort of the United Nations Conference on Trade and Development (UNCTAD), the Department of Economic and Social Affairs of the United Nations (DESA) and the United Nations Environment Programme (UNEP). It was prepared pursuant to recommendations of the Commission on Sustainable Development, at its fifth session, which concluded that:

"A proportion of technology is held or owned by Governments and public institutions or results from publicly funded research and development activities. The Government's control and influence over the technological knowledge produced in publicly funded research and development institutions open up a potential for the generation of publicly owned technologies that could be made accessible to developing countries, and could be an important means for Governments to catalyze private sector technology transfer. Proposals for the further study of the options with respect to those technologies and publicly funded research and development activities are to be welcomed".[1]

The application of new, resource-efficient and clean technologies holds a key to environmental sustainability at both national and global levels. In this context, the adoption of ESTs is essential for countries in order to maintain a balance between the objectives of development and those of the environment. Facilitating the use of ESTs in all countries calls for a combination of measures involving a broad coalition of institutions from the public and private sectors. Technology transfer to developing countries has traditionally been a complex and critical issue, which has not been resolved satisfactorily at the international level. However, with regard to ESTs, the stakes are higher compared with other areas, given the urgent nature of global environmental degradation and the degree of international commitments reflected in the discussions and agreements at the United Nations Conference on Environment and Development (UNCED) in 1992 and at the "Rio+5" meeting, held in New York in June 1997.

All major international agreements addressing global environmental problems, ranging from the Convention on Biological Diversity to the United Nations Framework Convention on Climate Change, and particularly the Montreal Protocol and its amendments, contain specific provisions regarding legislative, administrative or policy measures for access to and transfer of technology.[2] This is in line with the international recognition of "global commons", "intergenerational equity"[3] and the fact that economic development and environmental degradation are closely linked.

According to the World Resources Institute, technological transformation is a primary strategy for avoiding further environmental degradation. It is argued that "widespread, continuing development and adoption of ever less polluting and more resource-efficient products and services"[4] would be able to contribute to the expansion of wealth and productivity, and at the same time hold a key to environmental sustainability.

In several industrialized countries the development and diffusion of environmentally sound technologies has clearly contributed to innovation and the strengthening of economic competitiveness.[5] Governments that have recognized the dual purpose and importance of ESTs have put considerable public resources and finances into R&D activities that may result in the development of such technologies. Nevertheless, the expectations raised at Rio for a rapid

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[1] Paragraph 91, "Programme for the further implementation of Agenda 21", adopted by the General Assembly at its 19th special session, 23-27 June 1997.

[2] See chapter III for details.

[3] For a detailed discussion of these fundamental questions, see Edith Brown Weiss, In Fairness to Future Generations: International Law, Common Patrimony and Intergenerational Equity, New York, Transnational Publishers, 1988; and *Environmental Change and International Law*, Tokyo ,United Nations University Press, 1992.

[4] George Heaton, Robert Repetto and Rodney Sobin, *Transforming Technology: An Agenda for Environmentally Sound Technology in the 21st Century*, Washington, D.C. World Resources Institute, 1991, p. ix.

[5] Moreover, these technologies have often stimulated other technological areas. See, for example, the analysis of the economic, ecological and legal implications of over 1,400 publicly funded ESTs in Germany: BMBF, *Wirkungen der Förderung von Umwelttechnologie durch das BMBF*, Frauenhofer-Institut für Systemtechnik und Innovationsforschung, Karlsruhe, January 1997. See also the discussion of the economic potential of ESTs in E. U. von Weizsäcker et al., Faktor Vier, Münich, Droemer Knaur, 1996.

diffusion of ESTs to all parts of the world, including developing countries and countries in transition,[6] have not been fully realized.

Within the United Nations, the discussion on the use of publicly funded R&D and publicly owned technologies for environmental protection measures in recent years sometimes focused on the conversion of military R&D to civilian use. Thus, a report by the Secretary-General of the United Nations proposed, inter alia, that the technological capabilities of military establishments including their R&D endeavors, laboratories, equipment and expertise, be utilized for measures designed to protect the environment. Particular attention was paid to the reallocation of skills and capabilities with regard to "dual-use technologies" from military to environmental tasks in areas such as environmental monitoring, chemical analysis, cartography, medicine, microbiology and radiology.[7] The broad spectrum of the technological capacities mentioned in the area of defense-related R&D in that report provides some indication of the potential range of publicly funded technologies in other areas. However, so far, no systematic effort has been made to explore the potential that publicly funded R&D could offer in the generation, diffusion and transfer of ESTs.

The identification of appropriate mechanisms for the transfer of ESTs raises a number of issues. First, it is not known to what extent publicly funded R&D leads to the generation of ESTs and whether such technologies meet the specific ecological needs of all countries, particularly developing countries. Second, it is not clear under what conditions such technologies could be successfully transferred to third parties. Third, there are no readily available mechanisms through which publicly funded technology could be transferred to developing countries. These issues will be addressed below.

B. Methodology

This study draws on a number of case studies as well as a preparatory review meeting involving the three cooperating agencies and a selected number of experts. Country case studies included studies on Brazil, Canada, the Czech Republic, Germany, India, Japan, the Republic of Korea, the United Kingdom and the United States. This selection represents countries with developed and developing economies, as well as one country with an economy in transition, which are important producers and consumers of ESTs. Furthermore, two additional studies -- on the United States and the MERCOSUR countries -- were carried out on selected policy and institutional issues dealing with the transfer and commercialization of ESTs. In an attempt to gain a better understanding of the role of supporting institutions in the generation of ESTs, a review of publicly funded R&D in universities was also prepared, using

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[6] For the expectations raised prior to Rio, see, for example, the proposal for a "Strategic Environmental Initiative" made by Al Gore: Al Gore, *Earth in the Balance*, Boston, Houghton Mifflin, 1992.

[7] United Nations, Report of the Secretary-General on General and Complete Disarmament: Charting Potential Uses of Resources allocated to Military Activities for Civilian Endeavours to Protect the Environment (A/46/364), 17 September 1991. Compare also the UNCTAD study carried out for the Commission on Science and Technology for Development: United Nations, Economic and Social Council, Commission on Science and Technology for Development, second session, "Scientific and Technological Aspects of the Conversion of Military Capacities for Civilian Use and Sustainable Development", *(E/CN.16/1995/13), 3 March 1995*.

as an example leading universities in the United States. Existing provisions under multilateral environmental agreements are only briefly described, since they do not specifically refer to publicly funded or publicly owned ESTs.

The concept of technology applied by this study includes knowledge embodied in machinery and equipment, knowledge codified in patents and blueprints as well as tacit knowledge, including the special routines, practices and know-how to manage production processes. In much of the literature, technology “diffusion” refers to the wider utilization of technology, while “transfer” refers to technology that affects production and to its transmission to another party. In the international debate, there has sometimes been a notion that differentiated between the “transfer” and “commercialization” of technology. In this understanding, “transfer” was seen as a direct, even costless or preferential provision of technology, whereas “commercialization” of technology involved the sale or licensing by the owner or producer of it. As illustrated by the country case studies, governments today often equate “commercialization” with the transfer of technology.

As highlighted by the country case studies, there are no commonly accepted definitions of “ESTs”, although there are generally recognized features of environmentally sound technologies, and an increasing recognition that these distinguish them from other technologies.[8] It should be noted, however, that because of the evolving nature of environmental problems, ESTs have dynamic features in that what might be perceived as environmentally sound today may not necessarily be sound tomorrow. Equally, any technology must be viewed in its socio-economic and cultural context. Thus, what is environmentally sound technology in one country may not be so in another.[9] Providing an exact definition of ESTs is, at this stage, neither helpful nor desirable.[10] For the purposes of the present study:

> “The terminology ‘environmentally sound technologies’ refers to ‘clean’ technologies which are low in impact on the environment in terms of pollution and/or high in energy-efficiency compared to other technologies currently in use. Often, ESTs are being introduced to alleviate the adverse impact of development on the environment. ESTs may be categorized as follows:
>
> - end-of-pipe technologies designed for the treatment of pollution;
> - remedial technologies aimed at cleaning up damage or reclaiming resources that were formerly degraded;
> - process technologies producing goods or services with lower resource consumption or waste generation and
> - product technologies involving environmental improvement through

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[8] Chapter III elaborates on this point.

[9] See, “Environmentally sound technology for sustainable development”, *ATAS Bulletin*, no. 7, United Nations, New York, 1992.

[10] Nevertheless, some agencies have attempted to provide information on the range and types of ESTs available. See, for example, figure 2 in the present study.

> altered final or intermediary products which are less polluting and recyclable."[11]

In the context of this study, publicly funded ESTs are understood as those that are generated from R&D activities sponsored by the public sector. The results of publicly funded R&D may be disseminated through public institutions or private firms, or a combination of both.
The ownership structure, as is shown in this study, sometimes involves complex models that include both government and the private sector.[12] In carrying out this research work, answers to the following questions were sought:

- What is the extent of public sector financing for R&D activities?
- What are the range and types of ESTs developed as a result of publicly funded R&D activities?
- How are these technologies diffused or/and commercialized at the national level?
- To what extent are these technologies appropriate to third countries?
- What mechanisms are required to facilitate the effective transfer of such technologies to developing countries and economies in transition?

II. PUBLICLY FUNDED R&D IN THE GENERATION OF ESTs

This chapter provides data on the first two of our five basic questions (paragraph 12). Section A contains an overview of publicly funded R&D using data from OECD sources[13] and from the country case studies unless otherwise stated. Data in section B rely mainly on the case studies undertaken for this study.

A. The General Extent of Public Sector Financing in R&D Activities

The country case studies demonstrate that public funding remains a major source for R&D activities, although in most countries in which case studies were conducted, government's share in gross domestic expenditure on R&D has been declining in recent years.[14] However, this relative decline should not conceal the fact that it remains important in the countries under consideration (see figure 1). Moreover, in some countries in which the

[11] Quotation from project document.
[12] Publicly owned technology is clearly differentiated from technology in the public domain. Publicly owned technology is the product of publicly financed R&D, whether or not it is protected by intellectual property rights, while technology in the public domain is formally proprietary technology whose intellectual property protection has already expired or which never received or was never eligible for protection. The results of *publicly funded R&D* may be publicly or privately owned technologies or involve complex combinations of ownership. Most of this document will deal with publicly funded R&D, while the concept of public ownership will be referred to, but - overall - remains somewhat elusive.
[13] OECD (1996). "Industry and Technology Outlook", Paris, OECD (1997). "Science, Technology and Industry Scoreboard of Indicators", Paris.
[14] It was, however, often increasing in absolute dollar terms.

government's share in total R&D spending has traditionally been low when compared with the private sector (Japan, Republic of Korea) it appeared to be increasing in the early 1990s. In the Czech Republic, the one economy in transition that was part of this study, public funding for R&D is rising again after having experienced a steep decline. Finally, public, as compared with private, R&D support tends
to be considerably higher in developing countries than in developed countries (over 80 per cent in one case).

Figure 1
The relative importance of R&D spending by governments (1993-1995)

R&D/GDP	**Government share in total R&D expenditure**		
	High[d]	Medium[e]	Low[f]
High[a]		Germany United States	Japan
Medium[b]		France Canada	United Kingdom Rep. of Korea
Low[c]	Brazil India	Czech Republic	

[a] > 2.5 per cent.
[b] 1-2.5 per cent.
[c] < 1 per cent.
[d] > 66 per cent
[e] 33-66 per cent
[f] < 33 per cent

Governments, in general, are convinced that public support to R&D is important for ensuring a competitive economy, and emphasize this fact in public policy statements.[15] Several of our country case studies testify to this. Such statements are not mere rhetoric, as governments do follow up with public financing of R&D and with setting priorities among different technological areas. Even in countries that emphasize the predominant role of private initiative, political commitment to provide support to "key technological areas" such as information and communications technology remains strong.

[15] R&D continues to include scientific activities which may be neither directly nor necessarily related to competitiveness, but many public statements emphasise the latter.

All the developed countries provide direct support to R&D carried out in the private sector as well. On average, the rate of public-public versus public-private support in these countries remains constant, i.e. a decline in the overall support to public R&D institutions was paralleled by a decline in direct public R&D support to private companies. In developing countries, public R&D support continues to go predominantly to public institutions.

Public funding of R&D usually takes one of two forms: general support to national R&D institutions and laboratories that perform research in areas according to their mandate and designation, or direct funding of specific projects according to set government priorities. The latter could be carried out in public institutions, universities, both public or private, or in private companies. In some countries, in addition to the federal government, state or local governments provide substantial funding to R&D (e.g. Brazil, Germany, Japan and the United States).

On average, over the past decade, up to 40 per cent of annual national R&D spending within a number of OECD member States was publicly funded (see annex 1). The average of national public sector spending on R&D for the 15 EU member countries in 1993 was 39.7 per cent. The equivalent figures were 39.6 per cent for North America, 19.6 per cent for Japan and 36.2 per cent for the OECD as a whole.[16] While 1995 figures were lower (but higher for Japan), they remain significant: 34.5 per cent for the OECD countries as a whole, 36.1 per cent for the United States, 33.1 per cent for the EU and 22.4 per cent for Japan.[17] A high percentage of the finance for R&D activities in a number of developing countries also originates in the public sector.[18] Figure 1 summarizes the relative position of the ten countries covered in this study with respect to the share of R&D in gross domestic product (GDP) and the share of public funding in gross domestic expenditure on R&D (GERD).

Data available on total expenditure on R&D for OECD countries indicate that the rate of growth has declined in North America, the European Union and the Asia-Pacific region, causing the overall OECD R&D expenditure as a percentage of GDP to fall slightly from 2.3 per cent in 1985 to 2.2 per cent in 1993. The slight decline in overall R&D expenditure and the more pronounced decrease in the share of government funding of R&D in some OECD countries can be partially explained by a decline in defense-related R&D activities. But public sector funding of R&D in general has also come under closer scrutiny. Nonetheless, as the case studies conducted reveal, the role of the public sector as a source of direct funds for R&D activities remains significant. In addition, governments in many countries play an indirect role in funding corporate R&D, for example through the allocation of preferential financing and through tax incentives.

All country case studies provide details on the institutional framework that has been established to coordinate, guide, control and channel public R&D funding to the scientific community in the public and private sectors. For example, in Canada, these institutions range from the National Research Council to Networks of Centers of Excellence. In the United

[16] OECD (1993), "Science, Technology and Industry Outlook 1996", Paris, 1996, p. 239.
[17] OECD (1997). "Main Science and Technology Indicators 1997", Paris.
[18] Details for developing countries may be found in UNESCO, *World Science Report 1996*, Paris, 1996.

States, national laboratories play a central role in publicly funded R&D alongside public institutions such as the National Science Foundation that provide funding to public and private universities. In Japan, public assistance for R&D supports the work of laboratories of national universities as well as specialized public R&D institutes. In the Republic of Korea, there are various government-supported technology development programmes conducted by ministries and government agencies. These are programmes available to private industries and academic communities, designed to promote technological innovation in general. In the Czech Republic, the Academy of Sciences, although downsized, continues to play a central role in public R&D. The two studies carried out under this project in developing countries, Brazil and India, provide detailed evidence of government R&D programmes and institutional capacity-building.

B. The Role and Relative Importance of Publicly Funded R&D in the Generation of ESTs

This section focuses on the significance of publicly funded R&D in the development of ESTs and the range and types of ESTs developed as a result of publicly funded R&D activities. It also assesses the extent to which the ESTs generated as a result of publicly funded R&D meet the needs of developing countries and countries with economies in transition.

The findings of the country case studies show that the role of publicly funded R&D in the development of ESTs is vital. However, isolating the data regarding the ratio of public funding for R&D earmarked for ESTs proved to be a tedious exercise in many of the case studies. Even in the few countries that explicitly list technologies for "environmental protection" as a separate category of funded R&D, this category covers only a small percentage of ESTs. Other ESTs are found in fields as diverse as alternative energy technologies, ecologically benign agricultural technologies or technologies related to waste reduction.

Thus, in spite of the frequent use of the term ESTs in international forums and multilateral environmental agreements, the concept remains elusive at the national level. This point is highlighted by the Brazilian study, which notes that:

> "The concept of ESTs is very little understood in all institutions visited or contacted. Both in research institutes and in government agencies responsible for devising and implementing environmental and S&T policies, the technicians have difficulties in conceptualizing ESTs. This obviously creates predictable difficulties in the classification of projects whose objective is the direct or indirect development of technologies being considered in this study".

Nevertheless, a notional idea of technologies that can be classified as ESTs does exist. The UNEP typology presented in figure 2 illustrates such an approach.

Figure 2
Example of a typology of ESTs

Water pollution control and water supply	Technologies for water and wastewater treatment, water supply and water resources management
Air pollution control	Technologies for the control and treatment of air pollution emissions (NOx, SOx and CO – excluding greenhouse gases)
Noise and vibration protection and abatement	--
Solid waste management	Technologies for collection, transport, storage, treatment, recycling and disposal of solid waste
Hazardous waste management	Technologies for collection, transport, storage, treatment and disposal of hazardous waste
Energy	Technologies for alternative and renewable energy supplies and for energy conservation
Cleaner production	Integrated preventive environmental strategies for processes and products to reduce risks to humans and the environment
Land and agriculture	Technologies related to the sustainable development and conservation of land, agriculture and natural resources, including land remediation, soil conservation, mineral extraction, biodiversity, agro-chemicals, sustainable agriculture and afforestation
Construction, building and engineering	Technologies related to engineering, infrastructure development and building construction (the latter including machinery, equipment or methods/techniques of construction) which are environmentally sound
Global environment	Technologies for reduction of greenhouse gas emissions, mitigation of global warming and alternatives to ozone-depleting substances (ODS)

Source: United Nations Environment Programme.

The case studies show that the role of the public sector in the financing of R&D activities related to the generation of ESTs in this broad sense is considerable. The modalities of public sector financing of such activities vary between countries. There are also variations in the policies that governments have adopted as regards financing of the generation of ESTs. Some governments have developed clear policy guidelines not only on R&D financing, but also on the innovative activities required by recipients of such funding and the specific target areas requiring ESTs. In contrast, one finds countries where the public sector is to some extent active in environment-related R&D, but does not provide clear policy guidance. Thus, several country studies found that while government support programmes for the environment industry did exist, coordinated efforts for the development, growth and market access of environmental technologies and services were lacking.

The multifaceted nature of ESTs makes it difficult to provide accurate data on the proportion of public sector funding of R&D activities which are directed at ESTs. However, estimates of some components of ESTs are available. One source estimates the ratio for energy research at 5.5 per cent for Canada, 3.9 per cent for France, 20.5 per cent for Japan and 4.2 per cent for the United States.[19] Public R&D spending directly classified as targeting "environmental protection" is 0.6 per cent in the United States and 4.2 per cent in France and Germany.[20] In Germany, the share of federal funding targeted at EST-related R&D activities in total federal R&D expenditures was 2.25 per cent in 1996. This marks an increase from 1.67 per cent in 1990. However, these figures do not include funds earmarked for other EST-related activities in fields such as energy research and energy technology, innovation and improvement in basic conditions. Nor do they include EST-related R&D financed by the State Governments (Länder). In India, 4.1 per cent of the entire 1994-1995 R&D expenditure was spent on protection of the environment.

Translating the above percentage numbers into absolute figures reveals a considerable amount of public R&D spending. According to the OECD, many of its member States began to sponsor R&D programmes for cleaner technologies in 1989 and 1990.[21] By 1992, these programmes alone were investing over US$1.5 billion and growing rapidly. The programmes ranged from funds directed at advanced and engineering development of cleaner production and products to major process changes. The commercialization of these government-assisted cleaner technologies is deemed successful.

The country case studies reveal that a range of ESTs that could meet the needs of developing countries and economies in transition appear to be available in both developed and developing countries. In India, for example, publicly funded ESTs are found within a range of each of the following classifications: chemicals and allied, marine chemicals, plastics, resins, paints, insecticides, pesticides, agro-based, food processing, drugs and pharmaceuticals, leather processing, metallurgy, building and construction, mechanical engineering, instruments and devices, electrical, miscellaneous, and others. In Germany, the range of publicly funded ESTs which could also meet the needs of developing countries include the development of environmentally more friendly automobiles and a traffic management system for urban areas, the application of biotechnology for arid areas, the optimization of animal feeding and water management systems for mega cities in developing countries, and technologies for treatment and utilization of wastes.

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[19] *OECD* (1997).
[20] Rolf G. Sternberg (1996). "Government R&D expenditure and space: Empirical evidence from five Industrialized countries", in *Research Policy*, 25, pp. 741-758 (here: p. 742).
[21] *OECD* (1995). "*Technologies for Cleaner Production"*, Paris, p. 70.

Many countries included in the study have established national institutions or ministries designed to coordinate environmental activities, including those related to technology. In Canada, the Environment Technology Center (ETC) of Environment Canada was established as long ago as 1975 to provide specialized technical and R&D support for the department's activities. In Germany, environmental aspects, particularly environmental protection, are major criteria in taking decisions on research funding. The German study shows that partly because of a reduction in public resources available for R&D activities, the Government is now following an "integrated research approach" whereby research strategies are formulated in close collaboration with private enterprises, taking into account the needs of global markets and the export opportunities for German enterprises. To that end, R&D pilot projects in areas where German enterprises have a comparative advantage are encouraged. In line with this thinking, the integrated research approach provides incentives for the promotion of new technologies and the framework necessary for their effective implementation. Scientific institutions are also encouraged through public sector funding to play an active role in the targeted areas, which include ecological research, research in the field of environmental technology and environmental education. Priority is given to the promotion of environmentally sound technologies that allow a cleaner production process. For industrial sectors, priority is given to technological efforts that lead to a sound management of materials inputs and outputs. The importance of integrating management, planning, innovation and environmental protection features in the production process is recognized.

In the United Kingdom, several government ministries are responsible for promoting the development and diffusion of environmentally sound practices and technologies. The Department of the Environment, Transport and Regions, for example, carries out programmes for energy efficiency and environmental technology best practice. These programmes aim at stimulating the adoption of cost-effective technologies which have environmental benefits through industry's reduced use of raw materials and lower waste disposal costs.

In the Republic of Korea, a noticeable increase in government funding for clean technology development is observed. The country case study shows that almost every basic clean technology project within each of four major categories - product, process, treatment and recycling - was primarily supported by government funding, even though traditionally R&D had mainly been privately funded.

In Japan, among the institutions specifically geared to environment-related research is the New Energy and Industrial Technology Development Organization (NEDO). NEDO was established immediately following the second oil crisis as a core government institution for technological development. Similarly, the Research Institute of Innovative Technology for the Earth (RITE) was established in 1990 in order to support "innovative environmental technology development in response to global warming". At present, there are 16 national R&D institutes focusing on environmental technologies alone. Local public institutes are also active in this respect.

III. PATTERNS AND MODALITIES FOR THE TRANSFER AND COMMERCIALIZATION OF ESTs

How are ESTs diffused and/or commercialized and what mechanisms exist to facilitate the transfer of such technologies to third countries? This chapter describes established patterns of transfer of publicly funded R&D in the area of ESTs, including those related to existing Multilateral Environmental Agreements (MEAs). It takes stock of a variety of models that exist nationally and internationally.[22] It does so in an illustrative manner, as the scope of this study does not allow an exhaustive coverage of bilateral and multilateral initiatives.

Some developing countries continue to face difficulties in accessing foreign technology, including ESTs. However, technology transfer is a complex process that cannot only be defined in terms of access to technology (the supply side), but needs to be examined in terms of the demand side as well. On the demand side, for example, the small size of most firms in developing countries as well as the lack of support structures are impediments to obtaining technology. These issues are often neglected if discussions of policies for promoting the transfer and diffusion of ESTs focus primarily on the supply side.

The above considerations led to a number of questions. What are the modalities, if any, relating to the transfer and commercialization of publicly funded ESTs including relevant policies, institutional arrangements and aspects, and existing regulatory regimes relating to the protection, exploitation and diffusion of these technologies? Could governments influence this process? What are the implications of public-sector involvement in the financing of R&D for the ownership, transfer and commercialization of these technologies?

ESTs are different from other technologies, such as the new information and communication technologies, for a number of reasons: (i) compared with other areas, the stakes are higher in ESTs given the urgent nature of global environmental degradation and the degree of international commitment reflected in existing multilateral environmental agreements. In this context, it has been argued that the state of the global environment is sensitive for the national well-being of nations and that "environmental security" will become an increasing concern in the coming years; (ii) the framework for the introduction of ESTs is highly regulatory, ranging from areas such as wastewater treatment to CFC substitution; (iii) many governments have been funding R&D for the development of ESTs required to meet specific needs, including environmental regulations; (iv) unlike other technological areas, very often the development of ESTs necessitates public "seed" funds as incentives for companies to initiate EST-related R&D. Firms by themselves are often reluctant to develop ESTs if they are considered expensive and if the return is difficult to foresee (for example, if regulations and standards are vague); (v) many ESTs are commercialized by specialized small and medium-sized firms (SMEs). Often such firms must rely on support structures to develop markets, both domestically and in other countries. Unlike in other technological areas, few venture capital

[22] Chapter V will elaborate on the possibility of alternative transfer and diffusion mechanisms that could offer new opportunities for an accelerated use of ESTs throughout the world, including the developing countries.

firms see a market in ESTs to provide the initial support needed; (vi) many ESTs are developed and receive public R&D funding with very specific domestic applications and markets in mind and are thus not automatically suited to other markets, particularly the specific conditions and needs prevailing in many developing countries. For the above reasons, it is assumed that ESTs could - theoretically - be treated differently from other technologies in terms of the modalities of their transfer and diffusion.

1. Issues and policies

In most countries analyzed in this study, government policies and regulations play a role in the development, transfer and diffusion of ESTs. They stimulate innovation in ESTs through regulatory policies that set environmental standards in areas such as waste, water and emissions. For example, the Clean Air Act in the United States required 22 major metropolitan areas to improve their air quality or lose federal funds. This has led to considerable research activity in finding less-polluting transportation technologies.[23] A number of ESTs have been developed by traditional industries to meet regulatory needs.[24] In some countries, policies creating such demand are explicitly stated and consistent; in others, particularly the developing countries, a clear policy framework could not be identified.

All countries included in this study have established institutions dealing with the promotion of ESTs and different models of R&D community-enterprise cooperation without directly interfering in the transfer and commercialization process. Some governments have also introduced incentive schemes designed to facilitate or accelerate the development and application of ESTs. These include tax incentives, preferential loans, financial grants or similar measures designed to support private sector use of ESTs.

Some governments exercise a strong level of control over the selection of R&D projects and programmes to be funded, and - increasingly - this decision is made in favor of funding EST-related R&D. However, in most countries government involvement does not extend to the commercialization and transfer of these technologies.

Nevertheless, other governments do exercise a degree of control over technologies developed with government R&D funding, at least for a limited period of time. In the Republic of Korea, for example, institutions which receive public funds for R&D programmes own the intellectual property rights of the technologies developed. These could be national/public research institutes (NRIs), government-invested institutions (GIIs) or government-supported research institutes (GRIs), universities, research associations and other legal entities. Cooperative R&D programmes involving private companies and GRIs or universities are

[23] W. W. Clark and E. Paolucci (May 1997). "An industrial model for technology commercialisation: Fuel cells into design manufacturing", paper delivered at the International Conference on Product Design and Manufacturing, Stockholm.

[24] Lanjouw and Mody (1996), for example show that the level of innovation in ESTs as measured by patenting in the areas of air and water pollution is responsive to regulatory policies at home, but also abroad. The latter operates in particular when trade relations are involved. Air pollution limitation in Germany thus increased in response to car emission standards in the United States (J. O. Langjouw and A. Mody, "Innovation and the international diffusion of environmentally responsive technology", in *Research Policy*, vol. 25, no. 4, 1996, pp .549-572).

common. Since the 1970s, the Government has adopted various policy measures to promote such cooperation and such efforts receive top priority for research grants. Some of the technologies developed under public programmes are owned by these research institutes. The Republic of Korea study concludes that, as a consequence, some direct or indirect government influence does exist. This applies also to R&D related to clean production technologies developed under such programmes, which often fall into the category of "publicly owned technology.

A common trend in the transfer and commercialization of ESTs reflected by several case studies is to be found in collaborative efforts sought through networks, partnerships and alliances. Increasingly, the "research culture" and the "business culture", each of which are different,[25] join forces in the "demonstration" and "prototyping" of new technologies. Several countries refer to the importance of such public-private partnerships involving a broad range of economic actors ranging from universities and R&D institutions to government entities and private companies. While most such initiatives are designed for technology transfer and commercialization at the national level, a limited number of initiatives have been taken to develop similar schemes for cooperation internationally, including developing countries.

Many governments are conscious of the international dimension of global environmental degradation and the role of ESTs in addressing this problem. This continues to be a major challenge facing the international community. A recent OECD study concluded that:

> "Given that non-Member countries are predicted to triple their industrial output by the year 2010 as compared to 1990, direct application of cleaner production technologies outside the OECD area will be crucial for sustainable development. The OECD and its Member countries must therefore give attention to technology and information transfer."[26]

Accordingly, several industrialized countries are now developing schemes under their official development assistance (ODA) to facilitate the transfer of ESTs to developing countries, and some have earmarked a proportion of their ODA for environment- and EST-related projects (Germany, Japan and the United Kingdom, for example).

Canada promotes the transfer of ESTs through bilateral agreements. It has signed a host of Memoranda of Understanding on Environment Cooperation with other countries. While these agreements are general in nature, they facilitate specific projects, some of which involve technology transfer. For example, one such arrangement is the letter of intent with respect to the joint project known as "Watershed Management 2000 - Improvement of Water Resources Management in the State of Sao Paulo". This project involves a partnership between a large

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[25] They operate under different rules and norms. For the researcher, publications are a pathway to advancement; while this has been changing in some technological areas, it is still the basic cultural norm in most public R&D institutions. For the business culture, getting technologies commercialised and into the market-place is the incentive and basic driving force. This is a generalisation, however. As demonstrated by some of the case studies, there is already a degree of integration of the two cultures in some countries or academic fields.

[26] *OECD* (1995), p. 12.

number of Canadian and Brazilian institutions. While some of the start-up funding originates in Canadian ODA (Canadian International Development Agency (CIDA)) as well as "in-kind" contributions by participating organizations, it is anticipated that a successful start of the project will also attract other international donors with interests in Brazil (World Bank, Inter-American Development Bank). The project involves a broad range of support measures to improve water management and treatment in the State of São Paulo.[27]

A number of the country studies describe institutions, bilateral cooperation agencies and non-governmental organizations which have initiated similar programmes. Many of these new initiatives aim to increase North-South technology partnerships through the encouragement of joint ventures, licensing, joint technology development and the creation of information clearing-houses and "match-making" services, needed to make both suppliers and potential technology recipients aware of opportunities in the area of ESTs. Public support, including funding, is often a factor in the development of these initiatives.

Japan has developed an initiative for mitigating global warming - the Green Initiative. Its objective is to promote and accelerate the introduction and dissemination of technologies for energy saving and non-fossil fuel energy technologies in developing countries. Under this initiative, various programmes for technology transfer and financial assistance have been implemented or are in the planning stage. Similarly, the Green Aid Plan was developed in 1992 "in order to promote the transfer and dissemination of Japanese technology and experience to developing countries of Asia".[28] The programme concentrates on efficient energy utilization and prevention of industrial pollution.

The United States provides technical advice and facilitates access to private financing. The Country Studies Programme Support for National Action Plans assists developing countries and countries with economies in transition in carrying out technology assessment as a basis for developing national climate action plans.[29] However, two important mechanisms for the dissemination of ESTs by the United States to other countries (including developing nations) are also the Export-Import Bank and the Overseas Private Investment Corporation. The former provides companies with funds (e.g. credit, loans, guarantees) for the goods and services of a company that seeks to export. The Bank will target certain regions of the world and therefore give preferential rates and service to companies seeking business there.

Another example of a bilateral programme is the United States-Asia Environmental Partnership Initiative (USAEP). Under this programme joint study groups were formed involving universities and national laboratories from both regions with a view to facilitating the transfer of advanced environmental and energy technologies through private sector cooperation. The initiative includes face-to-face interaction between the different partner institutions as well as on-site environmental assessments and training programmes.

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[27] See the Canadian country study and the Canadian International Development Agency, *Watershed Management 2000 in the State of São Paulo, Brazil.*
[28] *OECD* (1996). "*Climate Technology Initiative: Inventory of Activities"*, Paris, p. 26.
[29] *Ibid*., p. 29.

In Germany, the Federal Government promotes the building of scientific and technological capabilities of developing countries, including in the area of ESTs. Related projects, which have specific research objectives, complement the development schemes of the Federal Ministry for Economic Cooperation, which support, among other things, the development and improvement of the scientific and technological infrastructure (higher education, technology centers, research institutes) in the developing countries. Environment-related funding and support focus mainly on energy research and energy technology, and the study of tropical ecosystems. Generally, cooperation in the field of environmental technologies concentrates on developing and adapting low-emission technologies for use in developing countries. Important activities are the development of ecologically sound manufacturing processes, sewage and waste treatment, as well as studies of soil and air pollution.

One example of public-private cooperation at the international level is the Technology Partnership Initiative (TPI) of the Department of Trade and Industry in the United Kingdom. The TPI was established to promote technology cooperation in the area of ESTs between British and developing country firms. Its main aim is to promote direct access by businesses from developing countries and newly industrializing economies to information on environmentally sound technologies available in the United Kingdom. It has established several criteria for ESTs: they have to be affordable; they have to be appropriate to the needs of a wide range of industrializing developing countries; and they have to enable businesses operating in developing countries to grow in accordance with sustainable development principles. The main mechanisms of the TPI are to expand existing channels of communication between United Kingdom businesses and those in developing countries; to provide information about the opportunities for joint ventures and other forms of partnership; to make available to businesses in developing countries case studies and guides to best practice; and to provide information on technological solutions and techniques and demonstration of leading-edge technology. The Initiative also covers environmental management and training and sources of finance. It has sponsored seminars and supported the work of international organizations (UNEP, UNCTAD) in these areas. Furthermore, it identifies United Kingdom companies prepared to part-finance training.[30]

There are a limited number of other pilot projects, mechanisms and programmes addressing issues such as financing of the various phases of technology transfer, creating awareness, finding partners, launching specific transfer processes and encouraging R&D institutions to transfer technology. Some of these are in the area of ESTs, while others address technologies in a more general way. However, all of them could serve as effective models for the transfer and diffusion of ESTs. For example, the United States Agency for International Development (USAID) supported a five-year University-Industry Linkages and Economic Development Programme. This project was designed to ensure collaboration between Northwestern University in the United States and the Autonomous University of Yucatan in Mexico, focusing on linkages between the university and the local productive sector. Its objectives were to develop joint research capabilities as well as an academic programme in

[30] Department of Trade and Industry, (1993). "Technology Partnership, Guide to UK Environmental Technology and Services", London, Stella Blacklaws (1995). "Environmental technology Cupertino", in *UNCTAD*, Technological Capacity-building and Technology Partnership, Geneva and New York, 1995.

technology and organizational performance, and to extend extension programmes of the Mexican university to assist local manufacturers.[31]

Similarly, a Yale University initiative, in collaboration with UNDP, supports the creation of public-private partnerships to tackle water, sewage and energy problems in urban environments. The project emphasizes eco-efficiency, stakeholder participation and replicability. It uses ODA to leverage private sector investments by creating joint ventures while building an effective enabling environment with solid supporting mechanisms at the same time.[32]

2. Multilateral initiatives

At the multilateral level, several initiatives are under way as well. Thus, the OECD and the International Energy Agency (IEA) are engaged as facilitators for technology transfer in various ways. One such example is the Climate Technology Initiative (CTI). CTI was launched in 1995 as a voluntary initiative by 23 OECD/IEA member countries and the European Commission to support the technology-related objectives of the Framework Convention on Climate Change. It generally aims at developing and disseminating climate-friendly technologies. In that context, joint research agreements involving scientists from a dozen nations have been signed under this initiative. At the same time, partnership agreements with five major international organizations have been concluded. The IEA provides the technical and staff support. Activities have included regional workshops in developing countries, and analysis of information centers and networks to support the climate change negotiation process.[33]

Another example of international cooperation is the IEA collaborative effort in the area of energy technology R&D. Each project is set up under an "Implementing Agreement", which provides a legal contractual mechanism. Within this framework, participating countries choose the particular tasks in which they wish to be involved. There are currently over 40 active IEA Implementing Agreements. Research expenditures are directly coordinated through the programme. Countries achieve a multiplier effect on their contribution, gaining access to results generated by all the partners. Implementing Agreements provide substantial leveraging of domestic expenditure through, among other factors, sharing costs, pooling resources, strengthening national R&D capacities and building a common understanding of the technical basis of issues.[34] International cooperation may include non-member countries. According to the OECD, IEA collaborative activities have been at the forefront of research to solve environmental issues related to energy technologies. In this context, new collaborative activities in the area of the environment have been initiated, such as "GREENTIE" and "CADDET Renewables", which are promoting the increased utilization of new environmentally benign

[31] Atul Wad, "University-industry linkages and economic development: Lessons and analytical perspectives drawn from the UDLP project", paper prepared for the VIth Symposium on Technology Management, Autonomous University of Yucatan, Merida, 4-5 December 1997.
[32] Environmental Health and Safety Management, Inc., *EHS Management*, 27 October 1997.
[33] CTI, Press Release, "UNEP joins forces with Climate Technology Initiative to combat climate change", Kyoto, 4 December 1997. See also OECD, *Climate Technology Initiative*, Paris, 1996.
[34] See, for example, IEA (1996). "International Energy Technology Collaboration: Benefits and Achievements", Paris, (OECD publication), pp. 15-17.

technologies to reduce greenhouse gas and other emissions.[35]

In addition to the agencies that have prepared the present document - UNCTAD, DESA and UNEP - several international organizations carry out work relevant to ESTs within their specific mandate. Often these include information, advisory services or "match-making" activities. For example, UNIDO, in cooperation with UNEP, has launched a programme for National Cleaner Production centers conducting in-plant demonstrations, providing training for cleaner-production assessors, disseminating information and giving policy advice. Specialized programmes including technology transfer exist in particularly polluting sectors such as the tanning industry.

The European Union (EU) provides public support for moving R&D, even in the private sector, from knowledge generator to potential users. It recognizes that SMEs often require financial assistance to turn research results into marketable products. One type of financial assistance is equity capital, and the First Action Plan for Innovation in Europe (1996) attempts to deal with a number of barriers to the commercialization of research identified by the Commission, notably the high costs of initial appraisal and the need for ongoing management and support. When the venture capital market is not very well developed, these factors create additional difficulties for SMEs. An Innovation and Technology Equity Capital "pilot scheme was launched in July [1997]...to lower these barriers by directly supporting the development of cost-effective appraisal and management procedures".[36] In addition, the EU has developed other programmes to move "publicly" funded R&D, e.g. R&D supported by one of the EU's "RTD" projects, to users; one is a programme to validate R&D results by setting up pilot projects as part of a transfer of technology process. The programme, an extension of the SPRINT specific projects, is part of the EU's Innovation Programme and is aimed at transferring generic technologies from one sector to another and encouraging the diffusion of such technologies across EU regions. It also seeks to foster links between the enterprise sector and research institutions. While the above initiatives focus on EU countries and firms, the EU has acknowledged that EU research policy must also take into consideration the needs of developing countries. The current EU research programme has allocated funds for cooperation with developing countries and for a regular exchange of knowledge between the EU and developing countries.

In 1984, an international research cooperation network in the area of science and technology - CYTED - was created, linking 21 Spanish- and Portuguese-speaking countries from Europe and Latin America. This programme, which is supported by several international organizations, involves different models of cooperation between universities, R&D centers and enterprises. Its primary objective today is to establish cooperation in research and technology development and the transfer of R&D results to the productive sector. It includes sectoral activities relevant to ESTs in areas such as energy conservation and biodiversity.[37]

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[35] *Ibid*., p. 20.
[36] "Capital for exploiting research results", in *Innovation and Technology* Transfer, vol. 4, July 1997 (EU Commission).
[37] *Noticias de CYTED (June 1997).* "Programma Iberoamericano de Ciencia y Tecnología para el Desarollo", Número 9, June 1997.

All major international agreements addressing global environmental problems, ranging from the Convention on Biological Diversity to the United Nations Framework Convention on Climate Change, and - in particular - the Montreal Protocol and its amendments, contain specific provisions regarding legislative, administrative or policy measures for access to and transfer of technology. However, in reviewing initiatives to implement these provisions, a general observation can be made that the use or development of appropriate modalities/mechanisms to facilitate the transfer and diffusion of ESTs has not been at the forefront of the policy deliberations under these agreements. The general focus is on "information", in particular the identification of technologies that are considered essential to the further implementation of the conventions, accessibility to information on these technologies as well as the modalities for the dissemination of this information. Concern about R&D basically related to the adaptability of available technologies to the specific needs of countries rather than research on, and development of, new technologies.[38]

For example, a significant part of the technology-related recommendations adopted by the Basel Convention centered on the establishment and networking of regional and/or subregional centers for training and technology transfer. Progress being achieved in establishing regional and subregional centers for training and technology transfer, and on organizational arrangements and the funding situation regarding the respective centers, will be reported to the Conference of the Parties.

The Conference of the Parties of the Biodiversity Convention centered its discussion on the usefulness and modalities of establishing clearing-house mechanisms to promote information exchange on scientific and technical matters, policy and management issues, technology transfer and capacity-building.

The Convention to Combat Desertification called for the development of new technologies to stop desertification or cope with its effects. Those technologies should be transferred to countries in need of them and adapted to local circumstances. In various contexts, the Convention calls for scientific and technical cooperation among the Parties to it in areas such as joint research programmes, information collection and dissemination, technology transfer, protection and utilization of traditional and local knowledge and know-how, conservation of land and water resources, and sustainable management of transboundary natural resources. Scientists world-wide are encouraged to contribute with their know-how and research results to this effort.

Under the Framework Convention on Climate Change, surveys are being conducted on technology transfer activities of member countries, as well as on the terms of transfer of technologies that are available and relevant to the implementation of the objectives of the Convention. Priority is given to methods for monitoring and assessing the effectiveness of policies and implementation strategies to support the use, adaptation and diffusion of technologies. The Global Environment Facility (GEF) provides for interim funding for specific

[38] The Montreal Protocol may be an exception.

well-defined projects.

Under the Montreal Protocol, the “Ozon Action Programme” was established as an information clearing-house in response to the realization that: (i) there is a clear need for technology transfer to comply with a legally binding international agreement; (ii) there are efforts to develop national strategies through country programmes; (iii) there is an extensive effort to obtain and disseminate, on a wide scale, information on the available technical options and sources of technologies, equipment and chemicals; (iv) there are extensive training and networking efforts to build local capacities for ODS phase-out; and (v) there is financial support for the entire effort. A specific feature of the Montreal Protocol is the creation of a multilateral fund specifically intended to accelerate the use of alternative technologies to CFC gases in developing countries. The establishment of this specifically focused fund has been widely regarded as a success, although there are a number of shortcomings.

3. Impediments to technology transfer and diffusion

As shown in this report, a broad range of ESTs are generated from publicly funded R&D activities that could meet the needs of developing countries and economies in transition. In many respects, the needs of developing countries, in terms of global environmental protection, are not different from those of developed countries. However, there are differences in the capacity and capabilities of countries to apply available ESTs effectively. The constraints that firms face in accessing ESTs available in both developed and developing economies originate from both supply and demand sides. Among the supply-side obstacles noted in the case studies are the protection or lack of appropriate protection of intellectual property (as discussed in chapter IV), cost factors (too expensive), lack of relevant information to make the right choice, the fact that some ESTs are not yet marketable or marketed, time-consuming licensing procedures adding to the cost of the technology, and inadequate policy and incentive measures in technology-producing countries to promote the diffusion of ESTs. Some ESTs are costly, especially for small firms in developing countries. This is partly because the technologies may be in their infancy or the main focus of the entities generating the technology may be on research rather than the economic viability and commercialization of the technologies generated.

On the demand side, some of the major impediments include financial constraints, lack of local capacity and the skills required to acquire, adapt and assimilate technologies, lack of awareness and relevant information on available ESTs, and the absence of regulations, policies, incentives and the instruments of enforcement to advance the utilization of ESTs. Firms, especially those in developing countries, are not often aware of the range and types of ESTs available and the benefits, in terms of efficient use of raw materials, clean-ups and competitiveness, arising from the application of such technologies. In developed countries, the formulation of explicit policies and the introduction of incentive measures specifically designed to influence both producers and consumers to use ESTs were instrumental in promoting their use. It is evident that the effective diffusion of ESTs is dependent on the local policy and regulatory environment conducive to wider use of such technologies.

The issue of affordability is often a major demand constraint, particularly where the economic conditions of the country to which the technology is to be transferred are very different from those of the industrialized country where the technology has been developed and applied. For example, the size of the market and the less sophisticated distribution systems and marketing channels may mean that production costs per unit will be higher and a high volume of production cannot be attained. The technology as applied in industrialized countries may well need to be adapted to these different conditions, which will also incur additional costs. Overcoming the initial barriers to the introduction of a new technology may require public sector funding, as deliberate efforts are required in constructing an economic and policy environment appropriate for the transfer and diffusion of ESTs and to sensitize potential users to the advantages of acquiring, adopting and assimilating ESTs. Yet these are not always present, as the case studies show.

Some country studies explicitly list impediments to the transfer and commercialization of ESTs at the national level.[39] A German survey of private and public enterprises and public institutions found that new products are too costly; the technologies generated are not readily marketable; there is a lack of awareness on the part of potential users; and the procedure for obtaining licenses takes too long, thus adding to the cost.

Often, specific policies for the transfer and diffusion of ESTs do not exist. For example, the country case study for Brazil found that "no discernible patterns for the diffusion of ESTs were identified in the survey". A similar observation was made by the special study on the MERCOSUR countries. The report of the Czech Republic concluded that

> "The overall regulatory regime is rather underdeveloped. The protection and exploitation of the results of R&D are subject to an internationally established legal framework that is in place.... However, there are no special instruments in place to stimulate the dissemination of results, the development of prototypes and/or the commercialization of the technological innovation."

In contrast, United States legislation, such as the Stevenson-Wydler Technology Innovation Act of 1980, is explicit in its intention of ensuring that publicly funded R&D is put to "commercial and useful purpose." However, the Bayh-Dole Act, also enacted in 1980, makes it clear that the primary aim of publicly funded R&D is to promote the commercialization of public availability of inventions made in the United States by United States industry and labor".[40]

A difficulty in commercializing publicly funded ESTs on a global level due to legal constraints is exemplified by a case study of fuel cells in the United States.[41] Publicly funded research in the area of fuel cells, as an environmentally friendly technology for automobiles, did not initially find a private firm ready to commercialize this technology, which had been developed in a national laboratory. Eventually, an international financial and manufacturing

[39] See also chapter IV for specific legal and institutional impediments.
[40] For details of this legislation, see chapter IV.
[41] Clark and Paolucci, *op. cit.*

consortium led by Australian investors entered into a Cooperative and Development Agreement with the laboratory. However, policies governing publicly funded R&D requiring "substantial manufacturing" in the United States proved to be an impediment to the transfer of technology. The technology was finally commercialized through the creation of an international consortium which involved an American firm.

As pointed out above, there are "cultural" gaps between the research communities and the private sector which partly explain the small proportion of R&D results that are transferred to the productive sector or commercialized.[42] More often than not, the incentives for the private sector to commercialize R&D results (market penetration, profit and equity) are different from those that motivate the public sector R&D institutions (publications, promotion and tenure). For instance, despite years of collaborative links between university researchers and industry promoted through EU programmes such as ESPRIT, interviews with both business and researchers show wide gaps in the work cultures and in the expectations they have of each other.[43]

IV. POLICY AND INSTITUTIONAL FRAMEWORK

The dominance of liberal approaches to economic management has entailed a shift in the choice of mechanisms to encourage the process of technology transfer. Increasingly, the private sector has been placed at the center of the technology transfer process in contrast to a state-oriented approach. This new trend does not preclude public authorities from assuming a role to influence the transfer of publicly funded technologies, and the existing legal regimes, with necessary variations, still include a number of public policy instruments that in the context of sustainable development imperatives deserve further consideration.

This chapter discusses policy, institutional and legal issues relevant to the transfer of ESTs derived from publicly funded R&D activities. It describes selected policies and mechanisms for the diffusion and commercialization of R&D results, with emphasis on intellectual property rights regimes, including institutional mechanisms in public entities. It draws on surveys undertaken in the United States, the MERCOSUR countries (Argentina, Brazil, Paraguay and Uruguay) and France. The French study also considered related policy measures of the European Union. The key findings and conclusions of these studies are summarized below.

A. Main findings of the surveys

The legal survey undertaken in the United States shows that, for at least the past two decades, the goals of policies have been to promote commercial development of federally

[42] Compare explanation in chapter III above.
[43] See B. Vavakova, "Building 'research-industry' partnerships through European R&D programmes", *International Journal of Technology Management*, vol. 10, nos.4/5/6, 1995 (Special Issue on the Evaluation of Research and Innovation), pp. 567-586.

sponsored technologies and to leverage research funding into areas where United States products have a strong comparative advantage in world markets. These goals pervade not only general statutory provisions applicable to technology transfer across the spectrum of federally sponsored research, but also more specific statutes concerning environmental technologies. The policy of the United States has strongly favored private appropriation of the results of publicly sponsored research through primarily the patent system. Two principal strategic motivations emerge from a review of legislative provisions governing the commercialization of government sponsored research. The first is a desire to motivate the private sector to pick up where government funding leaves off, so that research advances can be developed into useful new technologies;[44] and the second is the improvement of the competitive position of United States firms.[45]

Under existing law, federal agencies sponsoring research in United States-based institutions are directed to permit the latter to retain patent ownership, provided that these institutions are diligent about pursuing commercial development of the inventions either on their own or through licensees. In cases where the sponsoring agency retains ownership, the agency is directed to make technology transfer to the firm level a priority and is permitted to grant exclusive licenses to private firms in order to promote commercial development. Regardless of who owns the patent rights, preference in the selection of exclusive licensees is to be given to firms that agree to manufacture substantially in the United States. Sponsoring agencies retain “a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States any subject invention throughout the world”.

In France, there is no specific legal regulation on the commercialization of ESTs, with the exception of general provisions in Law No. 95-101 of 2 February 1995, relating to the reinforcement of the protection of the environment, which introduced some new principles to French law, and the regulations protecting the environment in general, which limit or prohibit the use of certain technologies. Nor does the French system provide for specific policies concerning the commercialization of publicly sponsored R&D. Nevertheless, it is worth noting that, in the French system, publicly funded research falls under two broad categories. The first

[44] With respect to this first strategic motivation, the findings set forth at the beginning of the Stevenson-Wydler Technology Innovation Act of 1980 make this explicit: “Many new discoveries and advances in science occur in universities and Federal laboratories, while the application of this new knowledge to commercial and useful public purposes depends largely upon actions by business and labour. Cooperation among academia, Federal laboratories, labour, and industry, in such forms as technology transfer, personnel exchange, joint research projects, and others, should be renewed, expanded, and strengthened”. The Bayh-Dole Act, also of 1980 -- aimed at encouraging small businesses and non-profit organisations to patent the results of government-sponsored research -- states that “It is the policy and objective of the Congress to use the patent system to promote the utilisation of inventions arising from federally supported research or development”.

[45] According to the Bayh-Dole Act, a targeted aim is “to promote the commercialisation and public availability of inventions made in the United States by United States industry and labour”. The Stevenson-Wydler Act’s introductory list of Congressional findings deplores that A[i]ndustrial and technological innovation in the United States may be lagging when compared to historical patterns and other Industrialized nations” and claims that technology and industrial innovation facilitate “creation of new industries and employment opportunities and enhanced competitiveness of United States products in world markets” and will “reduce trade deficits, stabilise the dollar, increase productivity gains, increase employment, and stabilise prices”.

relates to research conducted directly by a public entity (state services, state body or local community), in which case the results are the property of that public entity; and the second relates to research conducted by private entities, acting on behalf of or with the financial support of a public entity. These categories apply to all R&D activities, including those related to ESTs.

Since the mid-1980s, an important shift in the paradigm of publicly funded R&D has taken place in the MERCOSUR countries. Increasingly, public sector R&D institutions are encouraged to recover R&D costs through the appropriation and transfer to the productive sector of the results of their R&D activities. However, as in the case of France, the appropriation and transfer of the results of publicly funded R&D are not subject to a specific regime, but to general rules originating in different legal regimes, namely constitutional and civil law, intellectual property, contract, labor and administrative law. These regimes, as applied at the national level in each country, determine the general conditions for the appropriation and transfer of publicly funded R&D results. The current trend in public R&D institutions in the MERCOSUR countries is not simply to place R&D results in the public domain but, if possible, to claim intellectual property rights and demand compensation for their transfer.

B. Policy and institutional issues

The surveys of the regulatory and legal regimes governing technology transfer in the area of ESTs in the United States, France/EU and MERCOSUR countries have raised policy and institutional issues that include a broad range of questions relating to foreign access to technology, intellectual property rights and licensing. In this context, it was noted that the legal and institutional framework of ESTs did not differ from technology in general and that ESTs are subject to the same rules governing all results of publicly sponsored R&D. The United States is one country that has paid more attention to specific policies governing the results of R&D in general. In the case of the other countries reviewed in the project, general principles of law, either of a public or private nature, regulate the matter.

One issue raised by the study was that of the availability of ESTs that are publicly owned. The concept of “publicly owned” technology is distinctively different from that of “public domain”.[46] The latter means that the knowledge is freely accessible and usable, i.e. anybody can use it without authorization and compensation. In contrast, the concept of “publicly owned” technology indicates that there exists some form of appropriation based on the intellectual property rights (IPRs) held by the public entity. Because of the high cost of obtaining patents throughout the world, however, it may be that many ESTs that are covered by patents will remain unpatented in developing countries. In cases where there are no local patent rights covering the technology, it may be possible to obtain the necessary technical information from publications, foreign patent documents or government agencies, and put it directly to use.

[46] See footnote 12.

But even when patent rights do not compel developing countries to go through foreign firms to obtain access to ESTs, there may sometimes be technical advantages to collaborating with firms that have developed ESTs commercially and have extensive experience with these technologies. In other words, neither public domain nor "public ownership" is equivalent to immediate mastering of the respective technology. The economic agent needs the technological capacity to exercise those rights. This issue of technology, theoretically placed in the public domain, deserves further exploration, particularly in the context of publicly funded R&D. Here it is important to stress that there are situations in which it might be in the common interest of an R&D institution and of an economic agent to enjoy exclusivity in the use of a technology developed by the former that has not been protected in a particular country. The lack of intellectual property rights protection could be, in this particular case, an obstacle to the utilization of ESTs. In this instance, a case could be made for considering the conferring of a special status on the transfer of ESTs in order to protect the investment and the technology that otherwise would not enjoy protection under traditional intellectual property rights regimes.

As noted above, in a framework of increasing "privatization" of public research, "publicly funded R&D" does not generally mean that the results of the R&D are "publicly available", but that the results could be subject to appropriation under patents or other titles held by the entities that took part in their development. There is, however, a qualitative difference between technologies fully subject to private decisions and those that may not be exclusively subject to private decisions, the topic of this study. It has been observed that the public entity can still exercise some influence concerning the use and commercialization of publicly funded technology. For example, in the case of the United States, which has undoubtedly a highly elaborate legal regime on the subject, the Government retains rights to grant licenses on reasonable terms if (a) the contractor fails to take effective steps to achieve practical application of the invention; (b) such action is necessary to alleviate health or safety needs; (c) such action is necessary to meet requirements for public use specified by federal regulations; or (d) the contractor or its exclusive licensee has either failed to agree to manufacture substantially in the United States or is in breach of such an agreement.[47]

Furthermore, in the United States, some statutes (including the Clean Water Act and the Atomic Energy Act) provide for the issuance of mandatory licenses in cases where firms controlling the patent rights are not willing to license certain technologies on reasonable terms. The statutory provisions and implementing regulations make clear, however, that mandatory licenses are a remedy of last resort available only to parties that have been unable after reasonable efforts to obtain a license from the owner of the patent on reasonable terms. Even these limited provisions for mandatory licenses are extraordinary in the United States patent system, which as a general rule entrusts patent licensing to the realm of private bargaining. It could not be verified, however whether any such licenses have ever been granted.

In the other countries under examination, intellectual property rights held by public entities are generally deemed a "private" property of the State or of the parastatal institution, and they can therefore be assigned or licensed through contractual arrangements to third parties. In general, there are no restrictions on granting exclusive licenses, or even assigning

[47] *35 U.S.C.A. ' 203(1).*

them to a contracting party that has financed or co-financed the respective research project. The appropriation of the technology is subject to the general regime governing intellectual property rights, and in this context, compulsory licenses are provided in line with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

It was observed in several case studies that, in the generation and commercialization of ESTs, there is a trend towards partnerships or consortia in both the public and private sectors as well as between the public and private sectors. The following paragraphs describe some existing mechanisms in public institutions in the developed and the developing countries that could become important vehicles for partnerships or consortia to facilitate the transfer and commercialization of ESTs.

Universities play an important role in developing programmes for the commercialization of technology that are generated through publicly funded research. For example, four private American universities reviewed in this project - Columbia, Harvard, Yale and Stanford - were found to have special mechanisms for the commercialization of technologies. These universities are renowned for active collaboration between government and academia in specialized fields relevant for the generation of ESTs. The four universities have Offices of Technology Transfer and Licensing established during the 1980s. Each has the role of protecting the intellectual property rights developed by their respective researchers and the economic interests of the university, on the basis of the federal laws governing publicly funded R&D. Each institution is allowed to determine how royalty fees, royalty sharing and other compensation are allocated. For example, Harvard operates its royalty-sharing policy in its Office of Technology and Trademark Licensing through a distributed allocation to the inventor (researcher), the researcher's department, the faculty and the university in general. The main federal legislation that guides university policies in the area of publicly funded R&D is the Bayh-Dole Act of 1980. In this respect, the guidelines on university technology transfer developed by the Council on Governmental Relations (COGR) provide that “Universities should be extremely cautious in considering foreign licensees, especially if the research was funded by the United States Government. For those inventions, all exclusive licenses require the licensee, including foreign companies, to manufacture products substantially in the United States”.

In the case of the MERCOSUR countries, many institutions that undertake and/or fund R&D have also established their own policies and regulations on the appropriation and transfer of publicly funded R&D results. However, there is no general regime applicable, and, therefore, a high degree of decentralization exists. In order to define the legal status of a particular set of results of publicly funded R&D, it will be necessary to determine the extent to which the general legal regimes and/or specific institutional regulations are applicable. The policies adopted by public institutions involved in R&D activities generally define the allocation of rights between the institution and the research personnel, or between them and a third party that has contracted the research. Normally, the transfer of R&D results to third parties is promoted without discrimination in terms of nationality, capital, size or other characteristics of the receiving companies.

In practice, however, the number of patents actually applied for by universities and other R&D institutions, though growing, is very small. In the case of Brazil, the issue of intellectual property rights is quite new for universities. Each university defines its own policy for the appropriation and transfer of R&D results. The general approach is that such results are controlled by the universities themselves. When they are exploited through a license by a third party, the researchers may generally claim a participation in the benefits. In the case of Brazil, between 1988 and 1991, universities and R&D institutions applied for 222 patents, less than 1 per cent of patent applications made by residents of Brazil. The productivity of such institutions in terms of patents per researcher has been extremely low (less than one a year), with some exceptions.[48].

C. ESTs and the TRIPS Agreement

The prevailing paradigm, which favors the private appropriation of technologies resulting from publicly funded R&D, relates to the role of intellectual property rights in the transfer of those technologies. This points to the new features of IPRs. As highlighted in a recent study by UNCTAD, attitudes towards intangible property are actually evolving.[49] There appears to be an emerging global consensus that unauthorized copying of copyrighted material (software, music, films, etc.) and trademark products (clothing, cosmetics and jewelry) for purposes of resale is an illegitimate activity and should be eliminated. Attitudes towards creation, dissemination and ownership of technological information (for example, production processes for pharmaceuticals, biotechnological products) remain more divided. Against this new background, and in the light of a backdrop of growing concern over differences and inadequacies in IPRs systems and of the difficulties this situation posed for global exploitation of intellectual assets, countries committed themselves, in the Uruguay Round, to adopting a set of universal standards of protection. The Final Act, embodying the results of the Uruguay Round, contains in annex 1C the TRIPS Agreement.[50]

The basic principles of the TRIPS Agreement refer to criteria and objectives regarding the contribution that the protection and enforcement of IPRs should make to the promotion of technological innovation and the transfer and dissemination of technology. In this new framework, patents are to be available for any inventions, in all fields of technology. One of the few justifications for excluding patentability is for the aim of avoiding “serious prejudice to the environment”. The Agreement also refers to measures that countries may adopt to protect public health and nutrition and to promote public interest in sectors of vital importance to their socio-economic and technological development. These principles also provide that appropriate measures may be needed to prevent the abuse of intellectual property rights or practices which

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[48] According to Lanjouw and Mody (1996), among non-OECD countries in the 1970s and 1980s, Brazil “has been the clear leader: over 18 years between 1971 and 1988, Brazil granted 2,180 environmental patents”. In comparison, India granted 384 patents in the 15 years between 1974 and 1988; the Republic of Korea granted 436 patents in the 13 years between 1976 and 1988; and China, with a relatively new patents system, had granted 279 patents by 1988. (*op. cit*., p. 563). Of the patents, 68 per cent were granted to foreigners in Brazil, 63 per cent in India, 44 per cent in the Republic of Korea and 36 per cent in China (*op. cit*., p. 562).

[49] “Intellectual property is an essential component of an environment conducive to the creation and international transfer of technology” (see *UNCTAD IX, Midrand* Declaration and a Partnership for Growth and Development, para. 37).

[50] The Uruguay Round of Multinational Trade Negotiations, *Final Act Embodying the Results of the Uruguay Round of Multinational Trade Negotiations*, Marrakesh, Morocco, 15 April 1994.

unreasonably restrain trade or adversely affect the international transfer of technology.

The strengthening of IPRs as a result of the implementation of the TRIPS Agreement is likely to have a mixed effect on the transfer of ESTs to developing countries. On the one hand, stronger and broader IPRs would enhance the bargaining position of technology holders vis-à-vis potential licensees. On the other hand, the implementation of stronger protection of IPRs in developing countries may be a necessary condition for a transfer of technology to take place.

The TRIPS Agreement provides a number of mechanisms aimed at fostering competition and innovation and restoring market forces when these are unjustifiably suppressed or distorted by the exercise of patent rights. One such set of mechanisms is dealt with under the heading of other "uses without the authorization" of the patent-holder. Developing countries may require "uses without the authorization" of the patentee on a variety of grounds, which are not limited by the Agreement. However, these impositions are subject to conditions that attempt to balance the patentees' interests against those of the public, and these might constitute impediments to an effective transfer of ESTs to developing countries.

Both the public-interest clause and the measures to prevent abuse (respectively stipulated in Article 8 of the TRIPS Agreement) can justify resorting to "uses without the authorization" of the right-holder (compulsory licensing). Article 31 requires the would-be licensee to seek a negotiated license from the right-holder and, failing this, to pay equitable compensation. The refusal to grant a license on reasonable terms and conditions could, in itself, justify the granting of a compulsory license.[51] However, the implementation of such provisions in practice remains to be analyzed and no actual cases were found in the preparation of this study.

The requirement that would-be compulsory licensees negotiate seriously with right-holders to obtain exclusive licenses on reasonable terms should increase the pressure on patentees to accommodate pricing and other strategies to local market conditions. This, in turn, should lessen the need for governments to seek compulsory licensing in the first instance. Thus, the TRIPS Agreement does not limit the grounds under which a compulsory license may be granted. It is useful to recall that Agenda 21 (Article 34.18.e) suggested the adoption of compulsory licenses in the field of ESTs to prevent the abuse of IPRs, subject to the relevant international conventions and to "equitable and adequate compensation". Again, it appears that this provision has not yet been applied and no cases were found in the preparation of this report.

V. BUILDING NEW TRANSFER AND DIFFUSION MECHANISMS

The set of policies and measures that can be undertaken to enhance transfer of ESTs

[51] The practical effects of Article 31 of the TRIPS Agreement ("Other use without authorisation of the right holder") in the context of the overall provisions of the Agreement and of the Paris Convention are a subject that merits further examination and research.

needs to take into account the prevailing policy orientation towards technology transfer, as shown in this study. Technology can be transferred through various channels such as trade (purchase of equipment, final goods, licenses and services); investment (foreign direct investment and joint ventures and production); and the use of scientific results available in the public domain for the development of technologies within a firm. The importance of the different channels varies over time, involves the recipient and the supplier of technology in different ways, and requires different information and technological capabilities, and hence different sets of policies.

An effective process of technology transfer is essentially a process of “innovation” in product, process, organization or management routines for the firm adopting the new technology. A considerable body of literature dealing with the process of innovation shows that this is fundamentally an interactive process.[52] Firms are stimulated to change through their interaction with other firms - suppliers or clients - research institutions, business associations and other actors. Product design and quality improvements, adaptations required in order to utilize local inputs, and process changes that increase efficiency and reduce costs, may all be stimulated and in some instances supported through interaction amongst users and producers or between producers and other actors in the environment - local or long-distance. An effective process of technology transfer, therefore, will require interaction between user firms and the producers and/or adaptors of technology. The policy environment is also critical in stimulating innovation, since it shapes the parameters within which decisions concerning the adoption of a new product, process, organizational structure or management routine are taken. Developing appropriate policies will thus require further study at the national level in those countries interested in promoting the use of ESTs by locally based firms.

A number of factors have to be considered. These include lack of interest or stimulus on the part of the originating R&D institutions in engaging in the technology transfer/commercialization process due to cultural norms (researchers versus entrepreneurs), lack of knowledge of the process, and lack of financing and institutional support in-house for finding potential partners. There are a number of possible solutions to these problems, particularly if the objectives are (a) to ensure that publicly funded R&D is commercialized, and (b) to facilitate the transfer of ESTs to developing countries and countries with economies in transition, thus avoiding their falling further behind in meeting the goals of Agenda 21. It should be noted that, in the developing countries, the vast majority of firms are small. Many are family-owned and have a tendency to be risk-adverse, particularly when it comes to the introduction of innovations based on unproven technologies. Support structures that provide assistance in training and in debugging will have to be put in place where they do not now exist. Most of these firms have difficulty in securing loans from local credit institutions, and financing will be needed to make change possible. Few have scanning and networking capabilities that would enable them to access and evaluate technological information. There is a need, therefore, to develop a support structure designed to provide information on ESTs available and ensure an effective transfer of these technologies to SMEs. Some of the broader mechanisms required

[52] See, particularly, B. A. Lundvall, "Innovation as an interactive process: From user-producer interaction to the national system of innovation", in G. Dosi et al., eds.(1998), *Technical Change and Economic Theory*, London, Pinter Publishers, pp. 349-370.

to facilitate the transfer of ESTs to developing countries are discussed below.

An effective transfer and diffusion of ESTs to developing countries would thus require mechanisms that could cover the following set of tasks:

1. the identification of ESTs;
2. their acquisition;
3. the assessment of their utility to developing countries;
4. (a) the identification of potential users, most probably amongst SMEs in developing countries;
   (b) sensitizing them to the need to adopt environmentally sound technologies; and
   (c) creating an awareness of the accessibility of such technologies and the benefits (financial, quality of output, image/marketing, etc.) that they would bring to the firm;
5. to ensure the adaptation of these technologies to these users at minimal cost;
6. to finance the process of adaptation;
7. to maintain contact with the users for follow-up and debugging.

A technology pool, such as an environmentally sound technology rights bank (ESTRB), could be one potential solution to the problem of identifying and acquiring environmentally sound technologies, i.e. tasks 1 and 2 above. Such a mechanism would closely cooperate with and complement the existing initiatives and networks described in chapter III of this study. As shown in this study, most technological breakthroughs in environmental protection and conservation are of a proprietary nature. An ESTRB would act as an intermediary for proprietary ESTs by making them available to developing countries under conditions to be negotiated on a case-by-case basis. As technologies may include both patented and unpatented know-how, an ESTRB would have to acquire not only the patent rights to but also the related enabling knowledge for each specific technology in order to make possible the mastery of the technologies in developing countries.

While the technology owner, either private or public, would retain exploitative rights in the industrialized regions, the mechanism would aim to increase developing countries' access to environmentally sound technologies by: (a) negotiating the acquisition and diffusion of such rights with private firms and other technology developers, including public institutions, on a fair commercial value basis; (b) accepting patents as donations from both private and public sources; and (c) initiating licenses, commercial development agreements and "use" agreements with suitable "users" in the developing countries, under conditions to be negotiated case by case. The success of such a mechanism will depend on, among other things, reliable methods for the identification of available ESTs that could meet the needs of developing countries and are affordable. In this respect, there is a need for methodologies to develop inventories of ESTs and for the assessment of identified ESTs and their adaptability to developing countries' needs.

The effective transfer of technology, however, does not depend solely on the accessibility and the terms and conditions for the acquisition of technology, as is often assumed, but also on local demand conditions and, as stated in Agenda 21, on the prior "building of technical and managerial capabilities". An important element in the building of local capability for transfer of technology and innovation is the development of networks. The conditions for building such networks and possible structures are identified below:

First, the technology in question would have to be assessed in order to determine whether it will be usable by developing countries. It might be useful at this stage to put the originating research institute into contact with a network of other R&D institutions in developing countries which could assess the technology. Research and Technology Development Institutions (RTIs) that include local RTIs in both developed and developing countries already exist.[53] The principal tasks of this network would be to assess the utility of ESTs for potential users in the developing world (task 3, above), and ensure the adaptation of these technologies to user firms (task 5). The bulk of the work on adaptation would be undertaken by local RTIs in developing countries to reduce costs and ensure the capacity to undertake debugging (task 7) activities as required by their clients. Partnerships within the network between RTIs in developed and developing countries would provide additional capacity-building and facilitate debugging and the further adaptation of the technology, should these activities be necessary. The network would work closely with the private sector.

Second, adaptation and further development of the technology might be required in order to move it from the laboratory to potential users. Here partnerships could be explored involving the originating R&D institution and R&D institutions in those countries where a potential exists for applying a technology. Chapter III provides a number of examples of such partnerships.

Third, it would be necessary to encourage the development of pilot projects at home and abroad to show potential users that a technology is viable. The initiatives by the European Union described in chapter III could serve as a model for such projects.

Fourth, it would be necessary to support linkages between research institutes, where the publicly funded R&D on ESTs was being carried out, and R&D institutions in other countries where there may be local user-firms (three-way partnerships). This would speed up the diffusion of the technology.

An example of a three-way partnership might appear as follows:

Foreign R&D institute -- local R&D
Institutions local firms

[53] The core for the development of a network of RTIs could, for example, be found in two existing networks: the World Association of Industrial and Technological Research Organisations (WAITRO) and the International Association of Technology Assessment and Forecasting Institutions (IATAFI), both of which draw their members from developed and developing countries. Other institutions can be progressively identified and added to this core, including regional institutions such as the Asian and Pacific Centre for Transfer of Technology (APCTT) in Asia, and national institutions, for example the Raw Materials Research and Development Council in Nigeria and the Scientific and Industrial Research and Development Centre (SIRDC) in Zimbabwe.

A variant of such a partnership might appear as follows:

Originating R&D institute -- local firm
foreign firm

To further stimulate transfer and diffusion of ESTs in developing countries, a second network consisting of Centers for Innovation and Enterprise Development (CIEDs) might also be envisaged. These Centers would be identified from among existing business-related organizations in Latin America, Asia and Africa. The primary task of the CIEDs is to identify potential users and explore business opportunities for them, sensitize them to the need to adopt ESTs, and create awareness of the accessibility of such technologies and the benefits to be derived from their adoption. The CIEDs might also facilitate the search for funds to finance the process of adaptation (task 6). However, it is anticipated that the major cost of the adaptation process would be borne by the users themselves.

Thus, following identification of potential users for each type of technology, the CIEDs would play a critical role in forming potential users into user-consortia. For example, interested leather-tanning firms, dyeing firms, printing companies, paper and pulp manufacturers, chemical companies and other heavy polluters would be brought together into consortia. These consortia would collectively fund the adaptation process in local research and technology development (R&TD) institutions either through direct contribution or through local funding available for this purpose. The CIEDs would remain in contact with consortia members after the transfer and would play an intermediary role in the event of technical problems requiring further assistance from local or foreign R&TD institutions (task 7). They would diffuse the knowledge needed to overcome such problems as it becomes available and would progressively sensitize other local firms to the benefits that might be obtained through adoption of the “new technology”. Newcomers would pay a fee equivalent to the share paid by consortia members for adaptation by local R&TD institutions. This fee would be used by the CIEDs to continue their work in the transfer and diffusion of ESTs. Since user fees would largely cover the local costs of tasks 4, 5 and 7, the role of foreign assistance in the process of transferring and diffusing ESTs could then be limited to the following activities: financing tasks 1 and 2 - identifying and evaluating the suitability and adaptability of environmentally sound technologies for transfer to developing countries and participating in the financing needed to acquire the rights to ESTs.

Such a mechanism, building on and closely working with the existing initiatives described in chapter III, and mechanisms discussed above, could create a framework within which the necessary identification, assessment, adaptation and post-transfer follow-up could take place. It ensures that transfer of ESTs is effective by building technological capacity in both local firms and research and technology institutions, and promoting the interaction between them that is needed to stimulate and sustain a process of innovation. It does so, moreover, without prejudice to the form in which ESTs are acquired. Incremental support would be required to launch the process of creating a mechanism of this sort on a global scale.

VI. MAIN FINDINGS AND ISSUES FOR FURTHER CONSIDERATION

The findings of the study show that public sector funding remains a major source for R&D activities, although in recent years the public sector share in total R&D spending has declined in most countries covered by this study (see annex 1). Increasingly, the commercialization of publicly funded technologies has been emphasized with the objective of cost recovery and market-based diffusion of technologies.

In all countries, the role of publicly funded R&D in the development of ESTs is significant. Through both policy and public funding, the public sector continues to be an important motor in the development of ESTs. As figure 3 shows, there are many steps in the development, transfer and diffusion of ESTs for which public policies, initiatives and support structures provide a critical stimulus.

Although, as figure 3 also illustrates, ESTs are in some ways different from other technologies, the country case studies reveal that, in general, public control or ownership of the results of publicly funded R&D, including ESTs, and their transfer and commercialization is rarely exercised. In some countries, ESTs generated from publicly funded R&D activities are owned either directly by the research institutions concerned or through some form of co-ownership arrangement with the company(ies) commercializing the technology; in others, ownership is fully transferred to private entities. But overall, public sector involvement in the financing of R&D has few implications for the mode of ownership, commercialization, diffusion or transfer of these technologies.

The study reveals that both developed and developing countries undertake R&D on ESTs and that a broad range of ESTs is available to meet the needs of developing countries and countries in transition. However, only a small proportion of ESTs resulting from publicly funded R&D are patented, commercialized or transferred.[54] Among the reasons highlighted were the costly and lengthy process of obtaining patent rights, the lack of knowledge about the business aspects of technology development, the absence of an incentive structure conducive to the commercialization of research results, and the fact that much of the R&D activity is still too upstream in many countries. Consequently, relatively few of the technologies generated in public R&D institutions and laboratories reach the development, commercialization and transfer stages, and the mechanisms available for moving publicly funded technologies from public institutions to the commercialization stage are limited. In cases where patents on publicly funded ESTs were obtained and successful transfer has taken place, partnership with private enterprises has often been the main channel, though even here much more might have been expected.

[54] See, for example, *BMBF* (1997), p. 65.

Figure 3
Similarities and differences between ESTs and other technologies

	ESTs	Other technologies
Main drivers	Public policy-regulatory policies, or their absence; multilateral environmental agreements	- Market forces: demand, competition, production - Bottlenecks, etc.
Finance	Public funding vital; lack of venture capital	Largely private funding, including reinvested earnings, venture capital and sale of stocks
Location of R&D	Mainly in universities, public R&D institutes and laboratories	Mainly enterprise-based
Mechanisms for transfer	Transfer to private sector; emerging role for public-private sector partnerships (e.g. university-enterprise cooperation)	New structures through inter-firm R&D collaboration as well as partnerships of firms with public R&D
Commercialization	Increasingly private; many SMEs involved; support structures and incentives needed	Private
Application	Often site or locationally specific applications, some ESTs could be applied globally (e.g. CFC substitutes)	Increasingly global
Transfer to developing countries and countries with economies in transition	Commercialization; ODA; sometimes with funding from multilateral sources (e.g. multilateral fund under Montreal Protocol, GEF)	Almost exclusively through private commercialization

In both developed and developing countries, it is necessary to strengthen the policy framework and the support structures needed for the commercialization and transfer of publicly funded ESTs within and between countries. From the limited transfer and commercialization of ESTs resulting from publicly funded R&D within domestic and international environments and from the numerous statements to the effect that such technologies should be transferred, it is evident that market mechanisms are not yet sufficient to ensure a broad diffusion of ESTs everywhere. At the same time, however, global environmental degradation is worsening. Some of the key elements in the transfer of ESTs and mechanisms likely to bring about a more effective transfer of technology to all countries, particularly those in the developing world, have been discussed in chapter V. In this context, there is a need for governments to develop a variety of demonstration projects (including the pilot phase) for the transfer and diffusion of publicly funded ESTs, create better sources of information about the availability of ESTs originating from public R&D, and stimulate partnering between public and private sector institutions in order to ensure the transfer and more rapid diffusion of ESTs. This point may also require considerable sensitization of the R&D community to the need to transfer their results to users, either through working together to further develop the process/product, and build a pilot plant for testing and adaptation, or through licensing and other commercial means.

VII. IN SUMMARY

Many governments covered by this study explicitly refer in their public policy statements to the need to share ESTs with the developing world. Nevertheless, they have not yet incorporated formal policy measures to implement the recommendations contained in Agenda 21 on the issue of technology, including publicly owned technologies. Overall, and relative to these public policy statements, the extent to which and the pace at which ESTs are being transferred to developing countries and countries with economies in transition appear inadequate when compared with the expectations raised prior to and at the United Nations Conference on Environment and Development (UNCED) in 1992.

The problem, however, is not one of incompatibility between the policy objective of public R&D funding for domestic industrial competitiveness and the need for accelerated technology transfer in the area of ESTs. Rather, as the case studies illustrate, publicly funded technologies are increasingly commercialized on the basis of market mechanisms and cost recovery criteria. Most governments equate transfer of technology with commercialization, including in the area of ESTs. With this understanding, they appear to fulfil their mandate under Agenda 21 by transferring the results of publicly funded R&D to private domestic firms. Much of the publicly funded R&D, however, is never transferred, not even to local firms.[55] There is thus considerable room for the role that governments could play in exploring new mechanisms for the transfer and diffusion of ESTs resulting from publicly funded R&D.

While the predominant pattern for the transfer of ESTs, both at the national and international levels, is “commercialization”, some efforts have been made to aid the process of transfer of ESTs through bilateral and multilateral initiatives which are of a “classical” ODA type or are based on promoting new forms of public-private partnership for technology transfer that involve some public support. Thus, as shown in this study, several countries have launched initiatives, cooperation programmes and pilot projects that could serve this purpose, including policies and mechanisms to ensure financing of the various phases in the process of technology transfer. A number of these - which have been described in chapter III - are innovative models of technology transfer which could be adopted to accelerate the implementation of technology-related provisions in Agenda 21, including those referring to publicly owned technologies. These initiatives have wide-ranging objectives: creating awareness; finding partners; launching a pilot project; developing policies and programmes that encourage R&D institutions to transfer technology; creating adequate funding mechanisms for them; and finally, establishing policies that actively pursue technology partnership among enterprises. While these are promising developments, they are often scattered individual programmes, and funding for such activities remains relatively low.

In the above context, new policy initiatives may be required and support structures need to be strengthened. Thus, some of the initiatives discussed in chapter III deserve further attention. While an assessment of these programmes goes beyond the scope of the present study, this could be one area for further investigation by the Commission on Sustainable Development. Such a study could focus, in particular, on whether the initiatives identified above might concentrate more on publicly funded or publicly owned technologies than they currently do, especially with regard to technologies that are not being commercialized. Another focus could be on increased cooperation between the initiatives already in place for ESTs'

[55] Up to two-thirds, according to the innovation literature.

transfer and public R&D institutions, which usually lack the budget needed to carry out the transfer themselves. Linkages between ODA and public R&D institutions could improve and strengthen the transfer of ESTs and prevent companies in the developing world from falling further behind in the use and diffusion of ESTs. Incorporating the transfer of publicly funded ESTs into ODA policies could also be considered. Chapter V describes how new transfer and diffusion mechanisms could bring all these elements together.

Another area for further investigation could be the legal and institutional obstacles confronting the transfer of ESTs. Chapter III briefly illustrated some of these, and chapter IV pointed out that the legal and institutional framework governing the commercialization and transfer of ESTs does not generally differ from that of technology in general. Here one could argue that governments might consider exploring the possibility of exempting ESTs from some of the relevant legal provisions. However, given the difficulty in defining "ESTs" in the first place, this would require reaching a common understanding as to what types of technologies could be considered for such exemptions. The technologies listed in figure 2, as well as those needed under multilateral environmental agreements, could form the core of such a list. It would be more difficult to include ESTs with dual-use applications. Generally, in our survey of policy and institutional factors, IPRs -although sometimes involving costly and lengthy processes - did not seem to be the major obstacle in the transfer of ESTs. On the contrary, it was argued in the discussion that the presence of an effective IPR system facilitates technology transfer. On the other hand, provisions that do not permit the transfer of publicly funded technology to firms in other countries - even when no domestic firms are ready to commercialize them - could be regarded as an effective obstacle to the diffusion of ESTs.

As the above summary illustrates, there is considerable room for action by governments committed to the broad diffusion of ESTs on a global level, particularly of technologies that are the result of publicly funded R&D. Specifics could be built into the agreed recommendations of the International Expert Meeting in Kyongju for the sixth session of the Commission on Sustainable Development.

ANNEX I

GROSS DOMESTIC EXPENDITURE ON R&D (GERD) PUBLIC PERCENTAGE OF TOTAL GERD, 1985-1995

Year/type	**1985**	**1990**	**1995**
Country grouping	**Public % of total GERD**	**Public % of total GERD**	**Public % of total GERD**
Overall OECD	43.0	37.8	34.5
United States	50.3	43.8	36.1
Canada	48.9	44.3	37.7
European Union	44.4	40.9	33.1
United Kingdom	42.2	35.5	33.3
France	52.9	48.3	--
Japan	21.0	18.0	22.4
Germany	37.6	33.9	37.1
Korea (Republic of)	--	17.0	18.2
Czech Republic	--	30.6	34.9
India	88.5	87.3	84.6
Brazil	--	--	82.0*

Sources: OECD, UNESCO, and various national sources compiled by UNCTAD.
Note: * = Year 1994.

ANNEX II

LIST OF CONTRIBUTORS TO THE PROJECT AND STUDIES UNDERTAKEN

A. Country case studies:

Brazil:	Ms. Léa VELHO, and Mr. Paulo VELHO, University of Campinas, São Paulo.
Canada:	Mr. Trent GOW and Mr. Christopher HILKENE, Thompson Gow and Associates, Toronto.
Czech Republic:	Mr. Bedrich MOLDAN, Charles University, Prague.
Germany:	Dr. Hans-Peter WINKELMANN, Institute for Environmental Research (INFU), University of Dortmund.
India:	Mr. Upendra TRIPATHY, Director, Environment, Government of India, Bangalore Karnataka.
Japan:	Dr. Shuichi SASAKI, Global Industrial and Social Progress Research Institute, Tokyo, and Mr. Shouchuan ASUKA-ZHANG, Center for Northeast Asian Studies, Tohoku University, Sendai
Korea, Republic of:	Professor Il Chyun KWAK, Department of Regional Development, Kyungwon University.
United Kingdom:	Mr. Andrew J. BLAZA and Ms. Rita van der VORST, Imperial College Center for Environmental Technology, London.
United States:	Mr. Woodrow CLARK Jr., University of California at Davis and Aalborg University, Denmark.

B. Legal regimes studies:

MERCOSUR	Mr. Carlos CORREA, University of Buenos Aires,
United States:	Ms. Rebecca EISENBERG, University of Michigan Law School

C. Study on role of universities in the generation of ESTs:

Professor Kunsoo KIM,
Department of Chemical Engineering, Columbia University, New York

D. Preparatory project group

L. Mytelka, P. Roffe, D. Koenig and T. Tesfachew,
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PART II

THE ROLE OF PUBLICLY FUNDED RESEARCH IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES

Country case studies

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY-OWNED TECHNOLOGIES IN THE TRANSFER AND DIFUSSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES (ESTs)
THE CASE OF BRAZIL

by
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I. INTRODUCTION

The aim of this paper is to present data gathered on the state of the art of the development, promotion and adoption of environmentally sound technologies (ESTs) in the public research sector in Brazil. To achieve this, several interviews were carried out with different actors who play a role in the design and/or implementation of the policies which, in an explicit or implicit way, relate to this issue in the different administrative spheres.[1]

At the level of the States of the Federation, São Paulo was the only one to have some of its institutions chosen for this study. This was due to the proportion of its contribution to GNP (more than 40 per cent of the total), besides the ease of contact and access for the purposes of this research.

At the federal level, in addition to the Ministry of Environment, several other institutions were selected, contacted and visited due to their activities directly or indirectly related to sustainable development. The Ministry of Science and Technology, for instance, was selected because it is allocated a significant portion of the national research and development (R&D) budget. These financial resources are made available both to universities and research centres of the public sector and, to private enterprises, through different funding lines for the development of R&D activities. It is understood therefore, that all efforts and activities of technological development, be they nationally produced or, due to the absorption of ESTs by firms through import and adaptation, should in some way be represented in the chosen sample.

This study was significantly affected by the difficulty in obtaining information related to the development of ESTs in Brazil. This can be attributed to at least two factors. Firstly, it arises from the fact that the very concept of ESTs has not yet been incorporated by Brazilian public institutions-be they in charge of R&D policy, funding or performance. Consequently, there is no EST category in their portfolios for the purpose of classifying projects. Secondly, Brazilian public

[1] Annex I lists all the institutions that were contacted and Annex II identifies those responsible for the information obtained in each institution. A guideline of the information desired was forwarded by fax to some of the people. Others were personally interviewed, face-to-face, by telephone or by e-mail.

institutions are on the whole ill-equipped and lack the ability to manage, monitor and evaluate their own activities. This state of affairs in a way reflects the lack of demand for information and public accountability from policy makers and from other segments of society.

Indeed, the Federal Government, in its Annual Report on the Activities of the Ministry of Science and Technology (MCT), recognizes that a "limiting factor in the performance of the S&T sector has been the deficiency in the monitoring and evaluating practices as a mechanism for the improvement of the planning and coordination process". This lack of articulation and inability to monitor and evaluate research funding is repeated at the States' level, where the difficulty in obtaining data is even more striking.

II. ESTs: THE OVERALL ROLE, SCOPE AND RELATIVE IMPORTANCE OF PUBLICLY FUNDED RESEARCH

The structure which supports and fosters science and technology (S&T) develop ment in Brazil is fairly diversified. Taking into account the fact that Brazil is a developing country, it possesses and mobilizes a respectable number of institutions devoted to funding and implementing R&D activities. Nevertheless, the coordination of these activities alongside other public policies is considered unreliable.

The central coordinating organ of S&T policy in Brazil is the (MCT). As such it devises and coordinates government S&T policy and activities in all fields of knowledge, either directly or through subordinate agencies, such as the National Research Council (CNPq) and the Financier of Studies and Projects (FINEP), in addition to several research institutions.

The national indicators of science and technology produced annually by the Ministry of Science and Technology show that from 1990 to 1994,[2] science and technology expenditure remained at around 0.7 per cent of GDP. Brazilian GDP in 1994 was US$ 555.3 billion, with expenditure on S&T of US$ 3.9 billion[3].

The principal source of funding for S&T activities has historically been the public sector: in 1994, 57 per cent of the resources came from the Federal Government, 17 per cent from the State Governments and 8 per cent from public enterprises. It is estimated optimistically, since it was the first year in which information of this nature was collected from the private sector where the concept of investment in S&T is flexibly interpreted that, this sector provided 18 per cent of

[2] The last year for which information is available and not subject to revision due to modifications in the data-collecting methodology. Data for 1995 can be found on the MCT homepage, but they are estimates, awaiting confirmation.

[3] The more recent methodologies incorporated into the data-collecting process and the drawing up of S&T indicators-such as the inclusion in federal R&D expenditure of the salaries of full-time professors in the public universities-have increased the amount of expenditure on S&T to 1.1 per cent of GDP. This new procedure has been vigorously criticized by the research community, who refer to it as "make-up" or "manipulation of the data".

the investment resources for R&D. Such data highlight the fundamental importance of public resources for R&D investment in Brazil.

Publicly funded R&D thus comprises about 82 per cent of the overall R&D expenditure in Brazil. Moreover, as stated above, the Federal Government is the main R&D financing entity since, through its diverse ministries, it is responsible for 57 per cent of the investment resources for these activities. Part of the resources made available by the Federal Government for R&D expenditures are allocated to public organs or enterprises, which themselves carry out R&D activities. This is the case, for instance, of the resources allocated to the Ministry of Agriculture, Food Supply and Land Reform (MAARA), which is responsible for about 13 per cent of federal government financing for R&D activities, and which allots almost the whole of this to the Brazilian Agricultural Research Corporation (EMBRAPA). Thus, in 1994, EMBRAPA spent almost US$ 220 million, corresponding to 6 per cent of the overall R&D expenditure.

The greater part of federal resources for R&D is, however, managed by the Ministry of Science and Technology (about 42 per cent of federal government expenditure on R&D and 25 per cent of overall R&D expenditure). A small percentage of these resources is used directly by research institutes linked to the MCT and the CNPq, the rest being allocated to the funding of R&D programmes managed by the Ministry itself,[4] but mainly by CNPq and by FINEP. These funding programmes are fairly diversified, the mainstay of CNPq being the financing of projects submitted spontaneously and individually by researchers and, the provision of human resources for research, thus funding activities with no immediate return and, which are non-refundable. Traditionally, FINEP supports research projects submitted by research groups or institutions, often non-refundable, but it also has repayable financing lines for the activities of R&D in enterprises.

The other ministry which allocates a fairly significant proportion of federal resources to R&D activities is the Ministry of Education and Sports (MEC), to which all the federal public universities (responsible for a large percentage of the research carried out in the country) are linked. MEC has a special agency named CAPES (Brazilian Agency for Graduate Education), responsible for the support of graduate education, that is, for funding and assessing Masters and Doctoral programmes. MEC is responsible for 21 per cent of federal government expenditure on S&T and 12 per cent of overall R&D expenditure.

Little information is available with respect to the allocation of R&D expenditure in private enterprises. Nevertheless, it is well known that enterprises located in Brazil, whether they be national or subsidiaries of multinationals, tend to meet their innovation needs by buying technologies generated abroad. It is also common knowledge that very few multinational enterprises have in-house R&D activities in their subsidiaries in developing countries. Therefore,

[4] One example of R&D funding programmes administered by the MCT itself is the Support Programme for Technological Capabilities in Industry (PACTI), which encompasses such diverse instruments as the Alpha and Omega Projects, potential promoters of cooperative research in the ambit of the Federal Government. These instruments, which are little used as yet (only 13 enterprises have had their projects approved in the Omega project and just one Brazilian State has implemented something within the Alpha project), expect to be able to promote considerable participation of enterprises in the financing of R&D activities.

it is to be expected that most of the resources that private enterprises claim as being spent on R&D are in fact related to their funding R&D activities in or, contracting related services to, public universities and research institutes. Even this modality is not well developed in Brazil: for example, the University of Campinas, which is a typical research university located in one of the most heavily industrialized regions of the country, has less than 8 per cent of its projects funded by the private sector. Similarly, only 6 per cent of EMBRAPA's budget comes from research contracts with the private sector.

In view of the above, it can be concluded that the private sector's participation in the financing of R&D activities in Brazil is quite limited when compared to the role and scope of publicly funded research. This general pattern also applies in the case of generating ESTs.[5]

Even though public investment is far more important than private in generating ESTs, the proportion of the former is quite small in all the institutions, from which we obtained information. Owing to the difficulty of dealing with all the information obtained in a consolidated way, and so as not to run the risk of including incommensurable quantities, we shall present the data for each of the institutions studied, at the levels of the Federal Government and the State of São Paulo. An attempt to aggregate the information obtained from all the institutions which responded to our appeals is made at the end of this section.

A. Federal Government

In May 1995 a working party[6] called "Green Protocol" was set up in the Federal Government, with the explicit aim of "developing strategies and mechanisms for the incorporation of the environmental variable in the management and concession of official credit and fiscal benefits" for new projects to be funded with public resources. Taking into account the fundamental role of official funding agencies in implementing environmental policy through preventive action, the working party recommended a more forceful approach by those institutions when analysing projects and granting credit with government resources. Although the members of the working party asserted that the funding agencies represented were already asking that the norms of environmental licencing be complied with to obtain grants using official resources, they

[5] This state of affairs could change over the next few years, with an increase in the participation of private resources in R&D activities, thanks to Act No. 8.661 of June 2 1993, regulated by Decree No. 949 of October 1993, known as the "Programme for Technological Development in Industry and Agriculture/Cattle Raising" (PDTA/PDTI). For every monetary unit of fiscal exemption conceded by the Government, this law permits the enterprises to invest R$3,41 (three reais and forty-one cents) in R&D activities. The aim of this programme is to "stimulate entrepreneurial investments in research and technological development, with a view to increasing the competitiveness among Brazilian industries and agricultural/cattle raising concerns, through a permanent structure of technological generation."

[6] The working party for the drawing up of the Green Protocol comprised representatives of the following institutions: Ministry of Environment, Ministry of Agriculture, Ministry of Finance, Ministry of Planning, Brazilian Institute for the Environment (IBAMA), Central Bank, National Bank for Social and Economic Development (BNDES), Bank of Brazil, Federal Savings Bank (CEF), Bank of Northeast of Brazil, and Bank of Amazon SA.

noted that “it is evident that the observation of the environmental legislation is more effective in industrial projects, specially those situated in urban areas or that require large amounts of funds”.

Thus, the idea was that the evaluation of projects to be funded with public resources should incorporate the environmental costs, and in this way promote the recuperation and protection of the environment. The motivation of the Government in taking this initiative lies basically in boosting the competitive advantage of local firms which have often been precluded from export given their non-adoption of ESTs to respond to specific environmental needs. This is the case, for example, of the densely populated urban centres such as the city of São Paulo where during several days of the year air pollution reaches unacceptable levels.

At the federal level, besides the more general directive in relation to resource allocation for development within the parameters of environmental protection, there are a few disconnected efforts to finance ESTs developed by various institutions. In an attempt to identify where these funding activities for ESTs have been developed, various institutions conducting standard research and research R&D funding, related to the environment were contacted. The results were as follows:

1. EMBRAPA: Brazilian Agricultural Research Corporation

Created in 1973, EMBRAPA is a public company linked to the Ministry of Agriculture, Food Supply and Land Reform (MAARA) and has the institutional mission to generate, promote and transfer technology and know-how for the sustained development of farming, agribusiness and forestry segments for the welfare of society. Spread throughout the country, EMBRAPA has 49 research centres focusing either on agricultural products, on natural resources or, on services and, it employs over two thousand researchers, all of them trained in centres of excellence in Brazil and abroad.

Three methodologies were used in an attempt to identify the efforts of EMBRAPA in the generation of ESTs. The first involved interviewing some of EMBRAPA’s technicians and officials and talking informally with others in an attempt to grasp their perception of the relative importance of the generation of ESTs in the overall research effort of the institution. According to them, a considerable proportion (over 50 per cent, as stated by one high-ranking official) of the R&D activities of this institution are directly or indirectly aimed at the generation of ESTs. In these estimates, however, a rather flexible concept of ESTs was used, which included even the generation of new plant hybrids. Thus, it appears that these estimates are not very reliable.

The second methodology was based on the analysis of EMBRAPA’s annual report of activities in 1996. The latter has a specific section showing all results produced by the research projects carried out in that specific year by enterprises that gave rise to new technologies related to plants, animals, processes and equipment. From the succinct description of each one of the 57 listed results, it was possible to identify which of them could be considered ESTs and to which specific type of EST each one belonged. This is shown in Table 1 below.

Table 1
Proportion and types of ESTs in the technological results of EMBRAPA's research projects in 1996

Types of ESTs	ME	PC	EP	PD	EST	Total
Results (number)	6	4	2	9	21	57
per cent Type of ESTs	28.6	19.0	9.5	42.8		

Notes: ME = Monitoring and/or Evaluation activities; PC = Process Technology;
EP = End of Pipe Technology; PD = Product Technology.

Table 1 shows that 21 or 36 per cent of the technologies generated by EMBRAPA in 1996 can be considered ESTs. Most of them (about 43 per cent) were of the type PD (product technology) in accordance with the concepts used in this study. Within this type for instance, we included new varieties and crops of plants which incorporate the characteristic of resistance to diseases and insects, to avoid, or greatly diminish, the use of pesticides. We may, however, have been too optimistic in our classification since we proceeded with limited information about the new varieties. It may well be that those new crops or varieties, albeit resistant to diseases or insects, need more fertilizers and, in this case, they are certainly not ESTs.

In the category of EP (end of pipe technologies), we have for instance, classified technologies for the treatment of swine excrement in anaerobic lagoons. EMBRAPA also reports the generation of technologies which could be considered type ME (Monitoring and Evaluation) that, on the whole, seek to increase information about the natural environment in order to evaluate and monitor changes and impacts. The typical technology classified under this label is the spatial monitoring system for land use which consists of providing precise information to planning organs and to segments of society, offering a panoramic and objective vision of probable environmental impacts from each alternative use of land. Finally, we have classified as PC (process technologies) the type of ESTs which basically concerns technologies of biological control of plant diseases and insects. In 1996, four new technologies in this category were released by EMBRAPA.

Thus, using the procedure described above, we have found that as far as the number of projects in 1996 is concerned, EMBRAPA was quite active in generating ESTs for the agricultural sector. This picture however, is somewhat different when viewed from the actual investment of the institution in ongoing research projects. This was the third methodology we used to estimulate EMBRAPA's effort in the generation of ESTs.

At present, EMBRAPA is developing 619 research projects, organized into research and development programmes involving evaluation, handling and recuperation of natural resources, grain production, genetic resources, biotechnology, environmental protection, family agriculture etc. However, as in all the other institutions studied, there does not appear to be any concern in EMBRAPA about categorizing projects according to whether the technologies to be developed are environmentally friendly or not. Thus, after a series of interviews which sought to identify the characteristics of the ongoing projects, it was necessary to prepare, from the National Research Directory of that Corporation,[7] a list of projects which included at least one characteristic that would allow it to be categorised as an EST-generating project. Table 2 below shows in a succinct way the results of this work. Detailed results of the research, by research programme, are shown in Table A of Annex III.

Table 2
EMBRAPA's expenditures and percentage of total budget for developing ESTs in the agricultural sector - 1996

1996 Budget (R$1000)	**Total Spent in ESTs Projects**	**Percentage Spent**
565,700.00	44,520.00	7.87

The data contained in Table 2 show that, at least as far as resources invested are concerned, EMBRAPA has a considerably smaller involvement in the generation of ESTs than was found with the previous research methodologies. Some experts who saw this data tended to consider this last estimate, around 8 per cent of EMBRAPA's overall budget in 1996 in ESTs development, as being more realistic. Bearing this fact in mind, we proceeded to classify the identified projects into different types of EST as follows: EP (end of pipe technologies), RT (remedial technologies), PC (process technologies), PD (product technologies) and ME (monitoring and evaluation technologies). The results found are shown in Table 3.

[7] PRONAPA: *National Programme of Research and Development of Agriculture and Cattle Raising.*

Table 3
Proportion and types of ESTs in the ongoing research projects of EMBRAPA 1996

Types of ESTs	**RT**	**ME**	**PD**	**PC**	**EP**	**Total**
No. of EST projects	33	37	11	68	-	149
% of Type of ESTs	22.1	24.8	7.4	45.6	-	

Notes: RT = Remedial Technology; ME = Monitoring and/or Evaluation activities;
PD = Product Technology; PC = Process Technology; EP = End of Pipe Technology.

It is interesting to note that a significant proportion of the number of ongoing research projects at EMBRAPA are related to ESTs development –of the 619 ongoing research projects, 149 (about 25 per cent) may be related to ESTs. These however, represent only about 8 per cent of the research budget of the Corporation. Another striking feature is that considering results (Table 1) and investment (Table 3) according to the types of ESTs there is a notable different concentration in each effort. While RT (remedial technologies) which includes for example, technologies for recovering degraded pasture lands, accounts for 33 per cent of the ongoing research projects of EMBRAPA (Table 3), this category does not even appear when results are considered (Table 1). There is also a significant discrepancy in the proportion of PC (process technology) when we look at results and ongoing projects.

2. CNPq: National Research Council (Ministry of Science and Technology)

The CNPq has various instruments to fund research which can in some way be related to ESTs. Two of them are more representative and will be considered here: international cooperation and the RHAE Programme.

The RHAE Programme. This is a programme for qualifying human resources in strategic areas. This programme has as its objective “to contribute to human resources capabilities at all levels, in the priority areas for technological and industrial development in accordance with the directives of industrial policy, of external commerce and industrial competitiveness and, those related to human resource development detailed in the Pluriannual Plan 1991/1995 of the SCT/PR”. The environment is one of the six areas considered eligible for scholarships for study and research projects. Others are: biotechnology, new materials, informatics and microelectronics (hard and software), fine chemistry and basic industrial technology. The number of scholarships and the amount of resources allocated to this area can be seen in Table 4.

Table 4

Number of and expenditure on scholarships granted to the subprogramme environment as percentage of programme RHAE (1992-1997)

	1992	**1993**	**1994**	**995**	**1996**	**1997**
Rhae Total*	8301	3950	6843	9292	459	2104
Environment	796	547	804	309	60	277
per cent Envir./Tt	9.58	13.84	11.75	3.32	13.07	13.17
Tt/Year**	5174,0	3555,5	4936,6	1137,1	4159,2	2351,7

Notes: * = Total of scholarships awarded in all areas; ** = Money earmarked for environment scholarship in R$ 10^3 calculated as a function of the average annual value of the scholarship (Since scholarships can be provided for a few months or several years, the average value was calculated by adding the amount paid for all scholarships granted in the year and dividing the total amount by the number of scholarships granted in the same year).

International Cooperation. In this programme, the CNPq/IBAMA/DLR Agreement should be mentioned.[8] To date, 11 projects have been or are being developed in this programme at an estimated total cost of R$800, 000. Although this figure was provided by CNPq, it was impossible to obtain the desegregated amounts for each of the projects. Thus, Table 5 below lists the titles of all 11 projects and the institutions where they are carried out but does not provide specific investment figures.

[8] CNPq: *National Council for Scientific and Technological Development*
IBAMA: *Brazilian Institute of the Environment and Renewable Natural Resources*
DLR: *Deutsche Forschungsanstalt für Luft und Raumfart e.V Cologne*

Table 5
List of Projects and institutions funded within the international Cooperation agreement CNPq/ IBAMA/DLR

Title of Projects	Institutions Funded
1. Solar energy to dry tobacco leaf	Tobacco Industry
2. Environmental monitoring	Federal University of Bahia
3. Soil nitrogen fixation	EMBRAPA/Rio de Janeiro
4. Test for mercury	Centre of Mineral Technology/Rio de Janeiro
5. Heavy metal extraction	Centre of Mineral Technology/Rio de Janeiro
6. Treating mercury contaminated soil	Centre of Mineral Technology/Rio de Janeiro
7. Wall finishing	Federal University of Bahia
8. Biological tests for rivers	CDB/Joinvile
9. Low temperature waste treatment	Federal University of Rio de Janeiro
10. Biomass conversion in vitamin B12	CDB/Joinvile
11. ECOGOMAN	Private/public sectors
Total: 11 Projects	R$800, 000.

It must be pointed out that neither of these programmes has been evaluated to identify if/how the conversion of financial effort into tangible products, new technologies for example, has been achieved.

3. IBAMA: Brazilian Institute of the Environment (Ministry of Environment)

The R&D projects developed by IBAMA in the field of environmental technologies are grouped in the Development Division of Environmental Technologies (DITAM). DITAM's aim is "to seek and develop environmentally correct technologies (both processes and products) as a means of promoting sustainable development." The projects being developed by this unit are listed in table 6, with their respective costs at the end of 1997.

Table 6
Titles and cost of research projects being developed by DITAM/IBAMA

Project	Cost R$
Technologies of environment management	80 000.00
Alternative technologies to the use of chemical pesticides	82 000.00
Control of desertification	30 000.00
Reduction and recycling of residues	28 000.00
Brazilian network of environmental monitoring	50 000.00
Total	270 000.00

Source: Maria José Monteiro, technical advisor Ditam/Ibama.

4. New tendencies for funding EST projects in Brazil

Although there is no discernible trend in federal government funding of research projects which aim at contracting consultancies and developing and/or importing technologies which follow the principles of ESTs, some concrete actions are being taken. Even though concrete actions such as research funding are, as yet confined to a few organs, it has not been possible to detect a response from the research and productive sectors in the sense of producing and/or adopting a policy of technology change which would favour ESTs.

An example of financing specific lines for EST development is FINEP, which launched a funding category called GREEN FINEP. The goal of this special credit line is to create favourable conditions for the responsible development of national industry, promoting competitiveness that is compatible with the norms of environment management. GREEN FINEP is presented as “a new product which aims to encourage companies to adopt responsible policies in relation to the environment and to increase the competitiveness of their products in the external and internal markets”. FINEP emphasises in its brochure the relevance of adopting systems of cleaner environmental and technological management as a factor of “growth in sales in the external market”.

The target for this special line of funding are Brazilian companies, with or without national capital. Companies with foreign capital must possess a productive structure established in the country and their projects and processes must be developed on national territory. Among the various[9] areas for funding by this specific form of loan, are the “development, purchase, absorption and introduction of clean production technologies and technologies of corrective control associated with environment management.” The list of items that can be funded is

[9] Human resource development; development and establishment of information systems; support for establishment, adaptation and maintenance of Environmental Quality Control Laboratories; establishment of procedures to comply with the ISO-14000 series norms; establishment of environmental systems management; carrying out of environmental auditing; analysis of the life cycle of products; green stamp certification; analysis of environmental performance.

extensive[10] and the conditions of payment include an accompanying tax of 1 per cent of the financed value, besides interest rates[11] considered high even by FINEP technicians. The situation so far is that no projects have been contracted under this credit line and, despite our efforts, no information was provided concerning financial provisions for this. There are rumours, however that FINEP had earmarked nearly US$10 million for this purpose and up to the date of this report had only received a few letters of inquiry which did not ask for those resources.

B. At State level

As mentioned above, State Governments account for about 17 per cent of the overall R&D expenditure in Brazil. São Paulo State alone is responsible for more than half of this amount. The main reason for this, besides the fact that São Paulo produces almost 41 per cent of the GDP of the country, is that in this state there are various research institutes and public universities that are financed by the state Government. Among these, the Technological Research Institute (IPT) undoubtedly stands out.

(a) IPT: Technological Research Institute (Secretariat of Science and Technology, São Paulo State)

The IPT is one of the most important research institutions of Brazil in the industrial sector, although it also develops research activities with an interface with the agricultural sector. The importance of the participation of IPT in technological development in the State of São Paulo and in Brazil can be estimated from its budget for the 1996 fiscal year, which was R$220 million, representing almost one third of the Science and Technology expenditure of the State of São Paulo.

We ask the IPT to prepare, a list of all projects developed from 1992 onwards which explicitly or implicitly, considered environmental issues. This was an indirect way of answering some of the questions posed by our research. The projects selected in this search had to meet one or more requirements expressed as key words for the search, which were: environment, environmental impact, residues, emissions, garbage, recycling, compost, energy conservation, clean technologies and environmental management.

The greatest difficulty in gathering more objective data on the activities linked to EST development in IPT is, according to one of its directors, due to the fact that its organizational

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[10] Use of consultancy; in-house training for full-time staff responsible for coordination and for auditors and administrators participating in the establishment of environmental management; up to 50 per cent of the expenses of own staff for hours spent in training; short duration courses abroad to observe processes; acquisition/development of software aimed at environmental management; access to international data banks; acquisition of equipment, permanent materials, necessary work and installations for the establishment of environmental management; purchasing, development and transfer of technology associated with environmental management, etc.

[11] 24 months of grace, amortisation in up to 48 months and TJLP charges (long term interest rate) in addition to a spread of 4.5 per cent.

structure follows a horizontal model, structured by disciplines. Consequently, environmental issues that do not relate to a specific discipline permeate all the other disciplines.

An example of the difficulties found in gathering data on project funding for EST development can be seen from an interview with an IPT Coordinator. When asked how much of his budget was allotted to the development of ESTs, he replied that this percentage could vary considerably depending on the classification made. “For example”, he said “if you are considering process or new product technology, I would say a maximum of 3 per cent of the total however, if you consider the geo-technical area (environmental geology, civil or thermal construction, etc.,) then this value would rise to 18 per cent of the total”.

Furthermore, as the institution does not classify projects specifically in relation to environmental considerations we were obliged to classify all projects that showed some degree of concern for the environment, as being indirectly projects for EST development. The results are shown in table 7, which includes projects that led to patents, as well as those that were transferred to the productive sector, in the form of technology.

Table 7

Total number of projects (A) and total of projects for EST development (B) contracted by IPT between 1992 and 1997

Total (A)	**Total (B) ***	**Private Sector ****	**Concluded[12]**	**Technology Transferred**	**Patent *****
1292	78	20	58	6	3

Notes: * = All projects that showed some concern about the solution of environmental problems resulting from the productive process were considered ESTs; ** = The balance (58) is financed by public R&D agencies, universities etc., with public financial resources. The fact that the private sector is participating in 20 projects does not necessarily mean that it is financing these projects with its own resources. This is the case, as described below, of the development of biodegradable plastic by Copersucar/IPT, where Copersucar invests resources granted by FINEP, which are non-refundable; *** = All patent applications were made by private firms involved in the projects.

The IPT directors and technicians consider the most relevant and representative EST research project that for the production of bio-degradable[13] plastic from sugar cane.[14] The

[12] During the period covered in our sample (from 1992-1997), a total of 569 projects were concluded in IPT, of which 58 (10.2 per cent) included environmental issues.
[13] Totally biodegradable bio-polymers (polihydroxibutirate, hydroxibutirato-hydroxivalerato copolymer).

investments in developing this product are of the order of US$2 million, in partnership with the private sector (Copersucar),[15] financed with resources from PADCT[16]/ FINEP. The objective is the biosynthesis of a polymer and its subsequent extraction from high taste molasses (HTM) fermented with micro-organisms of the genus alcaligenes.

(b) CETESB: State Company of Basic Sanitation Technology and Environmental Defence (Secretariat of Public Services, São Paulo State).

CETESB's objective is to carry out activities related to environmental pollution control of water, air and soil through preventive or corrective measures. This includes undertaking studies and research, maintaining information and data-publishing systems, perfecting methods and processes for studies and projects and maintaining sanitary engineering and environmental control systems.

CETESB has three funds for pollution control of which only the Pollution Control Programme (PROCOP) is related to activities relevant to our interests. Even so, the research activities which this funding has historically encompassed are exclusively linked to end of pipe technologies such as the purchasing and establishment of control systems for particles material, the purchase and installation of pollution control systems (including imported machines and equipment); civil works related to the introduction of control systems in electrical and hydraulic installations and, in the operating and maintenance of these systems. Five projects were identified as being conducted by CETESB. According to one of its sector managers, "the possibility of creating a source of financing within this programme (PROCOP) for pollution prevention projects, is being studied. In this case, it would be possible to finance ESTs". CETESB claimed that it did not have sufficient information to answer any questions referring to the present stage of EST development in Brazil.

(c) New trend: clean technology centres.

At the States level, some efforts, albeit incipient, have been made to set up EST programme centres. Two cases deserve highlighting: the Clean Production Programme (PPL) in São Paulo and the National Centre of Clean Production (CNPL) in Rio Grande do Sul.

Clean Production Programme. The PPL was developed with the Fundação Vanzolini, of the Department of Production Engineering (DEP) of the University of São Paulo (USP). The general aim of the PPL programme is to "create opportunities for inserting Brazilian industry into the new competitive environmental strategies." To be more specific, the PPL proposes to promote clean production through case studies on product and process design; to evaluate competitive environmental strategies; to evaluate industrial projects and their environmental relationship and, to stimulate clean production as an instrument for quality, productivity, eco-labelling (ISO 14024)

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[14] Conventional plastics of a petrochemical origin represent 20 per cent of urban garbage, which signifies almost 900 thousand tons in São Paulo State alone.

[15] Central Cooperative of the Sugar and Alcohol Producers of São Paulo State.

[16] Support Programme for the Development of Science and Technology financed by a loan from the World Bank.

and environment management (ISO 14001). The programme also proposes to train, by means of specialization, graduate and post-graduate students and labour force specialized in environmental management. Furthermore, it offers specialized information and consultancy services in the areas of clean production strategies, clean materials, eco-design, clean technology & eco-products, eco-marketing, lengthening the useful life of products and, international contacts and cooperative projects. The target audience of this programme is fairly broad, ranging from industries to NGOs, trade unions and consumer associations. As it is an infant organization, it has not yet produced an activity report, so that it is not possible to determine with a minimum degree of precision what its influence has been in promoting ESTs developed by the public sector through the productive sector in Brazil.

The National Centre for Clean Technologies. The CNTL is one of the clean technologies centres that take part in the UNIDO/UNEP programme.[17] In cooperation with the National Service for Industry (SENAI) and the Federation of Industries of Rio Grande do Sul (FIERGS), this centre was created with the objective of being a facilitating instrument for the introduction and diffusion of the concept of clean technology in all national sectors. However, apart from the introduction project, the only resource available to the Centre was allocated by the Ministry of Science and Technology. This is for the launching of the Programme of Clean Production Techniques in Industrial Plants of the Metal-Mechanic Sector for the years 1996, 1997 and 1998, with a total investment of R$156.000,00.

Table 8 aggregates all the information collected regarding public funding for the development of ESTs. It presents the number of ongoing research projects in all institutions surveyed, which can be said to pertain to the category of ESTs as defined in the terms of reference. It also attempts to classify the projects under the various types of ESTs.

[17] This programme is aimed at environmental conservation which foresees the installation of twenty clean technologies centres all over the world.

Table 8
Ongoing research projects related to ESTs development in all institutions surveyed

	RT	**ME**	**PD**	**PC**	**EP**	**Total**
IPT	14	4		1	10	29
EMBRAPA	33	37	11	68		149
IBAMA		2	1	1	1	5
CNPq/Int. Coop.		3	1	4	3	11
CNPq/RHAE		18			6	24
CETESB					5	5
CNTL	51			17	32	2
Total	47	64	13	74	20	218

Note: RT=Remedial Technology; ME=Monitoring and/or Evaluation activities;
PD=Product Technology; PC=Process Technology; EP=End of Pipe Technology.

In summary, the following conclusions may be made:

Patterns of diffusion of ESTs. No discernible pattern for the diffusion of ESTs was identified in the survey.

Modalities for the transfer of publicly funded ESTs. At present there are two modalities for the transfer of publicly funded technologies (ESTs included) in Brazil. They are in the agricultural, pharmaceutical and food sectors, where the practice of patent granting, was only allowed in 1997 and technologies were transferred freely at no cost to the user. In the economic sectors the practice of patenting is accepted. However, it is very rare in public sector institutions without complementary funds from interested firms. Thus, they are the results of contracts and partnerships between public sector research institutions and private industries and, the issues related to intellectual property rights are negotiated case by case, often accruing to the private party as were the three examples cited in the case of IPT.

III. MAIN FINDINGS OF THE SURVEY

From this brief overview, the following conclusions can be drawn on the role of the public research sector in ESTs development in Brazil:

1. With regard to current trends, no activity related to ESTs, be it funding, choice or transfer of technology, appears to be part of the agenda of policy makers and technical advisors of the public research agencies. Neither Federal nor State Governments have formulated clear policies specifically in relation to the development or transfer of ESTs either to the agricultural or the industrial sectors.

2. It was not possible to detect in any of the institutions visited or from researchers interviewed, the existence of trends in terms of funding priorities, technology choice and transfer of environmentally sound technologies. The reply of a technical advisor from the IBAMA is a good example of this. In her own words "the definition of a policy that gives priority to the development of environmentally sustainable technologies to direct the policies of public sectors does not exist at government level."

3. Although the Government has no clear policy to develop and adopt ESTs, some agencies which foster research have offered specific funding for those technologies, with little success. GREEN FINEP is an example of this. This credit line however, is not of the preferential type and, according to some potential users, the interest rates are too high considering the goal they are aiming at.

4. Other special lines of credit, which aim specifically at ESTs development, have come only recently into being. These actions, which are very incipient and remain basically at the level of political discourse and papers -the best example being the Green Protocol- are more a result of demand from the international market for goods produced by means of an environmentally sound process (Green Stamp, ISO 14000 etc..) than from internal demand for clean technologies.

5. Even in the agricultural research sector, which could have a great impact on EST development, diffusion and adoption, concern with ESTs is yet to materialize. EMBRAPA, the most important agricultural research institution in the country, spent only a small percentage of its budget (7.9 per cent) on the development of environmentally sound technologies in 1996.

6. The concept of publicly-owned technologies does not appear to be appreciated in Brazil due to the fact that research institutions are not concerned with patenting the technologies generated and when the patent is requested, no attention is given to licencing. The recent research partnerships with the private sector have seen the beginnings of concern in this sense. The development of bio-degradable plastic in association with Copersucar[18] for example, albeit with a considerable part of the resources funded by government agencies, led the companies (Copersucar, Cromex[19] and IPT) to negotiate exhaustively the question of research secrecy, the joint revision of articles to be sent for publication and papers to be presented in Congresses. This example however, only highlights how decisions concerning intellectual property rights are negotiated case by case in Brazil where there is no pattern or tradition to abide by.

7. The concept of ESTs is also not very clear in all the institutions visited or contacted. Both in research institutes and in government agencies responsible for devising and implementing environmental and science and technology policies, technicians have difficulty in conceptualising ESTs. This obviously creates predictable difficulties in the classification of projects whose objective is the direct or indirect development of the technologies being considered in this study.

[18] Central Cooperative of Sugar and Alcohol Producers of the State of São Paulo
[19] Plastic industry of São Paulo

8. The lack of time in which to carry out the research did not allow a more detailed study of the sample. The universities involved in R&D activities (at the federal and state levels)[20] should be surveyed since, according to comments by some people interviewed, research directed at ESTs development is probably being carried out in this institutional context.

9. The total lack of centralized data, even at the institution level, was the greatest obstacle to the development of projects in Brazil. The institutions that are active in the area of ESTs development, do not have a central portfolio of projects. The case of IPT is a good example for, although it has many projects which could be categorized as ESTs, the search through its portfolio had to be made indirectly, almost manually. Several directors thought it an excellent idea to have a specific classification for projects which in some way incorporates the idea of ESTs.

10. With regard to R&D funding for ESTs, the participation of the private sector is minimal in Brazil. Traditionally it does not maintain in-house R&D facilities and, when needed, tends to contract research to public sector institutions. This takes place, often with funds partly originating from government agencies, which are most of the times non-refundable.

11. In the field of intellectual property, new patenting legislation only came into force, at the beginning of 1997. This allowed among other changes, the patenting of products and processes designated for the production of pharmaceuticals and foodstuffs. Historically in Brazil, public teaching and research institutions and institutes do not have offices to deal with the question of patents. Only recently, following the example of the University of Campinas (UNICAMP), offices within research institutions were created with the specific aim of evaluating projects with a view to their potential as leading to products worthy of patenting.

12. A similar situation arises with respect to agricultural production. The legal instrument that protects research activities in the field of plant improvement (Plant Breeder's Right) was passed in Congress recently,[21] and is now at the publication stage. Public research institutions in Brazil, particularly in the field of agricultural research, do not to date possess the mechanisms nor the institutional structure which would allow them to receive the benefits, through legislation, of the results of their research. Agricultural research institutions transfer to all those interested, at no cost, the right to use any technology they develop.

13. From this short research, one can conclude with a considerable degree of certainty that the demand for research and solutions for environmental problems, with the consequent development of ESTs, appears to be linked to technical regulations and the introduction of legislation that regulates the sector and, at the same time penalizes law-breakers. For instance, legislation devised for the prevention of pollution of water-tables by gas stations (a common accident in Brazil) has stimulated Petrobrás to develop and demand from its franchisers the adoption of installation norms and safety equipment as a preventive measure to control pollution.

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[20] In Brazil, only publicly funded universities, either federal or state develop R&D activities.
[21] *Law #9.456/97of 28/04/97*

14. The fact that environmental legislation is not complied with leads to less demand for studies and interventions by the R&D sector. For example, although Brazil has modern legislation on air pollution control, the lack of inspection and abidance has resulted in little demand for studies for ESTs development. A project for recycling wood in the Great São Paulo region would be opportune given the large amount of wood shavings and leftovers from civil construction. However, the lack of inspection and compliance with the law represses the demand for R&D solutions to the problem.

15. We would suggest as an innovative way to financing research in partnerships between the public and private sectors, the issuing of a bonus to non-polluting enterprises in a given sector or activity, for example in sugar milling and alcohol distilling, through bonds issued by the public authorities. These bonds, whose face value would be controlled by the market, could be negotiated to finance R&D in specific sectors.

ANNEX I

LIST OF INSTITUTIONS CONTACTED TO OBTAIN INFORMATION CONCERNING ESTs

ABC/MRE:	Brazilian Cooperation Agency
BNDES/MP:	National Bank of Social and Economic Development/ Ministry of Planning
CDB/MMA:	Biological Diversity General Co-ordination - Ministry of Environment
CENARGEM/EMBRAPA:	National Centre for Research on genetic Resources and Biotechnology/Brazilian Agricultural Research Corporation
CESP:	São Paulo State Energy Company
CETESB:	State Company of Basic Sanitation Technology and Environmental Defence
CNPMA/EMBRAPA:	National Research Centre for Monitoring and Environmental Impact Assessment / EMBRAPA
CNPq/MCT:	National Council for Scientific and Technological Development
CNTL:	National Centre for Clean Technology
CPI/CNPq:	Institutional Programmes Co-ordination
CTL:	Clean Production Centre - São Paulo State University (USP)
DDCT:	Development and Technological Capabilities Department – CETESB
DGA:	Environmental Management Directorate
DITAM/IBAMA:	Environmental Technologies Development Division -
DMA/FIESP:	Environment Department
DMA/MCT:	Environment and Infrastructure Division
EMBRAPA:	Brazilian Agricultural Research Corporation
	Environmental Planning Department -
FIESP:	São Paulo State Industry Federation
FINEP/MCT:	Financier of Studies and Projects
IBAMA:	Brazilian Institute of Environment and Renewable Natural Resources
INMETRO/MIC:	National Institute of Metrology
IPT:	Technological Research Institute -Secretariat of Science and Technology São Paulo
MAARA:	Ministry of Agriculture, Food Supply and Agrarian Reform
MCT:	Ministry of Science and technology
MIC:	Ministry of Industry and Commerce
MMA:	Ministry of Environment, Water Resources and Legal Amazon
MP:	Ministry of Planning
MRE:	Ministry of Foreign Affairs
SCI:	Secretary of International Cooperation/EMBRAPA

SCT:	Secretary of Science, Technology and Economic Development São Paulo State
SEA/ EMBRAPA:	Strategic Planning Secretary
SMA:	Secretary of Environment - São Paulo State
SSP:	Secretary of Public Services São Paulo State (SP)

ANNEX II

PERSONS INTERVIEWED IN THE INSTITUTIONS VISITED OR CONTACTED

Name and Academic Status	Position	Institution	Interview [22]
1. Ariovaldo Luchiari Jr, Ph.D.	Technical Director	EMBRAPA	IP
2. Braulio F.Souza Dias	General Co-ordinator	MMA	IP
3. Carlos Alberto Selke, Ph.D.	Int. Coop. Consultant	CNPq/MCT	IP
4. Dalmo M. de A. Lima	Chief of DMI	MCT	IP
5. Damião Guedes	Technical Advisor	MMA	IP
6. Damião M. Guedes	Technical Advisor	MMA	IP
7. Eliana Pontes	Technical Advisor	CENARGEM	IP
8. Enamar Fernandes Silva, Msc	Co-ordinator	CNPq/MCT	E
9. Flavio Avila	Planning Co-ordinator	EMBRAPA/SEDE	IP
10. Flavio Avila	Planning Co-ordinator	SEA/EMBRAPA	IP
11. Francisco Alves	Director	RSA	P
12. Francisco Reifschneider	General Secretary	SCI/EMBRAPA	IP
13. Heloiso Bueno Figueiredo	Director	MMA	IP
14. Hilário Baptista	Ombudsman	SOE/SP STATE	P
15. Ieda Botura	Manager	DPA/CESP	P, M
16. Isaura Frondisi	Environment Manager	BNDES	P
17. Ivonice Aires Campos	Special Adviser	MCT	IP
18. João Furtado, Ph.D.	Co-ordinator	CPC/USP	P, E
19. João Romano	Director	DDCT/CETESB	P
20. José Carlos Costa	Inst.Prog. Co-ordinator	CNPQ/MCT	IP
21. Luciano R.Coelho	Technical Advisor	E/FIESP	P
22. Marcio M. Santos, Ph.D.	Chief	CENARGEM P&D DEPT	IP
23. Maria José Monteiro	Technical Advisor	DITAM/IBAMA	IP
24. Marise Keller dos Santos	Co-ordinator	CNTL	P
25. Mauricio Frota	Environment Coord.	INMETRO/MIC	P
26. Milton Campanario, Ph.D.	Superint. Director	IPT	IP
27. Miriam Laila Absy	Manager	DITAM/IBAMA	IP
28. Paulo Kitamura, PhD	Technical Advisor	EMBRAPA	P
29. Roberto Domenico Lajolo, PhD	Technical Advisor	IPT	P
30. Rogerio Sá	Technical Advisor	FINEP	P

[22] IP: Interviewed Personally; E: by E-mail; P: by Phone; M: by regular (snail) Mail

ANNEX III

TABLE A

PARTICIPATION OF ESTS DEVELOPMENT PROJECTS IN THE OVERALL ONGOING RESEARCH PROJECTS OF EMBRAPA 1996

Programmes	A	B%	C	D%
1	3084,00	0,55	5331,11	0,94
2	2822,00	0,50	5140,05	0,91
3	1615,00	0,29	2780,37	0,49
4	5286,00	0,93	6958,67	1,23
5	2682,00	0,47	3320,82	0,59
6	4824,00	0,85	4752,80	0,84
7	2285,00	0,40	2855,01	0,50
8	1796,00	0,32	3431,45	0,61
9	1262,00	0,22	2439,50	0,43
10	1292,00	0,23	1268,49	0,22
11	1860,00	0,33	3031,76	0,54
12	1075,00	0,19	---	---
13	3289,00	0,58	3210,28	0,57
14	1724,00	0,30	---	---
15	2981,00	0,53	---	---
16	527823,00	93,30	---	---
Total	**565700,00**	**100,00**	**44520,31**	**7,87**

Abbreviations: A, Total expenditure in each Programme; B, per cent of budget; C, Total of each programme invested in the development of ESTs; D, per cent total of each programme invested in the development of ESTs.

Note: Values in R$ 1000.00 (R$ 1,00 approximately US$ 1.00).

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ESTs: THE CASE OF INDIA

By
Upendra Tripathy[1]

I. INTRODUCTION

The transfer and diffusion of ESTs[2] in India depend on the demand for, and supply of, ESTs The government can influence supply through appropriate state interventions such as public funding of R&D activities that generate ESTs and public ownership of such know-how which are available to the potential and willing users in industry. The Government can also influence demand through command and control measures, and through market instruments such as fiscal and monetary policies. Availability of information on ESTs and awareness of their potential use play an important role in shaping the demand curve for ESTs in the market and in reducing information costs. The existence of enabling institutions also reduces transaction costs. There are a number of factors that have been instrumental in creating demand for ESTs in India and they are important as they throw light on the shape and shift of the demand curve for ESTs In summary, in the Indian EST market, demand is shaped by a whole range of institutional, legal, economic and political factors. The indigenous supply of ESTs remains inadequate and information and transaction costs high. Similarly, the transfer of ESTs has been a bone of contention between developed and developing countries. India has been in the forefront in demanding the transfer of ESTs from developed to developing countries on acceptable terms. Hence, an understanding of the EST scenario in India will contribute to sound policy formulation on intra-country and inter-country generation and diffusion of ESTs.

The main objectives of the feasibility study are the overall assessment of the role of publicly funded research in the development of ESTs; the establishment of the range and relative importance of ESTs developed through publicly funded research, the examination of the pattern of diffusion and commercialization of these technologies at the national level, and finally the exploration of the potential and the mechanisms for the transfer of such technologies to third countries. Some other major and relevant questions addressed include the extent to which these technologies are being commercialized or transferred and through what means; the modalities for their transfer and diffusion particularly to developing countries; and what are the important economic, institutional, policy and regulatory issues.

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[1] Director, KSRTC, Bangalore Karnataka, India.
[2] For the purpose of this study, the term "environmentally sound technologies" refers to technologies which are lower in impact on the environment in terms of pollution and/or higher in energy and natural resource efficiency compared to technologies currently in use.

Environmentally sound technology, like technology *per se*, is a systematic knowledge of industrial arts. It is a complex process of transformation of natural resources into end products, without damaging the environment. An EST can be conceptualized to consist of four elements: technoware (i.e. equipment/machine), humanware (human skills/knowledge, environmental awareness), infoware (documentation procedures), and orgaware (managerial practices/societal linkages/environmental friendly procedures). The present study is rather more focused on the technoware part. But there is no intention to downgrade the importance of other components, which are in fact crucial for successful adaptation and absorption of ESTs in the process of technology transfer.

In addition, data availability on ESTs was found to be poor. Several problems were faced, apart from the availability of current data. Even many experts in the R&D areas, policy-makers, and entrepreneurs, with whom the author interacted, were not extremely familiar with the term - EST, although the idea had entered the mindset of all concerned, thanks to the coverage of environmental issues by local and national media. Even in the policy community, there is no broad consensus on what constitute ESTs. In most places, technology is perceived as an instrument of growth. The buzzword still is technology, and, unlike in developed countries, not ESTs.[3] Also, unlike in the developed countries, where environmental industries and ESTs have led to the creation of a number of organizations and policies, in India, the industry is yet to scale those heights of environmental friendliness in technology management.[4] Data published in 1996-97 pertain to the year 1994-95, the so-called time lag in government publications in India.

None of the R&D agencies listed a separate category of ESTs for public information. Even publications of lists of technologies for commercialization purposes did not separately list ESTs. The search on the Internet and in libraries did not produce very much, except some articles and books – Khanna (1995)[5] (1995)[6], and the Asia and Pacific Centre for Technology Transfer one publication by APCTT (1993)[7]. There was hardly any publication that gave the details of inventions and patents held by the private R&D sector in the area of ESTs. However, the Technology Information Forecasting and Assessment Council (TIFAC), an autonomous body under the Department of Science and Technology, has brought out a report that gives an interconnected picture of R&D in India. TIFAC has also attempted to establish a computer database in which environment friendly technologies compiled separately. However, this database is not yet complete and does not list indigenous ESTs as a separate category. A sample search generated a list of technologies, which were mostly foreign owned. The National Chemical Laboratory, Pune, has started a project to finalize a data base on environment related technologies. However, the project is still under progress.

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[3] In fact, it is interesting to note that the Confederation of Indian Industry (CII), in its study on environmental business opportunities in India, and on market potential for different ESTs, concedes "No Information Available", as regards the investments incurred in the market segment of cleaner technologies.

[4] The author had an occasion to work for IDRC, Ottawa, on EST transfer in the Indo-Canadian context and had visited the Environmental Industries Division in Industry Canada.

[5] Khanna, P. Environmental Technology and Industrial Development. In Science, Technology and Industrial Development in India, edited by S. C. Pakrashi, G. P. Phondke, New Delhi, Wiley Eastern. 1995.

[6] Shrivastava, P. Environmental Technologies and Competitive Advantage, Strategic Management Journal, 1995.

[7] APCTT. 101 Environment Friendly Technologies, New Delhi, 1993.

Keeping these constraints in view, the methodology adopted in this case study is mostly empirical in nature. Part of the paper is based on information generated through: a) an unstructured questionnaire mailed to 529 Scientific and Industrial Research Organizations (SIRO).[8]; b) visits to leading R&D institutes, such as the Central Power Research Institute (Bangalore), the National Chemical Laboratory (Pune), the Central Institute of Road Transport (Pune), the National Institute of Environmental Engineering (Nagpur), the Patents Information System Office (Nagpur); and c) discussions and interviews held with experts in the field, researchers from institutions that are engaged in ESTs, related R&D policy-makers, entrepreneurs, and those who are involved in the commercialization and transfer of ESTs. Data have been used from secondary sources, such as publications by the Government of India, State Governments, and publicly funded R&D organizations. To the extent possible, description of particular examples has also been attempted with the purpose of strengthening arguments and enhancing the utility of the study.

The paper is structured into four sections. The first section describes the overall role, scope and relative importance of publicly funded research. It starts by giving a brief overview of the structure of the R&D network in India and proceeds by analyzing current trends in R&D expenditure by the public and private sectors. It also discusses funding mechanisms, the rationale for government funding of R&D in this field and problems in analyzing the relative importance of publicly funded ESTs to privately funded ESTs. The second section summarizes the policies-including fiscal and institution-building policies- and practices used in the diffusion of the results of publicly funded R&D; it also examines the regulatory regimes in place and their impact on diffusion. Further, this part gives the details of patent regimes and the incentives and rights of individual scientists in the R&D institutional framework. The third section summarizes the modalities adopted by R&D institutions in the commercialization of their invented technologies, and analyses the problems faced by such institutions in the diffusion process of ESTs, in the absence of regulatory instruments and financial abilities to develop prototypes and pilot plants. In addition, it examines existing opportunities for facilitating and promoting the transfer of publicly funded ESTs to or among the developing countries and provides some examples of such transfers. Additional issues raised include: the role of multilateral agreements in the development of ESTs; experience in the process of absorption and adaptation; the stock of ESTs readily available for transfer to third countries; the use of public financing mechanisms, such as ODA assistance and multi/bilateral funding mechanisms to develop \ transfer ESTs; and the extent of tripartite research collaboration among R&D organizations of developed and of developing countries and private sector firms. The fourth section sums up the main findings of the survey by way of general evaluation of the status of publicly funded ESTs, and measures taken to support their development, transfer and diffusion. It also gives recommendations that emerge from the study.

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[8] The Directory of Recognized SIROs, published in November, 1996, lists 529 SIROs, of which 37 belong to agricultural sciences, 164 to medical sciences, 190 to natural and applied sciences, 115 to social sciences, and 23 universities. SIROs include both private and public R&D organizations. But not all SIROs have in-house R&D facilities.

II. THE STRUCTURE OF PUBLICLY FUNDED R&D IN INDIA AND R&D TRENDS

R&D institutions[9] in India can be divided into two categories: non-commercial and commercial. The first category includes mostly publicly funded, non-profit R&D institutions that develop technologies and pass them to industrial applicants. There are 529 such scientific and industrial research organizations (SIROs). These R&D institutions can belong to societies, associations, companies, research institutions, professional bodies, and universities. They get a registration identity from the Department of Scientific & Industrial Research, and this recognition enables them to avail prescribed income tax exemption and duty exemption on the import of essential equipment, instruments, spare parts, accessories, and consumables imported to promote R&D. In the first category one includes also institutional actors, such as the major scientific agencies, the central government departments and state government departments, and the industrial actors in the government-owned public sector undertakings, the joint sector industries. In the second category one has the private sector industrial enterprises.

The institutional sector includes: a) 13 co-operative research associations; b) 13 autonomous R&D institutes; c) 204 universities or similar institutions; d) 300 engineering and technical institutions; e) 8,613 colleges; and f) ten institutions of national importance. This sector is dominated by the following 12 major scientific agencies: the Defence Research Development Organization (DRFO), the Department of Atomic Energy (DAE), the Council of Scientific and Industrial Research (CSIR), the Department of Space (DOS), the Department of Science and Technology (DST), the Ministry of Environment and Forests (MOE), the Department of Ocean Development (DOD), the Department of Biotechnology (DBT), the Ministry of Non-conventional Energy Sources (MNES), the Department of Electronics (DOE), the Indian Council of Medical Research (IMCR) and the Indian Council of Agricultural Research (ICAR). These institutions together account for three-quarters of the total R&D expenditure incurred by the central Government. In addition, some Ministries/Departments carry out and sponsor R&D projects and have earmarked annual budgets. Some of these scientific agencies have R&D centres widely spread geographically. The CSIR has 40 laboratories and 100 technology-transfer centres; the ICAR administers 45 central research institutes with 160 regional stations, 30 national research centres, 80 all-India coordinated research projects, 28 state and 1 central agricultural universities, 120 zonal research stations, 222 sub-research stations, and 261 agricultural extension centres; the ICMR has an equally wide spread network of R&D institutions. The small-scale industries sector has six R&D centres. During 1994-95, together these centres spent Rs.5.14 million. Most of the R&D activities by the provinces were in the area of agriculture and allied sectors.

In the industrial sector, there are 1,053 private sector units, and 171 joint public/private units. There was significant growth in the number of R&D units in the private sector during the 1970s and 1980s. Lately this growth has slowed down as most private sector

[9] As on 1 April, 1994, 0.31 million personnel were employed in the R&D establishments in the country, including in-house R&D units of public and private sector industries. Of these personnel, 36.4 per cent were performing R&D activities, 31.4 per cent were performing auxiliary activities, and 32.2 per cent was providing administrative and non-technical support.

organizations have already established R&D units in the past to avail of government incentives.[10]

A. National R&D expenditure and proportion of publicly funded R&D

In 1994-95, R&D expenditure on the protection of the environment was 4.1 per cent of total national R&D expenditure. The Central Government spent 5.2 per cent of its R&D budget on environmental protection and the State Governments 8 per cent. This means that the share of the industrial sector was much lower. The R&D investments by major EST-related central government departments such as the Department of Environment & Forest, and the Department of Science & Technology are increasing. Expenditure on R&D by seven of the 17 highly polluting industry groups in the private and the public sector identified by the Central Pollution Control Board shows no general trend. In the leather, cement and fertilizers industries, the R&D expenditure level has remained almost stagnant. There is also no common trend between the public sector industries and the private sector industries in the same polluting industrial sector.

In terms of GNP, India’s current spending on environmental protection is in the order of 0.5 per cent. The total outlay from the central and state sectors during 1994-95 was US$ 381 million. The industrial sector spent US $ 1.1 billion.[11]

If one looks at R&D by sector, the private sector has spent (Unit: million Rs per year) 80.60 (1992-93), 54.16 (1993-94) and 80.06 (1994-95). Strangely, investment by the public sector in R&D pertaining to the protection of the environment was nil during the years 1990-91, 1991-92, and 1992-93. This is a serious matter as there are 211 public sector undertakings in India and most of these public sector undertakings are responsible for a large amount of environmental pollution. For example, gas flaring by India's Oil and Natural Gas Corporation (ONGC) is a major agent of environmental pollution. Further, some government departments, which are more likely to spend on the generation of ESTs, have not been able to completely utilize their allocated budgets. The Comptroller and Auditor General’s (CAG) report on R&D expenditures for the year 1995-96, which was recently submitted to the Parliament, expressed concern at the continuing decrease in R&D investment and the slow increase by the private sector,[12] although R&D has been recognized as the engine of industrial growth for achieving an edge in international competition. The CAG also pointed out that the scientific departments had shown savings of Rs.37.3 million, which was 6 per cent of their budgeted allocation. The DAE, MOE, MNES and the DOE were responsible for the non-utilization of funds. These departments are the major funding agencies of ESTs. However, these savings can not be taken as a problem of plenty. Sometimes, expenditures can not be incurred because of procedural bottlenecks.

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[10] The evolution of the number of in-house R&D units in the private sector has been as follows, (Number in brackets): 1951-1969 (117); 1969-1974 (156); 1974-80 (216); 1980-1985 (253); 1985-1990 (233); and 1990-1995 (116). Department of Science & Technology, 1996

[11] Source: CII. Environmental Business Opportunities in India, 1996.

[12] The remarks in the CAG report with respect to the private sector refer to R&D investment by the private sector as a per cent of sales turn over. Otherwise, the growth in R&D investment by the private sector has registered a higher growth than R&D expenditure by the public sector enterprises.

Trends in overall R&D investment that may possibly affect the generation of ESTs are discussed below. Between 1980 and 1990, world R&D expenditure, as a percentage of global GNP, increased from 1.9 per cent to 2.5 per cent. For the developed countries, the growth during the same period was from 2.2 per cent to 2.9 per cent. However, for the developing countries, R&D expenditure increased only marginally from 0.5 per cent to 0.6 per cent. In India, in the year 1992, R&D expenditure as a percentage of GNP in United States dollars was only 2.6, equivalent to 0.8 per cent of per capita GNP. Compared to other developing countries, some of which have had perhaps better economic performance, India's investment as a percentage of GNP has been remarkable. In terms of total GNP India invests more than China, but less than Egypt and Pakistan. In terms of per capita investment, India lags behind China, Egypt and Brazil (see Table 1).

Table 1
R&D expenditure as percentage of per capita GNP and total GNP

Country	per capita GNP	GNP
Argentina	0.3 per cent	2.29
Brazil	0.4 per cent	6.44
China	0.5 per cent	2.54
Egypt	1.0 per cent	5.55
India	0.8 per cent	2.39
Indonesia	0.2 per cent	0.87
Pakistan	0.9 per cent	2.35
Philippines	0.1 per cent	0.66

Source: DST 1996

One factor that may affect the future generation of ESTs is the declining volume of R&D investment in India. Although in nominal Rs. terms, planned allocation for science & technology increased by 2.2 per cent from Rs.1.42 billion in the Fourth Plan (1969-74) to Rs.117.65 million in the Eighth Plan (1992-97), R&D expenditure as a percentage of GNP is systematically declining from 0.96 in 1988/89 to 0.80 in 1995/96 (see Table 2) despite government policies and pronouncements to support R&D. Over the years, there have been only marginal variations in the government incentives available for increasing investment in R&D. In fact, there are new schemes in place to promote indigenous R&D. One frequently comes across the advertisements of the Department of Scientific and Industrial Research inviting proposals from Industry under the Programmes Aimed at Technological Self Reliance (PASTER) to extend financial support for technology development projects. Thus, the decline lies perhaps in the liberalization of the import regimes and the changed short-term economics of technology imports. In a liberalized economy, where competition becomes important, industry strives to adopt proven and catch-up technologies. Many industries perhaps become more risk-averse in a time without protection and subsidy. However, the scenario may change if the incoming foreign companies invest more in local R&D.

Table 2
National expenditure on R&D as a percentage of GNP
(in current Rs.)

Years	**Percentage**
1988-1989	0.96
1989-1990	0.92
1990-1991	0.85
1991-1992	0.83
1992-1993	0.81
1993-1994	0.86
1994-1995	0.81
1995-1996	0.80

Source: DST 1996

Another factor is that the Government remains the most important investor in R&D activities. In 1994-95, the Central Government alone accounted for 64.9 per cent of total R&D expenditure; the State Governments accounted for an additional 8.6 per cent and the public sector industries for 10.1 per cent. Thus, the private sector accounted for only 16.1 per cent of total R&D investment. Among the government agencies, DRDO continues to be the single largest spender of R&D funds, with 31.7 per cent of all funds spent by the 12 major scientific agencies of the central government. Public R&D expenditure has been growing more slowly than private sector expenditure as should be expected in a liberalizing economy (see Table 3).

Table 3
(in Rs 10 million)

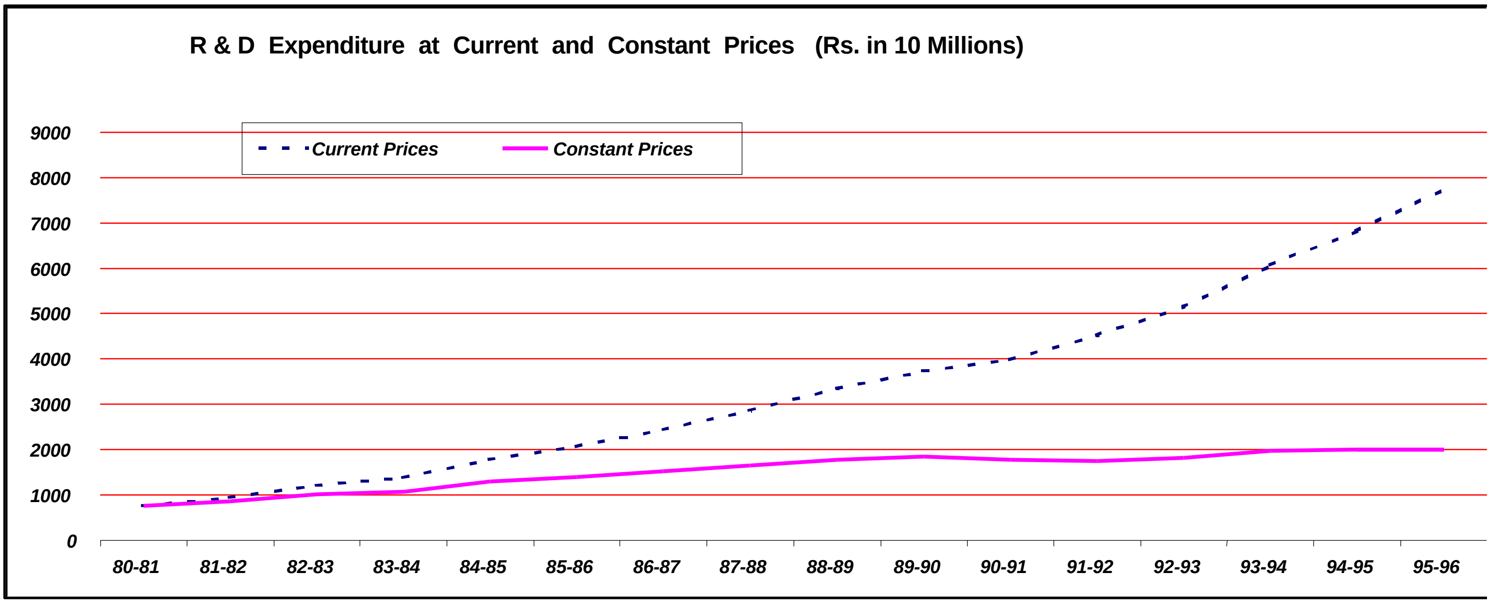
Sector	1990-91	1991-92	1992-93	1993-94	1994-95
Central Government	2 643.74	2 982.91	3 304.38	4 272.4	4 527.62
Public sector undertakings	414.53	484.38	513.95	542.81	685.33
State Governments	365.4	408.6	503.51	561.5	588.40
Private sector	550.0	636.9	836.25	982.54	1 119.57

Source: DST, per cent in Industry 1994-95, New Delhi 1996

The private sector has, invested more than the public-sector industries although the latter account perhaps for more environmental pollution since they operate mostly in infrastructure industries. In 1994-1995, the private sector spent 0.7 per cent of its sales turnover on R&D, compared with only 0.5 per cent by the public sector industries. But even in the private sector, R&D investment, taken as a per cent of sales turn over has declined from 0 .8 per cent in the 1988-1989 to 0.7 per cent in 1994-1995.

Expenditure on R&D at current and constant (1980-81) prices in the central, state and private sectors put together in India, between 1980-1995 is shown in Chart 1 below.

Chart 1
(in Rs. 10 million)



As can be seen, total R&D expenditure, although it has gone up almost seven times in nominal terms, has only grown hardly three times between the years 1980-19981 and 1995-1996.

B. R&D expenditure by the private sector

Looking specifically at the private sector, its contribution to R&D in financial terms has been better when compared with the expenditure of 171 R&D units by the public sector undertakings as mentioned above. Private sector R&D investment however, has been mostly in areas of import substitution, increasing sales through cost reduction, and diversification for new products. Surveys by the Ministry of Science and Technology have also found that private sector firms were giving, in general, much more importance to the purchase of new plant and machinery than to R&D.[13]

Expenditure by the private sector has also been growing faster than in the public sector enterprises. During the period 1990 to 1995, private sector R&D expenditure grew by 104 per cent as compared with only 65 per cent for the public-sector enterprises. This non-matching of the public sector with the private sector is a serious matter and needs the immediate attention of policy makers.

[13] R&D in Industry, 1994-1995, Government of India, Department of Science and Technology, New Delhi, 1996.

Five major private sector industry groups, namely drugs and pharmaceuticals (123),[14] transportation (34), chemicals (158), electrical and electronics equipment (158) and industrial machinery (52), accounted for 63.5[15] per cent of the private sector R&D expenditure.

So far as geographical distribution of private sector R&D units was concerned, 76.6 per cent of R&D units were located in the states of Maharashtra (389 units), Tamil Nadu (126 units), Karnataka (109 units), Gujrat (104 units), Andhra Pradesh (67 units), Delhi (39 units), and West Bengal (67 units). Maharashtra alone accounted for 47.5 per cent of total R&D expenditure in the private sector. Lack of geographical spread becomes a constraint to the spread of ESTs.

Further, R&D expenditure in the small-scale private sector, which accounts for 26.4 per cent of the physical units, is only 8.6 per cent of total expenditure. An additional policy constraint for the diffusion and adaptation of ESTs in the SME sector is that R&D intensity[16] in more pollution-prone sectors is lower than in less-polluting sectors (see Table 4).

Table 4

Sector	R & D/sales turnover (percentage share)	Number of R & D employees/1000 employees
Less polluting Scientific Instrumentation	3.46	60
Telecommunications	1.96	64
More polluting Boilers & Steam Generating Plants	0.67	18
Sugar	0.47	11
Cement and Gypsum	0.44	7
Leather and leather products	0.35	4
Metallurgical industries	0.33	6
Fermentation industries	0.28	16
Textiles	0.26	4
Paper and pulp	0.12	8
Vegetable oils	0.09	19

[14] Number in brackets is the number of units in the corresponding industry group.
[15] Ibid. pp.21-22.
[16] Ibid pp.28 R&D intensity in an industry is calculated by a composite index that takes into account (a) R&D expenditure as a percentage of sales turnover and (b) the number of employed in R&D per thousand employees.

C. Funding mechanisms, modalities and examples

The recent transformation in the funding pattern of publicly funded R&D institutions in India may have serious implications for the future generation of ESTs, depending on the type of demand that is met by publicly funded R&D institutions. Publicly funded R&D institutions in India, until the late 1980s, were mostly dependent on funding from the Central Government, Provincial Governments, Public Sector Undertakings (PSUs) and internal revenue generation. There were no concerted efforts by the publicly funded R&D institutes to mobilize funding from the private sector, as it was perhaps deemed to have an impact on the autonomy of the R&D institutes.[17] The Abid Hussain Committee in 1986, appointed by the Central Government, recommended that the Council of Scientific & Industrial Research (CSIR) laboratories should earn 30 per cent of their budgetary requirement from external cash flow. The CSIR laboratories have responded extremely well, although some have done far better than others in the mobilization of extra budgetary resources. In the 1990s, the reduction in government assistance as an aftermath of the liberalization of the economy, and with emphasis on economic self-reliance, funding from the private sector has been mostly welcome and sought after. Earnings of CSIR from private industry have risen from Rs.8 million in 1992-93 to Rs.210 million in 1995-1996.[18]

The coming of Transnational corporations (TNCs) in to various sectors has also given a further boost to R&D, as these enterprises have attempted to utilize the R&D expertise of the existing R&D institutions in India for reasons of cost advantage and local expertise. During the course of research, the author interacted with a research scientist, who proudly announced the funding of R&D projects by TNCs in the power sector. In fact, the TNCs have also shown renewed interest in some of the ESTs, which could not be commercialized earlier. What is interesting is the change in the perception and mind-set of managers in the publicly funded R&D sector. So far as R&D organizations are concerned, the volume of private funding depends on marketing efforts, good will in the market, and R&D infrastructure. Even government funding no more flows automatically. The allocation of R&D funds from the government has been linked to quantifiable performance criteria, such as the number of patents applied for/obtained, research papers published,[19] projects obtained from non-government sources, and the nature of R&D projects taken up. Although the concept of publicly funded R&D institutes carrying out a need-based technology development project, sponsored by a private sector industry, is not new, the number of such projects in the recent past has increased substantially. For example, the Central Electrochemical Research Institute (CECRI), in one of

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[17] Capabilities & Clients, CECRI, Karaikudi, Tamil Nadu, 1995, Vol. 1and 2 give examples of technologies developed at CECRI, including the ones with public-private collaboration. One example was of a Process For Bringing Down The Corrosion of Magnets in Contractors, sponsored by Larsen & Tubro Limited, 1972. However, such cases were not many until the late 1980s.

[18] Source: S&T: The Indian Scoreboard, by Dr. P. Rama Rao, the Deccan Herald, September 2, 1997.

[19] One marketing officer of a national R&D institute stated that the researchers had a ‘bad’ habit of publishing their research papers as quickly as possible. This made patenting of technologies difficult as the law does not permit patenting after the details of a discovery have been published. Hence in various workshops, researchers have been requested to be more discrete in publishing their research findings.

its publications in 1995,[20] lists projects and consultancies sponsored by, among others, private sector industries. There were several collaborative and sponsored projects from the private sector industries in the areas of corrosion science and engineering, industrial metal finishing, batteries and fuel cells, electro-chemicals, electro-metallurgy, electro-chemical, material sciences, pollution control, electro-chemical instrumentation, and membrane cell technology. This is true of most of the R&D organizations. The survey conducted with the SIROs found out that 61 of them who had responded to the questionnaire had 329 collaboration projects.

D. Relative importance of publicly funded ESTs compared to privately funded ESTs

It is rather difficult to make a comparison of the relative importance of ESTs developed in the private sector to that of the public sector for three reasons: a) private sector R&D efforts are more need-based and their outcomes are kept mostly confidential; b) publicly funded R&D, especially in the non-industrial sector, is mainly in theoretical fields; and c) there is no reliable database for inventions of ESTs by the public and the private sectors. However, what establishes the relative importance of the publicly funded ESTs compared to privately funded ESTs is that the Government has historically treated R&D as an infrastructure sector and resultant technologies as a sort of public good. Publicly funded inventions are subject to Government control. This makes the latter accessible to, and affordable by, industrial applicants. Moreover, precise statistics are not available on the number of ESTs that have been commercialized by the public or private sectors. But discussions with many important actors brought out the importance of ESTs generated by the publicly funded R&D institutions. It was also expressed by some that publicly funded R&D organizations will increasingly charge more and more for their technologies as the Government reduces grants and subsidies. With the opening of the Indian market, these publicly funded institutions will not have a captive market in future and will have to compete with other suppliers of ESTs in the market. The other suppliers may be foreign companies as well as privately funded R&D institutions. The increasing use of the existing infrastructure of publicly funded R&D organizations by private sector companies and TNCs may also have some future impact on the kinds of ESTs to be generated by these organizations. As the publicly funded R&D organizations get more and more oriented towards the market, the nature of their clientele may change and with it, even the relative importance of publicly funded ESTs as it exists today.

E. The Government rationale in providing R&D budget for ESTs

The liberalized industrial policy has greatly influenced the industrial R&D scene in India. With a target of accelerated industrial growth, freedom of enterprise has also to be harmonized with steps to contain industrial pollution and conserve natural resources through the promotion of appropriate technologies. Therefore, the Department of Industrial Development has created a separate Division to handle matters exclusively pertaining to environment and technology development. The first motive behind public funding of EST generation is to contribute to sustainable development. Second, the funding of ESTs, as stated

[20] Capabilities and Clients, CECRI, Tamil Nadu, 1995.

by Government, will help local firms compete with TNCs and avoid importing technologies, which are perceived to be inappropriate and costly. Third, the development of ESTs could contribute to the export of technologies. Recently, the Government of India constituted a task force to promote technology exports from India. To quote from a paper publicly circulated in one of the seminars of the task force:

> "Technology exports are being increasingly recognized as an important channel for enhancing national exports and promoting technical cooperation at international level. With the coming into being of the World Trade Organization (WTO) and along with it the strengthening of the Intellectual Property Right regime, technology is being increasingly traded as a commodity by many nations".

A fourth motive is the principle of self-reliance, where imported technology is perceived to be non-available or restricted, as it could be in the case of ESTs, due to either fear of infringement of intellectual property rights or the possibility of competition in third party markets. To quote from the Annual Report of the Waterfall Institute of Technology Transfer "In the last few years, access to technologies has become even more difficult, with new regimes of controls imposed on the transfer. Even relatively simpler technologies are not readily available for transfer due to the criteria of duel use; the possibility of a technology being put to uses beyond the purpose for which it was contracted. Thus, in the present global scenario technology needs in India and many developing countries are still to be met by imports and often with difficulty and on difficult terms." Fifth, as the Chairperson of the Scientific Advisory Committee to the Union Cabinet[21] mentioned, India is an important member of the developing world and needs to invest in innovation to be competitive and retain her political and industrial leadership. Finally, CSIR has some stated objectives which include technology generation, including ESTs, for under privileged sections of society (the poor, rural artisans, women, etc), and for improving the quality of life and the environment (in the areas of potable water, community sanitation, and fuel efficiency in burning fire wood). Other objectives are:

- To undertake application-oriented R&D activities and designs so that state of the art technologies are available within the country;
- To develop region-specific and appropriate ESTs for the country;
- To promote growth of industries in the large, medium and small scale sectors by making technologies available at affordable rates;
- To attain and maintain technological competence, enhanced self-reliance, and reduced vulnerability in strategic technological areas;
- To identify, formulate, implement and catalyze the establishment of R&D linkages among national laboratories, academic institutions, and industries so that the country has a strong research infrastructure in the areas pertaining to ESTs.
- To have a R&D base so that the buyers of ESTs could bargain import prices from a position of strength, and the price of imported substitute ESTs would not be abnormally

[21] Rao, C.N.R. Looking Back Over 50 Years, Science & Technology Section, Deccan Herald, 19 August, 1997, Bangalore.

high.

- To meet obligations under international environmental agreements by indigenously developing ESTs.

Thus one finds that several policy drives, such as the promotion of basic science, welfare-orientation, boosting the competitive advantage of local firms, responding to specific environmental needs, the need to meet standards under national laws and international agreements, constitute the motivation for public funding for the generation of ESTs. Although not clearly stated, many policy makers in the field feel that the emerging international and domestic environmental market, the possibility of India being dependent on foreign ESTs in the future, and the future competitive potential of ESTs developed in India, provide reasons enough to invest in the development of ESTs.

III. PATTERNS OF DIFFUSION OF ESTs

A. Policies and practices applied to diffuse the results of publicly funded R&D on ESTs

In 1991, the Ministry of Environment and Forests announced a fifteen-point action plan to improve industrial pollution control in the country. In addition, the Policy Statement for Abatement of Pollution, announced in 1992 by the Government of India emphasizes: a) pollution prevention at source; b) encouragement, development and application of best available practicable technical solutions; c) recognition of the "polluter pays" principle; and d) focus on heavily polluted areas and river stretches. The Central Pollution Control Board and the State Pollution Control Boards play a major role in implementing and monitoring the policies and programmes on the introduction of ESTs. The diffusion of ESTs in the industrial sector has been shaped mainly by five factors: a) economic benefits accruing from the adoption of ESTs; b) regulatory requirements to meet prescribed environmental norms; c) the existence of positive fiscal and financial incentives; d) funding by bilateral and multilateral organizations; and e) the presence of extension services by governmental departments, R&D institutions, and NGOs.

One can examine the diffusion of ESTs in the following four industrial sectors:[22]a) heavy industries, b) medium scales industries, c) the small scale sector, and d) the informal sector. The five factors mentioned above individually or/and collectively could influence the pace, direction and spread of diffusion of ESTs in each of the four sectors. Table 5 gives a matrix of the four industrial sectors and the five factors of diffusion, which provides a conceptual tool to examine the diffusion patterns of ESTs in India. Y indicates wide use of the designated factor for the diffusion of ESTs in the corresponding sectors. A blank does not mean that a given factor is not present. However, it does imply that its effects in that sector are not yet noticeable.[23]

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[22] This division is based on the value of capital goods prescribed by Government.

[23] This is merely a conceptual tool and Y-markings are based on discussions with various industrial actors. However, an empirical evaluation is a must to confirm its reliability and validity.

Table 5
Factor, Sector and Matrix

Sector/Factor	Economic gain	Regulatory needs	Incentives	External funding	Extension efforts
Heavy Industries	Y	Y		Y	
Medium Industries		Y	Y		Y
Small-Scale Sector	Y	Y	Y	Y	Y
Informal Sector					

In the heavy industries sector, such as steel,[24] mining, automobile, cement, sugar, thermal power, distilleries, fertilizer, oil refineries, petrol-chemicals, pulp & paper etc., a switchover to more productive ESTs has large financial implications. Moreover, alternative technologies are not indigenously available. For example, discussions of the author with an officer from the steel sector brought out how the technologies adopted in the 1960s had become outdated, when compared with international technological standards, and yet, it was not financially feasible at present, to discard the existing production technologies and to opt for more productive ESTs. However, in the automobile sector, the entry of Suzuki into the Indian market, through a joint venture with the Government of India to produce fuel-efficient cars has become a runaway success story. The environmental implication of this project, in terms of resource conservation, has been substantial.[25] Management in these firms is striving to get ISO 9000 and ISO 14000 certifications. As the urge to get these certifications has been mostly export-driven, the exporting industries have taken the lead. In the process, several environmentally friendly techniques and practices are being adopted. The phenomenon of judicial activism has also forced some heavy industries to adopted ESTs (Mathura Oil Refinery of the Indian Oil Corporation, a public sector undertaking, had to adopted ESTs to reduce

[24] Energy consumed in the manufacturing in India, measured in giga-calories per ton of steel stands at twice the international average. The figures are: France (5.07); Germany (5.20); Italy (4.01); Japan (4.09); Korea (5.21); **India (10.40**); United States (6.00); (Source:Bowonder & Miyake, 1988). This shows the urgent need for adoption of ESTs.

[25] This also shows how the Government's restrictive policies have prevented the flow of ESTs into India in the past.

sulfur discharge into the air to protect the Taj Mahal). Progress is being made in terms of management practices, fuel and energy conservation and control of wastage. In both these sectors, one can clearly discern a gradual shift towards the adoption of soft and hard ESTs, although a complete change in core technology is held back for reasons of finance and technology availability.

The small-scale industrial sector (SSI) in India has three million units. It employs about 14 million people, produces over 7000 items and contributes over 40 per cent of India's total exports. The industrial sectors dominated by small-scale enterprises are: chemical processing (organic and inorganic), metal finishing, textiles, foundries, rice-milling, food processing, brick making and stone crushing. Sectors like sugar, tanneries, pharmaceuticals, dyes and pesticides have both large-scale and small-scale enterprises. From the surveys conducted by the Central Pollution Control Board, it has been concluded that 25 to 30 per cent of the total small-scale industries in the country are of a polluting nature. Of these, only about one-fifth conform to environmental regulations in force.[26] A Technology Bureau has been established by APCTT, New Delhi, with cooperation from the Small Industries Development Bank of India (SIDBI), to help small and medium-scale sector entrepreneurs with problems relating to identification of technology needs, technology sourcing, technology choice, technology mix, technology transfer modalities and, more importantly, raising resources for appropriate technology acquisition. The market has made technology acquisition a professional activity. These days a firm needs considerable expertise and skill to find appropriate ESTs in the market.[27] The diffusion of ESTs in this sector has largely been due to the efforts of the Government, and to adequate financial assistance under multilateral and bilateral funding.[28]

A perusal of literature brings out clear trends about the nature of the diffusion of ESTs in seventeen categories of highly polluting industries. These industries are: aluminum smelters, caustic soda, cement, copper, distillery, dyes, fertilizer, iron & steel, leather, pesticides, petrochemicals, pharmaceuticals, pulp & paper, refinery, sugar, thermal power plants, and zinc smelter. The general findings by the pollution control boards have been as follows: The States of Maharashtra, Uttar Pradesh, Gujarat, Andhra Pradesh and Tamil Nadu have very large numbers of polluting industries. About 77 per cent and 15 per cent of these identified industries are respectively in the areas of water pollution and air pollution. Eight per cent contributes to both air and water pollution. Agri-based and chemical industries have major shares of 47 per cent and 37 per cent, respectively. The sugar sector has the maximum number of industries followed by pharmaceuticals, distilleries, cement, and fertilizers. In the petrol-chemical sector, 100 per cent of the identified 49 firms have adopted pollution control measures. In the sectors of caustic soda, pesticides, fertilizers, pharmaceuticals, cement, and dyes the introduction of end-of-the-pipe technologies is satisfactory. However, it is poor in the case of copper smelters, the iron and steel and aluminum sectors. Surveys by CII have indicated that 43 per cent of the non-complying units belong to the private sector, 9 per cent

[26] Delhi Pollution Control Committee has concluded that 20,000 out of the 80,000 SSI units in Delhi are polluting units.(Source CII 1996).
[27] The author came to know about a small-scale entrepreneur who paid a huge amount by way of license fee to a R&D institute. The product never took off because of technological inadequacies and post liberalization competition from overseas producers.
[28] Source: Annual Report 1996-1997, Ministry of Environment and Forests, 1997, pp.65-66

to the central government public sector and the remaining 48 per cent to the state government -owned public sector and cooperative units.[29] Analysis by provinces shows that 94 per cent of the identified industries in Gujarat have installed adequate emission and effluent treatment systems, followed by Tamil Nadu, Maharashtra, and Rajasthan with respective percentages of 91 per cent, 87 per cent and 85 per cent. The situation is not so promising in the states of West Bengal, Karnataka, Orissa, Uttar Pradesh, and Pondichery. CII estimates that 45 per cent of all sectors of industries including large, medium and small industries comply with prescribed environmental regulations. The compliance of large and medium industries in 17 categories of highly polluting industries is far better than the national average.[30] There are 1,551 large and medium industrial units,[31] of which 1178 have developed adequate facilities and adopted abatement ESTs to comply with prescribed environmental norms. 107 firms have closed down, 1,125 firms have adequate facilities to comply with the standards and 319 firms do not have adequate facilities.

However, the EST mix in the industrial sectors above has been composed of preventive, end-of pipe technologies and environmental-friendly management practices, depending on cost implications and regulatory regimes. In Calcutta City, most firms in the jute and textile sectors have installed effluent treatment plants. For example, some of the air pollution control equipment used are electro-static precipitators, cyclones with high efficiency tubes, bag filters, and wet scrubbers. Incinerators have also been tried. Cleaner technologies, including on-site recycling and recovery units have been placed in certain industries. Even common sewerage treatment plants have been set up by the central Government. The author's discussion with an officer of the Environment Ministry revealed several problems, which make the adoption of these ESTs partly ineffective. The private sector firms sometimes switch off effluent plants to save on energy costs. Citizens do not connect private lavatories with the public sewerage line, thus making the common sewerage treatment plant non-functional. In most of these cases, the diffusion of technologies has been driven by enforcement of regulations, government initiative and funding by international agencies. In some cases, as in the case of refrigeration and other CFC-related industry sectors, the urge to adopt indigenous or foreign ESTs has been in the hope of future exports and meeting international environmental requirements. The problem faced here is of a technology choice-whether to go for HCFC 134-a or for hydrocarbons, perceived as a choice between American and European technologies. Further, the Ministry of Power in the centre has moved the enactment of legislation that forces the small-scale energy sector industries adopted energy efficient technologies, such as energy efficient boilers. The judicial move to relocate polluting industries from inside cities like Delhi, Calcutta, and Mathura has also helped to createawareness for the adoption of ESTs. A researcher in the field shared his experience. His interviews with some

[29] This ownership-wise division of non-compliance will have important implications for EST policies in countries like India. The Government sector needs to do more to comply with environmental norms.

[30] Over 70 per cent of the identified large and medium industries comply with the legal norms in 1994 in comparison to only 24per cent in 1991.

[31] Most of these 1551 units are geographically located in Andhra Pradesh (173), Gujrat (177), Karnataka (85), Madhya Pradesh (78) Maharashtra (335), Punjab (45), Tamil Nadu (119), Uttar Pradesh (224) and West Bengal (58. Sector-wise, the concentration of these industries are in the area of distillery (177), fertilizer (110), leather (70), pesticides (71), pharmaceuticals (252), pulp & paper (96), sugar (391), and thermal power plants (97).

small-scale entrepreneurs revealed that those who evade paying electricity charges, or pilfer power, are the ones who are least inclined to adopt ESTs. In India, the level of pilferage of electricity is very high. Together with transmission and distribution losses, it represents almost 20 per cent of the total power generated in the country.

The adoption of ESTs in the informal sector has not yet been focused upon by governmental agencies. Market forces and NGOs will play a great role in this area. Moreover, most of the diffusion of ESTs has been externally driven (i.e. because of regulations, the need for export promotion or the availability of external assistance). The long-term success of such an approach will be determined by the involvement of NGOs in its implementation, and the extent to which such practices and technologies will result in enhanced profitability. One finds that the emphasis on technologies driven by the least-cost factors is gradually changing. Prospective buyers are aware of how cost constraint result in the adoption of outdated and obsolete technologies, leading to wastage of raw material and pollution problems. The establishment of the Indian Centre for the Promotion of Cleaner Technologies (ICPC) and the proposed database for comparative and environmental evaluation of various available ESTs will be extremely useful for the diffusion of ESTs in India. The World Bank has advanced US $ 2 million towards preparing a technology database. ICPC has also started a demonstration project – thermo-chemical concession reactor-utilization of distillery waste in sugar mill boilers – with a tripartite collaboration, including the private sector ESVIN group of companies.

1. The Transport Sector

One or more major policy instruments, such as incentives, regulations and extension services cause diffusion of ESTs in various sectors. The transportation sector, where regulations and incentives have played a major role, and the renewable energy sector where extension services and incentives have played a major role are described below.

In the transportation sector, the Government’s resolve to enforce vehicular emission norms in the recent past has helped in the diffusion of ESTs in the cities. The favourable price of compressed natural gas (CNG) as compared to the price of the substitute fuel (petrol in this case) had made the use of CNG in taxis an economically profitable proposition. Hence, the number of taxis using CNG has been increasing steadily. However, the same is not true for diesel-fueled public transport buses, since the price of CNG was more expensive than diesel and there were no other incentives to use CNG or regulation prohibiting the use of diesel in public transport.

Other government regulations, such as making catalytic converters in cars manufactured in the metropolis compulsory as from 1 April, 1995, led to factories, fitting cars with catalytic converters. Additional incentives include equal prices for cars with or without catalytic converters or for leaded or unleaded petrol (as practiced by public oil companies).[32]

[32] These incentives are of questionable significance. Lead-free petrol and catalytic converters should be priced appropriately.

An Indian PSU, Bharat Heavy Electricals Ltd. (BHEL) has developed a catalytic converter.[33] But industry sources feel that it would take some time before BHEL products matched imported catalytic converters in quality and price. At present, Maruti Udyog is importing the catalytic converters from Germany.[34]

The adoption of environmental and emission norms in the automobile sector has forced manufacturers to look for foreign collaborators, both in the light vehicle and heavy vehicle sectors. Volvo, the Swedish MNC, has started a production unit in India. TELCO and Ashok Leyland, two companies with production facilities for buses and trucks, are preparing to also meet the emission norms. Plans for the production of cars in India by several joint ventures also include emissions norms. Thus, the speed and diffusion of ESTs in the automobile sector has been a function of state regulations, judicial activism, technological innovation and public awareness.

2. The non-conventional energy sector

The diffusion of ESTs in the non-conventional energy sector has been rather impressive, notwithstanding the fact that planned expenditure on R&D in this sector shows a declining trend. This has been possible for a variety of reasons–multilateral and bilateral funding, credit availability, fiscal incentives for the production and adoption of ESTs, the involvement of NGOs, the existence of a sound indigenous R&D activity base and the consequent technological capability in this area. Extension services by a whole range of organizations created for this purpose perhaps played the most crucial role. Thus, two million bio-gas plants, 1.7 million improved firewood stoves, 20,993 photo-voltaic domestic lighting systems, 336,421 solar cookers and 31,226 photo-voltaic street light have been installed, and power generated from a variety of renewable sources. Some of these ESTs are indigenous and some are imported.

B. External funding and diffusion of ESTs India

External funding has been instrumental in transferring ESTs from developed countries to selected industrial sectors, but not between developing countries themselves. Some of these transfers have focused on ESTs appropriate to those segments of the economy covered by multilateral agreements such as the Montreal Protocol and agreements to reduce the emissions of gases with global warming potential (GWP). Some imported ESTs have been absorbed successfully, but there have been problems in other cases. ODA is not used as an incentive for public and private companies or institutions to be more active in transferring publicly funded ESTs, although it does play a significant role in the diffusion of ESTs and some R&D activities in certain sectors. For example, the Waterfalls Institute of Technology Transfer

[33] Some marketing professionals stated that although the BHEL product is not widely marketed, the availability of technology has brought down import prices substantially. This seems to be a major achievement in the newly emerging Indian market for technologies. This spin off effect is not often acknowledged.

[34] The author also learned that Sona Industries has started a joint collaboration with an EU firm to manufacture catalytic converters in India. This may create a competitive market for firms like BHEL, with implications for future R&D on ESTs.

(WITT), a registered R&D institution in Delhi, with the help of the German Agency for Technical Cooperation (GTZ), organized an international workshop in the area of ESTs and renewable energy sources.[35]

Two major nodal agencies that have played an important role in the flow of external funding to the non-conventional energy sector are the Ministry of Non-Conventional Energy Sources (MNES) and the Indian Renewable Energy Development Agency (IREDA), with provincial counter parts in the states to implement non-renewable energy policies. At the multilateral level, IREDA has mobilized assistance amounting to US $195 million from the World Bank for implementing the Indian Renewable Resources Development Project (IRRDP), which involves project financing to predominantly private sector firms in the small hydro, wind energy, and solar photo-voltaic sectors. These funs consisting of loans, grants and technical assistance come from IDA ($115 million), DANIDA ($50 million), GEF ($26 million) and SDC ($4 million). Private entrepreneurs and public sector firms have obtained a World Bank loan under IDA of $70 million for capacity generation of 100 MW of power[36] by setting up canal drop and dam toe-based small-scale power projects. Another proposal for US $218 million has been submitted to the World Bank for financing projects for bio-mass power generation through direct combustion and gasification technologies. The Asian Development Bank (ADB) is considering a US $150 million project for credit to solar, thermal, co-generation bio-methanation and wind-power based projects. A National Bio-Energy Board (NBB) has been set up in MNES to coordinate these projects.

The United Nations Development Programme (UNDP) has extended matching assistance of approximately US $10 million for a research project on the development of amorphous A-Si solar cells,[37] manpower training in the Unite States, the import of R&D equipment, and the import of technologies for sewage sludge treatment, treatment of leather solids, paper & pulp wastes, and the treatment of wastes of vegetable origin. UNDP/GEF approved in March, 1994, a technical cooperation project for the development of small hydro resources in the Himalayan and sub-Himalayan areas, with a US$7.5 million contribution from UNDP as and a matching contribution from the Government of India. The project envisages NGO/community participation. Some of the objectives pertain to international environmental agreements (i.e. reducing global warming, deforestation, and the protection of bio-diversity). The project provides for the establishment of three technology centres for technology development, manpower training abroad, 20 demonstration centres, and up-grading 100 water mills.

At the regional level, IREDA has signed a memorandum of understanding (MOU) with APCTT in the area of transfer of technology for renewable energy sources. India has Bilateral projects with several developed countries – the United States, Germany, Denmark, Sweden, Norway, Netherlands, Italy, Russia and Israel. Efforts have been made to cooperate with developing countries in different fields of renewable energy, technology transfer, and joint

[35] The proceedings of the workshop were subsequently published with financial help from the Ministry of Non-Conventional Energy Sources.

[36] The project does not permit state electricity boards to avail of funding for similar activities.

[37] As a result of this, single junction amorphous silicon solar cells have been made in the laboratory with efficiencies exceeding 12 per cent which are on par a with international levels of achievement.

ventures. These countries included the Philippines, China, South Africa, Cuba, and the Maldives. The United States provided US $5.04 million for the procurement of equipment and the training of Indian scientists in the United States in the area of R&D studies on woody bio-mass species for arid lands (1985-92). There are even institution to institution linkages. One interesting project involves a MOU between the National Renewable Energy Laboratory of the United States and the Solar Energy Centre of India for technological cooperation in the exchange of non-proprietary scientific information, test data pertaining to solar, thermal and photo-voltaic products, and joint technology validation and resource assessment. There are 53 MOUs signed between Indian and American companies \ institutions in areas of renewable energy. Sweden finances another interesting project on wave energy power plant. The A I MW Power Plant based on wave energy is proposed to be set up and commissioned by M/S Sea Power AB, Sweden, off the coast of the Andaman and the Nicobar Islands, on a build-operate-own (BOO) basis. The investment amounts to US $3million. Denmark also has funded several projects. Funding under multilateral and bilateral programmes, by way of grant, credit, investment or joint venture, have led to considerable diffusion of ESTs within India and internationally between India and developed countries. However, diffusion between developing countries is limited, and multilateral funding has not helped the diffusion of ESTs among developing countries themselves.

The R&D sector has benefited in the form of acquisition of equipment and soft ESTs in terms of man power training. Recently the Ministry reviewed its R&D approach and formulated a new strategy for R&D efforts in this direction.

Multilateral funding has been important also in the establishment of R&D institutions and patent information systems, both of which can be of great importance to the diffusion and generation of ESTs UNDP and UNIDO have provided assistance for setting up several R&D institutes such as the: a) the Ceramic Technology Research Institute in Bangalore; b) the Centre for Electric Transportation Technology in Bhopal; c) the Institute for Metal Forming in Hyderabad; d) the Combustion Research Institute; e) the Fluid Control Research Institute in Palghat; and f) the Pollution Control Research Institute[38] in Hardwar. Some of these institutes may act as prime generators of ESTs.

Several R&D organizations have been involved in the diffusion of ESTs with ODA assistance from various G-7 countries, mostly in the areas of renewable energy and pollution prevention in a variety of industrial sectors. The Department of Industrial Development, Government of India, started a Patent Information System project in 1980. With financial assistance of US $6.91 million from UNDP and a matching grant from the Indian government in 1992, supported by technical cooperation from the World Intellectual Property Organization (WIPO), the system was technologically upgraded between 1992-96. R&D personnel, industry, and business enterprises can now use the system, and patent agents in order to access patent information. International patent data for 55 countries are on CD-ROMs. The PIS centre charges nominal user fees. The author visited the centre to interact with the users, who expressed a desire that the system should be put on-line so that they could access it from any part of the country. The system could also have a facility for a news group

[38] The development objective of PCRI is to evolve industrial pollution control technologies with respect to air, water, noise, and solid wastes to avoid unintended negative externalities of economic growth.

for publicly funded R&D institutions in the country who could interact on-line and discuss projects, to avoid duplication of R&D projects, and strengthen R&D projects with mutual support.

C. Institutional participation in the diffusion of ESTs:

In addition to the various factors mentioned above, the diffusion of ESTs takes place as a result of the marketing efforts and strategies of almost all public institutions or corporations that own publicly funded ESTs and other technologies. The National Research Development Corporation (NRDC),[39] an enterprise of the Government of India under the Department of Industrial Research, was specially created in 1953 as a technology marketing corporation to serve as a vital link in the innovation chain and to act as a prime vehicle for technology transfer. The corporation has established linkages with a large number of technology generating agencies and has become a repository of indigenous technologies particularly those generated at public funded R& D institutions (e.g. CSIR, ICAR, ICMR, DRDO, BHEL, HAL). The NRDC also participates in the technology transfer process from the R&D centre to the pilot industry on a turnkey basis (i.e. from the bench scale to the pilot plant or prototype stage through specially designed funding mechanisms). The NRDC operates a network of 41 Rural Technology Demonstration-cum-Training Centres (RTDTC) in different parts of India and supports freelance inventors by providing financial assistance for the development of promising inventions, assistance for the patenting of completed inventions, awards to successful inventors and commercialization of such inventions. The NRDC has several publications containing lists of potentially marketable technologies, with technology codes, classifications and indices, as well as terms and conditions of transfer. The NRDC receives a share of the licence fee and royalties. It has technologies from 73 research laboratories. In the post-liberalization era, the NRDC even markets technologies from the private sector. It has marketed successfully several ESTs such as a technologies for the manufacture of zeolite A, an environ-mentally friendly intermediate for the manufacture of detergents; enzyme-based de-hairing of animal skin, prawn feed, invert sugar; BOD bio-sensors; artificial heart valves; acid proof cement from rice husk; carbon fibres; low cost systems for pollution control in vertical shaft kilns; eco-friendly garbage collectors; processes for enzyme based bio-detergents; enriched quick-cooking rice; mosquito fertility control processes; chlorine tablets; processes for the re-refining of used engine oil; and maintenance free lead acid batteries. The NRDC was assigned 38 technologies during the period 1994-1995 and 46 technologies during the period 1995-1996. China, Japan and other countries have shown interest in technologies for the manufactured of rice husk particleboard.

The CSIR has also several technologies. These include: catalytic converters and particulates traps for automobile exhaust emission controls, long-life radiator coolant, universal fibre making machines, rice husk ash nodules, kraft paper, using date palm leaves, facet masks for protection from traffic fumes etc. The valued of industrial production of

[39] The Remarkable role played by the Technology Development and Investment Corporation of India (TDICI) could also be taken into account. Some other relevant organizations are Directorate General of Technical Development, the Engineering Export Council, the Electrical Research and Development Association, the Foundation for Innovation and Technology Transfer, the Japan-India Technology Network, and the International Credit and Investment Corporation of India.

diverse materials, based on CSIR technology is estimated to be around Rs.26billion per annum. Seventy per cent of this production is in the chemical and petrochemical sectors. Technologies pertaining to several products can be termed as ESTs - detergent grade zeolite-A, thiophenate methyl, processes for the production of CFC substitutes;[40] heat resistant paints, ammonia free tanning of leather, glucose bio-sensors etc. Since its inception, CSIR has licensed 2500 technologies to 6500 licensees, 90 per cent of which are SMEs. The process of plan preparation in the CSIR laboratories facilitates the diffusion of technologies. Institutes, affiliated to, and funded by, CSIR prepare annual and five-year plans. Projects of national importance are proposed in these plans and funding is sought from the Government of India and outside sponsoring agencies. CSIR laboratories, as centres of technology generation, have experts from the academic, private and public sector industries, and other agencies who advise and make recommendations on the formulation of research programmes in accordance with the country's five-year plan and priorities, research needs, environmental problems and other policy objectives. The involvement of private sector industry representatives not only helps to bring inputs from the private sector, but helps also in the later diffusion of invented ESTs.

Some CSIR laboratories, such as CECRI in Tamil Nadu, have clearly stated objectives to create and improve technologies, especially from the point of view of pollution prevention and energy conservation. In one of its publications in 1995, CECRI advertised its Scientific, Industrial Liaison & Extension Unit (SILEU) as an excellent technology marketing group which deals with technology transfer, patents, liaison with industries regarding testing services, consultancy assignments, sponsored projects, trouble-shooting, feasibility studies, know-how release, and turn-key projects etc. Similarly, the Electronics Research & Development Centre of India (ER & DCI), in its annual report for the year 1995-1996, announced the establishment of a transfer of technology (TOT) cell. There have been a total of 61 technology packages transferred and 155 technology partners in the last five years.[41] Table 6 gives some figures about ESTs developed in recent years.

Table 6
(Number of technologies)

Technologies	**Years**	
	1992-1993	**1993-1994**
Products	4426	4729
Processes	1528	2383
Import substitutes	2548	2916
Design Prototypes	1266	1697

Source: R&D in Industry, 1994-1995, pp.89.

[40] It is important to note here that India, after becoming a party to the Montreal protocol in 1992, requires this technology to phase out Ozone Depleting Substances. The producers of CFCs in the private sector have attempted unsuccessfully to import the technology. In fact, this project at IICT, Hyderabad was partly funded by private companies who produce CFC in India. A pilot plant to produce HFC-134 a is being built.

[41] This is true of most other R&D institutes. The author interviewed some of the marketing people in the marketing department of the Central Power Research Institute (CPRI), Bangalore, and the National Chemical Laboratory (NCL), Pune.

As can be seen from Table 6**,** in 1992-1993, the industrial sector developed 1,266 design prototypes, and 1697in 1993-1994. In general of all the technologies licensed, only around fifty per cent reach the production stage which means that, in the absence of a good network of venture capital funding, the commercialization of ESTs is likely to be even lower.

D. Fiscal and monetary policies to promote ESTs

There are no exclusive fiscal or monetary incentives for the generation of ESTs, although proposals for EST development may get funding priority. The industrial policy statement of the Government of India in July 1980[42] stated that industrial processes and technologies aimed at optimum utilization of energy or the exploitation of alternative sources of energy would be given special assistance, including finance on concessional terms. Similar benefits were to be extended to activities that contributed directly to the improvement of the environment and reduced the deleterious effects of pollution air and water. However, the industrial policy statement of July 1991, while giving freedom for negotiating technology agreements in general, remains silent as regards environmental technologies. Existing incentives include:

- 125 per cent corporate income tax relief on in-house R&D. The level of the exemption was brought down from 133 per cent in the 1980s and further reduced to 100 per cent before being raised again to 125 per cent in the 1997-1998 budget, once the Government realized the importance of R&D in the liberalized economy.
- Complete exemption from import duty for R&D equipment, including equipment imported for environmental research. Under the Montreal Protocol Follow-up Action, the Government has also exempted customs and excise duty for equipment imported for phasing out ozone depleting substances by industry, whose projects have been approved by the Montreal-based Executive Committee of the Multilateral Fund. This government measure, combined with financial assistance from the Multilateral Fund, has helped the diffusion of ESTs in the air-conditioning, refrigeration and foam-making sectors.

Various financial institutions and commercial banks operate schemes that provide monetary incentives for the development and commercialization of indigenous technologies, including ESTs, in collaboration with the Industrial Finance Corporation of India, the Industrial Development Bank of India, the Technology Development and Investment Corporation of India, the State Bank of India, the Industrial Credit and Investment Corporation of India Ltd., the Commercial National Banks, and financing institutions at the provincial levels (State Financing corporations (SFCs) Such schemes include:

- Participation by financial institutions in the financial equity of companies buying indigenous or NRDC technology;
- Risk finance/ development loans for commercializing NRDC/indigenous technology;

[42] Office of the Economic Advisor. Ministry of Industry. Handbook of Industrial Policy and Statistics,1995.

- Interest subsidies up to Rs.5 million for commercializing un-commercialized technologies;
- Marketing assistance to small & medium scale industrial units, based on indigenous know-how;
- Technological consultancy, financial assistance, and interest subsidies for the manufacture and installation of renewable energy systems;
- Financial assistance under several schemes, such as: Seed Capital provisions, the Special Share Capital Scheme; Financial assistance to entrepreneurs under the Refinance Assistance Scheme, the Technical Assistance Fund Scheme, Venture Capital Funds, the National Equity Funds Scheme etc.;
- A soft loan scheme that gives preferential treatment for technology projects leading to better utilization of indigenous raw materials;
- Investment by R&D organizations in the equity of private sector companies in terms of knowledge and know-how; (introduced in the 1997 central government budget);
- Extension of conditional grants supporting industry-related R&D projects by financial institutions**.**

Financial assistance and fiscal incentives for pollution abatement. schemes include the following:

- Establishment of a Common Effluent Treatment Plant (CETP) for the SS sector, with assistance from the World Bank, the Central Government, the state Government, and the enterprises involved;
- A scheme to provide of 40 per cent subsidies for the adoption of clean technology in the SS sector and for setting up demonstration projects in areas of waste minimization, clean technologies, and waste recycling;
- A scheme to pay 75 per cent of project costs as capital loans at 15.5 per cent interest rates to large and medium scale units for the installation of effluent treatment plants aimed at waste minimization, resource recovery, and pollution abatement.
- 25 per cent rebate on waterless payable under the Water (prevention and control of pollution) Cess Amendment Act, 1981;
- Depreciation allowance at the rate of 100 per cent for installing pollution control equipment;
- Customs duty at reduced rates of 35 per cent plus 5 per cent auxiliary charges levied on equipment and spares for pollution control;
- Customs duty at the reduced rate of 25 per cent and full exemption from additional duty for kits required for the conversion of petrol driven vehicles to compressed natural gas driven vehicles;
- Excise duty at the rate of 5 per cent on manufactured goods that are used for pollution control;
- The exemption under section 35 of the income tax act on expenditure for carrying out programmes for the conservation of natural resources;
- The exemption of excise duty on the production of building materials using fly ash

and phospho-gypsum in quantities of 25 per cent or more as raw material;

- The exemption of excise duty on bricks and titles manufactured using, 25 per cent or more quantities of red mud as raw material; and
- The exemption of custom duty on the import of equipment, machinery and capital goods required for the production of building materials, using fly ash/phospho-gypsum such as bricks, lightweight aggregates and lightweight concrete elements.

E. Regulatory regimes relating to the protection and exploitation of the results of publicly funded R&D

1. General trends in intellectual property protection

ESTs are most sensitive to the intellectual property regime because most ESTs are innovative, nascent, and hence, risky. If there is no strict protection of intellectual property rights, entrepreneurs would adopt technologies because of the fear of future violation of intellectual property rights. However, the IPR regime in India is changing and will better facilities the diffusion of ESTs. The intellectual property protection regime in India, with constituent enactment – the Patents Act, 1970; the Patents Rules, 1972; Designs Act, 1911; Trade and Merchandise Marks Act, 1958; Indian Copyright Act, 1957; Drugs Act, 1940; - is undergoing a sea change in recent times. Proposed amendments to the Patents Act, 1970, which had not stimulated scientists to seek patent protection for their inventions, and had also discouraged foreigners from filing patents in India, are designed to rectify these anomalies. The Copyright Act was updated and amended in 1994.[43] As there are no arbitration mechanisms to settle disputes outside the courts, a new Arbitration Bill to establish such mechanism is before Parliament. The new Trademark Bill, 1995 may soon come into force. There are still some issues to be addressed. For example, India does not have any special trade secrets law, although it plays an important role in the field of EST transfer. The actors in R&D and industry circles are increasingly becoming more aware of legal provisions regarding patents, copyrights, trademarks, and trade secrets. Some years previously, although patenting was in vogue, awareness was not widely shared in R&D circles. Now researchers are very much aware of the significance of patenting their inventions. The Council of Scientific and Industrial Research, operating the largest network of R&D laboratories, now has a patenting division. More importantly, this division actively involves marketing people from the laboratories in the patenting process. Literature on patenting is widely circulated. Workshops are held regularly to highlight the wider issues pertaining patenting laws and regulations. The Ministry of Industry has also opened a Patent Cell to help R&D organizations. Scientists are now aware of the fact that they should not hurry to publish their inventions. They are also more sensitive about the marketing potential of their inventions and readily interact with private sector industries. Published data up to 1993-1994 shows an increasing trend in the number of patent applications filed by Indians,[44] with the possibility of more ESTs being patented.

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[43] However, the Designs Act, 1911 needs to be amended, but has not been taken up so far.

[44] Source: Annual Reports of the Controller General of Patents, Designs, and Trade Marks, quoted in R&D Statistics, DST, 1996.

Table 8
Patent applications filed 1989-1994

Year	Applications filed by Indians	Applications Filed by foreigners	Indian	Number of patents in force/Foreign
1989-1990	1 040	2 621	2 468	10 941
1990-1991	1 180	2 584	2 238	8 210
1991-1992	1 293	2 259	1 206	9 093
1992-1993	1 228	2 239	1 034	8 997
1993-1994	1 266	2 603	1 995[45]	7 281

As the table shows, there has been no change in the level of patent applications filed by foreigners,[46] but there is a definite decline in the number of patents in force. This may be due to delays in the sealing of patents and delays in the disposal of applications. Over the last 18 years, the average number of patent applications received annually was 3,320, whereas the average number of applications to be examined was only 555. There were a large number of applications carried forward each year. This proves the general complaint that the patenting infrastructure needs to be expanded and strengthened. The declining number of patents in force also indicates the increasing size of the public domain.[47] Discussions with people in the field of patenting, revealed four problems regarding the patenting of ESTs: a) long delays involved in the patenting process; b) the limited number of patent offices (i.e. inadequate patenting infrastructure[48] there are only four offices at Calcutta, Madras, Delhi and Bombay); c) the cost of patenting abroad, particularly in the United States, is relatively very high; d)

[45] Out of 1,995 Indian patents in force, only 236 patents belong to CSIR which also has 40 patents in force abroad. CSIR is the single largest applicant for patents in India, with around 25 per cent of patent applications. Source: CSIR Annual Report 1993-1994 and R&D Statistics, DST, 1994-1995.
52. During the piriod 1993-1994, the United States filed 1,136 applications, Germany 344, The Unite Kingdom filed 209, and Japan 104. Within India, the states\ provinces that top in the number of patents filed are: Delhi, Maharashtra, Tamil Nadu, West Bengal and Gujrat. During 93-94, the number of patent files respectively filed by them were 355, 382, 104, 89 and 61. There is an increasing trend in the number of patent applications filed by Indians. The number of patents filed abroad by CSIR has no clear trend. Year-wise figures are: 1990-1991 (15), 1991-1992 (8), 1992-1993 (19) ,1993-1994 (18), and 1994-1995 (29).
[47] The author's effort to obtain on the compendium of technological know-how in the public domain, could not materialize due to paucity of time.
[48] The publication also lists the institutions, both national and international, who receive regularly the patent office publications, on the condition that they may be seen by the public free of any user fees.

accessibility of patent data at national and international levels. The problem of accessibility to data bases by R&D and industry personnel is partly taken care of by the Patent Information System (PIS) based at Nagpur.

2. Rights of inventors vis-à-vis R&D institutions

The Indian Patents Act, 1970, has special provisions regarding persons employed in government services. Section 4 reads: "Subject to any special conditions of service, or to any special orders applicable to the persons employed in any particular department, all government servants are at liberty to apply for patents direct to the patent office." However, paragraph (c) of the same section imposes restrictions on employees of the Defence sector, the Indian Railways and the scientific and technical research establishments, who could only apply with the prior permission of the Government, and in accordance with such conditions that the Government may impose. With the onset of liberalization, the contribution of individual scientists is being taken into account by the concerned R&D institution. During the author's visit to a prominent national R&D institution, it was found that the individual scientists are now eligible to share a portion of royalties, and patents also show the names of the scientist/s concerned. Some R&D institutions also have several award systems to encourage inventions, and with the growth of revenue income from non-budgetary sources offer liberally travel and other facilities. Some publicly funded R&D organizations give a percentage of the royalty on inventions to the individual scientists. Some organizations, such as the National Chemical Laboratory (NCL) have introduced innovative projects create public trust funds with contributions from private client companies. The income from the trust goes in the form of annual awards for the best technology commercialized, the most valuable industrial contract, and special individual achievements. This strategy will no doubt be followed by other prominent R&D organizations. CSIR also provides financial incentives that ensure scientist-industry interaction by way of consultancy projects,[49] reimburses membership fees of professional associations, and sends scientists abroad under various exchange programmes.

NCL has an other innovative programme, the "Kite Flying Projects" which deals with daring intellectual pursuits. The incentive package now permits the R&D laboratories to retain their surplus earnings, and formulate incentive measures for their own scientists, thus providing a strong incentive for individual scientists to search for innovative ESTs for existing industrial problems. The post-liberalization package of individual and institutional incentives provides financial and psychological incentives to individuals and institutions to be innovative and to interact with industry. This is a policy area that needs careful examination in the context of each developing country.

3. Commercialization of technology

All R&D organizations follow four stages of research from the controlled setting of the laboratory to the commercialized production plant – (a) laboratory development of a technology, (b) bench mark development, (c) prototype development and (d) field testing for commercialization. However, because of financial and infrastructural constraints, scientists

[49] The individual scientist can have a financial share of Rs.100000 per year. The rest goes to the organization.

used to be more focused on laboratory development alone, the other stages being left to the marketing intermediary or the buyer of the technology. As a result, buyers had a number of field level problems and some R&D institutions did not have enough finance to develop prototypes. Recently, there have been changes in approaches. Now the R&D organizations consult potential customers at the stage of problem identification. Another factor that has developed is the creation of marketing departments within R&D organization, as against the earlier practice of handing over technologies for marketing to the National Research Development Corporation, with whom interaction used to be limited and infrequent.[50] Now there is more interaction between marketing organizations, individual scientists and technology buyers. Most R&D organizations have streamlined internal procedures that maximize quality of research and the relevance of technologies to existing markets.

4. Patent ownership contracts & licensing practices

Publicly funded R&D organizations follow mainly three types of technology transfer arrangements, depending on the nature of funding and problem identification. (a) All publicly funded inventions are licensed on a non-exclusive basis. The R&D institutions retain the freedom to sell the technology to other entrepreneurs.[51] This measure keeps the licensing cost comparatively low and does not limit the number of industries, which can benefit from inventions. Apart from the license fee, the R&D organizations also collect a royalty at a mutually agreed rate. Expertise is disseminated at laboratory or pilot plant level, depending on the complexity of the technology in question. (b) There are sponsored projects on problems identified by the R&D organization or the industry. As the sponsoring agency takes a risk, it has the privilege to have a limited exclusivity on the resultant know-how for a period not exceeding seven years. There are instances when sponsoring agencies have abandoned during implementations. After the expiry of the exclusivity period, the R&D organization can license the know-how to other parties. The ownership of the intellectual property is vested with the R&D institution. (c) The third methodology is collaboration between the industry and the R&D organization. They work jointly from the inception of the project by combining mutual areas of strength. The industry may have a limited exclusivity to use the resultant know-how for three to five years and the ownership of the patent is held jointly. Royalty accruing from third party licensing is mutually shared in agreed proportions. The terms and conditions in each of these three modes are included in contracts. Some contracts now provide for sub-licensing by the industry on mutually agreed terms, because the industry prefers safer to adopt a technology from a practicing industry partner. Transaction costs and information costs may also be less. In some cases, there has been 'joint sales' of know how (i.e. the first buyer helps the technology generator to sell the product for an agreed sum, by extending technological help for commercialization). There are also some exceptional cases where technologies have been licensed on an exclusive basis. However, these are very few and need to be encouraged on a larger scale.

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[50] Other problems with NRDC were that the corporation acted as an avoidable middleman and did not try enough to market technologies. More important reasons were perhaps increasing demand for home grown technologies and the need for raising non-government resources by the R&D organizations.

[51] However, a random check of the processes licensed by NRDC during 1995-1996 indicated that out of 24 technologies licensed, only two had been licensed 5 times and 2 had been licensed twice each. The rest had been licensed to only one party.

R&D institutions make permutations and combinations of these basic modes of licensing. Field conditions, the financial strength of the entrepreneur, and future projected sales shape the contractual terms, and conditions of licensing and royalty accrual cause some variations. The author's interviews with some marketing personnel revealed that ex-factory royalty was being collected following a system that ensured more royalty revenue when sales were higher. Some licensees had bought technologies on an “exclusivity of territory” and “exclusivity of time” basis. R&D organizations have also taken their technology fees in the form of equity.

R&D related scientists disclosed the following problems (a) lack of latest design and engineering facilities, (b) pre-production procedural and bureaucratic bottlenecks, (c) lack of reliable market data, (d) lack of techno-commercial and financial support for prototype/pilot studies, and (e) lack of post-commercialization feedback. Most R&D organizations lack pilot plant facilities and prototype designing facilities. In the small-scale sector, there are four government R&D institutes to develop prototypes. But the facilities they provide are neither adequate nor accessible to all who need to develop prototypes. Expertise sold by R&D organizations is mostly at the laboratory level. Commercial success of the technology depended on the efforts of the industrial buyer. This infrastructural weakness has made adoption of indigenous ESTs extremely risky. Recently, however several leading R&D organizations are developing prototypes and pilot plants with financial assistance from banks. Even the World Bank has come forward to extend loans in this respect. NCL, the leading R&D organization in the chemical sector, has obtained a World Bank loan of Rs.100 million to upgrade its pilot plant facilities. This would enable the R&D organizations to match the sales norms of foreign technology sellers by being able to provide basic design data, and performance guarantees. However, there are several other mechanisms to develop synergic interfaces between R&D institutions, academic institutions and industry. A study by the National Science Foundation, in 1982, identified 464 mechanisms[52] to develop an effective academic-industry interface. Some of these mechanisms such as research contracts, consultancy agreements, research consortia or industry cooperatives for R&D, and technology brokerage consultancy, etc. are taking root also in India.

IV. MODALITIES FOR TRANSFER OF PUBLICLY-FUNDED ESTs

A. The Present stock of ESTs

In 1995 the Sardar Patel Renewable Research Institute, Gujrat, published a profile of technologies in which 31 patented technologies are listed at various stages of development – laboratory development, bench development, prototype development, and field-tested. Eleven of these indigenous technologies belonged to solar energy usage, ten for bio-gas generation, and ten on gasification of bio-mass. These are mostly process ESTs. Some of them had been developed with public funding, and most of the technologies are not very costly or

[52] National Science Foundation, (1982). University-Industry Relationships. Fourteenth Annual Report of the National Science Board; NSF. Washington DC.

complicated. The publications of the R &D centres of the Bhaba Atomic Research Centre (BARC) and DRDO also list ESTs as spin-off technologies to be commercialized. This is true of almost all R&D organizations in India. The stock of ESTs patented, where patents have been applied for, and in the public domain is reasonably large. However, recent marketing efforts by R&D organizations are making these ESTs available and accessible. NRDC Processes, a book published by the NRDC in 1995, lists process technologies many of which can be termed ESTs. The number of such technologies in the rich depository of NRDC, without, the nomenclature of ESTs, is rather substantial. Table 9 below shows the approximate number of ESTs.

Table 9

Sector	**Total technologies**	**Potential ESTs**
Chemical and Allied	75	35
Marine chemicals	6	2
Plastics, resins, paints	27	15
Insecticides, pesticides	17	1
Agro-based	8	6
Food processing	28	20
Drugs and pharmaceuticals	30	25
Leather processing	9	6
Metallurgy	50	19
Building and construction	43	12
Mechanical engineering	30	8
Instruments and devices	258	80
Electrical	14	5
Electronics	14	0
Miscellaneous	50	10
BAR and HALT	10	5
DRDO technologies	38	12
Miscellaneous new technologies	72	20

These technologies were obtained by NRDC from 73 national research institutes. It was not possible to establish clearly the environmental qualities of all these technologies in the absence of descriptions of details of the technology compared to the technology it substitutes. But the figures under the column potential ESTs is based on discussions with two scientific personnel, one of whom from a R&D organization. A perusal of the published briefs on these technologies was not sufficient enough to verify the veracity of these figures. But one could safely conclude that there are a large number of ESTs in the repository of NRDC ready for transfer within the country and between developing countries. During 1994-1995, CSIR published a list of one hundred technologies.[53] Several of its 40 laboratories, which now independently market technologies, including ESTs, have several ESTs at their disposal. The author's survey of 529 SIROs included a question on the number of ESTs available with the agency. The matrix below has been used to make a sector-wise listing of types of ESTs available in the Indian R&D sector.

B. EST transfer to developing countries

NRDC has special schemes to offer know-how and technology packages to developing countries, where Indian technologies are considered very relevant and appropriate. The corporation has exported a number of technologies to Egypt, Indonesia, Kenya, Malaysia, Myanmar, Nepal Philippines, Sri Lanka, and Vietnam[54]. Some technologies have been exported even to developed countries including the United States and Germany. Examples of EST export from individual R&D institutes to other developing countries are not readily available. The NRDC has worked in 40 developing countries in several areas, including environmental pollution control and energy conservation in industry. The Indian Institute of Chemical Technology licensed its technology for the preparation of 10 undeconic acid by pyrolysis of castor methyl esters, to the M/S Design & Research Institute for Petro-chemical Engineering, China. The firm will build a commercial plant with 300 tons per annum capacity. 10-undeconic acid is an important chemical from castor oil, and its derivatives are valuable raw materials for the perfumery, drug, and engineering plastics.industries. Further, IICT finalized also negotiations with M/S Snochem of South Africa for the transfer of technologies for chlorpyriphos (a pesticide) and glyphosphate (an intermediate in the chemical industry) for a total sum of US $1.5 million NEERI has signed a memorandum of undertaking with the Mitsui Environmental Engineering Trust, Japan, to undertake joint research and development studies in collaboration with Japanese institutions of various measures relating to environmental protection.

India has the experience and infrastructure to transfer smoothly appropriate ESTs to other countries. It extended. support also to the Committee on Science and Technology in Developing Countries (COSATIDC) and the Federation of Asian Scientific Academies and Societies (FOASAAS). Partial financial support is given also to young scientists to participate in international conferences.[55] The scientific collaborative/exchange programmes, with academies of a number of countries, enable Indian scientists to visit research institutions/universities abroad and *vice versa* to pursue research activities. Many academies adhering to the International Council of Scientific Unions (ICSU), nominate Indian scientists for ICSU sponsors international positions in the unions, committees, and commissions etc. International conferences in India on technology generation and diffusion and prepares status reports on various scientific disciplines.

[53] Some of these technologies could not be classified in the absence of adequate information. Two of the APCTT's 23 technologies are developed by publicly funded organizations.
[54] Source Annual Report 1994-1995, NRDC.
[55] During 1995-1996, 88 scientists were deputed to collaborating countries and 33 scientists from these countries visited India, besides 230 scientists who were sponsored to participate in conferences held abroad.

Under the TATT scheme of the Government of India, are technology profiles[56] of selected target countries prepared and disseminated. Thirteen developing countries have been covered, including Egypt, Indonesia, Malaysia, Mauritius, South Africa, and Thailand. The Government provides partial financial assistance to set up demonstration models at pilot plant level in India as well as in the country to which the export of technology is envisaged. Four projects for the demonstration of technology in host countries have been supported so far. Activities under the TATT Scheme have had tremendous influence on the transfer and diffusion of ESTs. Moreover, recently, the Department of Scientific and Industrial Research (DSIR) launched a programme for stablishing technology business incubators in India with the financial support of UNFSTD (United Nations Fund for Scientific and Technological Development). One of the objectives of the programmes is to support entrepreneurs trying new technologies, upgrading technologies for export, or attempting to commercialize indigenous technologies. This programme is a useful mechanism and can be broadened to include the commercialization and export of ESTs.

The Government provides also incentives under the Programme Aimed at Technological Self-Reliance (PASTER) for the development, commercialization and export of home-grown technologies, including ESTs. The Government of India has (a) established a technology database and advisory services under the national register of foreign collaborations, and (b) supported technology export under the Transfer and Trading in Technology scheme (TATT).[57] There are no political or regulatory restrictions on the export of these technologies. India has streamlined its institutions and procedures to export whatever ESTs and other technologies it has developed. To provide an impetus and focus, a task force to promote technology exports has been constituted. There are no examples of EST transfers from India other countries as a result of international environmental agreements, India a recipient country. However, India is in the process of developing an ODS substitute to CFCs. The project is at the pilot plant stage. The technology is a product of a project sponsored by two CFC manufacturers in India with a national R&D laboratory. Once the project comes to the commercial production stage, India may be in a position to transfer this technology to other developing countries that will need it to meet obligations under the Montreal Protocol. There are also no instances of research cooperation between India R&D institutes, Indian industries, and R&D institutes from developed countries. However, as already cited, there are several bilateral R&D projects.

V. MAIN FINDINGS OF THE SURVEY AND RECOMMENDATIONS

A. General evaluation of the status of publicly funded ESTs

As more firms seek of ESTs. There will be an increasing demand for technologies from publicly funded organizations. Privately funded R&D organizations may not like to part with the ESTs they have invented hence, in the coming decades publicly funded ESTs will be the

[56] Technology profiles cover scientific and industrial infrastructure, future plans and projects, foreign company operations, technological requirements and resources of the targeted developing country.
[57] The TATT scheme, formulated at the end of sixth plan, began functioning in 1985.

only source of affordable and accessible technology to most of the firms that are not capable of importing appropriate ESTs. Further more R&D organizations are developing also a new sensitivity towards environmental matters for a variety of reasons, thus strengthening the status of ESTs. One of the R&D institutions, NEERI, was asked by the Supreme Court of India, to give its expert opinion on several cases pertaining to the environmental impact of huge infrastructural projects. In some cases, such expert opinion has gone against the Government and many international firms. Environmental NGOs have also become active and have resisted successfully large-scale projects, which they considered to be unsustainable. Very often such situations have resulted in cost and time over runs for national projects[58] and delayed investment by foreign companies.[59] Sometimes these developments made some policy makers feel that environmental activists are holding the nation to ransom. Thus, the future prospects for ESTs are also partly linked to the need for makers and industrial actors to develop a consensus that ESTs are necessary and desirable, even at an additional cost, and not pay merely lip-service to the concept and cause. However, that consensus has not been reached.

Most policy makers, give preference to growth technologies, as poverty eradication is the most important item on the political and policy agenda. Poverty is treated as the greatest polluting factor. The high level of Western consumption and the lop-sided distribution of world wealth provides a basis for some policy makers to feel, rightly or wrongly, that the whole concept of ESTs, as an offshoot of emerging international environmental regimes, is a constraint to fast growth. Thus, the future of the development, diffusion, absorption, and assimilation of ESTs into Indian industry is also inter-linked to the degree and extent to which such perceptions are shared in policy and industry circles. The policy implications of such a theme is that win-win ESTs will have a better chance of being adopted, as win-win ESTs do not pose any constraint to growth. ESTs that enhance productivity, cut down cost, conserve resources have also a better chance to be adopted widely. It was found also that energy pricing, and proper enforcement of pricing provisions, play a big role in the diffusion of ESTs. If energy costs are highly subsidized, or the users can escape paying the cost of power used, there will be no incentive to adopt alternative energy technologies, or even energy saving technologies. It has show that, some SMEs are not interested in the use of energy-saving technologies. The same may be true in several other sectors where government controlled prices of goods or services become a disincentive to the adoption of ESTs.

The study found that there are many ESTs, patented, not patented, and in the public domain. A list of these ESTs could be compiled, if necessary with vernacular translations, to make the information more accessible. The R&D organizations were not able to provide this information, as they have not clearly classified their technologies, nor did they have a readily available list of ESTs, which are in now the public domain, after the expiry of the patent period. However, several promotional measures to bring awareness of ESTs to several levels have led to a general appreciation of the problem among the important actors and institutions in the field. Several new and innovative organizations have been established and a focus is emerging to identify and popularize ESTs. In certain industry sectors, such as the pollution

[58] Tehri Dam and Narmada Dam are just two examples.
[59] Cogentrix power plant on the west coast of India is an example. The local NGOs continued to oppose the scheme until the High Court decided that the project could be implemented with necessary safeguards.

prone S&S sector, ESTs are spreading fast because of state intervention. But the spread is limited in the heavy industries sector, where large capital imputs may be required. The informal sector poses a daunting problem; no policies are in place to spread ESTs and a policy focus is required.

B. Measures taken to support development, transfer and diffusion of ESTs

Most measures to support the transfer and diffusion of ESTs in the Indian context have been due to government efforts and external funding by bilateral and multilateral agencies. There are finds a mix of command and control measures, and some incentives. The interventionist policies of the Government have been more active in the regulative aspects (i.e. enactment of laws and rules, and enforcement,[60] where they indirectly contribute to the diffusion of ESTs). At the micro level, there are some financial incentives to motivate firms to adopt and seek innovative ESTs in areas of waste minimization, resource recovery, and pollution abatement. A sectoral approach to identify seventeen polluting industrial sectors in the large, medium and small-scale sectors has laid the basis for a logical approach to the problem.

There is a strong network of institutions and actors to ensure that government policies and programmes pertaining to ESTs are implemented effectively. There is no exclusive R&D policy of regulative or incentive mechanisms to encourage R&D organizations to develop ESTs, nor a separate combination of fiscal and monetary policies to generate and encourage the diffusion of ESTs. At present, the implied policy is that, all other variables remaining the same, EST projects receive funding preference. The incentive policies, which apply to the development of indigenous technologies in general, apply also to the generation ESTs. It is being increasingly realized also that without a strong R&D base, the adaptation of imported and indigenous ESTs can become socially problematic. The study found also that mere hardware ESTs could not succeed in greening industries, unless they were adapted successfully to the organizational culture of a firm. However, there is increasing awareness of clean technologies in industry circles and this will encourage further R&D on ESTs.

C. Current trends in terms of funding priorities, technology choice, and transfer of technology

The current trend in funding priorities is towards the areas of renewable energy technologies, clean coal technologies, catalytic converters, and fuel cell technology. Multilateral funding, especially in the areas of renewable technologies supports some of these technologies. The Search for indigenous clean coal technologies is driven by environmental necessity and the need to reduce pollution in thermal power stations. Process ESTs like fuel cell technology and abatement ESTs such as catalytic converters are funded because of their future market potential in the transport sector. The development of appropriate ESTs for the management of degraded resources like land, soil, water, and management of urban wastes,

[60] Many developing countries have a tendency to 'legislate' the problems ‘out’ from above.

are also focused. Incidentally, waste management is an area where some technologies imported under multilateral aid programmes conflict with local ethos and cultural practices.[61] Firms are increasingly adopting pollution control strategies and beginning to prefer clean technologies when making technology choices. For a considerable period in the future, India will depend on imports of several ESTs. This picture emerges from a study of a number of areas with technology gaps, which have been identified by the Confederation of Indian Industries, and the type of ESTs in demand by the Indian environmental protection industry.[62] At the same time, with increasing interface with industry and increasing demand for ESTs, R&D centres will generate and transfer more ESTs to the industries in need.

RECOMMENDATIONS

A. Possible improvements in legal regimes: compatibility of law and commercialization of ESTs:

At the stage of conceptualization of an EST project it is necessary to examine the prevailing legal regime[63] as the commercialization of an EST may have various legal implications. During the survey, two such instances came to light. One was in Mumbai, where the transport authorities needed clearance under the Explosives Act before two transport buses could use CNG as a part of a pilot project. The second case was in NCL, Pune, where the commercialization of a pesticide technology was delayed for several years because of a failure to register the data on toxicity and bio-efficacy under the Insecticides Act, 1968. Therefore, before an EST is conceptualized, it is necessary to examine the legal regime to find out the applicability of various enactments. Two more Acts may be passed soon. The Biodiversity Conservation Act and the Plant Varieties Act. These acts are likely to set important norms for R&D in the bio-chemical and biodiversity spheres. Another important area is the enforcement of the legal provisions[64] of patent laws in a vast country like India, with the high enforcement cost being borne by the government. Rigorous enforcement of these laws will contribute to the promotion of the diffusion of more of ESTs. Finally, all types of ESTs, whether pre-hoc, post-hoc, process on product etc.- are licensed in the same way. However the terms and conditions that apply to an abatement or preventive EST need not be the same as a new process EST. In the case of abatement or preventive ESTs, it is in the

[61] Discussion with policy implementing officers brought out how several imported sewerage treatment plants are non-functional because the local citizens would not connect their own toilets to the main sewerage line because of cultural and cost factors. Another case was the disuse of electric crematoriums in certain riparian towns. People, in some places, do not use these technologies for religious reasons. However, no survey has been made by independent organizations to find exact reactions to the introduction of such technologies.

[62] CII. Environmental Business Opportunities in India. New Delhi. 1996. pp. 77, 54, 51, 48, and 40. EST needs of various sectors have been high-lighted.

[63] The Water (Prevention and Control of Pollution) Act, 1974; The Water (Prevention and Control of Pollution) Cess Act, 1977; The Air (Prevention and Control of Pollution) Act, 1981; The Environment Protection Act, 1986; The Public Insurance Liability Act, 1991 are some of the important ones in environmental legislation in India.

[64] Non-subsidized resource pricing, introduction of economic instruments, ensuring access to ESTs through information dissemination constitute other complimentary measures, which sometimes are included in the legal regimes as these measures need a strong legal basis.

interest of the society that there is no monopoly involved. The ESTs developed should be available to all on a non-exclusive basis. Even the licenses for new process ESTs are being given by the R&D organizations on a non-exclusive basis. Non-exclusivity prevents the entrepreneur from taking risks and the financial agencies from extending required venture capital. In view of this, some methods of exclusion, either on the basis of time or territory has to be worked out for process ESTs. Otherwise, there will always be a conflict between market needs and the licensing policies of R&D organizations.

B. Policies and practices that could be adopted in India and/or applied in other countries: R&D personnel in technology related management bodies

USAID funded a project in India, called the programme for the Advancement of Commercial Technology (PACT) were on the governing council of PACT. A number of representatives from R&D sector. There are several such national, bilateral and multilateral programmes, and as a matter of course they should involve personnel from the R&D sector, preferably from upper and middle levels of management. This will help in the generation and diffusion of ESTs by bringing together R&D personnel policy makers at different levels.

1. Golden triangle approach

The commercialization of innovative ESTs needs a favorable industrial and legal framework based on appropriate property laws, import and export policies, foreign investment policies, and institutional co-operation. Financial institutions have an important role in technology development by way of extending loans, working capital, margin money, seed capital and venture capital finance. Of late, important venture capital companies are coming up in India. The Technology Development & Investment Corporation of India (TDICI) is an example of such an institution. It was founded jointly by ICICI and Unit Trust of India (UTI), as one of the country leading venture capital companies. However, the crucial point is that there should be close liaison between financing institutions, industry and the R&D sector. In India NCL has tried achieve this by promising project financing to prospective buyers of technology. NCL contacts venture capital companies in advance to discuss the merits of untried technologies and will invariably give for funding preference to ESTs. This makes commercialization of untried ESTs easier. NCL calls this the “golden triangle” approach.[65] Methods which can be tried to bring finance, industry and technology together, and keep them together include the single window approach and technology commercialization workshops with targeted participation.

2. Tradable emission permits

In India, there are more than 2000 industrial estates or clusters.[66] However, the Government has not considered the concepts of tradable emission permits and bubbles. The introduction of these concepts in a cooperative mode in selected industrial clusters will raise

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[65] UNCTAD. From Technological Competence Building to Competitiveness. Challenges For Publicly Funded R&D in India: A Case Study of the National Chemical Laboratory, Pune, 1993.

[66] Environmental Business Opportunities in India. CII. Delhi, 1996, pp. 34

environmental awareness and encourage the adoption and diffusion of appropriate ESTs. The existing institutional infrastructure of the Central and State Governments will be able to administer these programmes.

3. Development of an interconnected database on ESTs

An interconnected database on ESTs is a necessity in India. At the macro level, there is little data available on ESTs. The first task is to identify and eco-mark EST type technologies. Once this is done, the database must include a list of ESTs in the public domain and under patent licences. Some licensees expressed the view that in the process of commercialization, hidden costs constrained industries from participating the generation of ESTs.[67] In this area, such an interconnected database could give more information to potential users of ESTs. This database should be accessible to the public and to potential users on the basis of user fees. More important is the establishment of connections between various databases now operating in isolation. There are several such databases, the important ones being the Environmental Information System (ENVIS), TIFAC-LINE, the Patent Information System (PIS), the International Network for Transfer of Environment Friendly Technology (INTET), and the Mechanism for Exchange of Technology Information (METI). This interconnection presupposes some sort of standardization or compatibility of hardware and software. The databases should also be able to give, where possible, a comparative picture of technology sources and technology choices. The potential customer may not be in a position to access the database personally. However, numerous promotional agencies, located in various regions of the country, could access the data and help potential customers. Awareness can be created among entrepreneurs through the use of various media networks. R&D organizations will also be connected to these databases. This will help inter-organizational communication and the flow of cost-effective information to the market. The interconnected databases could support also news groups for various R&D actors, and could even made accessible to other Internet users from other countries.

4. Specific policy measures exclusively for ESTs

At present, there are no exclusive fiscal or financial incentives for ESTs. Partly this is due to the lack of a database on what constitutes ESTs. The introduction of a policy to provide benefits exclusive by the adoption and or generation of ESTs may create some problems at the beginning but, in the long run, the benefits may outweigh the burdens. Such a policy measure may stimulate a debate on what constitute ESTs, and may influence R&D in that direction. There have even been debates on what constitutes R&D when firms have claimed various concessions under tax laws. An incentive policy package could in fact be introduced without an additional burden to the state exchequer if the existing tax relief and duty exemptions for the importation of R&D equipment were rationalized. Financing agencies could have schemes whereby EST projects could be financed with easier terms and conditions to enhance the utilization of venture capital.

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[67] One marketing official suggested that future EST development must attempt to include the potential customers from a more preliminary stage to cut down on time and cost.

5. The promotion of soft ESTs

Visits to some failed environmental projects, revealed some important points. Promotional agencies must bear in mind that the hardware part of ESTs is the least difficult item in the diffusion process. The practices and organizational cultures without which hardware transfers remains unwelcome grafts to eventually die after some time need to be addressed. The bureaucratic apparatus, which is largely involved in the diffusion process, misses this point. Hence the involvement of NGOs to address problems in a more organic manner and to reach out to workers and users, is a necessity. The effective diffusion of ESTs makes it imperative that cultural and organizational issues are identified and addressed. These are the areas of soft ESTs, which can be strengthened through a process of interaction that enables firms to "learn to learn". Feedback or evaluation studies on EST projects are rarely documented or published. As a result, policy makers are not able to use corrective mechanisms. Even when some evaluation studies have been available, the "fire-fighting" administrators have not had time to study these voluminous reports, resulting in the formulation of policies that perpetuate same mistakes of the past.

6. Policies and projects for the informal sector

The informal sector in India is huge and the most difficult sector to tackle. This has been confirmed by in some studies made by the Government of India in connection with the phasing out of CFCs. At present, there is no government interventionist policy to introduce ESTs into this sector. However specific attention should be paid to this sector and appropriate mechanisms developed to encourage and facilitate the introduction of ESTs. Furthermore, NGOs and field level environmental organizations have a coordinated role to play in this area, and some fiscal and financial policies introduced to encourage the informal sector to adopt ESTs and, at the same time, move into the formal sector.

7. Documentation and establishment of Waste Minimization Circles (WMCs)

Existing WMCs can be remodeled along the lines of the Kaizen groups in Japan, workplace with financial incentives and rewards for innovation. This scheme could be introduced into other countries, and with the help of NGOs as change agents into other industrial sectors in India, including the informal sector. There are 15 such groups now working in India in the SME sector, with great potential for the promotion and diffusion of ESTs. The preparation and dissemination of Documentation on various practices of WMCs will encourage others to innovate further.

8. Eco-marking of technologies as ESTs

The eco-marking of appropriate technologies[68] as ESTs will help their diffusion and transfer within and between developing countries. Notwithstanding the international

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[68] Eco-labeling & International Trade, an edited book by Zarrilli, Jha, and Vossenaar, brings out various issues pertaining to eco-labeling. Global Eco-labeling Network (GEN) has published literature on this subject.

controversy[69] of eco-labeling being a non-tariff barrier for developing countries, labeling will be of great help to small and medium size firms. Within the framework of an organizational network with the required expertise, the introduction of an eco-labeling scheme will contribute to a better participation in the international dialogue on this subject. There are technologies that can clearly be labeled as ESTs within the context of India. In fact, many export-oriented Indian industries are adopting ISO 14000 and ISO 9000. There are export-driven incentives, but at one point, firms were reluctant to adopt these certification schemes. India launched the ECOMARK scheme in 1991 and so there will be no institutional problems to extend the scheme to the areas of hardware ESTs.

9. Funds for R&D on ESTs under multilateral schemes

There is resentment in R&D, NGO, and official circles that R&D, development of ESTs, has not been financed under the Multilateral Funding mechanism of the Montreal protocol, and from GEF funds. The reason may be to avoid duplication of ESTs. However, funds could be earmarked for areas where the successful adaptation of even imported ESTs need R&D investment. In view of this, some multilateral funds should be earmarked for innovative R&D projects in areas pertaining to ESTs and international environmental agreements.

10. Strengthening and modernization of Patent Offices

The patenting process for ESTs needs to be shorter. To quote one R&D institution's response in this survey: “The current procedure for obtaining a patent is very lengthy, time-consuming, and very expensive. For our kind of an organization, the patent would lose its significance by the time we obtain it.” More patent offices are needed and there is also a shortage of patent consultants. Patent agents were perceived to be slow in action, although efforts have been made to train people on patent matters at various levels. New patent cells have been opened in R&D organizations. The cost of obtaining patents abroad is seen as discriminatory and puts Indian patent seekers in a disadvantageous position. The cost of obtaining one patent in the United States is almost Rs.300, 000, which is one thousand times more than the cost of obtaining a patent in India. Fighting a legal battle abroad on patent matters is even more expensive, and in future there may be many more such legal conflicts in areas of environmental technologies related to bio-diversity.

11. Upgrading the infrastructure and incentives for EST generation

For R&D institutions to be competitive and innovative in the areas of generation and diffusion of ESTs, they need a high level of investment to modernize their laboratories. In the past, in the absence of linkages with the private sector, this was not a priority area. Some R&D organizations need state-of-the-art equipment and training of their R&D personnel. Although various bilateral and multilateral schemes meet some of these modernization needs, the problem needs a more comprehensive and time by approach. This is an area where partnership with the private sector will be very helpful. One suggestion that came from the

[69] Ibid. pp. 310, Veena Jha discusses the modalities of harmonization of eco-labeling policies, by way of making it proactive, rather than reactive.

publicly funded R&D sector was that some of them that are internationally competitive, should be permitted to raise private funds on the market for R&D. There were two more suggestions. First, Public Sector Undertakings should provide a prescribed percentage of sales turn over to national laboratories to implement R&D on ESTs. Second, technology institutions must select more environmental for research areas by introducing novel and innovative incentive schemes. One such scheme could be to sponsor a number of scholarships in national universities for Ph.D. students to implement EST projects, with financial assistance from industry and Government. R&D institutions could allocate also a percentage of their R&D budget for the generation of ESTs.

12. Measures for risk-averse firms

The most common may to finance environmental ventures in India is through assistance from multilateral and bilateral agencies, mostly channeled through the Government. The IDBI has funded 91 projects and disbursed Rs.546 million to venture capital enterprises in the electronics, engineering, drugs, and pharmaceuticals industries.

Thus not much financing has been made available for the development of the ESTs in particular. The ICICI supports technology development and finances large and medium scale ventures. It has a subsidiary company called the Technology Development & Information Company of India Ltd. (TDICI), which operates technology-related venture financing schemes. However, given India’s size and needs, these venture capital schemes are not adequate. India's private venture capital industry is still in its infancy. Some companies in this field are: 20th Century Capital Corporation, Credit Corporation and Industrial Ventures Management, and Infrastructure Leasing and Financial Services (IL & FS). The promotion of venture capital for EST generation and development is a new concept and so far limited in its application. Most pollution prone industrial sectors have several firms that are highly averse to risk for a variety of reasons such as product price fluctuations, lack of alternative markets, and the nature of the competition etc. These firms usually avoid adopting ESTs. In addition to attempting to provide them with information on cost-effective, adaptable and affordable ESTs, and capital, the introduction of an insurance scheme to cover their risks should be considered. Such a scheme would encourage these firms to adopt ESTs availing themselves of the various venture capital schemes of financing institutions.

13. The need for a study on the participants

At present, the availability and priorities of international funding shape most of the EST diffusion policies of the Government of India. The other important point is that the more visible sectors, such as the transport sector, and the small-scale sector in cities, are accorded higher priority. Whereas other sectors such as mining, quarrying etc., need more innovative ESTs, they are less visible. Moreover, the diffusion process is from top-down. If it were a process starting at grass roots level it might be more sustainable. A case in point is the setting up of common effluent plants in and around Calcutta. Once the Central Government stops its hundred per cent subsidy, it is difficult to predict whether the resource-starved provincial governments will accept the financial burden. This applies also to several firms in the metropolis who have adopted pollution prevention technologies because of the enforcement of regulations. Thus a study of the actors in the process where environmental is an extremely important factor which is missing at present.

14. International credit for exporting ESTs through joint ventures

At the beginning of 1995 there were 117 joint ventures established by Indian companies into partners' foreign countries. There were 28 in Africa, 1 in Bangladesh, 11 in Indonesia, 21 in Malaysia, 8 in Nepal, 1 in Philippines, 17 in Singapore, 15 In Sri Lanka and 9 in Thailand. These Indian firms operating in other developing countries have acted as powerful conduits for the transfer of technologies. Consequently developing countries should

be encouraged and provided with the necessary finance to have more joint ventures based on their respective areas of strength and indigenously invented ESTs. However, there is a problem of lack of capital. The export of ESTs through joint ventures, and the implementation of projects need long term-credit assistance on soft terms, which at present the Export-Import (EXIM) bank and Export Credit Guarantee Corporation (ECGC) can not provide. Many other developing countries may have the same problem. A mechanism required to enable these countries to diffuse their indigenously invented ESTs to other countries. Between 1981 and 1994, Indian companies entered into 13, 419 collaborative agreements with foreign companies. Between 1990 and 1994, the average was 1,086 agreements per year. The new industrial policy introduced in 1991 and subsequent economic liberalization led to the establishment of more technical and financial collaborative agreements. It would be interesting to study the type of foreign ESTs that have been adopted in India, and the weighting given to ESTs in the process of technology choice. A comparative study the experiences of some developing countries in this respect could help to shape international focus on the diffusion of ESTs.

15. ESTs for social equity, resource planning and environment monitoring

In order to derive benefits from the results of R&D, several experimental projects are being supported in India through R&D field groups and voluntary organizations. Such projects demonstrate the changes that can be brought about in improving the living conditions of the rural population, including women and other weaker sections of society. Another example is the development of spatial data handling methodologies for local area planning. The emphasis has been in setting up computerized database on natural resources and socio-economic parameters at district level and supporting relevant application projects that will pave the way for the better management and utilization of natural resources. These applications have also great potential for being adopted in other developing countries. Similarly, there is a host of environment monitoring equipment, which has been developed in India. These technologies too have great potential for diffusion into other developing countries and vice-versa.

16. EST Information outlets

In addition to the large number of joint ventures set up abroad, India has also 93 wholly-owned subsidiaries in various developing and developed countries. These organizations can function as information centre for the diffusion of ESTs. Moreover, in India, there are around 10,000 environmental NGOs, and the Ministry of Environment and Forests has an NGO cell. These NGOs too could work as mini-outlets for the diffusion of literature on ESTs, published both in English and in vernacular languages. Such literature could reach the target groups in both urban and rural areas through the NGOs, and could be a strong policy instrument to bring about awareness among the actors in the informal sector.

17. Expenditure of the R&D cess

Under the Research & Development Cess Act, the Government of India has collected about of Rs.5.5billion. Though, in principle, the entire amount should have been at the disposal of the Technology Development Board, disbursements for R&D purposes was Rs.300 million in 1996-1997, and Rs.700 million in 1997-1998. The Government has retained a substantial amount of this fund part of which could be earmarked for the indigenous development of hardware and software areas ESTs. A further part of this fund could be made available as venture capital, at very nominal rates of interests, for the introduction of ESTs into the SME and informal sectors. The R&D process, if properly oriented, can give a boost to indigenous R&D on ESTs.

C. Innovative methods for financing public and private partnerships

1. An association for the promotion of ESTs in India

In India there are many organizations that deal with the supply of environmental goods and services which could form an association for the promotion of ESTs. A large number of environmental consultancy firms operating in India could also be involved. Various industrial associations such as the CII, the FICII, the ASHOCHAM have environmental divisions and could mobilize financial support from industry for R&D of ESTs. This proposed association for the promotion of ESTs in India should help shape the Government’s EST policy and represent industrial interests in promoting ESTs NGOs can be tapped to play a positive role. This association could (a) administer various incentive schemes, (b) motivate R&D organizations and the academic community to develop appropriate ESTs for various industries and regions in India, and (c) help to publicize ESTs and enhance citizens’ support for the development and diffusion of ESTs. Thus, the proposed association would provide a base for formal and informal interaction with government policy makers, NGOs, R&D organizations and industries, to design and consider various financial mechanisms for R&D cooperation.

2. South-south barter/exchange of ESTs

South-south exchange of ESTs between R&D organizations and firms, and the promotion of public-private partnership, requires a correct appraisal of available ESTs in various developing countries. There are several developing countries, like India, that have stocks of locally invented and appropriate ESTs. Some technology appraisal and exchange takes place during international trade fairs. However a focused method would involve an international organization making a comparative and sectoral list of available ESTs in various developing countries. This would enable policy makers in the developing countries to “barter technologies" for mutual benefit and to have a wider choice. A SWOT analysis, of the technology imports of various developing countries, would indicate those industrial areas where ESTs can be traded between developing countries. Even a listing of ESTs in the public domain of these countries would be useful, provided the users of these public domain technologies were given due and necessary technological assistance by some national or international organizations in translating and adopting public domain technologies. A SWOT analysis of the EST sector in the respective developing countries would help to dovetail inter-country and intra-country policies on the diffusion of ESTs. Such analyses will help also policy makers consider issues pertaining to the diffusion and export of ESTs.

3. Networking of R&D institutions

Networking between R&D institutions will provide a great impetus for the diffusion of ESTs, through problem identification, avoiding of duplication of research, the mutual exchange of data and research findings, and the sharing of expertise. However, to achieve such networking, the problem of motivation needs to be addressed. Most leading institutes seek strategic alliances with Western R&D institutions because of the possibility for bilateral assistance and the assumption that they might benefit in terms of acquisition of know-how. However, a parallel south-south strategic alliance between R&D organizations and industry partners may even be complementary to the present system of south-north alliances. These networks must include some industry partners, so that the transfer of technology from the laboratory to the field will be easier. This means that the network will have two components- an intra-country vertical components of R&D institutions with indigenous industry partners, and a horizontal component of inter-country R&D groups.

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
APCTT	Asia and Pacific Centre for Technology Transfer
ARI	Agharkar Research Institute
BARC	Bhaba Atomic Research Centre
BHEL	Bharat Heavy Electricals Ltd.
BI	Bose Institute
BOD	Biological Oxygen Demand
BOO	Build-operate-own
CAG	Comptroller and Auditor General
CBRI	Central Building Research Institute
CBT	Centre for Biochemical Technology
CCMB	Centre for Cellular and Molecular Biology
CDRI	Central Drug Research Institute
CDRI	Central Drug Research Institute
CECRI	Central Electro Chemical Research Institute
CECRI	Central Electrochemical Research Institute
CFC	Chloro Flouro Carbon
CFRI	Central Fuel Research Institute
CFTRI	Central Food Technological Research Institute
CFTRI	Central Food Technological Research Institute
CGCRI	Central Glass and Ceramic Research Institute
CII	Confederation of Indian Industry
CIMAP	Central Institute of Medicinal and Aromatic Plants
CLRI	Central Leather Research institute
CMERI	Central Mechanical Engineering Research Institute
CMRI	Central Mining research Institute
CNG	Compressed Natural Gas
COSATIDC	Committee on Science and Technology in Developing Countries
CPRI	Central Power Research Institute
CRRI	Central Road Research Institute
CSIO	Central Scientific instruments Organization
CSIR	Council of Scientific and Industrial Research
CSMCRI	Central Salt and Marine Chemicals Research Institute
DAE	Department of Atomic Energy
DANIDA	Danish International Development Agency
DBT	Department of Biotechnology
DNES	Department of Non-Conventional Energy Source
DOD	Department of Ocean Development
DOE	Department of Electronics
DOS	Department of Space
DRDO	Defense Research and Development Organization
DSID	Department of Scientific and Industrial Development
DSIR	Department of Scientific and Industrial Research

DST	Department of Science and Technology
EBR	Extra Budgetary Resources
EEC	European Economic Community
ENVIS	Environmental Information System
ER&DCI	Electronics Research and Development Centre of India
EST	Environmentally Sound Technology
FOASAAS	Federation of Asian Scientific Academies and Societies
GEF	Global Environmental Facility
GNP	Gross National Product
GWP	Global Warming Potential
HAL	Hindustan Aeronautical Ltd
IACS	Indian Association for Cultivation of Science
IAITT	Interaction with Agencies and Institutions on Technology Transfer
ICAR	Indian Council of Agricultural Research
ICICI	Industrial Credit and Investment Corporation of India Ltd
ICMR	Indian Council of Medical Research
ICPC	Indian Centre for Promotion of Cleaner Technologies
ICSU	International Council of Scientific Unions
IDA	International Development Agency
IDBI	Industrial Development Bank of India
IDRC	International Development and Research Organization
IFCI	Industrial Finance Corporation of India
IICB	Indian Institute of Chemical Biology
IICT	Indian Institute of Chemical Technology
IICT	Indian Institute of Chemical Technology
IIP	Indian Institute of Petroleum
IMT	Institute of Microbial Technology
IMTECH	Institute of Microbial Technology
IPPP	Industrial Pollution Prevention Project
IPR	Institute of Plasma Research
IREDA	Indian Renewable Energy Development Agency
IRRDP	Indian Renewable Resources Development Project
ISDOC	Indian National Scientific Documentation Centre
ITRC	Industrial Toxicology Research Centre
MNCs	Multinational Corporations
MNES	Ministry of Non-Conventional Energy Sources
MOEn	Ministry of Environment and Forests
MOU	Memorandum of Understanding
NAL	National Aerospace Laboratory
NAL	National Aerospace Laboratories
NBB	National Bio-Energy Board
NBRI	National Botanical Research Institute
NCL	National Chemical Laboratory
NCL	National Chemical Laboratory
NEERI	National Environmental Energy Research Institute
NEERI	National Environmental Engineering Research Institute

NGRI	National Geophysical Research Institute
NIO	National Institute of Oceanography
NISTADS	National Institute of Science Technology and Development Studies
NML	National Metallurgical Laboratory
NPL	National Physical laboratory
NRDC	National Research Development Corporation
ODA	Official Development Assistance
ODS	Ozone Depleting Substances
ONGC	Oil and Natural Gas Corporation
PASTER	Programmes Aimed at Technological Self-reliance
PCRI	Pollution Control Research Institute
PIS	Patent Information System
PSUs	Public Sector Undertakings
R&D	Research and Development
RRL	Regional Research Laboratory
RTDTC	Rural Technology Demonstration-cum-Training Centre
S&T	Science and Technology
SBI	State Bank of India
SCTIMST	Sree Chitra Tirunal Institute of Medical Science and Technology
SFCs	State Financing Corporations
SIDBI	Small Industries Development Bank of India
SIEU	Scientific, Industrial Liaison and Extension Unit
SIRO	Scientific and Industrial Research Organization
SME	Small and Medium Enterprises
SSI	Small-Scale Industries
SWOT	Strengths, Weaknesses, Opportunities, Threats
TATT	Transfer and Trading in Technology
TDB	Technology Development Board
TDICI	Technology Development and Investment Corporation of India Ltd
TELCO	Tata Engineering and Locomotive Co. Ltd
TIC	Technology Information Centre
TIFAC	Technology Information Forecasting and Assessment Council
TOT	Transfer of Technology
UNDP	United Nations Development Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFSTD	United Nations Fund for Scientific and Technological Development
UNIDO	United Nations International Development Organization
WIPO	World Intellectual Property Organization
WITT	Waterfalls Institute of Technology Transfer
WMC	Waste Minimization Circles
WTO	World Trade Organization

PUBLICLY FUNDED RESEARCH AND PUBLICLYOWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES (ESTs) THE CASE OF THE REPUBLIC OF KOREA

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INTRODUCTION

In the Republic of Korea, there are various government supported technology development programmes. These programmes are conducted by a number of different ministries and government agencies. It is however difficult to identify the EST- relevant programmes these projects. Many of the technologies already developed, or being developed, have potential to be used for the goal of sustainable development. As a result, this paper will deal with R&D programmes to confirm that GRI (Government supported research institutes) could play a catalytic role in the transfer of ESTs.

Chapter 1 describes the objectives and activities of various publicly funded R&D programmes the Republic of Korea. Chapter 2 analyses government policy and the current status of cooperative R&D. More detailed activities related to technology transfer are described in chapter 3. Finally, chapter 4 suggests future policy directions focusing on the application of AIJ the Republic of Korea.

II. PUBLICLY FUNDED R&D PROGRAMMES IN THE REPUBLIC OF KOREA

According to government data, there are more than 20 technology development programmes which are financed by public funds, a though public funds are provide to promote technological innovation in general these programmes are also supported partially from private industries and academic communities. The programmes are designed to improve technical competitiveness (not only commercial purposes but also to meet international responsibilities) of the Republic of Kore’s industries, using the most advanced technologies and technical know-how. These programmes are divided into two categories; grants and loans with favourable interest rates. Boxes 1 and 2 list the programmes according to category.

Box 1
Financial Grant and Financial Support

① Engineering Base Technology Development Programme
② Industrial Base Technology Development Programme
③ Strategic National R & D Project
④ Information Technology Development Programme
⑤ Energy Technology Development Programme
⑥ Joint Consortium for Industry-Research Community and Regional Development Technology Development Programme
⑦ KEPCO (The Republic of Korea Electric Power Company) Small and Medium Enterprise Technological Development Programme
⑧ Construction and Transportation Technology Research and Development Programme
⑨ The Republic of Korea Institute of Industrial Technology Research and Development Programme
10 Medical and Health Technology Development Programme

Box 2
Financial Loan

① CFC Substitution Technology Development Loan Programme
② Engineering Base Development Technology Loan Programme
③ Industrial Base Development Loan Programme
④ Science and Technology Promotion Loan Programme
⑤ Environmental Management Corporation Loan Programme
⑥ The Republic of Korea Industrial Bank Loan for Technology Development
⑦ Recycling Industry Promotion Loan Programme

The Government supported programmes have different objectives and conditions. However, the main objective of these programmes is to help the private sector in technological innovation efforts, which will require large long-term. Financing is provided on a matching fund basis between private and public sectors. Furthermore, the transfer and commercilization of the results of the technology development programmes are encouraged. Although most of these programmes have relevance to the EST categories, some of them with closer linkages need more detailed explanation.

MOST Programme

At the outset, the MOST (Ministry of Science and Technology) R&D programme carried out two types of research. One was government-initiated, which dealt mainly with high-risk research or research with public externalities. These projects were entirely government funded. The other was an industry-initiated project, which involved core industrial technologies that private firms could not develop alone, owing to the scarcity of investment funds and R&D capabilities. They were co-funded by the Government and participating companies.

In response to various new socio-economic demands, the programme was enlarged in 1994 to six categories of research. They are the Han Project (Highly Advanced National Project), the Strategic National R&D Project, the GRI Project (Government supported Research Institute Project), the International Cooperative R&D Project, the Nuclear R&D Project, and the research planning and Evaluation Project (see Table 1).

The Strategic National R&D Project supports the development of core industrial technology and research on mega science. It includes projects on biotechnologies, computer software, aerospace, and ocean-related technologies.

The GRI Project is being implemented autonomously to support GRI R&D in line with each institution's characteristics and mid-and long-tern R&D Plans. In addition, the Nuclear R&D Project, which aims to secure technological independence in the area of nuclear energy, and the Research Planning and Evaluation Project, whose goal is to enhance research relevance and productivity, are being implemented under MOST.

Table 1
Investment in MOST's national R&D programme, 1994

Project name	**Investment**	
	Government	**Private**
Han Project	572	845
Strategic National R&D project	338	334
GRI Project	400	21
International Cooperative R&D Project	44	17
Nuclear R&D Project	77	370
Research Planning and Evaluation Project	30	-
Total	**1461**	**1587**

Unit: 100 million won
Source: MOST

Table 2
HAN Project: product technology development

Project	Objective
Development of new drugs And agrochemical	Development of new drugs form traditional oriental medicines by 1996.
Development of broadband integrated Services and data network (B-ISDN)	Discovery and development of two or three new drugs and agrochemicals by 1997. Development of ATM (asynchronous transfer mode) by 1996. Development of B-ISDN by 2001.
Development of high-definition Television (HDTV)	Establishment of HDTV monitor technology by 1993. Development of transmission and broadcasting technology by 1994. Development of flat panel display by 1997.
Development of next-generation vehicle technology	Development of technologies related to next-generation automobiles and parts, including electrical vehicles to cope with environmental and energy problems as well as rapid socio-economic changes

Source: MOST

Table 3
Han Project: fundamental technology development

Projects	Objective
Development of ultra-large-scale Integrated circuits (ULSI)	Development and production of 256 mega KRAM by 1996.
Development of new advanced materials for the information Electronics, and energy industries	Development of 1 giga DRAM by 2000. Development of high value-added new materials and synthesis of ultra-pure raw materials that are important for the information industry and a highly developed industrial society.
Development of advanced manufacturing systems	Development of computer-integrated manufacturing (CIM) by 1996. Research and development of intelligent manufacturing system (IMS) by 2000.
Development of new functional Bio-materials	Development of high quality and high productivity biological resources expected to be important in 21st. century industries but now in the early stage.
Development of environmental Technology	Upgrading technology to solve national and global environmental problems and to provide a better human and social environment, as part of cooperation for global environmental protection and conservation.
Development of new energy technology	Development of highly efficient and clean energy: contribution to highly developed industry and society.
Research and development of next-generation nuclear reactors	Design and verification study for a new reactor concept; securing stable energy resources in preparation for the exhaustion of fossil energy

Source: MOST

MOST is supervising four projects out of a total of 11 in the HAN Project. They include the development of new drugs and agrochemicals, the development of ultra-large-scale integrated circuits, development of new advanced materials for the information, electronics, and energy industry, and the development of new functional biomaterials.

From 1982 to 1993, 284 technologies were commercialized and 444 technologies are being commercialized as a result of MOST's R&D programmes. There have been 1,454 (1033 domestic and 421 foreign) applications for industrial property rights and 665 (501 domestic and 164 foreign) have been granted. Furthermore, eight technologies developed in the MOST R&D programmes were with a total value of more than US$33 million exported to several foreign countries.

B. MOTIE’s R&D Programme

The MOTIE (Ministry Of Trade, Industry and Energy) Industrial Generic Technology Development Programme covers slightly different technology fields than the MOST programmes. It puts more emphasis on the development of pre-competitive technologies with spillover effects on related industries and core technologies with widespread applications in the private sector.

Table 4 shows the evolution of the number of projects and the amount invested by government and private firms between 1987 and 1995 under the Industrial Generic Technology Development Programme. As Table 5 shows, this programme has five research categories: pre-competitive bottleneck technology development projects, mid-term key technology development projects, long-term composite technology development (HAN) projects, international cooperative technology projects, and others.

Pre-competitive bottleneck technology development projects aim to meet technological demands from small and medium-sized enterprises (SMEs). Mid-term key technology development projects focus on technologies with large spillover effects on industry owing to inter-firm cooperative R&D. Long-term composite technology development projects are among the HAN Projects; they include the development of nextgeneration vehicle technology, advanced manufacturing systems, new energy technology, next generation nuclear reactors, etc.

KAITEC (The Republic of Korea Academy of Industrial Technology) manages the Industrial Generic Technology Development Programme andconducts an annual technology demand survey to identify industrial needs.

Table 4
Industrial Generic Technology Development Programme, 1987-1995

	1987-1990	**1991**	**1992**	**1993**	**1994**	**1995**
Number of Projects	951	551	499	446	424	500
New	622	332	199	276	176	-
Continued	329	219	300	170	248	-
Budget*	270	163	176	21	353	-
Government	102	71	73	89	141	191
Private	168	92	103	123	212	-

* Unit: 100 million won
Source: MOST

Table 5
Main project of the Industrial Generic Technology Development programme, 1987-1994

Project name	**Total**	**Government**	**Private**	**Remarks**
Basic technology R&D	973	389	584	Pre-competitive bottleneck technology, mid-term key technology, international cooperative technology Project.
Long-term composite Technology project	174	59	115	HDTV, next-generation vehicle technology, advanced manufacturing system, VLSL environmental technology, aerospace.
Technical support for SMEs	23	23		Support for promising SMEs, TBL, and regional San-Hak-Yun Consortium.
Management and evaluation	5	5		
Total	1175	476	699	

Unit: billion won
Source: MOST

MOTIE's alternative Energy Technology Development Programme is aimed at finding possible applications for 11 alternative energy sources, such as solar energy, bio-energy, wind power, etc. As explained above, this programme is now supervised by MOTIE, which launched also the Energy Conservation Technology Development Programme in 1992, to develop generic technologies in areas such as energy conservation and clean energy.

In the future, especially under the WTO regime, MOTIE's R&D programmes will take an indirect and industry-neutral course. As direct industry-specific support measures become invalid, S&T policy will focus on the construction of technological infrastructure and the promotion of private R&D.

To this end, MOTIE enacted the Industrial Technology Infrastructure Promotion Programme. The major projects of this programme include the development of research manpower, the construction of the technological information network, the expansion of R&D facilities, and the establishment of technical standards. These projects are carried out through joint public and private sectors investment, with government support provided on a project basis for a limited period of time. The specific projects are:

- Education and training of S&T manpower;
- Collection, analysis, and distribution of industrial technology information;
- Expansion of R&D facilities;
- Institutionalization of R&D activities (research consortia);
- Incubators for new technologies and the expansion of technological services;
- Reinforcement of the international S&T cooperation base;
- Promotion of technical standardization.

In this Han Project, the development of environmental technology is coordinated by the Ministry of Environment. In 1995, US$20 million were spent on environmental activities. (Ministry of Environment US$14million, Ministry of Science and Technology US$3 million, MOTIE US$2.8 million). Between 1992 and 1994, the Government allocated US$28 million while the private sector contributed US$33 million. By the year 2001, US$480 million (US$277 million from the Government, US$203 million from the private sector) will be spent on this programme. As in similar programmes, private-public partnership was encouraged but some of the projects were supported solely by the Government funding. Therefore, some of the technologies under this programme are owned by the Government or the GRIs.

C. Financial loans for technology development

In addition to government supported programmes, loans were provided to private industries, exclusively to the SMEs (small and medium enterprises) to help them to innovate environmental technological capabilities in response to ever-tightening environmental regulations. These are loans with relatively low interest rates (e.g. 6.0 per cent, compared to a market rate of about 11 per cent) for longer periods. This loan programme supports three main areas: pollution treatment technologies, clean technology development, and environmental industry promotion. Because this programme is purely a favourable loan programme, the ownership of the results will belong to the private enterprises. However, there is potential for government control in utilising the results for public purposes. The

Environmental Management Corporation, a semi-government institution responsible for environmental technology and industry promotion purposes carries out this programme.

D. Technical Support to SMEs

In addition to the loan programme, Environmental Management Corporation is providing environmental technical support to SMEs. This service is provided free of charge. In conjunction with the loan programme, this technical support programme is helping SMEs in identifying their technological needs and financing options.

Details of the support provided between 1992 and 1994 are listed in table 6.

Table 6
The support between 1992 and 1994

Programme	**1992**	**1993**	**1994**
No. of recipients	304	277	322
Loan amount (US $)	24 million	21.3 million	23.3 million
Technical Support (No)	230	333	339

Exchange rate; 1 US Dollar = 1200 won

Box 3
Areas of technical support were mainly in three categories:

① Pollution treatment operational training
② Environmental impact analysis
③ Technological innovation planning

The Environmental Management Corporation covers the costs of the support programme.

E. Recycling Industry Promotion Loan

This programme is designed to promote the recycling industry by providing loans with favourable annual interest of 6 per cent for up to 90 per cent of the project cost, the recycling industry can apply for a loan for a duration of up to 10 years. The Republic of Korea Resource Recycling Corporation, a semi-government body, manages this programme. Since 1994, US$111 million have been provided to more than 400 private recycling industries. The legal rights on technology developed under this loan programme, cannot be controlled. However, the Corporation must review project results by comparing performance to intended goals.

F. CFC Substitution technology promotion loan programme

This is a privately funded programme operated by the Republic of Korea Specialty Chemical Association. It was launched as a result of MOTIE’s legislation on ozone-depleting substances management and production regulation. In this sense, this programme can be regarded as a government programme designed to discourage production of ozone depleting substances and promote substitution technologies and materials. Any industry that is producing or using ozone-depleting substances must pay a fee that will be allocated to this programme. Since 1992, about US$28 million were accumulated. CFC substitution technology companies can apply for up to 90 per cent of project cost for their technology development at an annual interest of rate5 per cent. The developer owns the results.

G. Engineering base technology development programme

This programmed provided support of up to two-thirds of the whole technology development project’s costs if it has strategic importance to the industrial sector’s international competitiveness. According to article 13 of the Engineering Development Act of the MOTIE (Ministry of Trade, Industry and Energy), a recipient of funds is required to pay back up to 50 per cent of the programme funding only when the results are judged technologically and commercially satisfactory. Therefore, this is a public fund for a broad range of long-term benefits without any short-term commercial return. Private industries, research institutions and universities are to for apply. About US$309 million US Dollars are allocated for various projects, including international joint R & D projects (Table 7).

Table 7
Programme Details

Divisions	Budget 1996	Budget 1997	Remarks
Common core technology	51.3	56	Import substitution technology development
Long-term basic technology	38	54	Base technology for strategic Industries
Advanced technology	31.3	47.3	G-7 category
Aerospace technology	29.3	16.7	Airplane industry, satellite technology
Joint international R&D	2	2	APEC joint projects
Industrial packaging technology	4.7	8	Packaging
Clean technology development	3.3	8.7	Standardization, cleaner production
Other	9.3	11.3	Industrial parts
Total	**172**	**205.3**	

Unit: US$ Million Dollars (1 US Dollar = 1200 won)
Source: MOTIE (1997)

Host institutions that will benefit from the programme fund and own the intellectual property rights of the development results are from diverse backgrounds. They are national/public research institutes (NRIs), government-invested institutions (GIIs), government-supported research institutes (GRIs), universities, research associations and other legal entities that are authorized by the Government. A detailed description of the Government-supported research institutes is in appendix 1.

This implies that these semi-government bodies own some of the technologies developed under the programme. There has been some debate on whether these technologies are owned by government. Based on the examination of the operational statutes and unofficial discussion with members of various GRIs it is considered that technologies owned by semi-government bodies must be in direct by or indirect by controlle by the Government.

Compared to other government spending on technology development little attention, has been paid to ESTs related programmes. However, there has been a relatively noticeable increase both in the budgets for and the number of ESTs projects reflecting of the global trend in the greening of industries. However, ESTs projects are still a minority in the overall R&D programme. Tables 8 and 9 show how much the R&D budget has increased.

Table 8
R&D budget for government and private sector

Year	Government Budget	Private contributions	Number of Projects
1995	1.5 million	1.2 million	14
1996	2.8 million	2.7 million	32
1997	8.7 million	4.4 million	80
1998	34.7 million (planned)	n.a	n.a

Unit: US Dollars (1 US Dollar = 1200 won)

Table 9
Technology Budget Increase on each field

Area	1996 Budget	1997 Budget	1998 Budget	Percentage Increase
Industrial base technology	32	80	220	587.5
Engineering base technology	260	308	443	70.4
Clean technology	4	3	54	1250
Commercialization	200	255	360	80
State of the art technology	60	70	104	73
Total	**574**	**726**	**1,180**	**105.5**

Most technology development projects are being carried out by private industries in partnership with universities or research institutions. However, some are implemented through the Government funding from the GRIs. In four by the categories (product, process, treatment and recycling,) the clean technology development programme, most of the basic clean technology projects are implemented only with government funding. Some projects, due to their nature, to commercialized and make profitable. These projects are being carried by the Republic of Korea Institute of Industrial Technology, one of the GRI under the MOTIE (Ministry of Trade, Industry and Energy). The Government classifies these technologies as publicly owned clean technology. The Government can control such developed technology through total or partial IPR (intellectual property rights) ownership as a result of the R&D programmes.

For example, in Energy Technology Development Programme, MOER's alternative Energy Technology Development Programme is aims to find possible applications for 11 alternative energy sources, such as solar energy, bio-energy, wind power, etc. As explained above, this programme is now supervised by MOTIE. In 1992 MOTIE also launched an R&D investment programme called of the Energy Conservation Technology Development Programme, to develop generic technologies in areas such as energy conservation and clean energy development (Table 10)

Table 10
MOTIE R&D investment, 1994

Project name	Amount
Alternative Energy Development Programme	255
Energy Conservation Technology Development Programme	242
Clean Energy Technology Development Programme	20

Unit: 100 million won
Source: MOTIE.

About 66 per cent of the total budget for the Energy Technology Development is from public funds: These are: Special Account for the Energy Sector (49 per cent), KEPCO (the Republic of Korea Electric Power Company) R&D Fund (22 per cent), the Republic of Korea Gas Corporation Fund (4 per cent), and the Petroleum Fund (25 per cent). These are funds allocated from the national budget for public purposes. Between 1993 and 1997, US$125 million were spent on this programme.

The purpose of this programme is closely linked to domestic and global environmental concerns. Therefore, its results should be disseminated globally to contribute to sustainable development. It is interestingly to note that the programme is operational rules show its public nature. Article 32 of the operational statute states: “ intellectual property rights of the results of the public-private joint technology development programme will be given to the host public institution up to the budgetary portion of public funds. Moreover, if the host institution is a profit-making organization, the IPR will be owned by the Government.” This illustrates the public nature of the programme. Furthermore, article 34 states that the results of the programme must be widely used, unless restricted the Minister of MOTIE.

These public technology development programmes can be considered as non-commercial. Even though every programme requires a payback from the host institution’s commercialization of the results, it is a publicly financed promotion of science and technological innovation for the private sector. There is a trend towards reducing the Government’s share in order to increase the programme’s effectiveness and to avoid abuse. However, the amount of public spending on these technology development programmes will be growing in the foreseeable future if the economy continues to grow. The Government gives high priority to the development of technological capabilities in response to increasingly fierce competition in global markets. “Han Project (or G-7 Project)” the best example of the Government’s commitment to the promotion of science and technology.

II. ANALYSIS OF COOPERATIVE R&D IN THE REPUBLIC OF KOREA

Both competition and cooperation are regarded as actors in the field of technology development. Competition may stimulate technological innovation particularly when available resources are limited and technology is targeted. Cooperation among major actors can be vital to success when the linkage among actors creates synergy. Korean’s national system of technology development strategically reinforces cooperative R&D, which used to be called the triangle system of San-Hak-Yun cooperative R&D: R&D among industry, universities and research institutes. GRIs (Yun) now play the role of mediators between the two traditional partners of cooperative research, industry (San) and the universities (Hak).

1. Policy measures for promoting cooperative R&D

Cooperative R&D started in the 1970s when private companies commissioned R&D projects to GRIs. Since them the Government has adopted various policy measures to promote cooperative R&D. Some major measures are described below.

First, the Government enacted the Technology Development Promotion Law, which provided a legal basis for the establishment of an industrial technology research union. This was later reinforced by the enactment of the Industrial Technology Research Consortium Promotion Act. The S&T Promotion Law of 1991 guarantees the status and Wages of scientists engaged in exchanges. Most recently, in 1993, the Cooperative R&D Promotion

Law was enacted to provide participants with the funds, manpower, facilities, and information necessary for cooperation.

Second, top priority for research grants is accorded to cooperative R&D. Most national R&D programmes stipulate this.

Third, the Government expanded the scope of tax credits by implementing the R&D reserve fund system. Furthermore, the Tax Exemption Law allows about 10-15 per cent of total R&D investment to be exempted from taxation. This also applies to research commissioned by private companies to research institutes, universities, and research consortia.

Fourth, the Government supports industrial technology research consortia that carry out cooperative R&D. The Industrial Technology Research Consortium Promotion Act includes such support measures as funding, tax credits, etc., for research consortia. The Technology Trust Guarantee Fund provides technology developers with credit guarantees. The Government also supports research consortia by purchasing commercial products manufactured by research consortia.

2. Current status of cooperative R&D

There are several types of R&D cooperation in the Republic of the Republic of Korea. Sometimes all three major categories of actors are involved, sometimes only two of them. The Government encourages cooperative R&D primarily through national R&D programmes in which GRIs plays the catalytic role. Since the programme was conceived on the principle of cooperative research, the overall cooperation rate has been quite high. Cooperation is involved in 58.3 per cent of the major national R&D programmes. In the HAN Project, in particular, cooperation was encouraged from the planning stage and 80 per cent of the projects are undertaken in cooperation. In 1992, in the private sector, 284 private research institutes carried out 511 instances of cooperative R&D, of which 309, or 60 per cent, were joint research and 202, or 40 per cent, were commissioned projects. The overall rate of cooperative R&D was 13.5 per cent.

In the case of universities, SRCs and ERCs have served as the primary bodies for cooperative R&D. Among the 1,060 projects carried out by SRCs and ERCs in 1993, the rate of cooperative R&D between university and industry was 11.6 per cent, or 123 projects. This number indicates a sharp increase over previous years. Further, a number of academia-industry research institutes have been set up in several universities. Quite recently, cooperative R&D complexes were actively established in major universities. These complexes are designed to accommodate academia-industry cooperative R&D projects on a long-term basis. Industrial technology research consortia provide the linkage for cooperative R&D and facility sharing among private firms either within an industry or among industries. Started in 1982, 57 consortia were in operation as of 1994. In 1992, about 70 per cent of their research activities were cooperative R&D between consortium member companies or with other research organizations.

3. Other cooperative activities

Besides R&D projects, the Government supports the Study Circle Programme, which promotes informal meetings of researchers and practitioners from industry, academia, and research institutes. Currently, a total of 102 study circles, with 1,701 participants from various fields, are in operation.

Education and training programmes are being carried out between industry and universities, or between universities and research institutes. Small companies located in adjacent provinces are encouraged to use the R&D resources of universities in their regions to find solutions to technical problems.

The S&T information channel is another indispensable source of cooperative R&D. The Republic of Korea R&D Information Centre, established in May 1993 in Daeduk Science Town, collects and analyses technological information, and facilitates the exchange and sharing of useful information among prospective partners.

Sharing of large-scale, expensive R&D facilities also expedites cooperation. The Republic of Korea Basic Science Centre and its four branches in Seoul, Pusan, Taegu, and Kwang-ju support universities and related organizations by providing opportunities to use the Centre’s expensive high-technology equipment such as radiation light accelerator and plasma research equipment.

The industrial technology research associations offer another arena for cooperative research. These associations, formed by private firms engaged in a given industry, have grown in number from 11 in 1982 to 70 in 1993. Leading example are machinery, electronics, and software.

Box 4
Success Cases

It is hard to assess the performance of cooperative R&D. Developments of low-and high-density electronic switching systems (Time Division Exchange, TDX-1, TDX-10), 4M DRAM and 16MDRAM; TICOM1 and TICOM2 are the most frequently cited cases of successful cooperative R&D the Republic of the Republic of Korea. All involved a large-scale R&D programme for which ETRI and four private firms organized R&D consortia. The development of TEX was the most outstanding example, in that it made the Republic of the Republic of Korea an ESS-exporting country and put it at the level of advanced nations in telecommunications technology. After the TDX1 was developed through the consortium, the design technology was transferred to the participating firms for production. Later, the consortium developed the more advanced TDX-10.

In this cooperative R&D, the role of GRIs was essential. Using government funds, they accumulated first the necessary technologies, then transferred them to participating firms in the consortium, and finally assisted private firms in commercialization.

Factors for successful cooperative R&D in a large-scale R&D programme include well-defined goals, incentives to the participants, the moderating role of the Government, and a firm demand for the technology to be developed.

4. Difficulties in promoting cooperative R&D in the Republic of Korea

The Republic of Korea, R&D investment, facilities, and personnel are not equally distributed among industry, academia and research institutes (Table 11). This imbalance is due to several factors. Universities have emphasised education rather than research. Industries have depended heavily on technology transfer from developed countries or reverse engineering rather than in-house development. GRIs has preferred curiosity-driven research to practical work. Further, the distorted job market has hindered mobility among research institutions and industry.

Consequently, although over 80 per cent of R&D financing and 59 per cent of research personnel are in the private sector, only 8 per cent of PhDs are in the industrial sector. 76 per cent are in universities, where they lack research facilities and R&D funds and have little experience in field research. Although GRIs have abundant research experience and well-established R&D systems, they lack product development know-how and manufacturing technologies where industry has a comparative advantage.

Another difficulty for technology transfer is the lack of cooperative tradition in research. Many large firms are developing technologies for the domestic market, and use license agreements to increase production and sales of these technologies to other foreign markets.

In the light of this situation, the Government has tried to maximise national R&D capabilities by encouraging the exchange or sharing of complementary assets among major actors.

Table 11
Advantages and disadvantages of major actors

	Advantage	**Disadvantage**
Industry	80 per cent of R&D investment 59 per cent of R&D personnel Product development know-how Efficient manufacturing facilities	8 per cent of PhDs Heavy dependence on technology import Modification of imported technology Short-term development plan
University	76 per cent of PhDs Accumulated know-how in basic research	Concentration on education Basic theory Shortage of facilities and funding Lack of field experience
GRIs	Excellent manpower and facilities Abundant R&D experience Well-established R&D system	Shortage of field experience Weak basis in manufacturing technology Development

Source: MOST

III. PATTERNS IN DIFFUSION AND TECHNOLOGY TRANSFER

A. International Cooperative R&D Project

The International cooperative R&D (ICRD) Project,which started in 1985, has served as a major pipeline, mainly supporting individual projects initiated through bilateral agreements. Thus far, the Government has supported more than 600 collaborative projects through the ICRD Project, with a total of more than 33 billion won. Both in terms of number of projects and budget, the major partner countries have been Japan, the United States, Germany, France, Russia, and the United Kingdom. Collaborative projects with Russia increased rapidly in the 1990s. Recently, the range of partners has diversified widely.

Sub-projects under the ICRD Project are concentrated in areas such as aerospace, astronomy, new materials and mechatronics (Table 12), areas where the Republic of Korean technological needs are high and the partner countries possess technological superiority and a comparative advantage.

Table 12
ICRD by technology, 1985-94

	Number of projects	**Budget**
Information	15	8.8
Mechatronics	114	5.9
New materials	82	5.3
Fine chemistry	77	6.6
New energy	55	2.6
Air/space/marine	29	1.5
Transport	8	0.5
Medical/environmental/housing	9	0.5
Basic science	10	0.3
Other	232	2.9
Total	**631**	**34.9**

Unit: Billion won
Source: MOST

B. Bilateral cooperation

In general, bilateral cooperation with a foreign country is initiated by concluding an S&T cooperation agreement (STA). Projects agreed upon at bilateral meetings are implemented mainly through the ICRD Project under the framework of the National R&D Programme.

As noted, the United States, Japan, and the EU countries have been major partners for bilateral cooperation, although cooperation with Eastern European countries has increased in recent years. With the conclusion of the Republic of the Republic of Korea-Russia Science and Technology Cooperation Agreement in 1990, bilateral cooperation between these two countries is expected to increase rapidly. In addition, in 1992 the Republic of the Republic of Korea-China S&T Cooperation Agreement was signed. In an effort to play a catalytic role in the Asia Pacific Economic Cooperation (APEC) area, the Republic of the Republic of Korea Promotes technology transfer to developing countries in the region.

S&T cooperation with China is being carried out under the Republic of Korea-China STA signed in 1992. In accordance with the STA, a Republic of Korea-China S&T Cooperation Centre was established in Seoul in 1992 and a Beijing office was established in 1993. Also, 1993 the first Joint Committee in agreed to carry out joint research projects and exchange of 15 researchers from each country for post-doctoral training. The Republic of Korea-China Industry Committee has sought technological cooperation in such areas as automobiles, aircraft, HDTV, and communication devices.

S&T cooperation between the Republic of Korea and ASEAN (Association of South-East Asian Nations), started with the Partial Dialogue Partnership of the mid-1960s. This has been upgraded to a full Dialogue Partnership. Specifically, as the need to improve the ASEAN countries own technical development capability increased, the Republic of Korea was requested to assist in designing a S&T policy and a research development system. In response, the Government agreed to provide assistance in the form of special the Republic of Korea-ASEAN cooperation projects. The main basis of cooperation is the Project Management System, the Planning and Management System for Human Resources, and the Finance Administration Management Institute.

According to the Agreement on Scientific-technical Cooperation between KOSEF and CONACYT (National Council for Science and Technology) of Mexico, technical cooperation is expected to take the form of joint seminars, workshops, etc.

C. Multilateral Cooperation

Since the 1960s international agencies such as the UN Development Programme (UNDP), the World Health Organization (WHO), etc., have contributed greatly to Korean economic and social development. The international community now expects the Republic of Korea, which has gone beyond the developing stage, to play a more positive role as a donor, rather than as a recipient country. Responding to these expectations and pressures, the

Government plans to assume this role by transferring S&T experience and know-how to developing countries through major international agencies such as UNDP, the Economic and Social Commission for Asia and the Pacific (ESCAP), APEC, and the Association for Science Cooperation in Asia (ASCA), etc.

At the same time, the Government will start to cooperate with advanced economies through major S&T-related international organizations. Participation in OECD S&T activities may provide the fundamental momentum. The Republic of Korea will also use its S&T capability to play a leading role in APEC.

Since 1950, UNDP and other agencies have provided US$78 million for the socio-economic development of the country through such channels as the Technical Assistance Programme, the Expanded Programme of Technical Assistance, the United Nations Special fund, and the UNDP Country Programme.

The UN has now classified the Republic of Korea as a fully developed country able to share the cost of the UNDP's programmes. Specifically, in 1991, the UNDP Governing Council classified the Republic of Korea as a contributor country, meaning that contributes more to UNDP than it receives.

The Republic of Korea has participated actively in ESCAP activities since 1954 when it became a regular member. In order to strengthen its relations with ESCAP and to assist the economies of neighbouring developing countries, at the 43rd ESCAP Conference in 1987 committed an annual donation of US$300,000. These funds are allocated to projects related to the development of rural areas, human resource development, standardization, human settlements, and technology transfer to SMEs. In 1992, it increased its contribution to $400,000 in order to take a more active part in assistance programmes for least developed and developing countries in the ESCAP region.

APEC, an intergovernmental cooperative body, was established to contribute to and to develop the international economy through the growth and development of the Asia-Pacific region. As a founding member, government has participated of the Republic of Korea actively in APEC's S&T activities, such as cooperation on industrial S&T activities, marine resources, regional energy, and the development of human resources. In May 1995, the first APEC Technomart was held in Daeduk Science Town, thereby highlighting the Government’s effort to facilitate S&T cooperation in the Asia-Pacific region. The Republic of Korea also hosted the APEC Ministerial Meeting on the Telecommunications and Information Industry in 1995 and the APEC Ministerial Meeting on Science and Technology in 1996.

As a preliminary step expected to join the OECD by the end of 1996, and, , the Republic of Korea became a full member of its Committee for Scientific and Technological Policy (CSTP) in 1994. The S&T community, under the auspices of MOST, is now participating actively in various CSTP activities, such as working group meetings on the science system, science and technology indicators, mega science, biotechnology, and technology and innovation policy. Further, the Republic of Korea S&T statistics and indicators have been revised and improved to conform to OECD standards and criteria.

The delegates to the Ministerial Meeting of the Asian Region established the Association for Science Cooperation in Asia (ASCA) in 1970. Since then, the organization has contributed to S&T cooperation among regional countries by holding a series of conferences and various seminars and workshops. The Republic of Korea sponsors a ASCA co-ordinating office and publishes and distributes the ASCA newsletter. It also sponsors the Seminar on Constructing the Bio-engineering Material Information Network and the Workshop on Resource Development.

D. International cooperation in basic research and private R&D

1. Basic research

International cooperation in basic research is performed primarily by individual research institutes and universities and through KOSEF. International S&T cooperation is one of KOSEF's major functions, in addition to the cultivation of research and the promotion of science education.

In 1977 KOSEF signed a Memorandum of Understanding with the United States National Science Foundation, and subsequently signed agreements on bilateral scientific cooperation with more than 20 institutions in 16 nations. It currently supports activities, such as exchange of scientists, cooperative research, joint seminars, and the establishment of joint research facilities, etc. In 1993, KOSEF allocated 1.9 billion won to support 55 collaborative research projects, 25 joint seminars, the invitation of 80 foreign scientists, to the Republic of Korea and sending 100 Korean scientists abroad.

2. Global sourcing of private R&D

International R&D cooperation with foreign partners is still in an early stage. Since the 1980s, however, private firms have engaged in global sourcing of R&D resources and participated in collaborative R&D projects with foreign universities, research institutes, and large firms, and began to establish research centres abroad. Strategic technology alliances with foreign firms are a new phenomenon.

As of 1994, the Republic of Korea had about 50 private research centres abroad, including 20 research institutes and 30 in-house R&D laboratories (Table 13). They are mainly located in the United States, Japan, Russia, and major EU Countries, and focus on electronics and automobiles.

Table 13
Overseas research centres of The Republic of Korean firms as of October 1994

Parent firm	Country	R&D personnel	Year established
LG electronics	Tokyo, Japan	25	1981
Kumho Tire	Akron, OH, United States	8	1991
Kia Motors	Detroit, MI, United States	6	1991
Kia Motors	Tokyo, Japan	18	1992
Dong-Ah Construction	London, United Kingdom	5	1993
Daewoo Automobile	Worthing, United Kingdom	300	1994
Daewoo Electronics	Metz Technopole, France	7	1994
Daewoo Electronics	Paris, France	4	1994
Maxon Electronics	Kansas City, MO. USA	30	1981
Samsung ElectronicDevices	Berlin, Germany	6	1994
Samsung Electro	Byungsong, Japan	6	1991
Mechanics	Tokyo, Japan	8	1987
Samsung Electronics	Osaka, Japan	8	1990
Samsung Electronics	Surrey, United Kingdom	5	1994
Samsung Electronics	Moscow, Russia	22	1994
Samsung Electronics	London, United Kingdom	6	1994
Samsung Electronics	Boston, MA, United States	20	1991
Young Chang Akki	Fairfield, NJ, United States	16	1990
Yukong	New York, NY, Unite States	5	1994
Cosmo Laser	Akron, OH, United States	14	1992
Hankook Tire	Tokyo, Japan	5	1985
Hyundai Motor	Frankfurt, Germany	n.a	n.a.

n.a.: Not available
Source: STEPI. 1995

IV. FUTURE POLICY DIRECTIONS

As the economic power and international status of the Republic of Korean community become more important, its S&T policy must becomes more outward-oriented, in line also with the trend towards active cooperation in S&T. Therefore, its policy on international S&T cooperation is becoming more positive and strategic. In particular, it will need to find more foreign partners for cooperation and more diversified and sophisticated means of cooperation. To this end, the Government will endeavour to expand the range of foreign partners and to develop more strategic and effective modes of cooperation. Furthermore, the choice of technology fields for cooperative R&D will become more specific, based on the economic and technological characteristics of the partner country.

However, regardless of the importance of EST transfer and the an active role the government might play, unless there are economic incentives, technology transfer might not happen voluntarily, unless much more attention is paid to this issue.

Therefore it is necessary to create incentives, which are beneficial to both the investor and host countries. At present, one of the incentives available globally is AIJ(Active Implement Jointly). AIJ is a policy instrument resulting from climate change attention, which aims to facilitate CO_2 reduction through direct or indirect EST transfer. According to the principle of AIJ, an investor can adapt improved technologies and then, if environmental benefits (reduction of CO_2) take place, the investor can take his profit in various forms. So potential investors in developed countries can benefit from improved competitiveness and market access for their technologies. At the same time, investors from developing countries can acquire imported technologies. In other words, AIJ can satisfy both the investors and host countries through ESTs transfer.

Apart from the AIJ system, other incentives are needed for GRIs for cooperative R&D and transfer programmes. GRIs used to be more open-minded than private research institutions and companies. So if some incentives were to be provided, there is a high potential for GRIs to transfer publicly funded technology.

To encourage ESTs transfer, I would like to suggest some directions for future policies, such as the following:

- The Government of Republic of Korea should encourage ESTs transfer through cooperation programmes and economic incentives for domestic actors.
- AIJ can be an effective tool provided the system is properly implemented.
- The Republic of Korea should try to join an AIJ regime through voluntary participation.
- Appropriate incentives for GRIs should be introduced to make them act as a catalysts for technology transfer.

At firm level, smaller firms may face problems of time, costs, and technical expertise in accessing information on available technologies and on possible solutions. At the international level .it is much easier and more efficient for developed countries to transfer technologies than developing countries. Technology transfer is a common issue and joint efforts are necessary for it to happen. Therefore those actors with the required ability should concentrate on this issue with a view to making an impact.

V. CONCLUSION

General information about ESTs transfer in the Republic of Korea, the national reports to the sixth session of the UNCSD (UN Commission on Sustainable Development) which was published in December 1997. This report covered most of aspects considered for technology transfer such as at: institutional structure, policies, legal framework etc. According to the report, The Republic of Korea is still concentrating more on the development of technology rather on than the transfer of technology. However this paper tried attempts to show the potential for EST transfer in the public sector, especially through GRI.

The transfer ESTs is a very complicated process because EST itself is a state of the art technology in which a considerable amount of capital has been invested and where there are ownership problems. For EST transfer to be successful, various factors are required such as investment for ESTs, commercialization of developed technologies, related international regulations for developed technology transfer, high accessibility of the information, adaptability of the technologies, and the relation between ESTs and intellectual property rights, etc.

One of the most important roles for the Government is to invest in the development, ESTs, to give financial support for their commercialization, and to revise regulation on environmental standards. It has a comparative advantage in getting information and choosing proper technology in terms of adaptability.

The Republic of Korea, despite the fact that many R&D activities were concluded in the private sector, the GRIs owns a substantial number of technologies with close linkages to EST. In other words, the Government conducts clean technology research through its research institutions (GRIs) or universities. The institutions own the technology, but in this case, the government may use its leverage to encourage the transfer and commercialization of the results.

For the above reasons, the role of GRIs in the case of the Republic of Korea may be a key to a future catalytic role for the global transfer of ESTs.

This study has highlighted a number of issues. These are:

- how to mobilize this potential of GRIs for the global achievement of sustainable development.
- limiting the scope of ESTs would contribute towards obtaining practical results (e.g. to contribute to each multilateral environmental convention with global significance and urgency)
- what kind of reward could be provided for the transfer of government controlled technologies and know-how (e.g. ODA and the transfer of publicly owned ESTs).
- current WTO rules might have negative implications on the active role of government in terms of catalysing global transfer of technologies.

- Publicly owned technologies and publicly funded R&D should be evaluated in terms of their actual contribution to the goal of global sustainable development, particularly to developing countries.

This report shows that there is some potential for GRIs to participate in technology transfer if there are enough incentives and adequate policies. But compared with the economic position of the Republic of Korea in international society, the development and ownership of high technology is relatively low. Nevertheless, there are ways whecely a country can make a contribution to international society corresponding to its situation.

In conclusion, The Government of Republic of Korea and GRIs should foster ESTs transfer through appropriate economic incentives and policies.

ANNEX I

GOVERNMENT SUPPORTED RESEARCH INSTITUTES

In the Republic of Korea, three public institutes conduct S&T research: national/public research institutes (NRIs), Government-invested institutions (GIIs), and government (supported research institutes (GRIs). Among these, GRIs have captured the lion's share in terms of investment, manpower, and facilities.

NRIs are government organizations that conduct both testing and research activities. NRI researchers are civil servants. Currently, there are 83 natural science NRIs, of which 32 belong to the central government and 51 to local government. The main research area is agriculture (65); engineering (7), medicine (4), and physical science (3). While they are the majority in terms of numbers, the total R&D investment of these institutes is one-fifth that of the GRIs.

GIIs are public enterprises and participate in public research activities. Since 1992, the Government has been committed to promoting S&T investment by GIIs. Traditionally, GIIs, with a larger budget than the total government general account, invested less on R&D than private firms. GIIs responded positively by establishing several associated research institutes and increasing rapidly investment in R&D. At the end of 1993, investment in R&D by the 15 largest GIIs totalled 545.4 billion won, or 2.5 per cent of total sales. The two largest GIIs, The Republic of The Republic of Korea Telecom and The Republic of The Republic of Korea Electric Corporation, account for 80 per cent of total R&D investment. The R&D investment of some GIIs is so large that it could affect the level of national R&D investment.

GRIs have assumed the leading role in public research. They are semi-government organizations. Even though the Government pays them, GRI researchers are not civil servants. Presently, there are 22 GRIs under MOST, ten GRIs under MOTIE, and several under other ministries. In 1992, the budget for GRIs totalled 504.6 billion won, about half of which is the government contribution to GRIs via MOST, and GRIs under MOTIE received about 7 per cent of the total budget. Tables 2 and 3 give information on human resources and sources of research funds for selected GRIs.

1. The history of the GRIs

In the 1960s, the Republic of Korea laked the technological capabilities necessary for industrialisation. Imports of foreign technologies were the immediate solution. A more fundamental solution, however, was the establishment of industrial R&D institutions. The first big push came in the mid-1960s, when, on the initiative of President Park Jung Hee, plans were developed to establish Korea Institute of Science and Technology. The Battelle Memorial Institute of the United States drew up a detailed plan.

Table 1
Human resource statistics of individual GRIs, 1993

Institute	Foundation	Researchers	Admin. Staff	Ratio
Korea Institute of Science and Technology (KIST)	February 1966	659	175	79:21
Korea Research Institute of Machinery and Metals (KIMM)	December 1976	456	118	80:20
Korea Research Institute of Standard and Science (KRISS)	December 1975	378	94	80:20
Korea Atomic Energy Research Institute (KAERI)	March 1959	715	191	79:21
Korea Institute of Energy Research (KIER)	May 1976	271	67	80:20
Korea Institute of Geology Mining and Materials (KIGAM)	May 1976	365	78	82:18
Korea Ocean Research and Development Institute (KORDI)	October 1973	261	80	77:23
Korea Electric Technology Research Institute (KETRI)	October 1976	267	59	82:18
Korea Research Institute of Chemical Technology (KRICT)	June 1976	317	86	79:21
Systems Engineering Research Institute (SERI)	June1967	291	45	87:13
Genetic Engineering Research Institute (GERI)	February 1985	203	22	90:10
Korea Astronomy Observatory (KAO)	March 1985	64	25	72:28
Korea Aerospace Research Institute (KARI)	January 1988	102	25	80:20
Korea Institute of Nuclear Safety (KINS)	December 1981	243	64	79:21
Korea Science and Engineering Foundation (KOSEF)	December 1976	20	93	18:82
Korea R&D Information Centre (KORDIC)	April 1993	29	3	91:09
Science and Technology Policy Institute (STEPI)	January 1987	79	32	71:29
Korea Basic Science Centre (KBSC)	August 1988	71	23	76:24
Korea Advanced Institute of Science and Technology (KAIST)	February 1971	691	223	76:24

Source: Ministry of Science and Technology (1993), Plan for the specialization of GRIs

Table 2
Source of research funds of individual GRIs
(Million won, figures in brackets are percentages)

Institute	**MOST**	**Other Ministries**	**Private Contracts**	**Total**
Korea Institute of Science and Technology (KIST)	19 038 (79)		5 229 (21)	24 267
Korea Research Institute of Machinery and Metals (KIMM)	10 233 (42)	6 961 (29)	7 174 (29)	24 368
Korea Research Institute of standard and Science (KRISS)	7 439 (78)		2 088 (22)	9 257
Korea Atomic energy Research Institute (KAERI)	4 400 (7)	33 900 (53)		63 800
Korea Institute of Energy Research (KIER)	3 125 (41)	3 350 (43)	25 500(40)	7 683
Korea Institute of Geology Mining and Materials (GIGAM)	2 635 (32)	4 170 (50)	1 208 (16)	8 259
Korea Ocean Research and Development Institute (KORDI)	3 930 (42)	4 400 (47)	1 454 (18)	9330
Korea Electric Technology Research Institute (KETRI)	4 900 (29)	300 (2)	1 000 (11)	16 970
Korea Research Institute of Chemical Technology (KRICT)	8 500 (77)	476 (4)	11 770(69)	11 042
Systems Engineering Research Institute (SERI)	12 243 (72)		2 066 (19)	16 922
Genetic Engineering Research Institute (GERI)	5 779 (92)		4 679 (28)	6 281
Korea Astronomy Observatory (KAO)	512 (90)		502 (8)	572
Korea Aerospace Research Institute (KARI)	3 430 (43)	1 185 (15)	60 (10)	7 961
Korea Institute of Nuclear Safety (KINS)	2 630 (47)	2 503 (44)	3 346 (42)	5 636
Korea Science and Engineering Foundation (KOSEF)	63208(100)		503 (9)	63 208
Korea R&D Information Centre (KORDIC)	1 000 (91)			1 100
Science and Technology Policy Institute (STEPI)	2 870 (98)		100 (9)	2 923
Korea Basic Science Centre (KBSC)	625 (100)		53 (2)	625
Korea Advanced Institute of Science and Technology (KAIST)	4 000 (20)	6 540 (32)	9 619 (48)	20 159
Total	**160497(53)**	**63 785 (21)**	**76351(26)**	**300633**

Source: Ministry of Science and Technology (1993), Plan for the specialization of GRIs.

KIST was established as an integrated technical centre to meet industrial needs. As the country's first multi-disciplinary research institute, KIST covered a broad spectrum of applied research activities, including feasibility studies, technical services for small-and medium-sized firms, and engineering studies at pilot-plant scale. In the 1960s, KIST's R&D activities were directed towards finding solutions for simple and practical problems arising from the application of transferred technology.

Box 5
The Kist model

Since KIST was the first GRI, its establishment raised a number of serious issues. Difficulties and obstacles encountered by existing research laboratories were analysed, and factors contributing to the success of various research institutions in advanced countries were closely examined. As a result, the planning of this new research institute and subsequent specialized institutes involved three basic principles; autonomous management, research environment, and financial stability.

The Battelle Memorial Institute suggested that the institute separate from existing research organizations and became independent of the KIST Assistance Act of 1966 which made KIST an independent legal entity. In addition, the Provisions of the act set forth three other important characteristics of the KIST model: an endowment fund, contract research, and overhead cost self-financing.

- Endowment funding: The Act guaranteed the institute an annual endowment from the Government to be used for basic operations and capital expenditures for construction.

- Contract research: All R&D work commissioned to the institute would be contractual, whether it came from public or from private institutions. The purpose was first, to encourage industries to become actively involved in their projects and, second, to emphasise the responsibility of those in charge of a project.

Overhead cost self-financing: KIST has several research divisions, each with a number of research laboratories. These are the Institute's basic management units. Individual Laboratories should earn enough from research contracts to cover their overhead expenses for human resources and facilities.

(a) Establishment of the Republic of Korea Advanced Institute of Science

In the early 1970s, there was suffered a severe shortage of researchers with doctoral and master's degrees. Students of engineering and science had no choice but to go overseas, to the United States, Japan, or Europe, for graduate-level education. In 1971, the Government, anticipating increased demand for high-calibre S&T manpower, established the Korea Advanced Institute of Science (KAIS), as a graduate school for applied science and engineering, later renamed the Republic of Korea advanced Institute of Science and Technology (KAIST). This school is unique in that its faculty and students are fully supported by government. It is under the jurisdiction of MOST, whereas all other universities and colleges are under MOE. With top-quality entrants and world-class instruction and research facilities, KAIST has produced high-calibre graduates with masters or doctoral engineering degrees.

The expansion of the economy and the greater sophistication and diversity of the country’s industrial structure required that both the volume and scope of public R&D keep pace with the changes. A single entity such as KIST could not meet ever-increasing demands.

The solution was to spin off a number of specialized research institutes, each designed to develop in-depth capabilities in areas of high priority for industrial policy, namely shipbuilding, marine resources, electronics, telecommunications, energy, machinery, and chemicals. These spin-off institutes took over the R&D activities previously assumed by KIST. Since the 1970s, Daeduk Science Town has accommodated most of these institutes as well as many R&D laboratories of private firms.

(b) Restructuring of GRIs in the early 1980s

In the early 1980s 15 GRIs under the responsibility of various ministries were consolidated into nine large research centres under MOST. These new GRIs were all funded and monitored by MOST. A basic reason for the restructuring was to achieve critical mass quickly. Policy makers judged that, given total national R&D funding, there was more than the optimal number of GRIs. Therefore, they advocated restructuring in order to avoid overlapping R&D investment and to facilitate the management of GRIs.

(c) Involvement of GRIs in the National R&D Programme

Since the 1960s and until the early 1980s, the Government accounted for 70 per cent of the nation's total R&D investment. However, total R&D investment represented only 0.89 per cent of GNP. It was under these circumstances that the Government introduced, in 1982, the National R&D Programme (NRDP)

Thanks to the impetus given by the NRDP, total R&D investment increased dramatically. At the same time, the role of GRIs as the focal point of joint research between industry and academia was brought to the fore.

2. Current status of GRIs

(a) GRIs under MOST

Table 3 shows the research fields of the 22 GRIs under MOST. Two GRIs have recently moved from MOST to other ministries. ETRI moved to MIC, and the Korean Ginseng and Tobacco Research Institute moved to MAFF. A majority of GRIs are now located in Daeduk Science Town and in Hong-Reung Town in Seoul, the symbolic cradle of Korean S&T.

KIST has multi-disciplinary research fields, including chemical engineering, materials science, Science, and mechatronics. With some minor exceptions, the research fields of other GRIs are quite well defined and distinctive. The role and research fields of non-engineering research institutes are described below.

Table 3
Research fields of GRIs under MOST

Institute	**Field of research**
Korea Institute of Science and Technology (KIST)	R&D for national projects
Korea Research Institute of Machinery and Metals (KIMM)	Machinery and metals
Korea Research Institute of Standard and Science (KRISS)	Establishment of national standards
Korea Atomic Energy Research Institute (KAERI)	Atomic energy
Korea Institute of Energy Research (KIER)	Energy technology and exploitation
Korea Institute of Geology Mining and Materials (KIGAM)	Resource technologies
Korea Ocean Research and Development Institute(KORDI)	Efficient use of ocean resources
Korea Electric Technology Research Institute (KETRI)	Electric power
Korea Research Institute of Chemical Technology (KRICT)	Chemistry
Systems engineering Research Institute (SERI)	Software research and computer education
Korea Research Institute of Bioscience and Biotechnology (KRIBB)	Bioscience and technology
Korea Astronomy Observatory (KAO)	Space science and astronomy
Korea Aerospace Research Institute (KARI)	Aerospace-related technology
Korea Institute of Nuclear Safety (KINS)	Regulation on nuclear safety
Korea Science and Engineering Foundation (KOSEF)	S&T education
Korea R&D Information Centre (KORDIC)	Information technology
Science and Technology Policy Institute (STEPI)	S&T policy and management
Korea Basic Science Centre (KBSC)	Support to basic science and development of human resources
Korea Advanced Institute of Science and Technology (KAIST)	
Kwangju Institute of Science and Technology (K-JIST)	Provision of R&D facilities
Korea Cancer Centre Hospital (KCCH)	Cancer and radiation medicine
Nuclear Environment Management Centre (NEMAC)	Radioactive waste management

Source: MOST

(b) The Republic of Korea Science and Engineering Foundation

KOSEF supports basic research in university-affiliated R&D centres and manages several human resource development programmes, such as post-doctoral training and invitations to foreign scholars. In particular, KOSEF supports ERCs and SRCs in various local universities. These centres receive about US$0.7 million annually over a nine-year period.

(c) Science and Technology Policy Institute

STEPI has two basic roles: first, it conducts research on the whole spectrum of S&T policy: second, it plans, manages, and evaluates the NRDP, which is under MOST. In 1992, STEPI was designated as the central agency to deal with the management of the Han project.

(d) Korea R&D information Centre

KORDIC is a national S&T information centre, whose main function is to provide information-sharing channels for GRIs and universities. It was established in 1993 in order to expand and replace the existing S&T information system project. As a central information centre, it handles various tasks, such as on-line information distribution, software development, standardisation, database compilation, and education and training.

(e) Major GRIs Under other ministries

The Korea academy of Industrial Technology (KAITEC) was established in 1989, under MOTIE, to conduct R&D to improve the industrial competitiveness of the manufacturing sector. KAITEC also supports and directs the application of technologies by small and medium-sized enterprises. KAITEC was designated as the supervising agency of MOTIE’s NRDP To carry out these functions, KAITEC maintains several affiliated institutes, such as the institutes of Industrial Technology Policy (ITEP), the Korean Testing Lab (KTL), and the Industrial Technology Training Centre (ITC).

(f) Korea Institute of Industry and Technology Information (KINITI)

This institute succeeded the Republic of Korean Science and Technology Information Centre (KORSTIC), and since 1982has acted under MOTIE, , as the information centre for industrial technology. KINITI collects and disseminates various kinds of technical and business information.

(g) Korea Electronic Technology Institute.

KETI is a GRI under MOTIE. It conducts R&D on electronic technology.

(h) Electronics and Telecommunications Research Institute

ETRI, which recently moved from MOST to MIC, undertakes R&D on advanced information technology in areas such as telecommunications, computers, and semiconductors. ETRI also assures the linkage between university basic research and industrial product development.

(i) National Computerisation Agency

NCA was established under MIC to accelerate the construction of the national information infrastructure. It currently carries out such tasks as the audit of the government computer network, standardization of network technology, and research on the national basic information system.

As shown above, GRIs have responded to social and economic needs. They have made a substantial contribution to the development of the country's S&T in terms of enhancing awareness, improving the national technological capability, and developing human resources. However, as the economy moves out of the development stage and as other R&D actors in universities and private firms take greater responsibilities in these areas, the role of the GRIs needs to be reappraised and redefined.

In response, the GRIs are striving to meet the changing demands of society. At the same time, the Government is strengthening its support measures to GRIs. Specifically, in an effort to maximise research productivity, the Government intends to replace the lump sum support system by the so-called project-based system (PBS). Under the old system GRIs received separate funding for items classified as expenses and those classified as research projects. Under the new PBS, GRIs receives support from one fund, classified as research projects, which includes salaries. This makes it possible to clarify the amount expended and the manpower involved on each research project. Ultimately, a competitive system will be introduced, which will base R&D funding on research productivity. Under the PBS, the Government chooses the projects and gives the necessary research funds, including salary, to the project manager through the GRIs. Under this new system, GRIs will be supported on the basis of their individual projects, rather than on the lump-sum basis.

In conclusion, GRIs in Republic of Korea are in a transitional period. If GRI's own efforts and the new form of government support succeed, the research productivity of GRIs and the national S&T capability should improve.

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES: THE CASE OF THE CZECH REPUBLIC

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I. INTRODUCTION

To understand fully the issue of research, development and diffusion of environmentally sound technologies (ESTs), in the Czech Republic a brief account general of the scientific and technological research and development (R&D) in the country, within a historical perspective, is required.

The country is now in its eighth year of transition from a centrally planned and essentially closed economy towards a democratic and free-market society. The division of the Czechoslovak Federal Republic took place peacefully at the end of 1992 and two new States, the Czech and Slovak Republics, came into existence on 1 January 1993. The transformation proved to be an extremely complex and difficult process. Generally, it has been quite successful both economically and politically, at least in comparison with the other countries of the Central and Eastern European region. Several rounds of free parliamentary and communal elections have already taken place and all standard institutions of a democratic and civil society are established and working. The legal and institutional framework of the economic transformation is essentially completed. A few state-owned enterprises still exist and the Government holds a substantial part of the shares of several firms of strategic importance, including in the banking sector. The privatization process has proceeded rather smoothly and should be completed in the foreseeable future.

The deep and difficult transition process has not been accompanied by any dramatic social tensions or economic hardship for most of the population, despite the fact that during the first four years of the transformation process, there was a substantial drop in economic output (totalling about 25 per cent of the GDP). In the last four years, there has been modest economic growth, while the unemployment rate remains below 5 per cent and the yearly inflation rate around 10 per cent. One of the economic problems that has been of particular concern during the past few years has been the increasing trade imbalance, caused not only by a strong demand for Western high-quality consumer goods (including foodstuffs) but also by a high demand for industrial and other investment, including modern technologies. This phenomenon is directly connected to the topic of this study on the role of publicly funded development of ESTs, due to the fact that many of the imported technologies belong to this category.

Environmental improvement was a high priority among its people of Czechoslovakia after the fall of communism. There was a deep concern over health and other impacts of environmental pollution. The pressure from environmentalists and concerned citizens helped substantially to break down the communist system. After the establishment of democratic government, there was wide public support for radical improvement in the quality of the environment. Expenditure for the environment gradually increased from less than 1 per cent of GDP in 1990 and much less before 1990 to 2.7 per cent in 1996.

The transformation and restructuring of the economy have generally been orderly processes within a legal framework. This applies fully to the environmental area as well. From the very beginning of the transition period, environmental rules, limits and standards were never relaxed, in fact, just the opposite. All new laws were stricter than the old ones and the old ones that remained have been more fully enforced. Economic transformation also brought about the restructuring of the industrial base. Mining of coal and lignite and other minerals decreased and the structure of primary energy sources shifted from lignite and coal towards natural gas. The production of steel was almost halved. Agricultural production dropped both in absolute terms and in its relative contribution to GDP. These changes have had environmentally beneficial effects. Even if initial environmental enthusiasm and enormous support for any environmental measures to a large extent waned after several months, the environmental consciousness of society was raised to a relatively high level during the first phase of the transformation process and it remains at that level to date.

During the transition period, it became increasingly clear that the "macro-design" of the old system was fully absorbed into every detail of political and economic life. It meant that even if some economic and other areas and structures did not function so badly during the old regime, it was practically impossible to isolate them and transfer them into the new societal framework without doing harm. One working structure that worked fairly well in the past was the R&D system.

However, the old R&D system had some rather significant deficiencies. During the long years of communism, the state-owned industrial enterprises gradually cancelled their own programmes of technological development because they were unnecessary burden for them. They did not see technological innovation as essential. Thus, technological development became gradually disconnected from the real needs of productive enterprises and was transferred into what were called state research and development institutes and, in some cases, to the numerous institutes of the Academy of Sciences. An extensive chain of such institutes existed in the former Czechoslovakia covering practically all fields of science and technology. To a great extent, they were too large, costly and ineffective but they worked somehow, and in many cases their intellectual output level was rather high. This was mainly due to the fact that the area R&D was one of the few realms of relative freedom, and therefore many gifted people chose their careers in this area instead of joining the type of tightly controlled bureaucracy found in administrative or business institutions. After the fall of the communist regime, state R&D institutes gradually lost both their best people and financial resources. One after another, they disappeared. The Academy of Sciences of the Czech Republic (*Akademie vìd Èeské republiky*, ASCR) was substantially downsized and the whole system of publicly funded science and research almost collapsed. It has been gradually replaced by a new one that is essentially in place today and will be subsequently analysed. Notwithstanding the relatively advanced stage of the overall transition of society, the current system of publicly funded R&D is very new and is in the stage of fine-tuning and the completion of some missing elements. Nevertheless, despite the significant, yet not fully finished, overhaul of the whole structure, the new system is already working relatively well.

One of the reasons for this success is the relatively good and long tradition R&D in the former Czechoslovakia.

The dissemination of results and the diffusion of newly developed technologies was essentially non-existent during the communist regime. While research and development is mostly driven on the supply side by the curiosity and intellectual interests of the researchers, the implementation of new innovative technologies can work only if it is demand-driven. The demand can be created by market incentives only, and not by any amount of research or bureaucratic effort. Because a market system did not exist, such incentives did not exist and thus, state-owned firms had no interest in implementing any innovative R&D results that could only mean additional problems for them. It should be noted that one of the few exceptions was in agricultural development, namely, plant reproduction and animal husbandry. As will be seen, the diffusion and dissemination of new technologies are still missing to a large degree. One reason for this situation is the fact that this stage of the cycle was virtually non-existent during the days of communism and hence, no positive tradition was established. In addition, there is practically no policy for the facilitation and promotion of publicly funded and newly developed ESTs to developing countries.

II. ESTs: THE OVERALL ROLE, SCOPE AND RELATIVE IMPORTANCE OF PUBLICLY FUNDED RESEARCH

The overall structure of research and development, including financing, in the Czech Republic is established by the State Support for Research and Development of 4 May 1992, No.300/92 Sb., as amended by Act No. 2/95 Sb. Act No.300/1992 signalled the real beginning of fundamental changes in the organisation and funding of R&D in the Czech Republic. One of the results of this law was that public tenders for grants and the terminology used became compatible with OECD standards.

The supreme body in the field of science and research is the Council R&D of the Government of the Czech Republic (*Rada vlády pro vìdu a výzkum*), established by Its 15 members are all appointed by the Government and include eminent scholars, scientists and public representatives. Originally, the Council was a special advisory body of the Czech Government with no executive powers. Later, it was instrumental in the formation of the Grant Agency of the Czech Republic (*Grantová agentura Èeské republiky*, GACR), the first general grant-awarding agency. Since 1993, the Council has submitted annual final drafts of the state-supported R&D budget to the Ministry of Finance, which shows of the 19 different agencies channelling state support for R&D to individual institutions. It provides overall direction to the development of scientific and research activities. It also receives reports on individual scientific programmes and gives its opinions. Some of its conclusions may be formal recommendations to the Government and to individual ministries and, given the high status of the Council and its individual members, the recommendations are almost always followed.

The outline of the Government's R&D policy was formulated in two documents with the same name, "Principles of the Government of the Czech Republic for the Field R&D" ("Principles"). The first set of Principles was approved by the Government in May 1994 and the second set in April 1997. The 1994 Principles laid out the basic policy guidelines, such as increased support for science, research at universities, growth of targeted funding (particularly grants) at the expense of institutional funding and the gradual transition from single R&D projects to large, multi-project programmes, etc. Large cuts were incurred in total R&D funds and staff and, extremely modest support was given to industrial R&D.

The 1997 Principles addressed several newly emerged problems and declared the following goals:

1. Gradually increase direct state financial support to R&D, up to 0,7 per cent GNP.
2. Make the present system of state support compatible with that of the EU.
3. Greatly increase targeted R&D (the proportion of basic and university research, to, on the other side, should be roughly one to one).
4. Support R&D for infrastructure (communication, transport and information) and international collaboration in science.

The proportions of publicly and privately funded R&D are difficult to estimate because of the limited reliability of statistical data from the private sector. Public funds were estimated at 35 per cent of the total R&D expenditures in 1995.

There are two modes of financing publicly funded R&D:

1. Institutional funding: support goes to an organization *per se* from the relevant section of the state budget through its founding institution (usually sectorial ministries or the ASCR). The appropriation of funds is subject to an evaluation of the results of the institution.
2. Targeted funding: support goes to an institution or to individuals through various granting agencies or ministries, generally as a result of an open competition with other research institutions The proportion between them was estimated at 65 per cent to 35 per cent in favour of institutional funding in 1995.

Targeted support is provided through public tenders in two ways:

1. Grants to individuals or institutions projects are submitted to the GACR or to any of several granting agencies for a peer review process and approval by the agency. No restrictions are imposed on the topics of R&D project proposals (no scientific or sectorial priorities are in place) and.
2. Programmes: state support is required to be granted to more complex (i.e. mission-oriented) R&D projects that comply with the objectives of publicly declared sectorial programmes. Selection of the project proposals is carried out at the respective sectorial ministries on the basis of two independent assessments. Public tenders for the distribution of targeted funds were introduced in 1995 in order to make state support more transparent.

The following are priority areas for public targeted support through programmes:

1. Industrial R&D
   i) New technologies connected with the production of new materials or top-quality products.
   ii) Improved exportability through decreasing energy consumption in manufacturing or making better use of raw materials, etc and.
   iii) Providing for better technology transfer between R&D institutions and industry.
2. R&D for defence
3. Non-industrial R&D in the fields of agriculture, human health, environmental protection (including the utilization of natural resources) and the humanities (including social sciences, education, etc.)

All research projects with results exploitable by industry are eligible for public support to industrial R&D. Public support to industrial R&D has to be coordinated with export policy and should increase up to 20 per cent of total state support to R&D.

Two forms of public support are in place:

1. State subsidies: for projects with multiple utilization in industry, from 50 up to 75 per cent of the total cost of a research project, or from 25 per cent up to 50 per cent of the total cost of a development project.

2. Soft loans: public support to projects with individual implementation of results. The results of publicly supported R&D, including patents, are owned by the research institution that submitted the R&D project proposal and was awarded a state subsidy except for projects carried out at the request of the State.

After a sharp drop in public R&D funding at the beginning of the 1990's, slow and steady growth has taken place since 1993 (from CK 4 billion in 1993 to over CK 7.5 billion in 1997). At the beginning of the 1990's, most support from the state budget was given to basic research. At the ASCR, public support to industrial R&D was regarded as an undesirable intervention into the market driven private sector. The turning point occurred in 1996.

While public support to programmes amounted to only 6 per cent of targeted support in 1994, its share to programmes increased sharply to 40 per cent of total targeted public support in 1996. Nevertheless, some distortion in the structure of public support to R&D results from the underdeveloped R&D policy and the non-existence of industrial policy. Both forms of targeted state support to R&D create flexibility for the free orientation and choice of objectives of proposed projects. Also, projects, funded in the framework of sectorial programmes, are not mission-oriented in the sense of a single goal or shared objectives of the whole programme. These projects are only expected to touch the issue covered by the programmes's theme. Most R&D activities are based on various partial proposals from researchers and not on the elaboration of a R&D programme or an industrial policy.

Public financial resources for research and development are provided mostly by the general state budget. The Government prepares the budget proposal for Parliament every year and when the proposal is approved the state budget becomes a law. Most of the institutional money goes to the Ministry of Education, Youth and Sports, which generally supports scientific research at universities and the ASCR. The routine operations of various institutes, universities, etc. are financed out of these institutional funds.

Targeted support goes to individual projects, providing funds for operations, investments and also partly for wages. In this respect, the most important institution is GACR, which has at its disposal the most funds. The budget for GACR is shown under a separate heading within the general state budget and, it is as such, subject to parliamentary decisions. It is difficult to estimate the total amount of financial resources devoted to scientific research and technological development because of several deficiencies in data. For example, complete information on the detailed use of institutional funds is not available because of the unclear division between teaching and scientific work at universities and, for some other reasons as well. There are further difficulties related to the underdeveloped system and structure of science, research and development.

Analysis of publicly funded research and development should take into account the "very conservative" liberal (in the European sense) approach of the Czech Government, which has not changed dramatically since the beginning of the transformation process. The Government is essentially willing to finance only those programmes that are in the interest of the whole nation and not any particular or defined societal group or body and that cannot be served and financed by anybody else. Consequently, it follows that the development of technology is not a priority for public financing. It is assumed by the state that technological innovation is clearly in the interest and domain of business.

According to the official figures of the Czech Statistical Office, total expenditure on research and development as a share of GDP amounted to 0.40 per cent in 1993, 0.41 per cent in 1994 and 0.47 per cent in 1996. These figures are for grant funds only. This is appropriate within the context of this study. The institutional part of the financial resources is not important in this case because no research and development of ESTs is financed from from that category.

An overview of the total expenditures on research and development within the most important sectors is presented in Table 1. From these figures presented, it can be seen that the most important institution within the framework of this study is GACR. It was established in mid-1992 by a act of the Czech National Council No. 300/1992 Sb. "On State Support for Research and Development", now Act No. 2/1995 Sb. The Presidium of the GACR was named by the Government of the Czech Republic in December 1992, and the GACR began to function officially on 21 April 1993, when its by laws received formal government approval.

Table 1

State budget expenditure on research and development in the years 1994- 1996 (mil. CZK) in selected sectors

Sector	**State Budget**									
		1994			**1995**			**1996**		**1994-96**
	grants	inst.	total	grants	inst.	total	grants	inst.	total	Total
ASCR	314	1 152	1 465	316	1 172	1 488	365	1 348	1 713	4 667
GACR	450	16	446	610	16	626	750	19	769	1 841
Min. of Defence	23	0	23	53	0	53	80	0	80	156
Min. of Trade and Industry	79	0	79	99	0	99	61	0	607	178
Min. of Economy	208	0	208	199	0	199	0	0	0	407
Min. of Agriculture	217	186	403	221	25	473	268	143	411	585
Min. of Environment	46	171	216	77	171	248	131	175	306	770
Min. of Transport	14	11	25	13	13	26	47	14	61	12
Total Selected Sectors	1 349	1 536	2 885	1 588	1 398	3 213	1 701	1 698	3 946	8 615
Total R & D	1 649	2 567	4 216	2 106	2 757	4 863	3 387	2 847	6 234	15 313

Source*:* Control Evidence of Projects.

The function of the GACR is to provide, on the basis of public competition, financial support for research and development projects submitted by individuals or organisations and, financial support for projects which fall within the programme of the GACR. The executive authority of the GACR is its Presidium, composed of five members and headed by the president of the GACR. There area committees which are permanent advisory groups whose members are elected. At the suggestion of the area committees, the Presidium appoints sub-area committees, which deal more specifically with themes classified within the five main areas of academic and scientific research. A further administrative body is the Supervisory Board of the GACR, whose ten members are elected by Parliament. Its task is to review the GACR's activities and its management of financial resources.

The grant system and the selection process are implemented according to regulations that are regularly streamlined and modified by the GACR. They are published annually in a special issue of the Bulletin of the GACR entitled, "GACR *Grant System: Basic Information and Regulations"*, which may be obtained from the Office of the GACR. These regulations are based on systems devised by the Grant Agency of the Academy of Sciences of the Czech Republic, the National Science Foundation of the United States of America. and other similar organizations, notably those from countries of the European Union. The grant process takes place once a year. The time frame established by the GACR for the past few years will probably be maintained during the coming years. The GACR announces the annual competition for research and development projects and for projects falling within the programme of the GACR at the beginning of March. Applications must be received by 30 April. In May and June, external evaluators are selected to review the grant applications, while the advisory committees make its evaluations during the autumn. The Presidium of the GACR announces its awards at the beginning of December on the recommendation of the area committees, and the successful applicants receive contracts by the end of the year.

Due to the regulations currently in effect, the actual transfer of funds to the successful projects is a somewhat protracted process. This is because the GACR is a "budgetary" entity, which means that it is bound by the budgetary provisions of the State (Act No. 576/1992 Sb.) and the rules and regulations derived therefrom. One of the results is that funds awarded by the GACR may be transferred to the institution to which the authors of the project belong, only through the Ministry of Finance and the appropriate ministry to which the institution belongs. Thus for example, a project originating in a university must be funded through the Ministry of Education. In this way, grant funds are a part of the institution budget and therefore may not be carried over from one year to the next. For this reason GACR organises its competitions so that the award decisions are final at the very beginning of each year. For project contracts, the GACR guarantees that it will provide the financial resources stipulated in the contract and, on this basis the managers of the project may negotiate with their institutes at least for temporary advance funding.

This system of transferring and managing funds, to which the GACR is bound by the above-mentioned regulations, is different from that prevailing in countries of the European Union, where grant agencies have the status of foundations or funds. Thus they are able to manage their resources differently, and have the possibility of transferring funds directly through banks and carrying over funding from one year to the next. This makes for a more efficient use of resources. The GACR is currently making efforts to streamline the system of financing. The chief obstacle to GACR's work at the moment is the awkwardness and complexity of the current legislative framework, combined with a certain lack of readiness of the Czech economy and society as a whole to accept the basic features of the grant system.

This however, is a long-term problem which can only be solved through broad political and social changes.

A. R&D in technical, natural and agriculture sciences

1. Technical sciences

This area includes the entire field of technical research and development. Support is given to projects in the field of basic research, applied through a combination of grants and interest-free loans. Special attention is accorded to long-term complex projects. There are no fixed boundaries between fields; on the contrary, interdisciplinary efforts are encouraged in all areas within the scope of the GACR. A significant proportion of grants is for projects investigating problems involving the cooperation of multiple institutions. In this way, the human and technical potential of the universities, the institutes of the Academy of Sciences, government research institutes and industrial and private institutions working in the field of technical research and development, can be maximized.

The aims of technical service projects include the broadening of knowledge in particular area, the expansion R&D foundations into new technical disciplines and, the development and transfer of new technology contributing to increasing the competitiveness of the Czech economy.

The amount of funds awarded to individual projects varies greatly. Although the number of large-scale grants (normally over one CK million annually) is growing, there are still a large number of grants where annual support comes to between CK100,000 and CK300,000. This indicates the importance of these small grants for many of the institutes. As in the past, about 40 per cent of project applications are funded, and this proportion is regarded as appropriate.

2. Natural Sciences

The field of natural sciences, as defined for the needs of the GACR, is very broad. It includes a wide spectrum of disciplines from mathematics and information sciences to physics and chemistry, cellular and molecular biology, earth sciences and cosmology, and general and ecological biology. Its focus ranges from the broadest theoretical modelling of nature, to the application of theories and experimental methods, to the solution of concrete problems. It also reaches into other fields such as technology, biomedicine and agricultural science, where natural laws are the basis for solving the most varied material problems of humanity and its interaction with the natural environment. In this connextion, it also has much in common with the social sciences.

The GACR endeavours to stress the modern conception of the natural sciences, which emphasizes the gradual removal of classical boundaries between fields and, the rise of interdisciplinary fields, which are capable of quickly reacting to changing human needs. This is true of disciplines in the natural sciences as well as fields in which the natural sciences are connected with technological disciplines, medicine or agricultural sciences. This interconnectedness is perhaps best expressed in the exceedingly broad and complicated field of environmental studies and environmental protection.

In accord once with the general policy of the GACR, the Area Committee of Natural Sciences gives preference to large projects, especially those that incorporate interdisciplinary and inter-institutional cooperation. Basic research is emphasized, though appropriate attention is also given to significant applications. The GACR strives to contribute to improving equipment, launching complex projects, and training new generations of scientists through a programme of stipends for postgraduate students. The aim is to avoid neglect of any of the important scientific trends or viable institutions such as the universities, the Academy of Sciences, government institutions, or even independent researchers. Nevertheless, the most significant criterion remains the technical quality of the projects and their authors, which must measure up to international standards.

3. Agricultural sciences

The processing of new grant proposals, the results of interim project evaluations and the reports on the first completed projects in the area of agricultural sciences, demonstrate both the strengths and weaknesses not only of Czech institutes and researchers, but also of the members of the area committee and sub-area committees and of the referees. There have been some outstanding results from work done by experienced researchers in cooperation with Czech and foreign experts. They have published their findings in leading international journals following a rigorous review process. But to a lesser extent, there are less carefully conducted projects whose lengthy reports request extensions solely on the basis of an examination process, and whose researchers content themselves with publishing their results in less exacting journals or in the popular press. Some have restricted publication of their work to papers read at conferences or to summaries which give little idea of what has been accomplished and how. But it is gratifying that the GACR has contributed to changing suchuntenable attitudes. It has not only declined to renew projects which fail to meet required research standards but has also changed the composition of its sub-area committees to render them better able to fulfil their mission. A thorough and responsible evaluation of proposals also plays a significant role, as does the monitoring of progress by the sub-committee's reviewer, which helps to identify any possible problems in time and maintains the principle of putting financial resources to the best possible use.

Aside from the demands it places on the project applicants, the grant system also contributes to the improvement of equipment and the introduction of more modern methods. One of the conditions is that equipment and methodologies be made available to other researchers and used as far as possible for other tasks. These conditions are fulfilled at the work site, and applications for new equipment are judged according to its usefulness for larger numbers of researchers. The requests of the grant applicants must be relevant to the needs of the institutes in which they work and, resources obtained from various sources must be responsibly pooled to assure the greatest possible success of the project. A further highly significant contribution of the grant funds is that they may be used for participating in international conferences. Here too, the evaluators of the applications for such travel grants, as well as the directors of the institutes, must take care that the trips will be used to the best effect, so that through active participation, research results will be tested and personal contacts will be made with leading researchers in the field. Only persons who directly participate in such conferences are capable of determining if their participation yielded the desired results and, this knowledge should be the criterion for evaluating further applications, not only for travel grants but also for new projects.

With the active help of the GACR, institutions conducting agricultural research are seeking fundsto solve pressing problems. There are many experienced and tireless researchers in the universities, the institutes of the Academy of Sciences of the Czech Republic, the institutes of the Ministry of Agriculture and, those of the private sector who are capable of using the funds offered by the GACR to conduct more basic research, which is the chief aim of the GACR. In this way, the resources devoted to applied research may be put to better use and, cooperation among various institutes may contribute to the practical application of research results obtained by the institutes of the Academy of Sciences and the universities.

According to the official records of GACR, it is evident that no special attention is devoted to ESTs. The amount of support for individual fields and the proportion of grants devoted to the development of ESTs is given in tables 2 and 3.

Table 2
Financial support for field in years 1993-1996 (mil. CK)

	1993	**1994**	**1995**	**1996**	**1993-96**
Technical Sciences	52	124	171	225	572
Machinery	11	28	41	50	130
Electrotechnology	11	28	34	42	116
Building and construction	9	22	33	50	115
Chemical technology	7	16	20	19	63
Mining	4	8	9	10	31
Material engineering	9	21	33	53	117
Natural Sciences	64	137	193	215	609
Chemistry	28	39	61	63	192
Biology	7	17	23	29	75
Agricultural Sciences	27	72	90	113	302
Wooder plants science	6	13	22	33	75
Soil biology	5	14	15	11	44
General technology	5	14	15	11	44
Total GACR	201	450	610	750	2 011

Source: Bulletin GACR

Table 3
Support for ESTs (mil. CK)

					1993-96	
	1993-95	**1994-96**	**1995-96**	**1996**	**Total**	**%**
Technical Sciences	28 200	17 500	15 500	7 100	68 300	11,9%
Machinery	4 300	4 400	6 200	2 700	17 500	13,5%
Electrotechnology	0	0	600	0	600	0,5%
Building and construction	8 600	1 800	900	300	11 700	10,2%
Chemical technology	6 800	9 900	4 100	2 000	22 800	36,1%
Mining	5 600	1 500	1 100	1 100	9 300	29,6%
Material engineering	2 800	0	2 700	1 000	6 400	5,5%
Natural Sciences	4 700	5 100	1 100	3 800	14 800	2,4%
Chemistry	1 800	1 600	0	3 800	7 200	3,7%
Biology	2 900	3 500	1 100	0	7 600	10,2%
Agricultural Sciences	1 800	0	2 800	0	4 700	1,5%
Wooder plants science	400	0	0	0	400	0,5%
soil biology	1 400	0	200	0	1 600	3,7%
General technology	0	0	2 600	0	2 600	6,0%
Total GACR	34 800	22 700	19 500	10 900	87 800	4,4%

Source: Bulletin GACR

The information given on the GACR is extensive because this agency serves more or less as a model for other institutions financing research and development. They follow similar rules even if the thematic definition of they support projects varies according to the interest of the institution. Most ministries are supporting research and development in their own fields. Some of them have established their own grant agencies as relatively independent bodies (e.g. the Ministry of Health), in other cases these operations are part of their existing structure. In the following section, only those institutions where at least a part of the resources are devoted to the development of ESTs will be discussed.

It must be stressed that no specialized programme or institution in the Czech Republic is explicitly supporting research and development specifically focussed on technologies that are environmentally sound in the sense of the UNCTAD definition. Nevertheless, many on going R&D activities contribute to the development of ESTs and their implementation and dissemination. For the Ministry of Environment, the environmental aspect is naturally the most important one but, support of technologies and/or their development is outside its main mission. However, the environmental dimension is regarded as an important issue generally and particularly important in all research and development activities. This notion is enhanced in the formulation of most of the programmes of the various grant agencies where the environmental aspect is often stressed. If the grant application contains a credible promise of a positive effect on the environment, the likelihood of it being accepted is improved. The applicants are generally aware of this situation and many of them have genuinely tried to bring about some concrete environmental improvements. This contributes to a relatively high number of projects targeted in the direction of ESTs, even if there is no specific programme in this direction. The main institutions supporting development of ESTs and their programmes are:

(a) Ministry of Industry and Trade

In 1996, the Ministry of Industry and Trade took over the activities of the Ministry of Economy, which ceased to exist. It supports a relatively large number R&D projects (table 1). Overall, the Ministry has the second largest programme R&D (after the GACR) and it is focussed mainly on the development of new technologies. The Ministry reported 11 programmes in 1997 with total financial support of almost CK900 million. ESTs are not among the stated priorities, but environmental impacts are often taken as criteria in the course of the selection process. The following fields are of interest with respect to EST.

1. Chemical industry: especially low-volume technologies. The chemical industry is a broadly developed industrial sector but in the past it was mainly focussed on low-quality, high-volume products. Within the new market situation, indigenous firms are either sold to big foreign (mostly multinational) companies or, they encounter great problems. The Ministry is supporting many diverse initiatives in this field including biotechnology.

2. Machinery: A limited number of projects are addressing technologies in this field. They are focussing on rather marginal problems such as the use of biodegradable lubricants. It is a witness to the general decline of this industrial sector that once was the flagship of Czech Republic industry.

3. Textile industry: Only a few projects in this sector could be considered as ESTs. For example, a project on the general ”ecologization” of the textile industry, a very detailed project on the production of new biologically-active synthetic fibers, is being implemented.

4. Waste recycling: This is one of the main fields where many projects to develop ESTs are supported. The topics include the recycling of catalytic converters in cars, the recovery of usable materials (so-called secondary raw materials) from a wide array of industrial processes in machinery and other fields and the recovery of usable material from discarded consumer goods such as batteries.

5. Industrial and hazardous waste disposal: The largest number of supported projects is in this sector. A broad spectrum of wastes from the chemical industry, electronics and other sectors are subject to recovery or safe disposal. High-tech solutions for toxic waste disposal such as plasmochemical burners or the use of biotechnological methods using microorganisms.are being developed. Several projects deal with various technologies for the safe disposal of radioactive waste.

6. Abatement technologies: The Ministry supports only a few such projects mostly in the field of energy production, as the development of these technologies is mainly the concern of the Ministry of the Environment.

7. Uranium industry: It should be noted that there are many defunct installations of the uranium industry including mines, settling ponds, processing plants and the like in the Czech Republic. The country’s rich uranium deposits were extensively exploited during the communist regime and all the products were shipped to the former Soviet Union. The legacy of the uranium industry represents one of the greatest examples of so-called old environmental damage. Uranium is no longer mined in the Czech Republic.

8. Radon programme: The country’s rich and numerous uranium deposits are a reflection of the generally high concentration of uranium and other radioactive elements within the bedrock. As a consequence, many areas experience the adverse environmental effect of the gaseous product of radioactive decay-radon. Radon is seeping into houses and public buildings (e.g. schools), where unacceptable levels of this pollutant are often found. Technologies for both new buildings and abatement methods are being developed under this programme, financed jointly by the Ministry of the Environment and the Ministry of Industry and Trade.

9. Agriculture: The Ministry of Industry and Trade is complementing the Ministry of Agriculture in this field and focusses its support on the development of supplementary technologies for agriculture such as new types of pesticides (including the support of integrated approaches to plant protection) or new fodder for cattle and other animals.

10. Forestry: A few projects deal with the development of ESTs for the lumber industry.

11. Energy: The Czech Energy Agency works within the framework of the Ministry of Industry and Trade (energy is one of the important responsibilities of the Ministry). Among other things, it functions as a grant agency supporting projects aimed to develop technologies improving energy efficiency and renewable sources of energy. The energy sector is an area where a large number of projects are being supported. Projects for improving the present technology of energy production in power stations, co-generating units, etc. (e.g. fluidized bed combustion) are probably the most common. Many projects aim to improve energy efficiency in heating buildings. A broad amount of support is given to the solution of various problems associated with nuclear energy, particularly those related to safety. There are a few projects focussed on the development of electric cars and other electric vehicles for urban transport.

In the course of this study, all projects supported by the Ministry were assessed regarding the development of ESTs. In many cases, it was not clear if a given project fitted into this category or not, according to the limited information given in the registers. Therefore, it is not possible to quantify the percentage of EST-related projects. However, a rough estimate is between 25 per cent and 30 per cent of the overall R&D expenditure of the Ministry.

(b) Ministry of Agriculture

The Ministry is responsible for agriculture, forestry and water management. Its programme R&D is rather large, similar to that of the Ministry of Industry and Trade and ESTs represent an important part of it.

It focuses on the following fields:

1. Agriculture: A very large number of projects dealing with various aspects of ESTs in agriculture are supported by the Ministry. Several projects are focussed on decreasing the amount of harmful substances (heavy metals, namely cadmium, pesticide residues and other persistent organic pollution (POPs) in the food chain. New technologies are being developed for more environmentally-friendly plant protection including using novel micro-organisms and natural pest enemies. The environmentally-friendly use of fertilizers and methods for organic fertilizing are the subject of some projects. Numerous projects deal with various aspects of agricultural waste and its use mainly for energy production. Soil protection, namely erosion mitigation, is a topic of several projects. Some of them are focussed on the use of marginal lands and landscape conservation. There is a general surplus of agricultural production in the Czech Republic and some arable land, especially in the marginal areas, is being abandoned. There is a lack of promising technologies for environmentally-friendly and sustainable use of such land. The traditional technologies are, for the most part, environmentally sound but unacceptably labour intensive and hence, very costly. Many projects are energy-related. They are focussed on improving energy efficiency in agriculture, growing various plants for energy use (the whole ”Oleo” programme deals with the growing and use of rape seed) and, the production and use of ethanol. Fewer projects than in the past focus on plant and animal breeding because it is a subject of privately funded research.

2. Forestry: The projects supported by the Ministry of Agriculture deal mainly into technologies used for the protection of forests from the harmful effects of air pollution and on the reforestation of damaged forests. (It may be noted that the area of forests damaged by air pollution in the Czech Republic, namely acid deposition, is the largest in Europe. More than 60 per cent of forests are, to some degree damaged and about 5 per cent are completely dead and replaced by non-forest vegetation.). Some projects deal with technologies for the lumber industry.

3. Food industry: The projects are mainly concerned with decreasing the contamination of food by harmful substances.

4. Water resources development: Several projects include proposals for technologies dealing with the management and the optimization of the water use for various purposes.

5. Waste water treatment: Projects are focussed on tertiary treatment using advanced methods including biotechnology and the removal of specific pollutants such as POPs polychlorobipheryls (PCBs).

6. Various technologies: The Ministry of Agriculture supports not only agricultural and forest production but also the development of various technologies based on agricultural products such as raw materials. These are technologies for textiles, lubricants, fuels (as mentioned above), building and construction materials, packaging materials (e.g. using starch as a raw material) and other industrial materials. A rough estimate of the percentage of EST-related projects is in the range of 35 per cent-40 per cent of all R&D projects supported by the Ministry.

(c) Ministry of Transport and Communications

The Ministry has a limited programme supporting research and development and it finances only a few projects on the development of ESTs. They are rather diverse and somewhat unsystematic aiming in very different directions e.g., water protection against pollution from railway traffic, ecological effects of natural gas used as an automobile fuel or, the optimization of the use of land lots adjacent to expressways. Unfortunately, the transport sector in the Czech republic is becoming one of the main environmental offenders as in other industrial countries. This is mainly due to the increasingly rapid use of private motor vehicles and, at the same time, a decline in the use of mass transit.

(d) Ministry of Defence

A small part of the Ministry of Defence’s research programme (generally classified) is devoted to the development of ESTs specifically related to military installations (e.g. protection of ecosystems adjacent to military activities).

(e) Ministry of the Environment

The Ministry has a relatively large research and development programme but only a limited part of it could be categorized as focussed on technological development. Naturally, if any such project is supported by the Ministry of the Environment, it should lead to the development of an EST. The Ministry reported seven R&D programmes in 1997 with total value of CK150 million. Most of the programmes are focussed on various aspects of the environment, its degradation and protection. The Ministry supports more theoretical research, along with the exploitation of its results, rather than focussing on EST-related research and development.

A relatively limited number of projects are difficult to divide into distinct categories or sectors because they are very diverse and complement programmes from other ministries. The following are more specific:

1. Abatement technologies: A few projects are focussed on air pollution abatement, waste water treatment, solid waste disposal and land reclamation.

2. Technologies dealing with subsurface waters and geology. The Ministry is responsible for geological research and development and, in this context supports some technological projects such as technologies for the preparation of the (planned) permanent radioactive waste disposal site or clean up methods for polluted groundwater reservoirs. The share of technology-related projects is roughly estimated at about 25 per cent of the overall R&D budget of the Ministry.

(f) State Environmental Fund

The State Environmental Fund is important institution supporting various environmental activities and that operates as an independent body within the framework of the Ministry of the Environment. It was established by Act No. 388/1991 Sb. ”On the State Environmental Fund.” According to the Directive issued by the Ministry in 1992, the resources of the Fund can also be used for the development and implementation of ESTs. Among the stated objectives of the fund are the:

1. Development of ESTs in general. Starting in 1998, a special programme targeted at the development of cleaner technologies was launched

2. Implementation of sources of renewable energy

3. Improvements in energy efficiency

4. Development of abatement technologies

The overall expenditures of the fund is between CK4 to 6 billion annually. Until 1996, practically all resources were devoted to clean up technologies of the end-of-pipe category, mostly municipal waste water treatment plants and air pollution abatement equipment.

In 1995, the Ministry of the Environment supported a research study devoted to environmentally sound production. Seven sectors were investigated in terms of space and opportunities for the introduction of ESTs. The results of the research led to a very specific evaluation of the situation, including proposals for EST and organizational and legal measures (voluntary agreements between state administration and industry, environmental management systems - ISO 14000). The study can serve as a good basis for R&D and/or industrial policy demanding real mission-oriented, focussed, and complex R&D.

(g) Academy of Science of the Czech Republic (ASCR)

The largest scientific and research body of the Czech Republic is the ASCR. The Academy is formed by a chain of Institutes, most of them founded many years ago. Their main mission is to pursue basic research and to provide post-graduate education. During the communist period, it was shaped along the model of the Soviet Academy and relatively well-funded. Now it is substantially downsized (at least by 50 per cent) but, it is still a strong scientific institution. Given the relatively high level of support for the Academy, the share of basic research amounts to almost 40 per cent of the total public support for R&D. This is more than in most advanced economies where the corresponding numbers are between 5 - 13 per cent. (On the other hand, research at the universities remains underdeveloped about 22 per cent of total public support as compared with support in the European Union almost 30 per cent). In comparison, industrial R&D amounts to 14 per cent in the Czech Republic as compared to 20 per cent in the EU. Defence R&D is 10 per cent in the Czech Republic, and 19 per cent in the EU. However, these numbers are slightly misleading due to the fact that the ASCR also pursues technological research.

The ASCR has a wide programme in its grant agency, which is open to any applicant. The rules are roughly similar to that of the GACR. A relatively substantial part of it, in many scientific fields, could be categorized as the development of ESTs (table 4).

In conclusion, it may be stated that the research and development of modern technologies, including ESTs, is currently not a high priority for the Government and hence, the financial resources from public budgets are relatively modest. On the other hand, R&D is basically supply-driven because it is in the interest of researchers to get grants or other funding for their work. The financial resources are limited but, nevertheless available, and many valuable R&D projects are being undertaken.

Table 4
Financial support for grants of ASCR

	1993		**1994**		**1995**		**1996**	
Technical Sciences	10 600	12,7%	8 800	15,4%	7 600	14,3%	10 600	12,4%
Electrotechnology		0,9%		0,3%		0,5%		0,4%
Mechanics		4,4%		6,0%		6,8%		5,5%
Material sciences		4,6%		4,0%		3,6%		3,7%
Chemical Engineering	14 000	16,8%	11 800	20,7%	10 800	20,3%	15 600	18,3%
Chemical engineering		1,7%		2,7%		2,8%		1,5%
Organic chemistry		1,4%		2,8%		6,5%		4,4%
Biochemistry		2,5%		3,2%		2,4%		1,0%
Molecular and Cell Biology	9 500	11,4%	6 200	11,0%	7 200	13,6%	10 400	12,2%
Micro and Biotechnology		3,8%		1,3%		1,1%		1,1%
Total	83 200		56 700		53 300		85 300	
Grants potentially useful for	16 000	19,3%	11 500	20,3%	12 600	23,7%	14 900	17,5%

Source*:* Academic Bulletin 6/17.

B. Patterns of diffusion of ESTs

Compared to R&D, the dissemination of the results of projects and their use in actual technological practice by individual enterprises is different. It seems that this activity is not of significant interest. The Government has no clear policy to effectively promote the diffusion of results and, there is no general interest among enterprises to be innovative.

Various of publicly funded R&D projects are registered in a Central Project Registry (*Centrální evidence projektù, CEP*). This information is available on Internet. In addition to the CEP, a Registry of Information on Publications *(Registr informací o publikacích, RIP*) also exists where all resulting publications including patents are registered. These institutions are part of the activities of the Council R&D and were created by the (already quoted) Act No 2/95 Sb. The patents and licences are registered by the Bureau of Industrial Property of the Czech Republic (*Úøad prùmyslového vlastnictví, ÚPV*). All grant agencies and ministries have a register for their own projects. Overall, no one institution has complete information on the results of publicly funded R&D. The most extensive register is the CEP, but only projects of a scientific or research nature are registered. There is no complete centrally established list or register of the results of various programmes supported by sectorial ministries. It is in fact difficult to find information on a specific technology. There are many private institutions, either of a business or non-profit character (NGOs), where information on technologies can be obtained. These are both general (e.g., Chamber of Commerce, Union of Industry and Transport) and specific in nature (e.g., Association of Producers of Environmental Systems, APES).

The overall regulatory regime is rather underdeveloped. The Czech Republic is a party to international legal instruments on intellectual property and similar agreements. Necessary national institutions and instruments are in place. The whole system has however, only a basic shape. For instance, there is no clear division between publicly owned technologies and technologies in the public domain. These issues are not yet perceived as important issues.

If there is a patent granted for a technological innovation that is a result of a project partly or wholly financed from public budgets, the owner of the patent is the institution that proposed the project and worked out the technology. For example, if an enterprise applies for a grant for a new technology and the result is patented, then the applicant enterprise is the owner of the patent. The situation is generally the same regardless of the exact mode of financing. It could be a full grant, partial support or a soft loan. In all cases, the owner of the patent is the applicant institution. If this happens to be a private body, the developed technology is neither publicly owned nor in the public domain.

The government has no consistent policy toward supporting the dissemination of publicly funded research and the development of technologies including ESTs. The protection and exploitation of the results of R&D are subject to an internationally established legal framework that is in place in the Czech Republic. However, there are no special instruments in place to stimulate the dissemination of results, the development of prototypes and/or the commercialization of technological innovation.

C. Modalities for the transfer of publicly funded ESTs

There is practically no policy for the facilitation and promotion of publicly funded and newly developed ESTs to developing countries. The Czech Republic is only starting to consider its development aid for developing countries in connecxion with its recent membership of OECD (1995). No consistent framework in this field is in place.

However, it could be envisaged that in the near future some appropriate policy will be developed. It cannot be expected that such a policy will be oriented specifically to the transfer of ESTs. The emerging international aid programme is only starting to take fundamental shape and is not oriented to any specific direction. There is no connecxion to existing bilateral or multilateral environmental agreements. The policy of publicly funded R&D has been almost exclusively oriented towards domestic issues. In the field of ESTs, the programmes are defined to help solve indigenous environmental problems such as waste disposal, restoration of radiation-contaminated areas or agricultural use of marginal lands. If any technology is developed, it is rarely applicable outside the specific local setting. On the other hand, there are growing numbers of environmentally-oriented SMEs that may seek their opportunities abroad. They may use technologies that were developed fully or partly with public support. There is no reliable information available about such cases because thy are exclusively private initiatives and no public information is available. In any case, such activity is not on any massive scale.

It should be noted that in the Czech Republic, a relatively long and successful tradition does exist in technology transfer to many developing countries. Czech technology in the field of energy production, water resources and other natural resource exploitation has a long tradition covering many decades. Some of those technologies are relatively environmentally-friendly such as efficient water pumps exported to many Latin American countries. Such technology certainly cannot be placed under the title of ESTs because it is not particularly innovative, even if sometimes the best available design is used. However, the technology often helps to achieve the efficient and rational use of natural resources. The advantages of this technology where equipment in general are reliability, long life-span and the ability to be easily repaired. From the point of view of environmental benefit, such technologies could be very important. No R&D is required for such technology, privately or publicly funded.

D. Main findings of the survey

Technological research and development, including the development of ESTs is not currently among the priorities of the government. Financial support is relatively low compared to other OECD countries. For various reasons, there is a relatively high level of support for basic research, namely at the Academy of Science of the Czech Republic, and less support for applied and technological research and research at universities.

The reasons could be summarized as follows:

1. Relatively strong current position and high intellectual level at ASCR.

2. Long tradition and a well-established institutional framework for basic research pursued by ASCR.

3. Lack of clear industrial and technological policies by the Government including the policy of technological research.

4. A ”conservative” liberal attitude by the Government that basically leaves technological development in the hands of the private sector.

5. Lack of an institutional framework for the dissemination of technological results.

6. Lack of targeted governmental support for technological innovation within the private sector.

7. Lack of institutional and legal structures, regulating and stimulating the dissemination of technologies, including intellectual property rights, licencing, patents, etc.

The economic transformation from a Soviet-style centrally planned economy to a modern market-oriented economy governed by liberal laws is an enormously difficult task and the scope of problems and obstacles is immense. It is more than natural that the Government and the whole of society concentrate on absolutely essential tasks and concerns, disregarding less essential details however important they may be over the long term.

During the first three years of the transformation process, economic output measured by GDP dropped by 20-30 per cent. After three consecutive years of modest economic growth (3-5 per cent yearly increase of GDP), the Czech economy again encountered some problems resulting in a substantial slow down. The basic goal of both the economy as a whole and many individual firms is simply to survive or to achieve modest growth. Such a situation is not conducive to technological innovation and advancement, which thrives more typically in a situation of massive economic expansion. There is no explicit pro-export policy or support for the dissemination of any advanced technologies including ESTs.[1] A basic prerequisite for any substantial improvement in the present situation is first and foremost solid economic growth. Only after this is achieved will the development of new technologies, including ESTs, be perceived as an urgent task.

The Czech Republic became a member of OECD in 1995 (followed by Hungary and Poland a year later). The Government understands that the country is changing from being a beneficiary country to a donor country and, is seriously preparing to devise a policy for the disbursement of international aid to developing countries. Hopefully, in the not very distant future, there will also be support for the development and transfer of ESTs.

[1] According to my experience as chairman of the Board of Directors of the Regional Environmental Centre for Central and Eastern Europe in Hungary, the situation in other Central and Eastern European countries with economies in transition is not much different. It should be kept in mind that the Czech Republic belongs to the more advanced group of the CEE countries. The situation in other countries of the region is almost certainly no better than it is in the Czech Republic. This case study on the Czech Republic could thus serve as a model for the whole region.

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ESTs: THE CASE OF CANADA

by
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I. INTRODUCTION

Sustainable development was defined by the World Commission on Environment and Development (the Brundtland Commission) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In essence, the Commission stressed that our long-term economic well-being is inextricably linked to the environmental health of the planet and that economic growth is dependent on environmental renewal, thus reversing earlier assumptions of economic development and environmental quality as being competing or even opposing goals.

Over the past decade, an increasing number of countries, including Canada, have accepted the sustainable development approach as being "a wise public investment like preventive social policies and preventive health care" (in the words of *Creating Opportunities*, the governing Liberal Party policy platform "Red Book"). Implementing sustainable development, however, implies a number of far-reaching changes in how we organise ourselves as a society and how we manage industrial processes and our natural resources, as well as an enhanced understanding of how nature works. Sustainable development also requires cooperation among nations. This can only be achieved if we have access to reliable information and an understanding of environmental issues that will allow us to make responsible environmental, social and economic decisions.

The Earth Summit held in Rio de Janeiro in June 1992 brought the world together to focus on the need to address the wide-ranging socio-economic and environmental challenges facing the international community. A strong message coming from the Summit was that in order to achieve sustainable development, all nations and all sectors of society must find effective means of working together. The Canadian Federal Government is firmly committed to fostering these partnerships.

Canada has been at the forefront of efforts to facilitate this transition towards sustainable development. Federal and provincial governments are becoming increasingly involved in researching, developing and transferring environmentally sound technologies. Some of these projects feature direct transfers of Canadian technology and expertise related to specific environmental challenges, while others place more emphasis on capacity development (a process of strengthening a recipient country's public and private sector institutions and people to develop the capability and skills to achieve environmentally sound forms of economic development through the use of modern technologies and management systems, a competent workforce and appropriate laws and regulations).

The purpose of this paper is to examine the role and significance of publicly funded research and publicly owned technology in Canada in the transfer of environmentally sound technologies (ESTs).

The main objectives of this study are to:

- Assess the overall role of publicly funded research in the development of ESTs;
- Establish the range and relative importance of ESTs developed through publicly funded research;
- Examine the pattern of diffusion and commercialization of these technologies at the national level;
- Explore potential mechanisms for the transfer of such technologies to developing countries; and
- Assess the relevance of the subject to future policy initiatives.

Two of the primary questions that the study addresses are:

- To what extent has publicly funded research and development (R&D) contributed to the development of ESTs?
- Are these technologies being commercialized or transferred? If so, through what means?

In examining the role of publicly funded research and publicly owned technologies in the transfer and diffusion of ESTs, available literature from various federal and provincial departments and agencies were examined. Key individuals from various government departments and agencies (including Environment Canada, Industry Canada, Natural Resources Canada, Statistics Canada, the Department of Foreign Affairs and International Trade, The National Research Council, the National Round Table on Environment and the Economy and the Canadian International Development Agency, British Columbia Ministry of Environment Lands and Parks, Ontario Ministry of Environment) have also been consulted to gain a sense of trends and the drivers behind Canadian environmentally related R&D and technology transfer.

This paper is not intended to provide an exhaustive overview of public involvement in the development and dissemination of ESTs. Rather its emphasis is on recent experience, and the directions in which public involvement is moving and possible future avenues for promoting EST development and transfer.

II. PUBLICLY FUNDED R&D AND CANADA'S ENVIRONMENTAL INDUSTRY SECTOR

A. Proportion of publicly funded R&D to overall R&D expenditures

While total business enterprise expenditures on R&D (BERD) in Canada have risen over the past 20 years from 0.4 per cent to 0.8 per cent of Gross Domestic Product (GDP), it is still a relatively low ratio for Orgainization for Economic Cooperation and Development (OECD) countries. Total BERD in Canada were similar to those of the "middle rank" OECD countries but were less than others such as Japan (2.1 per cent), the United States (1.9 per cent), Germany (1.8 per cent) and Sweden (1.6 per cent). The small size of many Canadian companies accounts for much of this. In 1991, almost half of all R&D expenditures in Canada were accounted for by only 25companies.[1] Other contributing factors are the branch plant nature of many large firms and limited access to the capital needed to support technology development.

Most countries, particularly Sweden, Germany and Japan, have increased their industrial R&D effort over the last 20 years. In comparison, Canadian effort has increased relatively little. While the business sector's participation (natural sciences and engineering only) in gross domestic expenditures on research and development increased from 33 per cent in 1971 to 54 per cent in 1991, the federal government and the higher education shares fell correspondingly from 29 per cent to 16 per cent and 34 per cent to 26 per cent respectively. Provincial governments maintained their share of all R&D performed in Canada at approximately 3 per cent.[2]

The National Research Council maintains that 25per cent of all R&D spending in Canada comes from the Federal Government.[3] However, 1997 estimates recently released by Statistics Canada suggest that the federal contribution to R&D expenditures is substantially less (approximately 15 per cent). According to Statistics Canada, total expenditures for R&D in Canada for 1997 were slightly less than $13.3 billion. Of this amount, approximately $2 billion was funded by the federal government. Provincial funding is estimated to have contributed an additional $170 million.[4]

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[1] The Task Force on Sustainable Wealth and Job Creation (1994). *Towards an Innovation Strategy,Final Report,* Ottawa: Government of Canada, Preamble.
[2] Statistics Canada, *Research and Development - 1993 Intentions* (1993).Ottawa, Government of Canada, p. 15.
[3] *National Research Council Homepage,* (Ottawa, government of Canada, 1997), http://www.corpserv.nrc.ca/
[4]Statistics Canada, *Estimates of Canadian Research and DevelopmentExpenditures (GERD), Canada, 1986 to 1997,and by Province 1986 to 1995 (1997).* Ottawa, Government of Canada, p. 3.

B. Relative importance of publicly funded ESTs

Government funding for research and technology development has been critical to the growth and survival of many small technology-driven environmental companies. Canada's historically low level of R&D, particularly in the private sector, and the small domestic market have been important factors in determining the focus of government support.

Government support programmes for the environment industry promote the development, growth and market access of environmental technologies and services. Although there are a wide variety of programmes offered by both federal and provincial governments, they tend to be focused on applied research, technology development and export development.[5] They do not, however, reflect a coordinated approach (although some newer programmes suggest the emergence of new government strategies designed to provide more effective and comprehensive support to the industry).

Cooperation between government and industry representatives has helped to identify and fill gaps in government support for funding, commercialization, future human resource requirements, management and marketing. Federal and provincial governments are exploring new ways to support science and technology (S&T) and the EIS in an era of diminishing budgets and increasing international competitiveness.

To address the new agenda, a review prepared by the federal Interdepartmental Task Group on Sustainable Wealth and Job Creation, argues that Canada must develop a systematic approach to innovation, "*a strategy that mobilises powerful new combinations of people, capital, resources and ideas.*"[6] The study recognises that government support of S&T has been a critical factor in the development of innovation in Canada and describes a new role in which government acts as a facilitator of interactions between distinct operating components - educational, industrial, university and governmental.

> "The connection between S&T and wealth creation is through innovation – the process by which new or improved products and processes are developed and introduced into the marketplace. Innovation is no longer conceived as a linear process, solely dependent on technology-push and market-pull. It is a dynamic, iterative and turbulent process involving scientific discovery, applied research, development, investments, markets and sales."[7]

[5] Environment Canada, (1996). *Technology, Competitiveness and Canada's Environmental Industry: An Outlook into the Future Development of the Industry,* Ottawa, Environment Canada,, p. 5-16.
[6] The Task Force on SustainableWealth and Job Creation (1994). *Towards an Innovation Strategy, Final Report,* Ottawa: Government of Canada, Preamble.
[7] *Ibid.,* p. 5.

A close cooperative relationship between government and industry has been the hallmark of the environmental industry in many European countries and Japan. Government departments of industry frequently work closely with private industry to mobilize and leverage environmental technology development. In the Netherlands and Denmark, for example, environmental technology policies focus on cooperation between users, suppliers, developers and consultants to ensure at an early stage that technology is what the user needs. In Canada, there is a growing cooperation among stakeholders, though rarely does this involve participation of both users and suppliers.

The Canadian environmental industry is young and dynamic, hardly more than a decade old, with a high proportion of firms that were created within the last five years. Because much of the industry is technology-based, and these technologies are created to meet highly diverse and changing markets, the sector is in a constant state of renewal and consolidation. Since this sector is so new, and difficult to define, there is little aggregate data available regarding R&D expenditures. We have relied heavily on a Statistics Canada survey on R&D expenditures for pollution abatement and control (PAC).[8]

In 1993, R&D expenditures for PAC incurred by firms accounted for CDN$133.7 million, a 32 per cent increase compared with the 1990 level. Industrial research institutes added an additional CDN $14.9 million in1993, especially for paper and allied projects.

From 1990 to 1993, R&D expenditures for PAC represented only 2 per cent of total R&D expenditures. This low percentage is likely to be an underestimate because of those firms which invested in R&D to improve production efficiency. These firms would likely not report such R&D expenditures as PAC-related even though pollution abatement may bring additional benefit.

R&D expenditures made for PAC were performed by two categories of firms: suppliers of environmental goods and services and users of environmental goods and services. Examples of the first category include engineering and services firms, machinery firms and industrial research institutes. In1993 the most important industries in the second group, in terms of PAC R&D expenditures, were the chemical products industry, the primary metals industry, and the paper and allied products industry. “Other industries” also reported significant PAC R&D. The largest R&D expenditures for PAC in 1990 and in 1993 were made by the engineering and scientific services industry (CDN $24.3million), a component of the “environment sector.” Even in 1991, when the primary metal industry spent the most on PAC R&D, expenditures made by engineering and scientific services were the second largest.

[8] This section relies heavily on data obtained from Statistics Canada (1993*). R&D for Pollution Control and Abatement in Canadian Industry for 1990,1991, 1993,* Ottawa, Statistics Canada, as well as anecdotal information provided by Environment Canada, Industry Canada, and Natural Resources Canada.

The largest expenditures made by firms on PAC R&D in 1993 were found among the engineering and scientific services industry, industrial research institutes, other industries and the chemical products industries. The engineering and scientific services industry saw its share of PAC R&D expenditures increase from 14 per cent to19 per cent between 1990 and 1993. Industrial research institutes saw their share of PAC R&D expenditures increase between 1990 and 1991 before stabilising in 1993 at 11.6 per cent.

Even though PAC R&D expenditures were a small proportion of total R&D expenditures reported by Canadian industry as a whole, they accounted for a large proportion of total R&D for firms that did report PAC R&D expenditures, particularly the machinery and fabricated metals industries (65.1 per cent and 51.6 per cent shares respectively). In 1993 PAC R&D performers spent 13.6 per cent of their R&D expenditures on PAC R&D, but that share declined from 1991 (17.7 per cent) after having increased from 1990. This was true of most industries and industrial research institutes, even though the number of PAC R&D performers actually increased between 1990 and 1993 from 267 to 423. Two exceptions were the engineering and scientific services industry and the machinery industry, for which PAC R&D as a percentage of total R&D expenditures made by PAC R&D performers almost doubled between 1990 and 1993.

C. Rationale for public funding for EST development

The rationale for public funding of research and development has changed dramatically over the last 20 years. Gone are the days when government research establishments could be described as “universities without students”, when the test of acceptability for investigation was whether the project was “mission-oriented” and when scientists were free to pursue esoteric ideas and be judged only by their peers on scientific merit. The same is true of government funding programmes. Governments are no longer in the business of buying research for its own sake. Technologies developed with government funding no longer sit on the shelf waiting for someone to come along and discover commercial uses.

In Canada, the need for greater direct environmental, economic and social benefits from government expenditures in science and technology combined with severe and continued fiscal constraint have forced a new discipline that focuses on the impact of the government’s technology investment rather than its scientific quality. Cooperative arrangements with provinces, academic institutions and, more recently industry, are increasingly important as the government focus has shifted from science and research to R&D for economic development.

D. Types of ESTs developed as a result of publicly funded R&D

Publicly funded R&D in Canada relating to ESTs has produced a variety of technologies spanning the range from pollution control and abatement to pollution prevention and process design. A brief description of some of the main federal government organizations involved in R&D and some examples of success stories are presented below.

1. National Research Council

The National Research Council (NRC) is a federal agency reporting to Parliament through the Minister of Industry. Its mission is to support national science and engineering activities, perform and stimulate investment in research and development, and develop vital expertise and knowledge. NRC maintains that "environmental soundness" is a quality that all its technologies must possess in order to be economically viable. Thus, from one perspective, all of NRC's research budget is spent on ESTs.

The NRC strategic research focus is to try to reduce, through better product and process design, the need for traditional types of ESTs. Nevertheless, the NRC recognises that one can never totally eliminate the need for them, so they make some R&D investments in this area. Examples of ESTs NRC is currently working on are:

- Soil bioremediation;
- Soil chemical remediation;
- Treatment of tailings ponds (fine solids suspended in water) associated with exploitation of tar sands;
- Waste water treatment using membrane separation technologies;
- Waste water treatment using electrochemical methods;
- Treatment of air emissions using gas separation membranes;
- Hydrate formation for carbon dioxide disposal; and
- Plastics recycling and landfill disposal.

About 3 per cent of NRC's R&D budget is invested in such technology developments.

All technologies have associated with them a cost of managing the environmental aspects of using the technology. NRC has established a small Environmental Management Office in the Institute for Chemical Process and Environmental Technology (ICPET) to develop methodologies for estimating the environmental management costs for any given technology. Elements of these costs are:

- the costs of compliance (e.g., investments in end-of-pipe technologies) ;
- the costs of waste management and disposal;
- the costs of recycling/recovery of materials;
- the costs of clean-up after accidental releases;
- the costs of contingent liability and environmental insurance;
- the costs of risk assessment and product stewardship (LCA);
- the costs of emissions monitoring and public reporting; and
- the costs of public discussion and dialogue.

By examining these costs and examining ways of reducing them while achieving the same or better levels of environmental protection, NRC is trying to make its technologies "environmentally sound".

Some of the manufacturing sectors that benefit from ICPET expertise are:

- Primary metals processing;
- Plastics and rubber;
- Petroleum refining;
- Process and environmental equipment and systems suppliers;
- Food and beverage processing;
- Specialty chemical products;
- Pharmaceuticals and medical products; and
- Electrical and electronic products and processes.

ICPET has recently entered into an agreement with the Republic of Korea’s Samsung Advanced Institute of Technology (SAIT) to collaborate on research on new materials for lithium ion cell batteries. Researchers from ICPET and SAIT will work together to advance base technology, already developed at NRC, to the point where this technology can be used to produce battery materials that can be commercialized. Lithium ion cell technology is expected to help meet market demand for economical, less toxic, rechargeable batteries that deliver higher performance than batteries currently on the market.

ICPET is also involved in a unique cooperative research consortium called Foam Tech. ICPET, with the Institute for Research in Construction, and the Industrial Materials Institute, are working with industry giants such as Dow Chemical, ICI and Owen Corning Celfortec, and with medium-sized companies like Quebec-based Cascades Inc. to develop replacement technology or alternative manufacturing processes that will eliminate the need for CFCs and HCFCs in the manufacture of foam polymers.

2. Networks of Centres of Excellence

The federal Networks of Centres of Excellence (NCE) programme is an innovative approach to R&D designed to develop Canada's economy and improve Canadians' quality of life. The programme produces significant research discoveries and innovations, ensures that they are transferred to potential industrial and public policy users quickly, and trains highly qualified researchers, often in settings outside the in university.

The 1997 federal budget stabilizes the NCE programme funding at an annual allocation of $47.4 million. Future funding cycles will be increased to seven years from the current four years. NCE funding encourages private and public sector collaboration. Marketable products and processes based on Network research are being commercialized by Canadian firms.

The Networks focus on four specific challenges. They endeavour to:

- Stimulate internationally competitive, leading-edge fundamental and applied research in areas critical to Canadian economic and social development;
- Develop and retain world-class scientists and engineers in key technologies essential to Canada's productivity and economic growth;
- Create nation-wide multidisciplinary and multisectoral research partnerships that integrate the research and development priorities of all participants; and
- Accelerate the exchange of research results within the Network and the use of this knowledge within Canada by orgainizations that can harness it for Canadian economic and social development.

Canada's three national granting councils - the Natural Sciences and Engineering Research Council (NSERC), the Medical Research Council (MRC) and the Social Sciences and Humanities Research Council (SSHRC) - and Industry Canada have combined their efforts to support and oversee the NCE initiative. Altogether, there are 14 Networks of Centres of Excellence, in the areas of health and biotechnology, information technology; natural resources; infrastructure; and human resources.

3. Environment Canada

The Environment Technology Centre (ETC) of Environment Canada was established in 1975 to provide specialized technical and R&D support for the department’s many activities. The Centre deals primarily with technologies for the measurement of air pollutants in ambient air and air pollutants emitted from mobile and stationary sources, the analysis of a wide variety of organic and inorganic compounds in diverse sample matrices, the clean-up of leaking hazardous waste sites and the response to pollution emergencies such as oil and chemical spills. Most of the R&D work, and some technical support services, are undertaken in collaboration with the public, private and academic sectors. Some R&D is also done in cooperation with international partners. A significant part of the work is performed by contractors working on and off-site.

The Annual Departmental Reference Level scientific budget for the Centre (including salaries, capital, operations and maintenance) is about $8 million. In an average year, another $3-5 millions are received through cost-sharing Joint Project Agreements (JPAs) with collaborators in the public and private sectors. JPAs usually involve another $5-10 million through work-sharing agreements. The Centre has a staff of about 100 with typically another 50 to 60 workers on-site: contractors, students, post-doctoral fellows and visiting researchers.

ETC developed Environment Canada’s patented Microwave-Assisted Process (MAP). The MAP technology uses microwaves and solvents which are relatively transparent to microwaves to extract chemicals from various matrices. The applications of the technology include a rapid sample preparation method for the analytical laboratory and a cost-effective replacement for conventional industrial extraction processes.

4. Natural Resources Canada

CANMET, the Canada Centre for Mineral and Energy Technology, is a federal government laboratory within Natural Resources Canada. CANMET conducts and sponsors research for the economic, safe and environmentally responsible recovery and use of Canada's vast mineral and energy resources. As a Technology Centre, CANMET has formed many alliances and partnerships with industry, other federal departments, provincial governments, universities and international agencies to share the costs and risks of R&D. Such alliances ensure that Canada achieves maximum return on its R&D investment and facilitate the implementation and commercialization of CANMET-sponsored technologies by industry to generate wealth, create jobs and improve the quality of life Canadians enjoy.

Under its mandate, CANMET works in partnership with Canadian minerals, metals and energy industries to enhance their competitiveness, to assist them in improving health, safety and environmental protection, and to improve and develop energy efficiency and alternative energy technologies. In addition to serving traditional clients in the energy and minerals sectors, CANMET works with orgainizations in related sectors (e.g., buildings, automotive and consulting industries) and those that cluster around the resource industries (e.g., equipment suppliers and manufacturers, consulting engineers). Many of the companies in these related fields are small and medium-sized enterprises which have the potential for high growth and job creation but require research and technical support to take advantage of new opportunities.

A notable contribution was CANMET support for the development and technical demonstration of the Ballard Power Systems Inc. Proton Exchange Membrane (PEM) fuel cell and associated equipment for use in mass-transit systems. CANMET's support in the development and demonstration led to the world's first fuel-cell-powered, zero emission transit bus running on hydrogen. Ballard is one of the world leaders for fuel cell technology applications in the automotive industry. With Daimler-Benz, Ballard recently developed a new prototype fuel-cell-powered Mercedes Benz, and they are currently conducting fuel cell research for the big three American automotive companies: General Motors, Ford and Chrysler.

Also, in cooperation with CANMET, Conserval Engineering Ltd. is continuing to lead the world in the development of cost-effective solar air heating systems for commercial and industrial buildings. Conserval's perforated absorber SOLARWALL is the world's most efficient solar air collector.

III. PATTERNS OF THE DIFFUSION OF ESTs

A. Regulatory regimes relating to the protection and exploitation of publicly funded R&D

Intellectual Property Rights perform a dual function of facilitating the diffusion and transfer of intellectual property while bestowing on inventors a return for their creativity, investment and perseverance. Technology transfer activities and licence agreements entered into under Canadian Law are generally affected by:

- Principles of Common Law and equity in each province except for Quebec, where the Civil Code system governs contract law and the protection of confidential information;
- Federal statutes that govern intellectual property including the Patent Act, Trade Mark Act, Copyright Act, Industrial Design Act, Integrated Circuit Topography Act, Plant Breeders' Rights Act, Public Servants Inventions Act, Competition Act, Corporations and Labour Unions Return Act, Income Tax Act and Part IX of the Excise Tax Act;
- Statutes that control exports or investments including the Export and Import Permits Act and the Investment Canada Act; and
- Conventions to which Canada has subscribed including the Paris Convention for the Protection of Intellectual Property, the GATT and NAFTA.

Government departments engaging in R&D and technology transfer activities also have policy statements pertaining to intellectual property. Environment Canada's Intellectual Property Policy provides a solid example of how intellectual property rights encourage diffusion of publicly owned or publicly funded environmental technologies. This policy applies to all intellectual property of a technological nature originating under the auspices of the various Environment Canada responsibility centres, such as inventions software, know-how, trademarks and industrial designs (definitions are provided in the Appendices). Intellectual property which can be is copyrighted, but not technological in nature (i.e. other that software), are not subject to the application of the policy. They are instead subject to the Government of Canada Communications Policy.

The objectives of Environment Canada's Intellectual Property Policy statement are to:

- Transfer suitable technologies which result from ongoing EC R&D programme activities and thereby,

  - encourage beneficial application of environmental technologies to improve the quality of life for Canadians;
  - support the sustainable development of Canadian economic activity for increased international competitiveness and job creation;
  - help support further R&D activity from royalty revenues returned to the originators of intellectual property; and
  - promote collaborative arrangements between the Department and Canadian industry and universities and other governmental orgainizations, domestically and internationally, for the development and application of environmental technologies.

An issue of concern to both government and industry with respect to international technology transfer is the lack of universally accepted and enforced international laws pertaining to intellectual property. For example, countries not subscribing to the Paris Convention for the Protection of Intellectual Property tend not to be targeted for technology transfer, and in cases where these countries get involved in technology transfer agreements, Canadians have been reluctant to transfer new, state-of-the-art technologies.

B. Relevant financial and institutional policies

Over the last several years, a number of federal(and more recently provincial) initiatives have been implemented to encourage R&D and the diffusion of resulting technologies. Some of the most relevant initiatives are described below.

1. Canadian Environmental Industry Strategy

The federal Canadian Environmental Industry Strategy (CEIS) was introduced in 1994 following extensive consultations with industry, provincial governments and other stakeholders across the country. The Strategy has three principal components:

- A core strategy consisting of 20 initiatives involving $15 million in funding;
- Continuing programmes and activities of a number of federal departments and regional agencies; and
- New initiatives to assist and support Canadian environmental industries.

The core strategy's major focus is improved access to domestic and global markets. The 20 initiatives are divided into the following four areas:

1. Delivering federal government support to the industry in a direct, easily accessible, service-oriented and cost-effective way (two initiatives);
2. Supporting the development and commercialization of innovative environmental technologies (three initiatives);
3. Improving access to domestic and global markets for Canadian Companies (12 initiatives);
4. Partnerships with the Canadian Environmental Industry.

The Strategy is generally viewed as a success by the environmental industry. Funding for CEIS was scheduled to terminate at the end of fiscal year 1997. Canada's environmental companies have been urging the government to renew the CEIS, with a new mandate that would broaden participation to include a number of traditional industries involved in environmental technology development because of their impact on the environment. (e.g. the mining and pulp and paper industries).

2. Technology Partnerships Canada

Technology Partnerships Canada (TPC), which was announced in the 1996 budget, is a new funding approach to help firms in Canada compete in high technology industries. Every investment is fully repayable and the government shares, with the private sector, the risks and rewards. By 1998-1999, TPC will have invested $250 million annually. A key objective of TPC is to level the playing field with foreign competitors who are backed by their government's technology programmes.

The fund’s focus is on:

- Environmental technologies;
- Enabling technologies (such as biotechnology, selected information technologies and advanced manufacturing technologies, which make many industries more efficient and productive); and
- The aerospace and defence industries, including defence conversion.

The kinds of environmental technologies targeted by TPC are those with global growth potential. Technologies currently being given priority are:

- Air pollution;
- Clean car technologies with significant environment impact and technological advancement;
- Liquids pollution;
- Pollution prevention;
- Recycling;
- Soil remediation;
- Solids pollution;
- Waste reduction;
- Water conservation;
- Water pollution; and
- Water treatment and purification.

3. Western Canada Environmental Technology Loan Fund

This $40 million, seven year loan programme, was established by Western Economic Diversification, Environment Canada and the Toronto Dominion Bank to help lay the foundation for long-term stability and growth of small to medium-sized companies in Western Canada’s EIS. The loan programme is an incremental source of debt financing for eligible firms involved in environmental product, service and technology development and commercialization. This includes R&D leading to commercialization, pre-commercial and commercial product development, innovative scientific and technical services for environmental conservation, protection or enhancement and market development and expansion. At the beginning of 1997,six loan applications, valued at $1,909,500 collectively, had been approved by the TD Bank and accepted by the proponent.

4. The Environmental Technology Verification Programme (ETV)

The ETV Programme is designed to foster the growth and marketability of Canada's environment industry, by providing validation and independent verification of performance claims. This new initiative promotes the credibility of Canada's environment industry internationally while building sustainable industry capacity at home. A key component of the Programme is that it gives companies a Government of Canada “Verification Certificate" enabling innovative environmental technologies to access markets more effectively.

By providing a level playing field with similar initiatives in other countries, the Programme ensures that Canadian companies remain competitive. In Canada, as in the United States, verification is seen as an important tool for accelerating the application of innovative technologies and creating new business opportunities and jobs, while also protecting the environment.

5. Canadian Environmental Technology Advancement Centres

In 1993, in partnership with provincial governments, environmental industry associations, and the private sector, the federal government supported the development of three Canadian Environmental Technology Advancement Centres (CETACs) to help meet the needs of Canada’s growing environmental industry.

Located in Alberta, Ontario and Quebec, the CETACs are private sector, not-for-profit corporations, operating at arm’s length from government. The federal government committed $12 million dollars start-up support to the centres over four years ending in September 1997 and has recently renewed support to the centres by providing $1.5 million per year.

Each centre’s goal is to assist small and medium sized enterprises commercialise environmental technologies by providing comprehensive technical services, access to investment capital, business counselling, and regulatory and market analysis. In addition, all of the CETACs have been developing their own programmes and initiatives to support and lead environmental industries in their respective regions.

Collectively, the centres have demonstrated, and continue to demonstrate, their ability to successfully fulfil their mandate and service Canada’s SMEs. Furthermore, they constitute a national network for the delivery of public policy and are in a strategic position to deliver government initiatives targeted at the environmental industry (Note - the CETACs have been selected to deliver the ETV programme mentioned above).

C. Regulatory instruments for stimulating development of ESTs

The relationship between environmental regulation, industrial competitiveness and innovation is complex. Michael Porter, the Harvard expert on competitiveness, has argued that while there may be an initial increase in costs, environmental regulations can pressure firms to upgrade their competitive advantage by improving product and process quality.[9] This can create demand for environmental products and services and encourage innovation.

Studies have borne out Porter's contention, but only when there is a large domestic market, a predictable regulatory approach, regulators who understand both markets and industry and a supportive institutional framework. Historically, this scenario has not existed in Canada. For example, in the Canadian pulp and paper industry, environmental regulations did not stimulate innovation in the industry.[10] In part, this was due to weak enforcement. When upgrades were made, over time, it was for a variety of reasons, only one of which was Canadian government regulation.

Today, there is an understanding of the direct link between an effective environmental policy framework and the development of ESTs. "Canadian firms will be in the strongest position in those areas where future regulatory requirements in Canada lead those of other countries."[11] Canadian governments have accepted that the environmental industry (and he development of ESTs) can best be advanced by taking measures to solve environmental problems while also adopting policies that support the development of a strong and competitive industry.

The primary vehicle for carrying out the federal role in environmental regulation is the Canadian Environmental Protection Act (CEPA). Proclaimed in 1988, CEPA's mandate is the identification and control of toxic substances. Its approach to toxics covers emissions on land, air and water and regulates their use from manufacture through to final disposal, to the extent that these aspects of regulation do not fall under provincial responsibility. CEPA's focus is preventative, using regulations and enforcement together with a package of non-regulatory approaches, such as guidelines, codes of practices, incentives and the development and transfer of pollution measurement and control technologies.

In practice, provincial regulations have tended to follow the federal lead. Where provincial regulations are "equivalent" or stronger, these apply in place of CEPA regulations. Where CEPA applies, federal-provincial administrative agreements frequently delegate the responsibility for applying the regulations to provincial authorities.

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[9] M. Porter (April 1991). "America's Green Strategy," Scientific American", p.168, quoted in R.Doering et al. (1992), "*Environmental Regulations and the Pulp and Paper Industry: An examination of the Porter Strategy*", Ottawa, National Roundtable on the Environment and Economy, p.1.

[10] Doering et al., p. 17.

[11] Ernst and Young (1993), "Human Resources in the Environment Industry", Ottawa, *Employment and Immigration Canada*, p.68.

The resultant "system" has been characterized in numerous studies as fragmented and inconsistent, in both formulation and application. Overlapping, duplicating and conflicting rules have created a jurisdictional maze that has steadily increased as environmental concerns and regulations have proliferated. In addition to the confusion and administrative difficulties, jurisdictions can "pass the buck" when problems arise, and the fragmented system strengthens opposition to regulation of any kind.

Enforcement, the critical component of any regulatory system has been weak and sporadic. Rather than providing the final word, regulations have often been the starting point for negotiation between the regulator and the regulated. Follow-up through prosecutions and fines has been relatively rare.[12] Therefore, regulated industries have been reluctant to make large investments in environmental products and services.

Even within the context, however, the federal government can point to some important successes for CEPA, such as strengthened health protection and disease prevention through reduced exposure to toxins, improved connections between science and decision making, enhanced dialogue with the public and industry and better intergovernmental coordination. With respect to the development of ESTs, it could be argued that CEPA has encouraged the implementation of end-of-pipe environmental technologies.

Critics of CEPA note a failure to back up these successes with effective enforcement of regulations. The Canadian Institute for Environmental Law and Policy points to the low level of prosecutions under CEPA and the Fisheries Act (averaging 10 per year) and questions the ability of the federal government to preserve the regulatory legitimacy it will require to carry out its pollution prevention and sustainable development goals. An independent review by Resources Future International, commissioned by Environment Canada, found that while CEPA helps the federal government assert national leadership in environmental protection, implementation has been hampered by a patch work of regulations and enforcement schemes.[13] CEPA is currently being updated in order to address these weaknesses.

The command and control approached of some regulations, such as Ontario's now defunct MISA Programme, have proved to be complicated and expensive for both government and industry. Requirements for the use of the Best Available Technology (BAT) or Best Available Technology Economically Achievable (BATEA) require the regulator to possess information about the abatement costs of each firm, which leads to lengthy negotiations. For example, the process followed by the Ontario Ministry of Environment and Energy consists of the following steps:

[12] Doering et al., p. 4.

[13] Environment Canada (1996), "Technology, Competitiveness and Canada's Environmental Industry: An Outlook into the Future Development of the Industry", Ottawa, *Environment Canada*, p. 5-6.

> "Consultation with each industrial sector through joint technical committees; review of available data from various studies, monitoring programmes and similar regulations in other jurisdictions; completion and review of economic studies, including the recommendations of the MISA Advisory Committee; and public review of regulations and supporting studies. Only through this rigorous process will the ministry identify and set BATEA discharge limits."[14]

In addition to the complexity and expense of this approach, it can actively encourage endless bargaining and discourage innovation. In the end, it is simpler for the polluter to adopt the technology suggested by the regulator than to search for the best and least expensive alternative. Furthermore, the tendency to focus on emission controls, which set out a fixed limit (e.g., so many parts per thousand), does not take into account the carrying capacity of the receiving body (lake, stream, valley), the impact of increased plant capacity or the construction of additional facilities.

There is no question that progress has been made under this system, but it has hardly been as environmentally effective or as cost-effective as it might have been. Worsening environmental conditions point in the direction of more stringent requirements (which is supported by the form of the revised CEPA Bill that was introduced in the House of Commons in late 1996, and is now be redrafted). The test will be to find ways that are cost-effective, provide a competitive advantage for the environmental sector and avoid adverse competitive impacts on Canadian industry.

The downsizing of government and the concern about government debt mean here will be fewer resources available for many traditional government activities. There is a danger that government will be unwilling or unable to carry out its legitimate regulatory role. Indeed some observers have expressed the concern that programme reviews, harmonization and regulatory flexibility will eventually result in an abandonment of public environmental responsibility.

In addition to establishing regulatory requirements, Canadian governments are also pursuing a number of other policy options including economic instruments, voluntary and hybrid agreements, pollution prevention strategies and green procurement. Each of these policy options is discussed below.

1. Economic instruments

"The purpose of integrating costs into pricing is not to provide a toll road for polluters, but a pathway to innovation. The incentive to lower costs is the same one that currently operates in all businesses, but in this case the producer's most efficient means to lower them is not externalizing these costs onto society, but implementing better design."[15]

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[14] B. Laplante (1990), "Environmental Regulation: Performance of Design Standards", in G. B. Doern, ed.,*Getting it Green, Case Studies in Environmental Regulation,* Toronto: CD Howe Institute, p. 69.

[15] P. Hawken (1993*).*" The Ecology of Commerce*"*, New York: Harper Business, p. 83.

To date, Canada has had very little experience in using economic instruments to achieve environmental goals. In fact, some existing economic incentives, such as those to support the growth of the petroleum sector or the use of pesticides, are disincentives for more environmentally sound practices, such as energy conservation or the reduction or elimination of pesticide use. Even one of the few environmental incentives, the Accelerated Capital Cost Allowance (ACCA), introduced in 1983 to cover air and water pollution control equipment, has recently been criticized for encouraging "end-of-pipe" investments rather than pollution prevention."

The use of economic instruments can have a strong impact. Gasoline and carbon taxes in Europe have had a profound influence on the efficiency of cars. Increased dumping fees at landfill sites have spawned waste reduction measures and a wide range of recycling initiatives. Effluent fees stimulate input reductions through substitution or internal recycling. Emissions trading systems can encourage the adoption of technologies that reduce emissions to a minimum.

2. Voluntary and hybrid Agreements

Voluntary action is particularly important in Canada, where cooperation and multi-stakeholder consultation are preferred to a command and control approach. Because such agreements lack both economic incentives and legally enforced regulations to produce action, there remains only community spirit, peer and/or public pressure or the recognition that cost savings could be achieved. Since most arrangements are very new, their effectiveness in reaching environmental goals has yet to be established.

The former ARET (Accelerated Reduction/Elimination of Toxics) Programme is a good example of this approach. In the spring of 1994, the ARET Committee challenged Canadian companies and government facilities to meet government targets for the elimination of certain toxic substances. After less than a year, 138 companies and seven government departments reported emissions reductions of 10,300 tones from 1988 levels and had committed themselves to a reduction of an additional 8,500 tones by the year 2000. The ARET process allowed emitters to participate with maximum flexibility. It should be added, however, that the ARET Committee originally included environmental and labour groups, but they withdrew when consensus could not be reached on elimination rather than reduction of toxic substances.

ARET was one of several government-corporate agreements that involved voluntary action. In Ontario, there are sector-focused programmes involving the automotive, metal-finishing, dry cleaning and publishing industries. For example, the Automotive Manufacturing Pollution Prevention Project is a cooperative effort of the Canadian Motor Vehicle Manufacturers' Association (MVMA), Environment Canada and the Ontario Ministry of Environment and Energy. Begun with three large car makers, Chrysler, Ford and General Motors, a goal was established to "produce a verifiable reduction of persistent toxic substances as well as other environmental contaminants of concern used, generated or released by the participant member companies."[16] As a result, an initial 65 substances were identified. Thecompanies are now working with suppliers on the early reduction of 29 of the 65 targeted substances. A similar process is also under way by the Automotive Parts Manufacturers' Association with a goal of reduction and/or elimination of identified substances.

Other important initiatives to promote voluntary action programmes include the chemical industry's "Responsible Care" initiative, the Canadian Manufacturing Association's (CMA) Manufacturing Environmental Performance programme, and the federal government's Volunteer Challenge and Registry Programme to encourage firms to reduce greenhouse gases.

The National Pollutant Release Inventory (NPRI) is a hybrid programme, in that firms are required to report to Environment Canada on their emissions of 178 specified substances "of concern", but are not required to do anything about them. The system, which is modelled on the U.S. Toxics Release Inventory (TRI) of 331 substances, does not police or control the amounts, but will make an annual report of releases, by company, available to the general public. Public accessibility is key to this programme. It is believed that inaccuracies will be reported by employees, communities, competitors or environmental groups. It is also expected that concerns over negative public reaction to high emissions will encourage reductions.

3. Pollution prevention

The pervasiveness of environmental problems in the 1980s served to highlight the limited success of pollution control efforts and led to calls in the 1990s for more effective ways to preserve the environment. With the wide acceptance of the concept of sustainable development, emphasis has shifted to pollution prevention. It thus becomes crucial that the environmental industry develop the technological capacity to assist its clients in finding effective and efficient preventative solutions. It is argued that the new technology curve or frontier will be occupied primarily by pollution prevention technology - that is, new products, inputs or production processes. The use of initiatives to bring firms into environmental compliance using new technology is termed innovation driven pollution prevention. The Canadian government has tried to promote innovation driven pollution prevention by adopting a National Pollution Prevention Strategy, and by making pollution prevention the cornerstone of the new CEPA.

[16] Projet de societé , *Planning for a Sustainable Future, Canadian Choices for Transitions to Sustainability*, p. 4.

4. Greening government

Reforms to the Environmental Assessment and Review Process, announced in1990, included the creation of the Canadian Environmental Assessment Act, which was intended to ensure that environmental considerations were included in federal government planning and decision-making processes. The Act came into effect in October 1994 and applies to projects for which the federal government holds decision-making authority. The Act is administered by the Environmental Assessment Agency, which operates at arm's length from the government.

As a further measure to ensure that the government does act on its commitment to sustainable development, a Commissioner of the Environment and Sustainable Development has been appointed under the Auditor General Act. The Commissioner monitors and reports to Parliament on the government's performance in integrating environmental concerns into its decision making. In his first report to Parliament in March 1997, the Commissioner highlighted key weaknesses in the federal government’s management of sustainable development issues including: the gap between commitments and concrete action; a lack of coordination among departments and across jurisdictions; and inadequate review of performance and provision of information to Parliament.

The federal government purchases close to $9 billion worth of consumer, commercial and industrial goods and services annually. It also owns or manages 41 per cent of Canada's land mass. It is Canada's largest commercial landlord and owns or leases 25 million square meters of office space in more than 50,000 buildings and facilities. Its commitment to "green" procurement and the "green" enhancement of the Federal Building Initiative announced in the Canadian Environmental Industry Strategy are expected to open up new markets for environmental goods and services.

IV. MODALITIES FOR THE TRANSFER OF PUBLICLY FUNDED ESTs

The number and variety of vehicles that the federal government uses to promote technology transfer are an indicator of the high priority that Canada places on technology transfer. Technology transfer has a great deal of appeal because it fulfils a number of public policy objectives. First and foremost, technology transfer enables Canada to meet a number of its international environmental commitments. As a member of the OECD and the United Nations, Canada has taken on a leadership role in developing the means for addressing global environmental imperatives. In addition to addressing common environmental interests, technology transfer is an effective means for fulfilling trade, economic development and job creation objectives. By showcasing Canadian technologies and expertise internationally the government helps to create international demand for Canadian private sector products and services.

A. Bilateral international agreements

International agreements constitute the primary means by which Canada promotes the transfer of technology. Canada has signed a host of Memoranda of Understanding on Environment cooperation with other countries. While these agreements are general in nature they facilitate specific projects, some of which involve technology transfer.

One such arrangement is the letter of intent with respect to the joint project “Watershed Management 2000” - Improvement of Water Resources Management in the State of Sao Paulo in Brazil. This project represents a three year partnership between Environment Canada and several public sector agencies in the State of Sao Paulo, Brazil, as well as a CDN $3 million contribution from the Canadian International Development Agency. The project will address two main priorities: the development and application of an integrated computer-based decision support system to guide the management of the watershed of the Piricicaba River, which is the main source of potable water for the city of Sao Paulo; and to improve sewage and sludge management in the Metropolitan Sao Paulo Region.

The project started with a first work session held in Brazil during the last two weeks of March 1997. Some thirty joint activities were expected to take place in Brazil and Canada during the 1997/98 fiscal year in support of watershed priorities.

B. Transfer of ESTs under international multilateral environmental agreements

While Canada conducts a substantial proportion of its technology transfer activity through bilateral international agreements, Canada views international multilateral environmental agreements as an effective tool for facilitating technology transfer to developing countries. In particular, Canada views the Interim Multilateral Fund created at the Second Meeting of the Parties of the Montreal Protocol, as a highly successful means of promoting technology transfer. In 1987, Canada was instrumental in the creation of the Montreal Protocol on Substances that Deplete the Ozone Layer, an international framework to curtail the depletion of the ozone.

Over the past nine years, Canada has reduced it use of ozone depleting substances much faster than required under the Montreal Protocol or its own regulations. In no small part, this success can be attributed to Canadian business initiatives in setting a new standard for industry and regulation around the world. Canadian companies have also been able to benefit from the bilateral arrangement available under the Multilateral Fund.

Under the rules of the Multilateral Fund, developed countries may reserve 20 per cent of their contribution to the Fund for bilateral projects with Article 5 countries who have completed a country programme. Through its bilateral projects, Canada has been successful in providing developing countries with the technology and expertise they need to comply with the Protocol since the creation of the Multilateral Fund, Canada has participated in bilateral projects with several Article 5 countries including: Brazil, Chile, China, India and Venezuela. Environment Canada, as lead agency, is responsible for negotiating, approving and implementing these bilateral projects. These projects are considered highly desirable as they:

- Promote Canadian expertise in alternative processes, substances and technologies;
- Assist Article 5 countries in meeting their phase-out schedules and consequently their commitments to the Protocol;
- Meet Environment Canada's environmental objective of eliminating ozone depleting substances;
- Provide international leadership visibility for Canada in resolving the problem of ozone-layer depletion;
- Encourage joint-venturing by the private sector; and
- Complement Canada's foreign policy objectives.

More than US $3 million is available for Canadian bilateral projects for the 1997-1999 period.

Examples of bilateral projects undertaken to date include:

- A project in support of Brazilian efforts to eliminate the need to import halons. This two year project (US$499,360) involves the transfer of halon recycling and reclamation equipment and laboratory analysis equipment. In addition, the project involves the transfer of expertise, including an engineering training programme, technology transfer workshops and follow-up monitoring. The project also works toward modifying technical standards and regulations in Brazil to discourage the use of halon fire extinguishants and to encourage the use of non-ozone depleting substance fire protection alternatives.

- The transfer of a methyl bromide recapture and recycling technology to Chile (US $317,000). The technology is designed to work in conjunction with fumigation chambers for the recapture of methyl bromide used in commodity fumigation. The first unit has been installed in a fumigation chamber used to treat fruit destined for export. This project was the first of its kind in a developing country as developing countries do not currently recapture, recycle or reclaim methyl bromide.

- A project in Venezuela (US$495,285), forming part of a larger project under the UNDP programme for the “Implementation of a Programme for the Recovery and Reclamation of Refrigerants”. The Canada-Venezuela component will help to support Venezuela’s efforts to reduce its emissions of ozone-depleting substances by providing a domestic refrigerant reclamation operation and outlet for recovered refrigerants. The establishment of a reclamation centre will include the following: provision for the supply of refrigerant reclamation equipment for CFCs, HCFCs and HFG refrigerants; provision for the supply of analytical laboratory equipment for the testing and recertification of reprocess material to the virgin standard of purity (ARI-700 or ISO equivalent); full operational training of local equipment operators; laboratory equipment training and operator testing with the option of certification; and full technical assistance for 18 months.

Another multilateral agreement through which Canada is transferring technology is the Canada-Southern Cone Environmental Technology Initiative (CANSCET), a programme under the Canadian International Development Agency (CIDA) Technology Transfer Fund for the Southern Cone. The goal of the CANSCET initiative is to support the transfer of technology know-how in areas which address the environmental priorities of the Southern Cone countries of Chile, Argentina, and Uruguay, and at the same time developing long-term sustainable institutional alliances between Canada and these Southern Cone countries. Waste and wastewater management have been identified as priority subsectors to be addressed under CANSCET.

Canadian participation in CANSCET reflects a 'Team Canada" partnership, involving Environment Canada, Industry Canada, and the Regional Office for Latin America and the Caribbean Office of the International Development Research Centre (IDRC). CANSCET is a responsive fund and as such, projects to be supported under the Initiative will be generated in direct partnership with the federal environmental agencies Chile, Argentina, and Uruguay.

Total resources provided to CANSCET by CIDA and the Canadian partners of CANSCET (Environment Canada, Industry Canada, and IDRC) were expected to amount to US$650,000 over 1997 and 1998. Additional financial and in-kind leveraging will be sought on a project-by-project basis from other public and private sector partners participating in each project, resulting in a programme with resources expected to total over US$l million.

As a programme of technology transfer and cooperation, CANSCET will support existing and developing cooperation mechanisms established under the Memorandum of Environmental Cooperation signed between Canada and Chile and the Memoranda of Environmental Cooperation signed between Canada and Argentina and between Canada and Uruguay. The priorities established under these Memoranda will provide an important focus for the development of projects which will be supported under CANSCET.

C. Departmental initiatives

In addition to bilateral and multilateral agreements, government departments also develop international programmes that address departmental mandates, but may not necessarily fall under the auspices of existing international agreements.

Environment Canada's International Environmental Management Initiative (IEMI) is one of the programmes of the Canadian Environmental Industry Strategy. The objective of the IEMI is to transfer to developing countries and countries with economies in transition, Canadian government and private sector expertise relating to regulations, policies, and technical programmes. IEMI strives to enhance environmental management capacity of developing countries, while at the same time promoting Canada's environmental industry by facilitating the transfer of expertise on environmental management infrastructure to support the export of Canadian environmental technologies and services.

During its inaugural year (1995/96), IEMI provided a total of US$405,000 of support, or one-seventh of the total US$3 million spent on the 16 projects carried out in Latin and South America, Eastern Europe, China and Asia. While the results achieved by the IEMI to date are somewhat preliminary, early evidence suggests that progress has been made in increasing access to foreign markets, sharing expertise, and boosting Canada's export of environmental products and services.

V. TWO CASE STUDIES

1. Ballard Power Systems' Proton Exchange Membrane Fuel Cell

Ballard Power Systems Inc. of Burnaby, British Columbia, was founded in 1979 to develop and manufacture advanced lithium batteries for specialty applications. In 1983, the management of the company, in investigating environmentally clean energy systems, identified Proton Exchange Membrane (PEM) fuel cells as an undeveloped technology with significant commercial potential.

The Ballard Fuel Cell is a proprietary zero-emission engine that converts natural gas or methanol fuel into electricity without combustion. Ballard Fuel Systems is the world leader in the development of PEM Fuel Cell power systems. Their fuel cells are currently in use by several international companies including Daimler-Benz, General Motors, Nissan, Honda, Volvo/Volkswagen and Hitachi. Their dominant position is reflected by the 191 granted or pending patents covering fuel cell technology.

Ballard began development of the PEM Fuel Cell through contracts with the Canadian government. The company considers the early federal government support it received to have been crucial in attracting initial investors.

The government's participation in the development of the Ballard Fuel Cell is summarized below:

- CANMET of Natural Resources Canada began working with Ballard on the development of the proton exchange membrane in 1985. CANMET provided over $2 million and technical support over a ten year period.

- In 1991, Ballard entered into a contract with CANMET, the Government of British Columbia and B. C. Transit to design, build and test an early 32 ft. prototype fuel cell powered transit bus. The total contract amount was $6.3 million, with the federal government providing $1 million.

- Ballard received another $6 million from BC Transit, the Government of British Columbia and CANMET in 1994 to design, build and test a 40 ft. commercial prototype zero emission transit bus. The prototype was completed in 1995, one year ahead of schedule.

- In 1994, Ballard was awarded a $3.7million contract from the Canadian Department of National Defence for the development of fuel cells for powering submarines in the Canadian Navy.

- In 1996, Ballard received a $30 million repayable contribution from Technology Partnerships Canada for stationary fuel cell development. The $30 million constituted approximately 32 per cent of Ballard's three year, $94 million programme to commercialize fuel stationary power plants. The contribution will be repaid by way of a royalty based on future commercial sales of the stationary power plants and 150,000 common share purchase warrants that Ballard issue.

- Also in 1996, Ballard signed a memorandum of understanding with the Province of British Columbia and B. C. Transit for the demonstration of three Ballard Fuel Cell transit buses. The $8.6 million, two year programme included $8.37 million for Ballard for the three fuel cell buses, spares, fuel, programme support and the continued testing of Ballard's commercial prototype fuel cell transit bus. Under the terms of the memorandum of understanding Ballard issued the Province of British Columbia 180,000 common share purchase warrants.

- In April 1997, the Canadian Government announced that it would collaborate with the United States government in the Unite States Partnership for a New Generation of Vehicles programme and the Ford Motor Company to develop a fuel cell engine. This fuel cell engine will be delivered to the Ford Motor Company for integration into Ford's P2000 research vehicle which is being developed under the PNGV programme. The total Government of Canada contribution to Ballard will be approximately $8 million, representing 80 per cent of the development costs.

2. Environment Canada's Microwave Assisted Process (MAP)

Environment Canada's patented Microwave Assisted Process had its origins in research conducted by Agriculture Canada during the late 1980s at its facility in Hyacinthe, Quebec. At the time, Agriculture Canada was investigating new techniques and technologies that might be useful in the extraction of flavours, colouring and fragrance in food processing research. The MAP technology was developed as a result of this research. It was felt that MAP, which involves extracting soluble products from a wide range of materials using a microwave applicator as an energy source, might have significant commercial applications because it offered numerous advantages over conventional extraction methods. It reduces production time, energy, solvent consumption and waste production, while increasing extraction yields and extract purity.

In early 1990, the inventor of the MAP technology, Dr. Jocelyn Pare, recognised the potential for applying MAP in the environmental area (e.g., extraction of contaminants from soil, water and air) and moved to the Emergency Sciences Division of the Environmental Technology Centre at Environment Canada. In the process, patents for the MAP technology were transferred to Environment Canada.

At that time, no specific environmental applications had been developed. Dr. Pare pursued his research into MAP applications on a part-time basis, with an annual budget of approximately $100,000. By 1994, demand for MAP applications was such that it warranted the creation of a MAP Division within ETC to accelerate the development of environmental applications. The MAP Division employs 10 people and has an annual budget of approximately $300,000 with an additional $900,000 each year generated through partnerships and cost-sharing arrangements with the private sector.

MAP was transferred to the private sector in April 1993 when ETC entered into a licensing agreement with Hewlett Packard (HP), which gained the rights in various fields of activities that require analytical capability such as chemistry, environmental sciences, food science, forensic science and cosmetics. Transfer of the technology was precipitated by a number of meetings in early 1992 between Dr. Pare and HP representatives, in which it was demonstrated that an early prototype MAP application developed by ETC would render a competing technology, developed by HP, obsolete within one year. As part of the terms of the licensing agreement, ETC received approximately $500,000 in initial financing, in-kind contributions in the way of prototypes developed by HP, and royalties on future sales (expected to commence in late 1998).

At present, there are six licencees of MAP applications including HP (three on an analytical scale and three on a pilot scale), which have resulted in diffusion of MAP technology within Canada, as well as transfer to the United States, France and China. All revenues generated through licensing agreements are reinvested in the MAP Division. As a result the Division is self-sufficient and requires no additional funding.

VI. MAIN FINDINGS OF STUDY

Canada has been at the forefront of efforts to facilitate the transition towards sustainable development, and a significant component of this effort has been its active programme of research, development and transfer of ESTs. Canada can be proud of the leadership it has shown both at home and abroad, while at the same time recognizing that more, and better, work still needs to be done.

Industrial R&D expenditures in Canada have risen in the past 20 years, yet they are low relative to other OECD countries. Total expenditures for R&D in Canada for 1997 were slightly less that $13.3 billion. Of this amount, approximately 15 per cent were to be funded by different levels of Canadian government.

R&D expenditures for pollution abatement and control by Canadian industry represent approximately two per cent of total R&D expenditures. Even though PAC R&D expenditures were a small proportion of total R&D expenditures reported by Canadian industry as a whole, they accounted for a large proportion of total R&D for firms that did report PAC R&D expenditures.

Government funding for research and technology development has been critical to the growth and survival of many small technology-driven environmental companies. Canada's historically low level of R&D, particularly in the private sector, and its small domestic market have been important factors in determining the focus of government support. Government support promotes the development, growth and market access of Canadian environmental technologies and services. These programmes tend to focus on applied research, technology development and export development. They do not, however, reflect a coordinated approach. Programmes such as the Canadian Environmental Industry Strategy, however, suggests the emergence of greater coordination.

Both the federal and provincial governments continue exploring new ways to support S&T and the EIS in an era of diminishing budgets and increasing international competitiveness.

In this context, the rationale for public funding of research and development in Canada has changed dramatically over the last 20 years. The need for greater direct environmental, economic and social benefits from government expenditures in science and technology combined with severe and continued fiscal constraint have forced a new discipline that focuses on the impact of the federal government's technology investment. As a result, cooperative arrangements with provinces, academic institutions and, more recently industry, are increasingly important as the federal government focus has shifted from science and research to R&D for economic development.

Over the past several years, a number of federal (and more recently provincial) initiatives have been implemented to encourage R&D and the diffusion of resulting technologies as means of developing Canada's environmental industry. Currently there is a widespread understanding of the direct link between an effective environmental policy framework and the development of ESTs. Canadian governments have accepted that the environmental industry can best be advanced by taking measures to solve environmental problems while also adopting policies that support the development of a strong, competitive industry.

Ironically, the Canadian regulatory system has been characterized in numerous studies as fragmented and inconsistent and, it could be argued, discourages innovation and the development of ESTs. Overlapping, duplicating and conflicting rules have created a jurisdictional gridlock that has steadily increased as environmental concerns and regulations have proliferated. Enforcement, the critical component of any regulatory system has been weak and sporadic. Rather than providing the final word, regulations have often been the starting point for negotiation between the regulator and the regulated. Follow-up through prosecutions and fines has also been relatively rare. Therefore, regulated industries have been reluctant to make large investments in environmental products and services and the process redesign necessary to move towards pollution prevention.

An independent review commissioned by Environment Canada, found that while CEPA helps the federal government assert national leadership in environmental protection, implementation has been hampered by a patchwork of regulations and enforcement schemes. There is no question that some early progress was made under this system (CEPA is generally credited with helping to proliferate traditional end-of-pipe environmental technologies) but it has hardly been as environmentally effective or as cost-effective as it might have been. Worsening environmental conditions point in the direction of more stringent regulations (which is consistent with the intentions of the new CEPA Bill).

The downsizing of government and concerns about government debt mean there will be fewer resources available for many traditional government activities. There is a danger that governments will be unwilling or unable to carry out their legitimate regulatory roles. Consequently, the are examining a number of policy alternatives such as economic instruments, hybrid and voluntary agreements, promoting pollution prevention and a move towards green government as means promote the development of ESTs and meeting environmental commitments.

In recent years, technology transfer has been given high priority in Canada. Technology transfer has a great deal of appeal because it fulfils a number of public policy objectives. First and foremost, technology transfer enables Canada to meet a number of its international environmental commitments. As a member of the OECD and the United Nations, Canada has taken on a leadership role in developing the means for addressing global environmental imperatives. In addition to addressing common environmental interests, Canada views technology transfer is an effective means for fulfilling trade, economic development and job creation objectives.

However, the lack of universally accepted and enforced international laws pertaining to intellectual property has been found to limit the effectiveness of technology transfer initiatives. Countries that do not adhere to the Paris Convention for the Protection of Intellectual Property are viewed as potential risks and are often discriminated against. When these countries do become involved in technology transfer initiatives, the projects tend to involve out of date technologies which limit the environmental benefits.

International agreements constitute the primary means by which Canada promotes the transfer of technology. Within this context, Canada has found international multilateral environmental agreements to be highly effective tools for facilitating technology transfer to developing countries. In particular, Canada encourages the uses of mechanisms like the Interim Multilateral Fund created at the Second Meeting of the Parties of the Montreal Protocol. Under the auspices of the Multilateral Fund, Canada has participated in bilateral projects with a number of Article 5 countries including: Brazil, Chile, China, India and Venezuela.

From the Canadian perspective, by creating mechanisms under the Conventions on Global Climate Change and Biodiversity, similar to the Interim Multilateral Fund, the international community could facilitate greater global activity under these Multilateral Agreements.

Canada has taken some important steps towards ensuring that its publicly funded and publicly owned ESTs contribute substantially towards quality of life and wealth creation, and it has done so with some success. Several government support programmes point to the emergence of a coordinated and comprehensive programme for the development and transfer of ESTs that may serve as models for other countries to emulate. However, a number of factors, both domestic and international in nature, continue to hamper efforts in this regard.

Very recently environmental concerns have taken front stage again in the Canada media. A significant causal factor is the international spotlight that has emerged from the Kyoto conference on global climate change. It is expected that this renewed priority will have a number of positive effects, including giving added impetus to government leadership in facilitating the development and transfer of ESTs.

ANNEX I

INTELLECTUAL PROPERTY

1. Definitions used in Canada

In Canada, Intellectual Property is defined as information which is useful or of value and is transferable. It includes:

(a) Inventions, which are protected by patent or secrecy. Inventions are defined as "any new and useful art, process, machine, manufacture or composition of matter, or any new and useful improvement in any art, process, machine, manufacture or composition of matter."[17] Patentable inventions are those that in addition to meeting the above criteria also meet the criteria of ingenuity or non-obviousness;
(b) Software and other texts which are protected by copyright;
(c) Know-how, which is protected through secrecy with the support of the Common Law on confidential information. Know-how can be defined as any useful technical or scientific information that is not protected by statutes and could be commercially exploited. Examples include production techniques and chemical formulae;
(d) Trademarks, which are marks used to distinguish wares or services manufactured or sold, leased or hired or performed;
(e) Industrial designs, which cover the appearance of industrially produced articles;
(f) Integrated circuit topographies which refer to the three dimensional hill & valley configuration of the electronic circuits embodied in integrated circuit products or layout designs.

2. Ownership of Intellectual Property

As stated in the Public Servants Inventions Act, the following inventions and all rights associated with them in Canada or elsewhere, are vested in the Crown, namely:

(a) an invention made by a public servant

  (i) while acting within the scope of his/her duties or employment, or
  (ii) with facilities, equipment or financial aid provided by or on behalf of Her Majesty;

(b) an invention made by a public servant that resulted from or is directly connected with his/her duties or employment.

Where an invention is made jointly by a public servant and another person outside the public service, the ownership provisions stated above apply to the interest of the public servant in the invention.

[17] *Patent Act, R. S., c. p. 4, s. 2.*

As of 18 December, 1991, ownership of intellectual property arising under government contracts involving research and development is initially presumed to vest with the contractor, unless it is determined by the responsibility centre that Crown ownership is justifiable.[18]

The above Treasury Board Policy is intended to apply to contracts involving R&D that results in outputs of a technological nature which may be protected under statutes such as the Patent Act and the Copyright Act.

Prior to awarding a contract to which this Treasury Board Policy may apply, the responsibility centre and the contractor must clearly determine and agree to ownership rights to be provided in that contract. One or more of the following factors can be used to support a finding that the presumption of contractor ownership is not supportable:

(a) title to background technology vests with the Crown and the contractor is simply adding to the technology package by providing a service;
(b) prior obligations to a third party or parties (such as a research partner, research consortium) would preclude title vesting with the contractor; the contractor has no intention or capability or pursuing commercialization in a timely manner in Canada;
(c) national security;
(d) the main purpose of the work is to generate knowledge and regulatory information for public dissemination; and
(e) mutual agreement.

Ownership of copyrighted intellectual property which is not technological in nature must be referred to chiefs/heads of publication groups within the respective government departments.

3. Patents

A patent is a grant by the government that confers, for a limited time, rights on its owner to preclude others from making, using or exploiting the patented invention in return for public disclosure of the invention. In Canada, patents will last up to 20 years from the date of filing. Patents upon which maintenance fees are not paid can lapse before their full term expires. Disclosure of an invention prior to filing of a patent application will, in most foreign jurisdictions, make it impossible to obtain a valid patent.

[18] Treasury Board Policy Decision 817067*: Policy Ownership of Intellectual Property Arising Under Government Contracts Involving R&D.*

4. Software and Other Texts

All written material and software produced under the direction of a federal government department is vested in the Crown. In Canada, copyright protection is automatically acquired by the Crown upon creation of the written material or software, with the application of the proper marking requirement or copyright notice; therefore, registration is not required. Registration may, however, be required in other jurisdictions such as the United States. Copyright generally exists for 50 years from the date of first publication of the work.

5. Know-how

As previously mentioned, know-how is essentially protected through secrecy. Specifically, such information cannot be disclosed to an outside party until after a Confidential Disclosure Agreement has been signed. Improper disclosure of know-how information may prevent the licensing of that information.

6. Licences

A licensing agreement is a contract in which rights to use protected technology and know-how are granted to another party. Licensing agreements are negotiated on a case by case basis and generally address:

(a) The type of grant and the specific applications of products and processes relating to the licenced intellectual property
(b) The licensing fees and royalties payable
(c) Protection of the intellectual property and its improvements
(d) Performance guarantees which provide for termination of the licensing agreement or Cancellation of any degree of exclusivity where the licence is not demonstrating effective use of the rights granted
(e) Infringement litigation and indemnification
(f) Duration, termination, general terms and conditions

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PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES (ESTs)
THE CASE OF THE UNITED STATES OF AMERICA

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I. INTRODUCTION

Soon after President William Clinton and Vice-President Albert Gore took office in January 1993, it became evident that one of the new administration's goals was to take a global view of the issues of environment and sustainable development. In June 1993, President Clinton issued Executive Order #12852 under the Federal Advisory Committee Act, creating the President's Council on Sustainable Development (Council). Initially charged with creating a "national action strategy on sustainable development" (Building on Consensus, 1997:3) and promoting public awareness of environmental protection, the Council, by 1996, began to concentrate on linking local organizations and resources for environmental protection, while encouraging new environmental research and development.

However, the Council was never intended to fund its own programmes or support those of others. With its limited funds, the Council thus became a "networking" and facilitation organization. Even then, by the end of the millennium and Clinton's term in office, most of its environmental initiatives will have been transferred to other agencies, departments, groups or just left to the "market" (private sector) which rarely capitalized on the earlier initiatives unless there was government funding.

The overall thrust of the Clinton administration's environmental agenda was set in the White Conference on Environmental Technology held in 1994. It linked the environmental needs of the planet with the technological advances to a US$300 billion global business (Conference, 1994:9). Noting that there were obstacles, including "cost equations", "reinventing government", "creating trust between industry and government", Vice-President Gore cited several initiatives that the Administration was undertaking. Among these initiatives, he reported on "Technology for a Sustainable Future: A Framework for Action" (1993), which became the impetus for a number of federal government initiatives concerning the environment, including a new cooperative programme between the technological capabilities of the United States Department of Energy and the United States Environmental Protection Agency; a series of studies from the National Science Foundation; and new federal funds for research and development, some of which were focused on the environment.

By that time, the Council issued its first report to the President, "Sustainable America: A new consensus for prosperity, opportunity, and a healthy environment for the future" (March 1996) with a clear message indicating that the Clinton administration had limited federal resources for the environment and must leverage local government and business efforts. Indeed, President Clinton acknowledged such a pragmatic policy in his letter to the Council members dated 25April, 1997: “Your latest report, Building on Consensus, points to many exciting efforts now being undertaken by businesses, state and local governments, and communities throughout America.” (Building, op. cit., 1997:15). In other words, there were no new federal funds, therefore local communities and businesses needed to shoulder the burden of environmental regulation, protection, restoration, and new technological implementation.

Thus, a fundamental tenant, formed in 1993 developed into a national policy by 1996 for the entire two terms of the Clinton administration: to protect the environment also meant stimulating the economy, but with fewer governmental resources (support services, funding, and procurements). The administration strategy in 1993 was to leverage large sums of federal funds into new technologies along with consortia of businesses, universities and research organizations. ESTs were a sub-set of these focused technological areas, known as “dual-use” technologies. These policies were re-enforced and institutionalized by the United States Congress (both the House of Representatives and Senate) in 1994 and in a bipartisan consensus on achieving a balanced national budget by 1998.

Both political parties had formed another major national policy by the millennium: fewer government funds for environmental and energy technological research; but more funds for military and defence operations as needed. Creative researchers and scholars would “tailor” their work to the national interest while trying to pursue environmental and energy technologies. As one government official observed, “climate change is an acceptable bi-partisan avenue for research, whereas today global warming, environmentally sound technologies, or eco-systems are not.” (Atcheson, 1999)

For example in early 1999, a predominant Republican Senate introduced bi-partisan legislation supporting climate change technologies and even creating an Office of Climate Change in the United States Department of Energy. This legislation was bi-partisan and a direct response to the Kyoto accords which had initially been opposed by the same politicians. Hence, researchers in government and the private sectors can seek R&D funds that approximated earlier work, but under a different label.

II. OVERALL IMPORTANCE OF PUBLICLY FUNDED RESEARCH ON ESTs

The following remarks may be helpful in understanding the funding policy of the Federal Government for R&D of ESTs:

1. Despite increasing evidence that publicly funded R&D has had a significant impact on economic growth, federal budgets are being reduced, constrained or micro-managed in these areas. The key concept behind the current public policy toward R&D in the United States is the economic “push-

pull" model. It is based on the perception that R&D must not be pushed out of universities and laboratories into the private sector. The argument is that the private sector (“market”) is the one that must see the demand and need for new technologies first. At that point, then and only then, should public R&D funds be expended on what the private sector feels are the most significant research areas. Consequently, environmental R&D is often viewed as government environmental policy turned into research programmes. The argument is that ESTs need to be funded and commercialized by the private sector, in particular, to meet the environmental policy demands of the Government. Thus, while the Government creates the regulatory demand for ESTs, it places the R&D burden on the private sector or more recently on the state, regional and local authorities. The result is that new innovations and technologies are far too speculative and costly (even though they are far superior and offer “cleaner” solutions to environmental and energy problems) for private firms to implement or introduce into the marketplace.

2. The balanced federal budget in 1998 had been accomplished in part by the cutting of “applied”and“demonstration” oriented projects from federal R&D budgets. The application of ESTs (applied publicly funded R&D) remains a lower priority, much to the detriment for the further diffusion of ESTs through public support from financial, trade, legal and other means. Today in the 21st Century, the use of more politically correct concepts such as “climate change” (Atcheson, 1999) will mitigate this problem to some extent. However, even there, a number of problems arise when trying to get public-funds for ESTs.

One problem has been that no “new” funds are made available. Rather, the focus on climate change and the for example promise by President Clinton in a major policy address on the issue in early 1998, to allocate over US$1 billion to funds new R&D solutions for the climate, was not forthcoming. The promised US$1 billion was already committed to other existing programmes. No new funds were provided. Consequently, private companies and local governments are expected to shoulder much of the financial burden for commercialization and diffusion of publicly funded ESTs.

Another problem concerns new legislation in the 2000 Congress which strongly indicated a bi-partisan support for climate change. A 1999 bill in the United States Senate, for example, would even create an Office of Climate Change in the United States Department of Energy with authority and money for new publicly funded programmes for energy and environmental R&D. Nevertheless, advocates for the legislation fear that there will be no new funds and simply a re-shuffle of the existing resources with perhaps more bureaucracy.

Finally, world events (the conflict in Kosovo for example) are taking large sums from American surplus revenues. Tangential to these activities are related demands from the American armed services for new weapons and machines for future “conflict situations.” In other words, scarce R&D funding is being diverted from environmental and energy research into military and defence programmes.

A. Trends on Publicly funded Research

According to *Science* (March 21, 1997: 1729), the United States funds just under 50 per cent of its total research and development from public funds. While it is not stated, that per centage assumes that the amount does not include defence or military related R&D. In comparison to the United States, according to the Science report, Japan funds about 30 per cent of its R&D using public funds, while Germany and the United Kingdom are about at the same level as the United States in terms of publicly funded R&D compared to their overall R&D spending. With slightly more than half of R&D funding coming from the public sector, France is the leading country in this respect.

The United States has seen its R&D funding as a portion of real GDP decline over the last 50 years despite coordinated efforts by the science community to maintain and restore at least current levels of funding. In 1994 for example, funding for R&D as a percentage of GDP was 2.54 per cent in the United States and the United Kingdom, 2.38 per cent in France and 2.33 per cent in Germany. However, in Japan and in the Republic of Korea, it was 2.9 per cent and 2.6 per cent respectively (ibid., p. 4). The declining trend in R&D funding in the United States will challenge American competitiveness in technology innovation and diffusion.

A more detailed analysis is shown below of the R&D budgets which is linked up with tables 1-6 of Appendix A. The figures and data contained in tables 1-6 come from the following document: International Plans, Policies, & Investments in Science & Technology. US DOC, Office of Technology Policy (April, 1997).

Table 1 shows the total amount of R&D spending on all areas in the United States compared to some other developed countries. It is interesting to note that three areas, namely Energy, Environmental Protection, Earth & Atmospheric and Defence are the most prominent. These areas tend to be the ones that have public funds for ESTs included in their budgets, while others do not. Hence, the total amount does not reflect the total of those areas, but instead of all areas including several not listed. As demonstrated by the figures shown in table 1, the United States lags behind other countries in funds spent R&D targeted toward environmental protection. When compared to energy expenses, the amounts (except for Japan) are similar. However, the United States far exceeds other countries in defence funded R&D projects. While the number is large, there are large sums (several billions of dollars) spent under defence programmes that are targeted for environmental restoration of closed military bases throughout the United States and other environmental R&D costs that are not readily apparent in the total defence funding numbers. Section B gives more details on the United States Department of Defence (DOD) funding areas for ESTs.

Table 2 shows that the United States total funds for R&D in science and engineering was US$28 billion in the financial year 1995, (the last year when actual figures were available). That amount does not account for the administration and operations of federal agencies which, according to *Science and Technology in Congress* (May 1996: 3) amounted to US$102.6 billion in the same financial year. The same journal estimated for the financial year 1997 budget that the request was about US$300 million less or US$102.3 billion.

Table 3 specifies the amount of money in millions US$ spent by the Federal Government for basic research by science and engineering fields for the period 1985-1995. When data contained in table 3 is compared with those contained in table 4 for applied research in the same fields, it appears that basic non-defence research has garnered steadily increasing funds over the above stated ten year period. Thus, federal and non-federal R&D expenditures at academic institutions by field and source of funds, as specified for 1993 (NSF, 1996: 172) in table 5, remained fairly consistent throughout the 1990s.

Finally, table 6 provides details on defence and non-defence budget proposals by the President projected to 2002. It may be noted that, in contrast to other federal funds for R&D, the NSF budget projections from 1996-2002, show only a small reduction (NSF, 1995) since, as in the case of academic institutions, its research is considered “basic”.

In reviewing figures and data contained in tables 1-6, the following general observation can be made: federal funding of ESTs is difficult. We must assume therefore, that life sciences, environmental sciences and certain portions of engineering are seen as part of publicly funded ESTs. However, Berg and Ferrier (1997) also note that “the development of new manufacturing technologies may be pertinent to the environmental, but be reported as manufacturing R&D” (1997: Ch. 3, p.40) and hence not clearly seen as ESTs. Specifically referring to R&D for environmental technologies, Berg and Ferrier (1997) note that “Formal systems for reporting R&D sponsorship are incomplete and even for federally sponsored R&D, reported in ways that make the information hard to interpret” (1997: Ch.3, p.39-40). The reason is that the actual publicly funded R&D work is embedded in the agencies and departments, which do not allow any distinction between R&D funding and administrative costs. Hence, while programme divisions can be identified, there are funds expended for R&D projects whose budgets also reflect administrative costs.

Finally, the most feasible approach seems to be to examine the overall budgets for those federal agencies and departments that fund ESTs. In table 6, the most recent funding patterns are reflected. Noticeably absent is the United States DOC (NIST programmes in ATP and TRP) since much of these funded were scheduled to be reduced in 97 and it is too difficult to isolate the EST projects within each of the budgets. For the financial year 1998, the ATP was authorized around US$200 million. TRP was expected to receive about the same amount. Both programmes are set to disappear within the next two fiscal year budgets, so that there will be no new funding at the turn of the century. Funding ATP and TRP are considered obligations to on-going R&D projects.

The United States Department of Transportation (US DOT) is included in the tables, because its Partnership for a Next Generation Vehicles (PNGV) has been authorized to continue for some years ahead (funding range from US$150 to US$200 million). PNGV was conceived as a multi-agency/department fund for new technologies for vehicles, with a strong focus on environmental and energy R&D. “The goal is to produce prototype vehicles by the year 2004, which can achieve up to 80 miles per gallon, can accelerate from 0 to 60 miles per hour in 12 seconds, can hold six passengers, can meet all safety and emissions requirements, and can be purchased for approximately the same cost as today’s comparably sized cars.” (Lash and Buzzelli, 1997: 11) Most of the federal funding (estimates run from 65 to75 per cent), however, has gone to industry (defined as the American Auto Makers -the “big three” in Detroit) and industrial consortium members, rather than federal R&D laboratories or universities.

The difficulty with PNGV has been that it falls into the general political debate in the United States over transportation and pollution. The American automobile industry has resisted strong environmental legislation for vehicles, including opposing to state and federal zero emission legislation . PNGV members are on the one hand opposed to environmental legislation and on the other competing to develop new ESTs technologies. The industry (including the oil and fossil fuel industries) knows that low and zero emission vehicles are inevitable and the American global competitors know that environmental concerns and constraints are a significant market-driver for developing new ESTs.

Other industrial-based consortia, such as the United States Battery Consortium (USABC), also resist new ESTs because they fear that theymight challenge their industry. Clark and Paulocci (1997) document that problem in an analysis of R&D in fuel cell technologies, where traditional industrial partners in consortia resist new technological advances. The R&D results are that a disproportionate amount of funds are not provided for “ground breaking” ESTs and those R&D funds that are available are directed to maintaining the *status quo* industrial consortia market and technological self-interests.

For example, at a recent meeting (fall 1998) at a major California university, the topic was fuel cells. Most of the researchers attending the day-long meeting were funded by USABC and related battery companies, and concluded that fuel cell research was irrelevant or useless and wasteful or too costly for any new advantages in electricity generation and storage. In fact, most of the attendees made fun of the over US$450 million pledged by the United States automobile makers for new fuel cell research. In short, historically strong vested interests in the lead-acid battery industry influenced researchers who refused to consider more environmentally sound and safe technologies.

B. Federal Technology R&D Programmes

The United States administration’s strategy in 1993 took the following two forms:

1. The creation of the Technology Reinvestment Programme (TRP) with funds amounting to US$1.3 billion in 1993 which were carried over from the Bush Administration (1992) as savings from cut-backs in the United States Defence Department (DOD), known at the time as the “peace dividend.” TRP was composed of five federal agencies, each allocated funds to administer in a national competition under the co-ordination of the DARPA (Defence Agency for Research and Policy Administration). Associated with the TRP, but set up separately within the United States Department of Commerce (DOC) was the Advanced Technology Programme under the auspices of the National Institute for Standards and Technology (NIST), the Manufacturing Extension Programme (MEP), the Regional Technology Alliances (RTA), and others, with a total budget of

US$625 million. The TRP budget had been cut already from its initial billion plus level to only US$245 million.

1. Federal funds concerned with Workforce and Community Transition programmes. These funds are primarily administered through the United States Department of Labour (US DOL), with a budget of more than US$1 billion in 1993 which was increased to US$1.2 billion in 1994.

A series of initiatives were taken to fund new technologies and businesses, such as loan guarantees, small business innovative research, and related dual-use technology programmes. The total funding came to almost US$900 million in 1994. The DOD funding for all Defence Reinvestment totalled over US$2.7 billion. DOD in the early 1990s became one of the largest federal resources for environmental research, development and demonstration in large part due to the need to clean-up base closures. From 1984, when Congress established a separate environmental clean-up budget for DOD, funding went from US$250 million to over US$5 billion in the financial year 1994 when it reached its peak (Hicks and Daggett, 1996: 1). Today, while declining, the environmental funding level remains at about 2 per cent of the total DOD budget. (ibid., p.5).

Nevertheless, funding for these DOD basic programme areas has declined overall. For example, the Environmental Technology Programme had a total of US$425.79 million in 1993. By 1996, it had US$218.4 million or a 25 per cent decline (ibid., p.12). Yet DOD is not the only federal agency impacted by a concern to balance the federal budget. According to "Appropriations Summary for financial year 1997" (NIST, 1996), the Advanced Technology Programme saw its budget reduced from US$220 million in 1996 to US$200 million in 1997 the Congress and the President canelled out most of these funds to balance the budget by the year 2002.

Looking only at those agencies and departments from Office of Technology Administration (OTA) data in 1995 that have a direct environmental R&D concern, the Unite States Department of Energy (DOE) saw its 1996 budget reduced from US$30 billion to about US$23 billion in the Year 2002. NASA foresees a reduction from US$95 billion to US$65 billion during the same period. United States Department of Transportation (DOT) appears to drop from US$480 billion in 1996 to US$400 billion in 2002; US Department of Interior (DOI) from US$525 billion to US$380 billion; and most disturbing of all is the EPA reduction from US$540 billion to US$450 billion. The only with funding agency that appears to be stable during this time period is the NSF with a US$2.25 billion budget in 1996 reduced to US$2.1 billion in 2002.

Currently, there appears to be a strong trend toward less publicly funded R&D (by 1996, 50 per cent less) and more private sector funding when seen as a percentage of the GDP (see attachment from US DOC, "United States Sources of R&D Funding", 1997: 7). By the turn of the century, the situation had become acute. More funding for R&D in general was made possible by the private sector. For public funding in ESTs, R&D had all but been curtailed.

Banks and Heaton (1995) estimated that the "environmental technology (publicly funded) budget was minuscule in 1987, and even today at an estimated US$4 billion it represents only about 6 per cent of the public R&D funding." (1995: pp. 47-49). The sources for the actual estimated funds are difficult to quantify and are a "best guess" (Banks interview, 1997). While the authors may be slightly biased in their negative assessment of the lack of R&D funds for ESTs, they nevertheless make the point that the relatively low portion of R&D public-funding for ESTs is staggering in comparison to other publicly-fund R&D areas.

III. PATTERNS OF DIFFUSION

There are several essential questions that have to be answered. What is the empirical evidence that connects publicly funded R&D and commercialization of the results of this R&D? What mechanisms have to be established and modalities applied to bring the results of publicly funded R&D to the marketplace? How can industry and government work together most effectively in the process of diffusion of publicly funded ESTs?

Dr. Francis Narin began to publish quantitative data that addresses some of these issues in the mid and late 1990s. Narin documents a connection between United States publicly funded R&D and commercial interests as seen in patent citation data. Narin, Hamilton and Olivastro (1997) document how industrial patent citations in chemistry and physics are directly linked to publicly funded R&D support from the top United States federal agencies and departments. In other words, publicly funded R&D in science directly impacts upon economic growth.

Narin, however, assumes that patents are a significant business strategy or economic indicator and that quantitative patent citations are hard evidence and central to support that argument. To date, the methodology and resultant findings are the best empirical data available. Industry, scholars, and government tend to agree with the correlative linkage between patents and business or economic development.

Constructive scepticism must be brought to bear on these studies that attempt to link business development and patents. For example when statements are made, such as the recent "Competitiveness of the United States Environmental Products and Services Industry" from the US DOC (March 25, 1997): "The vast majority of environmental R&D in the past two decades, which amounts to over US$00 billion, has been conducted with little direction from the market or input from the private sector." (Berg and Ferrier, 1997: Ch. 1, p.5)

Clearly, the market is not the *ipso facto* sole purveyor of environmental demand, needs and concern for ESTs or public environmental policy for that matter. Industry should not be the final determining factor or even the initial consideration in implementing publicly funded ESTs. Industry "demand" for ESTs often is narrowly defined to established vested corporate interests, market share, competition and sales/marketing. The business model bottom line in America is shareholder dividends and quarterly performance. Rarely is there a concern for the environment in general and public interest research specifically. Hence, the Government must continue to play a strong role in the creation (R&D) and diffusion of publicly funded ESTs.

The US DOC Report is correct, however, in stating that there will be a US$180 billion environmental industry in the near future and that it will evolve from a pollution control and waste management service industry into a totally integrated resource management industry expanding beyond the "traditional resources of water, energy, timber, and land to include materials, property, ibid., Ch.1, p.4). Critical to the future of the environmental industry is continuance of publicly funded R&D for ESTs and the appropriate strategy diffused these results get into practical applications in concert with industry.

A. Laying the foundation

In the 1980s, concerns about industrial competitiveness and the desire to use federal science and technology spending most effectively led Congress to pass legislation easing restrictions on public-private cooperation in developing and using technology. At the same time, declining defence budgets and the growing reliance of the national security on civilian-dominated technologies like electronics led defence agencies to seek cooperative arrangements with industries in those "dual-use" areas of technology. These initiatives reflected a trend toward expanding the federal role beyond the traditional funding of mission-oriented research and development. They also reflected a trend toward facilitating technological advance to meet other critical national needs, including the need for the economic growth that flows from the commercialization and use of technologies and techniques in the private sector.

Until passage of the Stevenson-Wydler Technology Innovation Act of 1980, which directed federal laboratories to help transfer their technologies to the private sector, technology transfer was not part of the mission requirements of most federal agencies. In the same year, the Bayh-Dole University and Small Business Patent Act gave recipients of federal research grants better access to patents for federally funded innovations. Both initiatives were based on the belief that some technologies developed in pursuit of federal agency missions might have commercial applications and thus might be of economic benefit to the nation. Both acts initiated a period of profound change at federal laboratories and at universities throughout the United States.

In 1982, the Small Business Innovation Development Act established the Small Business Innovation Research (SBIR) programme to increase research and development by small high-technology businesses. Congress once again demonstrated its belief that cooperative technology programmes could have a dramatic impact on the United States economy. The act requires all federal agencies with large extramural research budgets to set aside a certain percentage of their R&D funding for grants to small firms. The SBIR effort has become one of the most visible technology development programmes at the federal level and has sponsored 25,000 companies since its inception.

The Federal Technology Transfer Act of 1986 (FTTA) and the National Competitiveness Technology Transfer Act of 1989 expanded federal technology transfer, authorizing new "cooperative research and development agreements" (CRADAs) between federal laboratories and other parties, including private firms, universities and government agencies at all levels. The intent of these CRADAs is to provide additional incentives for the transfer and commercialization of technology.

Out of these initiatives grew a dramatically new role for a venerable agency. Under the Omnibus Trade and Competitiveness Act of 1988, the National Bureau of Standards became the National Institute of Standards and Technology (NIST). More substantively, the act established the Manufacturing Technology Centres (MTCs) programme (for technology extension to small firms) and a programme of research grants known as the Advanced Technology Programme (ATP). MTCs were created to facilitate the direct transfer of knowledge and technologies developed under the programmes of NIST to manufacturers. The ATP provides seed funding to companies and consortia to accelerate the development and commercialization of high-risk technologies with substantial potential for enhancing United States economic growth.

A second, parallel strain of the recent cooperative technology movement is the new emphasis on “dual-use” technologies and the quest for new civilian missions for the laboratories of the Department of Defence and the Department of Energy. The laboratories of the Departments of Defence and Energy are aggressively pursuing cooperative relationships with the private sector.

To meet the common technology needs of civilian industry and national defence, Congress passed the Defence Conversion, Reinvestment and Transition Assistance Act of 1992. Under this Act, the Department of Defence, in particular the Advanced Research Projects Agency (ARPA) devised the Technology Reinvestment Project (TRP) to be administered by multiple agencies. The multiagency TRP includes programmes in three principal focus areas: technology development, technology deployment and manufacturing education and training. It is co-ordinated by the Defence Technology Conversion Council, chaired by ARPA, and operates largely through “dual-use partnerships” that involve private firms and any of a variety of participating federal agencies (ARPA, the Department of Energy, NIST, the National Science Foundation, NASA, and the Department of Transportation). About US$472 million in grants were awarded in the first year, 1993), and US$474 million in financial year 1994.

The legislative groundwork for the TRP was laid during the previous administration, which carried out multiagency “cross-cutting” reviews of federal science and technology activities by function through the Federal Co-ordinating Council on Science, Engineering, and Technology (FCCSET). However, the TRP was established by the current administration, which has promised to follow through on the effort of fully developing it and of cooperating more effectively with the States.

B. Federal approach to the diffusion of publicly funded ESTs

Technology transfer, within the Federal Government and as a result of most publicly funded research, is the administration of paperwork centred on intellectual property created as a result of publicly funded R&D: patents, copyrights, trade marks, industrial licences, etc. Rarely do technology transfer offices market and sell technologies. None provide capital or assistance in raising capital for business development of the technologies. In other words, technology transfer for the Federal Government (and often at universities and state levels) is an administrative function and not a commercial one.

Almost all federal laboratory technologies available for commercial application have been historically taken "off-the-shelf". That is, the technologies were developed for other purposes, usually military or defence. Throughout the early and mid-1990s, the Federal Government actively supported technology transfer activities at very high levels of funding. For the DOE, technology transfer was called an "initiative" (TTI) and received US$250 million at its peak in financial year 1995. The concept for TTI was that the Federal Government would fund its side of a collaborative R&D effort, while industry or consortia partners were to fund their own activities. Attacked by the 1994 conservative Congress as a form of "corporate welfare", the TTI was drastically reduced. By 1998, the amount was less than US$50 million and scheduled to be cancelled out by 2002. The prevailing Congressional attitude is that industry should fund its own R&D activities.

Most federally funded R&D projects have their current technologies described in books, magazines, or newsletters, on-line at web sites or in annual technology reports. Lawrence Livermore National Laboratory (LLNL), Opportunities for Partnership published two volumes, for example, in 1994 and 1996. NASA does the same thing through a company who publish, Tech Briefs, which is a monthly magazine featuring new NASA technologies.

In both cases, a one-page description outlines each technology available for transfer to businesses, listing the laboratory contact person with telephone, fax, and e-mail addresses. Usually the technology transfer office handles the inquiries, but a large number are directed toward the principal investigator or other scientists because the inquiry is often one seeking "technical due diligence" on the federal research or checking the enterprise's own technical competence. In other words, an enormous amount of time and resources must be devoted to queries about technologies with very little resources available to respond, and certainly no federal funds for research collaboration with others.

Over the last decade, since technology transfer was established by Congress in the late 1980s, the LLNL, for example, filed about 100 patents annually on technologies and then attempted to "license" them. The intellectual property protection and subsequent procedures to commercialize technologies are common throughout the Federal Government. The result is the "technology push model" described above which is the standard publicly funded approach and accepted process for most federal government research and development projects (CRS, 1996: 3 and Clark, 1996).

National laboratories tend to expand or modify the basic technology push model through many common economic development strategies: business plans, licence agreements, conferences, incubators, small business technical assistance funding, among others. The technology push model is inadequate and woefully unproductive using almost any benchmark for measurement or evaluation.

Intellectual property rights play a significant strategic role in the dissemination of ESTs. "A comparison of patent systems in Japan, the US and Europe" (Morgan and Morgan, 1993: 263) illustrates the point as seen on chart 1. In each of these industrialized areas of the world, the patent application is based on the "first-to-file" while in the United States, it is the "first-to-invent". While that issue is being hotly debated and may soon be "harmonised", the Unite States scientific community sees itself at a tremendous disadvantage since other countries or companies may file the invention made by American researchers before these can do it themselves, since the filing counts and not the creation of the invention itself. Therefore, the american researchers are reluctant to share their discoveries and intellectual property for fear that the work will be "stolen" or filed in other countries.

C. Impact of Federal Legislative Measures On The Diffusion Of Publicly Funded ESTs

Federal legislation in the early 1980s, specifically the Stevenson-Wydler Technology Innovation Act of 1980, allowed access to the federal laboratory system by United States public and private organizations. The Federal Technology Transfer Act (Bayh-Dole) of 1986 further simplified the process for American universities (and by extension, national research laboratories) to obtain patents and hence to allow the transfer (exclusive and non-exclusive) to American private enterprise (Mowery et al. 1997) stated as "significant by manufacturing in the United States". Since then, public R&D institutions have created patent and licensing offices and specialists as patents and copyrights have expanded greatly. Perhaps a great quantitative indicator for growth in this area would be a count of the number of attorneys in this field over the last ten years. The hypothesis would be a substantial growth (by several factors).

In many public institutions, researchers are now rewarded for their patents in terms of promotion, royalties, profit participation and academic stature. Another "P" has been added to the Publich or Perish" rule for university tenure - "Patent". Under the United States Constitution, Article I, Section No. 8, Clause No. 8, all inventions, creative work and discoveries are protected:

> "to promote the progress of science and useful arts, Congress is vested with the right to grant to authors and inventors the exclusive right to their writings and discoveries".

This use has resulted in volumes of patents, copyrights and trademarks (symbolized respectively as: ®, ©, ™) covering individuals and companies in the United States. Such protection has been upheld many times in court and is best stated in the Supreme Court ruling "Inventions Patentable" with "whomever invents or discovers any new and useful process, machine, manufacture or composition of matter, or any new and useful improvement therefor, subject to the conditions and requirements of this title" (35 USC § 101).

Patents have grown in importance over the last ten years as seen in the large numbers registered, the legal profession specialization, and the international significance in trade negotiations. The most current data available from 1993, with 1983 and 1989, show:

Chart 1
United States patents of american and foreign origin

United States Patents	**#s in 1983**	**#s in 1989**	**#s in 1993**	**Totals: 1983-1993**
United States Origin	38 167	50 185	53 730	487 652
Foreign Origin	23 989	35 352	44 326	407 592

Source: United States Patent and Copyright Office, Technology Assessment and Forecast Report, 1993

Prior to 1980, there were 788,521 domestic origin patents and 316,537 foreign patents. While United States domestic origin patents still are numerically more than foreign ones, the their show in 1993 dropped to 18 per cent. The five years trend clearly demonstrates an increase in all patents with a significant closing of the gap between American and foreign origin patents. As the above figures show, there has been a 71 per cent increase in United States domestic origin patents from 1983 to 1993 with a corresponding increased of 54 per cent of foreign patents during the same two time periods.

D. Diffusion mechanisms and modalities

The mechanisms for the diffusion of ESTs in the United States follow a somewhat consistent pattern. At federal or national level, Congress has enacted laws that outline procedures. For example, the United States DOE and other federal agencies and departments approach the diffusion of ESTs on three distinct levels:

1) Basic research and development, leading to potential demonstrations.
2) Intellectual property (e.g. patents and copyrights) for licensing.
3) Work for others or contacts from companies or other public funded institutions.

The United States DOE divides intellectual property into exclusive and non-exclusive fields of use: geographical regions of use and technological sectional areas. In most cases, licences are non-exclusive. In all cases, due to federal legislation, the licensee must do “significant manufacturing” in the United States”. The licensee need not be an American controlled or owned company, but the technology can not be taken aboard and commercialized. There are a number of approaches that companies and laboratories have created to conform to this requirement while encouraging “foreign” investment as a new source for R&D funding.

Congressi’s intent was to keep American technologies in the United States in order to stimulate jobs and not lose advanced technologies to other countries or foreign companies. This concern underlies the problem with ESTs being transferred or licensed to any foreign company or government.

The issue rests at the heart of ESTs being commercialized outside the United States.

The diffusion and dissemination of ESTs must be an “interactive” process (Clark, 1996; Clark and Paulocci, 1997; and Clark and Fast, 1998) requiring non-linear and parallel processing, rather than linear thinking and administrative processes as is currently the procedure in technology transfer, or simply a “market pull” model as advocated by DOC and industry.

A far more viable approach can be seen where industry, the researcher is interacting with business and industry at a far earlier stage. Projects formulated under a Work For Others (WFO) agreement, whereby non-disclosure agreements (NDA) are executed, provide an early collaborative relationship in the early stages of R&D activities. From that point, the industrial partnering, technology transfer and legal offices are involved in the initial stages of work to protect the business and intellectual property rights of all the partners. In other words, the process is “iterative”, non-linear and parallel.

The following case examples of this interactive, non-linear and parallel processing approach have been successful at LLNL, UCB, DOE and the DOS:

1. Fuel Cells. As cited in the references to this report (Clark, 1996; Cooper and Clark, 1997; and Clark and Paulocci, 1997), zinc air fuel cell technology (ZAFC) was originally seen as a replacement or hybrid with batteries in vehicles. While ZAFC was not funded by the PNGV or other federally funded effort, it was internally supported by the LLNL own research and development funds. From that initial funding, the DOE in 1997 provided some further research funding.

   In early 1997, an international financial and manufacturing consortium lead by a group of international investors successfully entered into a cooperative research and development agreement (CRADA) with a federal laboratory and began a two year concentrated effort to bring ZAFC to the marketplace. However, transportation was not the market driver, as previously envisioned by the inventor and the laboratory. Instead, the financial backers saw greater potential, applications, and positive environmental impact when ZAFC was used as an energy storage device to save and redistribute power for use in regions. Transportation could later be “mapped” onto the ZAFC energy storage systems through its related “zinc recovery unit” developed at a University of California campus.

2. R&D collaborative international workshops is another successful case. Today with the internet, e-mail, and web sites, the process of communication has become even easier. However, there is still a need to match and couple researchers with one another in order to identify mutually interesting problems, find funding sources, and plan projects. The international networks are a new form of interaction for many publicly funded R&D projects.

   Two workshops have been designed to accomplish the goal of establishing international networks in ESTs:

(a) US DOS and US DOE jointly sponsor a workshop where scientists from energy and environmental laboratories share information on project planning, systems, and new technologies in an attempt to collaborate on mutually beneficial projects. New energy and environmental technologies are planned to be explored jointly. The final purpose is to demonstrate the new technologies in Eastern and Central Europe as well as North Africa, with funding from the European Union.

(b) The Centre for Sustainable Development is organizing, with funding from the Asian Environmental Partnership (AEP) programme of USAID, a workshop to facilitate the interaction between ten researchers from a variety of Northern California academic institutions and laboratories and their counterparts in the Philippines. The objective is to discuss ways to collaborate to solve water, energy and environmental problems in Manila. Joint R&D projects are projected to emerge from the workshop which are intended to be funded by international organizations such as the Asian Development Bank, the World Bank and others, in collaboration with private sector corporations.

3. Federal cooperative technology programmes. Federal cooperative technology programmes are directed towards promoting private sector participation in publicly funded R&D efforts. These efforts, funded by federal agencies and sometimes channelled through state programmes, aim to develop technologies in selected areas. Companies wishing to participate must meet the specific criteria for each programme. These programmes can be divided into five categories: Technology development, industrial problem solving, technology financing, start-up assistance, and teaming.

4. Technology development. Technology development focuses on providing help to companies in developing or adapting technology. This category includes programmes that provide financing to industry and require companies to enter into consortia with other companies, government agencies, or universities. Some of the other major federal efforts of this type are the Department of Defence’s Manufacturing Technology (MANTECH) Programme, Semiconductor Manufacturing Technology (SEMATECH) Programme, and the Technology Reinvestment Project (TRP); the Department of Transportation’s’ Intelligent Vehicle Highway Systems (IVHS) Programme and National Magnetic Levitation Initiative (MAGLEV); the joint venture aspect of the Department of Commerce’s Advanced Technology Programme (ATP); the National Science Foundation’s Research Centre’s Programme and the Small Business Technology Transfer (STTR) Programme.

5. Industrial problem solving. The Extension Service of the U.S. Department of Agriculture is the prototype for the technology extension/deployment (TE/D) programmes of state and federal agencies. As part of its industrial problem solving activities the Service uses a network of extension agents to diffuse the results of USDA-sponsored research and development, bringing improved methods to the nation’s farms. Today, the Federal Government uses a similar

approach to help commercial firms through programmes such as the Manufacturing Technology Centres of the National Institute for Standards and Technology. (The MTC programme has received significant funding under the technology deployment portion of the Department of Defence's Technology Reinvestment Project.)

Other major federal industrial problem-solving programmes include the Flexible Computer Integrated Manufacturing Initiatives of the Department of Defence, the Defence Programmes Small Business Initiative of the Department of Energy, the human resources assessment projects of the Department of Labour, and the private sector outreach of the Regional Technology Transfer Centres of the National Aeronautics and Space Administration.

6. Technology financing. Technology financing focuses on providing access to capital for companies. This includes programmes that provide financing to industry for specific technology projects that do not involve the use of consortia. There are no federal programmes that provide direct general-purpose financing for technology-based companies. Federal initiatives of this type include the direct grant aspect of the Advanced Technology Programme (ATP) and the "cross-agency" Small Business Innovation Research Programme (SBIR), the Department of Energy's and the Environmental Protection Agency's NICE programme, the Technology Initiative (ETI), and NASA's Aerospace Industry Technology Programme (AITP).

7. Start-up assistance. Federal start-up assistance for small technology-based companies has been limited. No discrete or unique federal programmes exist for it. On an *ad hoc* basis, however, some agencies sponsor small business incubators. One could argue, for example, that the Department of Commerce's Advanced Technology Programme (ATP) provides such assistance.

8. Teaming. Four key agencies (the Departments of Commerce, Defence, and Labour, and the National Aeronautics and Space Administration) provide assistance to industry through information dissemination, networking, and databases. Part of the Technology Reinvestment Project (TRP) awards classified under Industrial Problem Solving are as much teaming as problem solving. Additionally, the TRP has made strategic partnerships a major goal. These efforts seek to facilitate greater collaboration among government, industry and universities by increasing the awareness of cooperative technology efforts.

The Federal Government's overall approach to cooperative technology programmes changed in the late 1980s. It not only anticipated state collaboration, but also sought it out. Interestingly, the perceived success of the states' technology development and industrial extension programmes motivated the creation of the federal technology extension programme. Because of NIST's pursuit of state partners and its relatively high national profile, the NIST Manufacturing Technology Centres had a significant impact on the states. Today, the technology extension/deployment model is the most widespread of the cooperative technology programme types: 40 states now sponsor technology extension/deployment programmes.

More recently, the multiagency Technology Reinvestment Project (TRP) led by the Department of Defence, has influenced the states significantly. TRP's high visibility in the business community and media has caused several states that previously had only a slight interest in cooperative technology programmes to initiate ambitious efforts to co-ordinate responses to the TRP solicitation, provide matching funds, and lobby for their states' shares in the initiatives.

E. Technology innovation and diffusion at state level

States have different mechanisms in diffusing ESTs. A state will want to diffuse ESTs primarily in order to encourage job creation. Advance technologies are seen by state and local governments as either creating new jobs locally or as providing the demand for people to be hired within existing companies. Most United States fund public universities, so that research on campuses is clearly owned by the state. In recent years, however, states have gone beyond the university campus to encourage research and development in technologies.

All 50 states have cooperative technology programmes aimed to improve each state's ability to develop and absorb new technologies through the creation of strategic partnerships between the State and Federal Governments, industry and university and research institutions. In financial year 1994, 34 per cent (US$127.5 million) of total state cooperative technology programme funds was directed toward the elements that make up this category: university-industry technology centres (US$104.6 million), university-industry research partnerships (us$12.1 million), government-industry consortia (us$4.8 million), and equipment/facilities access programmes (us$6.0 million).

Cooperative technology programmes are administered by government agencies, state-chartered and not-for-profit organizations, and universities. Programme administration includes a number of functions that vary by state priority setting, resource allocation, oversight, evaluation, and industrial assistance. The mission and emphasis of these activities is a function of state philosophy and direction. In most states, state employees play a narrow role, with independent organizations doing much of the work. Some have state employees interacting with industry, while others rely on technology centres and outreach organizations to help the companies. Most states use a combination of approaches, both retail (direct company interaction) and wholesale (through intermediary organizations).

State cooperative technology programmes have run through three phases. During the first phase, which lasted for two decades beginning in the 1960s, federal efforts drew a number of states into the arena. In many states, the first foray into cooperative technology programmes involved science and technology advice from formal state advisory bodies that were established in the 1960s with funds from the United States Department of Commerce's State Technical Services (STS) programme. The second phase occurred during the 1980s, largely without federal participation. States designed strategies, established programmes, and met the initial organizational challenges through experimentation and entrepreneurial leadership and administration. The predominant model at this time was technology development through university-industry technology centres. The third phase began in the late 1980s and early 1990s and continues to this day. During this phase, the state programmes have grown into mature organizations with stable funding and institutions. Many states began full programme assessments and maintained programmes even in the face of state fiscal crisis. During the third phase, the Federal Government began to influence state programme activities. Federal support for industrial extension and problem solving was reflected in state programme priorities. As federal cooperative technology programmes grew in the early to mid-1990s, state efforts to secure federal funds by providing matching dollars and maintaining parallel programmes increased dramatically.

Nineteen States now have “seed capital” or early stage venture capital funds for assisting new technologies to enter the market place. This is an extremely new perspective in American publicly funded R&D since historically the Government does not provide “equity capital” to businesses. Government, while providing R&D grants, has always played the role of “debt” provider to business development. Thus, with these new state seed capital funds, a new era or role has emerged for publicly funded R&D.

Most of the American state seed capital programmes provide open competition for proposals by individuals, small or large companies that must be matched by private capital (or in-kind contributions) or other public funds. The funding can be from two to three years and has few strings attached, other than reporting on progress. Alaska, for example, through oil revenues, established an endowment that provided US$8.5 million for its cooperative technology programmes in financial year 1994

Alaska will allow its funded projects to be located in another state as long as the it sees some benefits (return on its investment, use of its universities, royalty fees, employment or other). Kansas has one of the most aggressive state technology commercialization programmes. It relies heavily on marketing (world-wide) and technical assistance to companies that locate there. Maine, on the other hand, acts as a facilitator through its Science & Technology Foundation which secures public funds and then dispenses them through programmes and projects.

The larger states, such as California and New York, have developed state-wide programmes that regularly solicit proposals for new technologies and companies. Through a formula, funds are dispersed after a peer review process. In California, the process has been institutionalized through the “Gold Strike” programme which divides the state into regions with local administrators and identifiable “industrial clusters” (Hinton, et al., 1997). Funds are allocated annually by the state legislature and then dispensed through the Commerce & Trade Agency (part of the Governor’s administration). The California programme was created in 1993 by the Governor’s Executive Decree to meet the challenge of the state-wide depression caused by the conversion of defence industries and base closures.

More recently, the state support of high technology commercialization and especially ESTs can be seen as a very significant shift in the economy. California and other state economies have grown and prospered since the late 1990s. Hence the initial purpose of state funded technology research into commercial ventures is less relevant. However, the new challenge in almost every state is de-regulation of the energy (hence environmental concerns for ESTs) industry. Heretofore, the energy industry, represented by the power / utility companies, had been regulated. In California, for instance, after 1 January 1998, the entire industry will be de-regulated (based on legislation signed into law in California in October 1996). The situation is similar in other states. New York state has a "phased" or gradual approach while Maine has not yet set a time limit.

For the regulated energy companies now facing deregulation, competition will come from anywhere and everywhere. Companies will know no global boundaries. While energy is the main strategic theme for these companies, ESTs are one of their most significant tactics. The de-regulated change at the state level has meant that some states will try to support their own industries in a variety of ways. In California, the state California Energy Commission (CEC) will administer over US$200 million in new "public-interest" energy and environmental research (PIER), development and demonstration funds annually for four years. The legislature approved the public-funds in 1998 to stimulate more advanced technological business development of environmental and energy research in the state. The intellectual property rights of the ESTs are not clear; nor are the transfer and commercialization of the ESTs. Much of decision making on these issues is on a case-by-case basis.

Universities have even different mechanisms for handling intellectual property. Only within the last ten years, has intellectual property been seen as a significant incentive within the academic world. The Massachussets Institute of Technology (MIT), Stanford and the University of California System now receive annual revenues from licences averaging about US$40 million each, albeit most of the money is derived from only one or two patents. Nevertheless, US$40 million to the universities is considered new money for the inventors, departments, and campus. Each institution has its own formula or policy for dividing the revenues.

F. Barriers to the diffusion of publicly funded ESTs

Regarding the market deployment of energy technologies, a survey of eight technologies (OECD, 1997) notes market barriers "within a setting in which governments want to leave technology deployment primarily to market forces, only those barriers that involve some element of market failure call for government action." (1997: 18). The survey outlines nine types of market barriers: information barriers, transaction costs, risk, financial barriers, price distortion, market organization, excessive and costly regulations, capital stock turnover rates, and technology-specific barriers (ibid. pp. 19-29). However, it ignores the role of government which often needs to go far beyond that of the market itself.

The diffusion of technologies in the United States is marred by the lack of government involvement in three significant areas for publicly funded ESTs:

1. Government funding of any technology lacks incentives that take into account the public institutional "culture" of individuals involved in these new discoveries. While the financial

incentives in the public sector are often much better in terms of royalties and fees, the fact remains that publicly funded researchers are not motivated necessarily by money in the future. Public researchers are less interested in royalties and equity shares, and more interested in funded research. They often live and survive by annual research grants for their work.

2. Bureaucratic barriers to publicly funded research and development are legendary and somewhat correct. The reality is that there are often ways around these barriers, when the individuals and organization are well-motivated. The problem is not the regulatory barriers, but the simple fact that the public sector moves at a slower pace than the private sector. While researchers may want to see their discoveries disseminated, the administrators and staff may not. Organizations tend to protect themselves, especially in the United States where litigation (note the exponential increase in the numbers of intellectual property lawyers) is the normal way of doing business. The consequence for public institutions is that they will be overly careful in negotiating and signing agreements.

3. The United States government needs to play an active financial role in the diffusion of ESTs, not just the financing of research and development. Begun during the Bush, administration and promoted early in the first term of the Clinton administration, the active role of government finance was seen in many new programmes (e.g. TRP, DARPA, and ATP). However, this approach to support the diffusion of new technologies was labelled “corporate welfare” by powerful conservative groups in the American Congress.

The result was to impede and even eliminate such productive and stimulating economic programmes. However, the difference in how American technologies are publicly funded as compared to other industrialized countries. was forgotten in the debate, American companies are at a serious disadvantage as compared to companies located in other industrialized countries. As documented above, case after case can be cited on how negatively this policy impacts global American industrial competitiveness.

IV. MODALITIES/MECHANISMS FOR THE TRANSFER OF PUBLICLY FUNDED ESTs TO DEVELOPING COUNTRIES

The approach of the United States to the transfer of publicly funded ESTs to developing countries is very limited. As noted above, there are legislative and legal barriers. In a recent discussion with senior staff at the United States Department of State (US DOS), the issues became very clear. The United States takes the position that while government should assist the diffusion of ESTs, the burden is on companies to do so. In fact, the US DOS “does not promote technologies.” Nor does the US DOS fund research and development. Through the US AID programme, which is part of the US DOS, demonstration or field tests might be funded. As noted earlier by Banks and Heaton (1996), however, advanced technologies are rarely factored into the dissemination model for ESTs (interview with M. Bacca, 1997).

The two major mechanisms for the dissemination of ESTs outside the United States (including to developing nations) are through the Export-Import Bank and the Overseas Private Investment Corporation (OPIC). The former provides companies with funds (e.g. credit, loans, guarantees, etc.) for the goods and services of a company that seeks to export. The Ex-Im Bank will target certain regions of the world and therefore give preferred rates and service to companies seeking business there. Since its inception in the mid-1930s, the Bank has had an admirable record of promoting American goods and services.

The OPIC fund is essentially an equity investment by the United States Government in companies seeking to export their products and services. Over the last few decades OPIC has played an increasingly significant role in fostering American corporate sales. In general, OPIC has done well and is considered an economic success.

Neither financial source is widely known within the United States environmental business community and is rarely used by the R&D owners of EST patents and copyrights. The gap can be seen in the lack of company or firm (s) awareness about how to market ESTs. Reasons why this is the case, vary from the need for large sums fund manufacturing and marketing, to concern over market shares already dominated by certain companies who do not want competition from new technologies. Internationally, in other words, American environmental companies are not motivated to commercialize their technologies or publicly funded ESTs.

The US DOC has attempted to solve some of these problems, but with marginal success. Most of its efforts are policy oriented and industrial sector specific. Therefore, the US DOC tends to promote trade missions and conferences where issues are discussed. While this is important for building relationships and connections, it is not enough. The need exists for bridging the gap between the environmental industry(s) and new ESTs technologies in very part of the world.

In recent years, the Government has taken a new (although in some ways not so new; and the strategy is being imitated by many states) strategy to "semi-privatize", heretofore areas of governmental monopolies. As Government Executive reports with its "The
(June 1995: 17), there are many variations of privatization now in vogue within the Federal Government. In the attached chart, "A Mixed Bag" (Government Executive, February, 1995: 40), there are numerous examples of governmental ownership turned into private or quasi- or mixed ownership.

The difficulties American companies are confronted with in entering international markets can be exemplified by the following two cases:

1. Case Study I: A publicly funded EST - "Dynamic steam stripping"

Because of environmental remediation needs at LLNL due to its earlier use as a Naval Air Station during World War II, LLNL scientists developed a new EST with UCB professors. “Dynamic steam stripping” basically forced a plumb into an underground collection area that could then be easily extracted. Rather than the current method of pump and treat or capping a contaminated area, this technology proved to be efficient, cost effective, and environmentally friendly. Intellectual property rights reside with the UCB and LLNL staff scientists. Since both UCB and LLNL are part of the University of California system, IP issues were relatively simple and straight forward for the collaborators. Nonetheless, the biggest problem was to try and find public funds to demonstrate the EST. With the current cut back in federal funding, the only solution was to find a small environmental company and focus on the environmental remediation of San Francisco-Bay Area military bases. Large sums of funding from DOD are available for base closure clean-ups. This is the current strategy under way. US$25 million was awarded to the project in the summer of 1996.

Once dynamic steam stripping is demonstrated on sites, the environmental company should be able to introduce the EST to the global marketplace. However as Berg and Ferrier (1997) point out, most American environmental companies do not work internationally. Furthermore, the environmental industry is undercapitalized. Therefore taking a new EST into the market, even within the United States, will be slow and costly unless regional governments and stronger industrial partners are found.

This same observation has been made by DOE executives who have been promoting the use of advanced clean coal technologies for the last four to five years (interview Atwood, 1997). They argue that clean coal technologies can substantially lower CO_2 emissions, but that the small size of the companies and difficulty in penetrating market, has left many of these environmental companies too little capital for quick and effective installations.

2. Case Study II: A private sector development of EST through public funds
ENVIROGEN: “Bioreactor systems for industrial wastewater treatment”

Envirogen Inc. is an environmental biotechnology company engaged in the development and design of advanced systems to treat and degrade hazardous wastes”, according to it its 1997 Annual Report to shareholders. As a small publicly traded company (NASDAQ) with revenues of about US$13 million, it does not have the budget or resources to develop its own environmental technologies. Hence in the mid-1990s, the company participated in the Small Business Innovative Research programme (SBIR) which provides private companies with three stages of funding beginning at US$100,000.

Envirogen became a success story with SBIR funding from the United States Air Force and two subsequent rounds (over US$300,000) from the National Science Foundation. In other words, public funds were used to fund a private company’s R&D work in ESTs. In this case, Envirogen’s “treatment system was comprised of a fluidized bed bioreactor (FBR) , an air stripper and a gas phase bioreactor (GPR)” that successfully cleared two Air Force sites at the 90-99 per cent level of chlorinated and non-chlorinated hydrocarbons (FBR) as well as soil vapour extraction with pump and treat operations with air stripping (GPR).

Because of the publicly funded R&D effort, the company saw 61 per cent growth in its revenues and now (three years later) hires 100 full time people. Its major problem is being able to sustain its growth and compete in the marketplace. Fierce competition is leading to a consolidation of companies as contracts become fewer and government environmental clean-up resources become tighter. More significantly, the international marketplace, especially in developing countries, is a strong potential but SMEs need distribution and financial mechanisms to penetrate those markets.

V. MAIN FINDINGS OF THE STUDY

A number of recent studies (Narin, Hamilton and Olivastro, 1997; Berg and Ferrier, 1997) have attempted to examine the impact of publicly funded research and development on the economy. These studies indicate that indeed public funding of research and development yielded enormous economic benefits to the United States economy. Some political leaders even credit the sustained economic recovery of the mid-late 1990s to the early investment in research and development by the Bush and Clinton administrations.

In publicly funded research activities, technological solutions to satisfy both long- and short-term technology demands should be targeted. Usually, the market has a simultaneous need for quick short term or linear research solutions to immediate problems and for longer term enabling technologies for competitive posturing as well. Several studies, including Porter (initially 1980 and 1990, and more recently on sustainable development, 1995) have suggested that companies and nations can be “green and competitive.” Other scholars, especially Saxenian (1994) argue that competitive advantage can be seen regionally, as she compared the high tech areas of Silicon Valley in California to Route #128 surrounding Boston. Her work identified a number of elements that distinguished Silicon Valley from Route #128, and hence made it far more competitive and ultimately successful.

By identifying the characteristics of a region, economic analysts can build non-linear and interactive models for economic programmes in any region. This is currently the emphasis in California for its economic development as a result of Defence Conversion (see Clark, 1995), and an overall State Strategic Plan issued in 1996 and again in 1998. California is divided into five “Regional Technology Alliance” (RTA) geographical areas. Unfortunately, most of the analyses and policy recommendations take the "economic cluster model" within the region and then apply such an analysis in all industrial cases. In every RTA throughout California, for example, the environmental industry was never considered a “cluster”, therefore depriving it of governmental resources, public attention and financial support.

The value of "cluster concepts" tends to limit and focus economic development upon targeted industries. However, industrial clusters create narrow and short term foci for business development which often ignore start-up and new industrial areas. A far better approach would be to gather like-oriented industries into “networks” that evolve over time (Hakansson, 1994; and Hakansson and Snehota, 1995) cutting across industries but related in other ways: manufacturing to distribution to marketing/advertising etc.

Another economic development approach for new advanced technologies is advocated by Castells and Hall (1994), after considerable study of successful high tech areas and regions in Europe. The authors conclude that the successes of these high tech areas or "technopoles" rests on their combined and linked dedication to research, educational and industrial development in one geographical location. The concept has gained considerable attention in the United States.

An ideal approach to the commercialization of publicly funded ESTs is still not known. It becomes, however, apparent that an ongoing and continuous dialogue between government (defined as federal, state and the universities) and industry (private companies) must occur, eventually leading to the formation of relationships and specific activities that will promote and facilitate the diffusion of publicly funded ESTs.

Publicly funded research in federal laboratories often takes a long time to get into the marketplace. The main reasons are that industry demand is not directly impacting the researcher, and that publicly funded research has only been focused on the national market. The CRS, in commenting on the technology transfer of ESTs (1996: 7-8) makes somewhat the same argument. The “laboratory culture” for R&D does not need to respond to the intensity and competition of the domestic marketplace (and it should be added, the international marketplace). While this “research culture” is good in the sense that the researchers can look at longer-term problems and create appropriate solutions, it can also be difficult for those in industry or political decision-makers who desire or need quick and immediate technological solutions. Industry must spend large sums of R&D funds to get quick and immediate results in order to compete. Often this gives industry a short-sighted and often less creative view of problem solving.

The university environment and “culture” are totally different from those of both industry and federal laboratories. For most research universities, the purpose of research is long-term and directed toward graduate training. While innovation and market impact are important they are the “raison d’être” for academic staff. Even the academic reward systems and incentives are oriented toward long-term goals. Hence the funding of R&D within the university rarely corresponds with industry expectations and market demands. A good example of this is the dynamic steam stripping noted earlier, co-developed at UCB and LLNL. The EST took over two years to enter the demonstration phase, despite the United States Navy committing demonstration funds (estimated at US$25 million) because the UCB and LLNL staffs were not motivated to commercialize the discovery.

A stronger orientation towards the international market could also open up new avenues for the transfer of publicly funded EST to other countries. A similar strategy was proven successful in the semiconductor industry, as Morgan and Morgan reported in 1993. When public funds are used to develop environmental (or other) technologies, an American firm must be involved in their commercialization and transfer. Technology transfer centres can successfully serve as “data banks” or "brokers" in the technology transfer process. The Asian Development Bank, for example, has gone so far as to create a network of such centres throughout Asia.

The role of government has shifted from regulatory concerns to financial support and internationalization (through bank guarantees, patent protection, trade agreements and other means). The emergence of international strategic alliances between partners in the environmental industry and the Federal Government is the most viable approach for transferring ESTs into other countries. Along with such a strategy must be concern over issues of intellectual property, equity and debt financing, profits and losses, and management of companies. In short, government can take the risks in R&D that industry is loath to do.

Capital and finance remain the key to transferring technologies from the research culture to the international business culture. Again government plays a key role: it can provide the contacts and capital to move technologies into the marketplace. Two things need to change (at least more rapidly): one is that government can take an "equity" in companies that it supports. Such a role for government would also necessitate it taking an ongoing role in the oversight and management of the company. (Clark and Jensen, 1994). The other change for government concerns its need to co-ordinate and even collaborate with industry on public policy related to technology research & development. EST is an excellent example about how this might occur. Regulations for zero emission vehicles in California, federal clean water acts and other regulations have been an impetus and catalyst for new inventions to solve environmental problems. Research funds need to be made available to fund multiple solutions.

VI. SUGGESTED AREAS FOR FURTHER ACTION

1. In-depth Case Studies on "best practices": These case report's need not pick a "best case" and present it in detail. Instead some ideas and examples could be presented. It would be interesting to pick several base cases and focus on how EST was developed into a viable commercial product. If the EST has not been internationalized or diffused to another country, then a next step in this project might be to provide some diffusion funds and follow how the publicly funded EST goes "international." Such a case and subsequent analysis would be very useful for other American publicly funded ESTs.
2. Examination of promising selected modalities/mechanisms for technology diffusion that appear to be promising for the diffusion of EST. The examples in the case study, especially the international connection in the commercialization of an EST and the workshops linking American R&D staff from laboratories and universities with in-country counterparts, provides a modality worthy of further study.

3. Analysis of governmental policies for promoting technology diffusion and transfer: extrapolating the conclusions from this Case Study into the policy making arena, provides many challenges. One is clearly that decision makers rarely diffuse technologies. What then are the mechanisms or modalities to be created to diffuse ESTs.? If it is not technology transfer, then what is the policy

and programmatic need? Some practitioners of technology diffusion refer to the transfer of technologies as “a body contact sport” in that people and their interactions are responsible for the commercialization of technologies. While this is true on some levels, the fact remains that diffusion of technologies is not serendipitous -- it takes effort and must be institutionalized. How can this be done? And what governmental policies need to be created to do so?

What are the institutional relationships most appropriate to the diffusion and transfer of publicly funded ESTs at both the federal and state levels? A new form of technology diffusion must be identified and studied which requires the strong support of the Federal Government (financial, legal, procurement, trade, etc.). Without central government support, ESTs will not be commercialized. Furthermore, business and government need to create new institutional relationships. What are these? And how must policy(s) change to accommodate them? In other words, the R&D support must extend into the diffusion and application of ESTs. Finally, whatever the new form of technology diffusion, it must be examined, evaluated (beyond the rhetorical and promotional schemes), and itself formulated into a viable institution for the diffusion for ESTs.

4. Re-orienting federal technology cooperative programmes: federal technology cooperative programmes have a great influence in the orientation of R&D in state programmes and in those companies which participate directly. Given this fact, several issues would require further study, such as the following: Could federal cooperative technology programmes provide easier or preferential access for marketable technologies to developing countries? Should these technologies be limited to specific sectors of concern such as environment and health? How would this conditioning of grants or loans be done and how much could the Federal Government influence these transactions in order to leverage the transfer of these technologies to developing countries?

5. Making technology diffusion and transfer measurable: the most common approach today, because it is a search to quantify rather than understand, explain or predict, is the identification of patents. An attempt should be made to move beyond simple patent counts and understand the source (citations) of the research and their institutions. While this is a significant step forward and necessitates in-depth investigation, it still begs the question: how are ESTs (or any technology) diffused? And can this information be formalized? and/or quantified? What is the role of entrepreneurs, as defined as a group not as individuals, in the diffusion of ESTs?. In any commercialization of a new technology, there is the need for some entrepreneurial group to take the technology into the marketplace. Companies rarely do this on their own. Yet today, we see three kinds of “entrepreneurs” those acting outside a company who are creating a start-up company; the “entrepreneur” or those starting a new venture within a company; and the “civic entrepreneurs” or those working within government by innovating and starting a new governmental institution or organization. Unfortunately, we do not know enough about these people and their relationship to ESTs. In particular, we do not know enough about these people in other countries, especially in developing countries.

6. The role of international support in the diffusion and transfer of publicly funded ESTs: the key question will be how do international financial institutions interface with publicly funded ESTs? There is no easy answer to that in the United States. For one thing, banks in the United States are viewed strictly as "debt" institutions. The R&D community do not consider a bank as either investing in R&D or leveraging the R&D for commercialization. A series of policy studies linking international finance with publicly funded ESTs would be useful and highly productive. The World Bank and other international banks can play a significant role in the transfer of publicly funded ESTs.

"Green accounting" is a concept gaining credibility in other parts of the world. For example, in Germany, the "take-back" laws require companies who manufacture and sell products to take them back. Hence, companies need to factor into their revenues and expenses "green accounting". Factoring this concept into generally acceptable accounting practices might be an excellent approach to assisting the diffusion of publicly funded ESTs.

"Sustainable equity" is an approach often discussed in Europe. Some countries diffuse technologies through innovative public-funded programmes. These programmes provide an interesting and unique mix of private and public interests working together for creating new industries in developing countries. More research needs to be done and especially on how these programmes can be applied in the United States.

ANNEX I

LISTE OF ABBREVIATIONS

ATP:	Advanced Technology Programme (part of NIST)
CEC:	California Energy Commission
CRADA:	Cooperative Research and Development Agreement
DARPA:	Defence Agency for Research Programme Administration (was re-labelled ARPA and then back again)
ESTs:	Environmentally Sound Technologies
IEM:	Interaction Economic Model
IP:	Intellectual Property
IPO:	Initial Public Offering
LLNL:	Lawrence Livermore National Laboratory
MEP:	Manufacturing Extension Programme
NASA:	National Aeronautical Space Agency
NDA:	Non-Disclosure Agreement
NIST:	National Institute of Standards and Technology
NSF:	National Science Foundation
PIER:	Public Interest Energy Research (California Energy Commission)
PNGV:	Partnership for New Generation Vehicle (multiple United States Department programme)
OECD:	Organization for Economic Cooperation and Development
OPIC:	Overseas Private Investment Corporation
OTA:	Office of Technology Administration (within the US DOC)
OTP:	Office of Technology Policy (within the White House)
R&D:	Research and Development
RTA:	Regional Technology Alliance
SME:	Small and Medium Sized Enterprise
TRP:	Technology Reinvestment Programme (part of five agencies and department programme)
TVA:	Tennessee Valley Authority
UN:	United Nations
UC:	University of California
UCB:	University of California, Berkeley
US DOC:	United States Department of Commerce
US DOD:	United States Department of Defence
US DOE:	United States Department of Energy
US DOI:	United States Department of Interior
US DOS:	United States Department of State
US DOT:	United State Department of Transportation

USEC:	United States Enrichment Corporation
US EPA:	United States Environmental Protection Agency
WFO:	Work For Others
ZAFC:	zinc air fuel cell
ZRC:	zinc air recovery unit

ANNEX II

Table 1
Country, year of coverage
millions of US Dollars

	Unite States 1994	**Japan 1994**	**Germany 1993**	**France 1993**	**United Kingdom 1994**	**Italy 1993**	**Canada 1992**
Grand total	68 331	18 099	14 991	13 716	8 669	8 042	3 370
Energy	4.2	20.5	4.3	3.9	1.1	4.0	5.5
Environment Protection	0.8	0.5	3.7	1.3	2.0	2.5	2.1
Earth & Atmosphere	1.4	1.2	2.8	1.1	1.9	0.9	3.5
Defense	55.3	6.0	8.5	33.5	44.5	6.5	6.2

Note: Grand total includes all areas; select areas are presented herein; areas listed thus will not equal Grand Total.
Source: Office of Technology Policy, *International Plans, Policies, & Investments in Science & Technology*, *April 1997,* US Document.

ANNEX III

Table 2
Selected federal research obligations by agency and field financial year 1995 million US Dollars

Agency	Total	Life Sciences	Environmental sciences	Engineering
Total: All Depts. & Agencies	28 161	11 609	2 690	5 629
Agriculture	1 315	1 016	12	62
Defense	4 262	322	256	2 161
Energy	3 380	269	400	674
Interior	584	115	309	100
Transportation	310	7	5	190
AID	271	217	0	0
EPA	415	114	177	122
NASA	3 6822	169	797	1 552
NSF	2 219	350	471	310
TVA	34	13	1	2

Note: Total All Fields includes all areas; select areas are presented herein; areas listed thus will not equal Total All Fields.

Source: Office of Technology Policy, *International Plans, Policies, & Investments in Science & Technology, April 1997,* US Document.

ANNEX IV

Table 3
Federal obligations in basic research by science, engineering field millions US Dollars

Field	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Total/All	7819	8153	8944	9474	10602	11286	12171	12490	13399	14043	14201
Life Sciences	3787	3859	4364	4502	4916	5176	5434	5842	6289	6674	6898
Environment	126	126	141	147	157		187	202	223	260	261
Total Env. Sciences	70	749	781	873	1017	1275	1264	1304	1533	1575	1526
Atmosphere	209	240	244	281	316	441	449	435	635	650	633
Geography	250	266	266	267	335	440	449	520	555	563	528
Ocean	219	224	250	269	294	300	198	210	207	16	214
Other	21	19	21	55	72	92	118	132	136	146	151
Engineering	884	969	990	1006	1184	1102	1234	1250	1207	1325	1286

Note: Total All Fields includes all areas; select areas are presented herein; areas listed thus will not equal Total All Fields.

Source: Office of Technology Policy, *International Plans, Policies, & Investments in Science & Technology, April 1997*, US Document.

ANNEX V

Table 4
Federal applied research by science and engineering field: financial year 1985-1995

Field	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Total/All	8315	8349	8999	10163	10453	11286	12490	12490	13399	14043	14201
Total/Life	2576	2606	2980	3223	3579	3660	4069	4069	4483	4676	4711
Environment Bio	135	138	149	154	210	174	309	309	333	349	352
Total Environment	704	733	731	734	758	899	904	904	1075	1257	1764
Atmosphere Sciences	277	281	309	307	272	330	332	332	349	421	353
Geography	179	178	176	174	220	230	209	209	243	259	295
Ocean	179	205	178	191	198	220	249	249	260	308	275
Other	69	68	68	62	78	128	114	114	223	269	241
Engineering	2733	2770	2917	2950	3258	3234	3711	3727	4292	4375	4343

Note: Total All Fields includes all areas; select areas are presented herein; areas listed thus will not equal Total All Fields.

Source: Source: Office of Technology Policy, *International Plans, Policies, & Investments in Science & Technology, April 1997,* US Document.

ANNEX VI

Table 5
Federal and non-federal R&D expenditures at academic institutions, by field and sources of funds, 1993

Field	**Total**		**Federal**	**Non-federal**	**Federal**	**Non-federal**
	US$ Million	**Per cent**	**US$ Million**		**Per cent**	**Per cent**
Totals & E	19,911	100	11,957	7,954	60	40
Total Sciences	16,760	84	10,098	6,661	60	40
Total Environment	1,317	6.6	870	447	66	34
Atmosphere Sciences	211	1.1	160	51	76	24
Earth Sciences	415	2.1	242	172	58	42
Ocean	460	2.3	331	128	72	28
Other	229	1.2	135	94	59	41
Total Engineering	3,151	15.8	1,858	1,293	59	41

Note: Total All Fields includes all areas; select areas are presented herein; areas listed thus will not equal Total All Fields.
Source: Office of Technology Policy, *International Plans, Policies, & Investments in Science & Technolog*y, *April* 1997, US Document.

ANNEX VII

Table 6
Analysis of projected effects of president's financial year 1998 budget on federal R&D budget authority, in millions of US dollars

Total R & D	1997	1998	1999	2000	2001	2002	% Change Current US$	1997-2002
Defense	**37,461**	**36,780**	**35,870**	**4,190**	**33,672**	**35,056**	**-6.4 %**	**-17.7 %**
NASA	**9,315**	**9,604**	**9,537**	**9,387**	**9,293**	**9,331**	**0.2 %**	**-11.9 %**
Energy	**6,129**	**7,250**	**6,185**	**5,967**	**5,962**	**5,886**	**-4.0 %**	**-15.5 %**
Defense	**2,775**	**3,676**	**2,543**	**2,514**	**2,583**	**2,558**	**-7.9 %**	**-19.0 %**
Non-Defense	**3,353**	**3,574**	**3,642**	**3,453**	**3,377**	**3,330**	**0.7 %**	**-12.7 %**
NSF	**2,424**	**2,519**	**2,530**	**2,536**	**2,543**	**2,550**	**5.2 %**	**-7.5 %**
Interior	**581**	**608**	**608**	**609**	**609**	**610**	**5.0 %**	**- 7.6 %**
Transportatio n	**650**	**684**	**684**	**684**	**684**	**684**	**5.2 %**	**- 7.4 %**
EPA	**510**	**554**	**571**	**588**	**605**	**624**	**22.3 %**	**- 7.6 %**

Note: Total All Fields includes all areas; select areas are presented herein; areas listed thus will not equal Total All Fields.
Source: Source: Office of Technology Policy, International Plans, *Policies, & Investments in Science & Technology*, April 1997, United States Document.

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ESTs: THE CASE OF GERMANY

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I. TRENDS IN THE FEDERAL GOVERNMENT´S RESEARCH AND TECHNOLOGY POLICY

A. Structures of the German Research Funding System

In order to assess the role of publicly funded ESTs in Germany it is first necessary to look at the current public R&D policy in general. The German research system and the interaction of the various partners is divided into R&D-performing and R&D-financing sectors. This structure, which is commonly applied to make international comparisons, may be used to describe the relationship between the sectors and their components as well as their development over time.

1. R&D Performing Sectors

The R&D performing sectors Germany are the higher education sector, the government and private non-profit sectors and the business sector.

The higher education sector (universities, comprehensive universities, Fachhochschulen) has a share of about 19 per cent of R&D expenditure in the gross domestic expenditure in Germany, with a focus on natural science (28 per cent), medical science (26 per cent), engineering science (19 per cent), humanities and social science (19 per cent) and, agronomy (5 per cent). Research in the higher education sector receives substantial funds from the German Research Foundation (DFG), its largest provider of external funds.

The government and private non-profit sectors include research institutions owned by the Federal Länder and local governments, such as Länder institutions with research functions. They perform research tasks which contribute considerably to fulfilling the departmental functions of the various ministries, e.g. in the areas of agriculture, health, environment, materials, raw materials, metrology and defence. The private non-profit-organizations (national research centres, institutes of the Max Planck Society (MPG) and the Fraunhofer Society (FhG), research institutions from the Blue Lits, Academies of Sciences, scientific museums, libraries etc.) and government research institutions receive 15 per cent of gross domestic expenditure on R&D. Non-university research institutions and projects are jointly funded by the Federal and Länder governments.

The third and largest research sector is the business enterprise sector which has the research facilities of business and institutions for cooperative industrial research and development. At present, they account for about 66 per cent of domestic R&D expenditure (1991: 69 per cent).

2. R&D-Financing Sectors

The largest R&D financing sector is the business enterprise sector (61 per cent: 1994); the Federal and the 16 Länder governments rank second (37 per cent), private institutions and the external sector contribute about 2 per cent. Since the late 1980s the business sector´s share has been declining (1989: 63 per cent), while the contribution to financing national research and development by government and the external sector has grown. However, internationally in terms of industry´s contribution to financing, Germany still has a leading position among the G7 states, behind Japan (68 per cent) and ahead of the United States (59 per cent). In Sweden and in Switzerland the business sector makes a similarly high contribution to R&D financing (62 per cent and 67 per cent respectively).

Figure 1, shows in a short and simplified way the structure of the German system of financing R&D in general.

Figure 1
Report of the Federal Government on Research 1996

B. Public Funding of Research for the Development of ESTs

1. Data Sources for the Study

It is different to analyse EST from statistics because EST is not in one single branch. German statistics are structured according to sectors (information, services, manufacturing, agriculture) or branches, in all of which ESTs are included. In addition, ESTs are funded from different departments of the Federal and state governments. Another problem is the use of the term EST, as definitions vary in some cases (but only in details) so that the comparison of different studies and analysis may be vague.

The following analysis is based on data extracted from research reports of the Federal Government and some of the states. The most detailed information was available for the expenditure of the Federal Government (Federal Ministry of Education, Science Research and Technology (BMBF)) and was taken as the main basis for this study. Some examples from special foundations with environmental concern (Bundestiftung Umwelt) and from the Länder are also considered. A questionnaire which was distributed to selected institutions provided additional information. Some previous research studies were also taken into account, such as a 1996 study conducted by the Fraunhofer-Institut (FhG-study) evaluating the funding of ESTs by the BMBF during the period 1980 to 1992.[1] The analysis however, does not consider public funds being granted by specific federal or state departments or public grants.

2. R&D Funding Priorities

EST`s are mainly part of the funding area F (environmental research and climate research), but can also appear in other funding areas such as energy research and energy technology (funding area E) or innovation and improved basic conditions (funding area T). (BMBF; Report of the Federal Government on Research 1996, Abridged Version, p.130). Total funding allocated to environmental concerns, is estimated at between DM 2.5 and 5.4 billion. The estimates are so wide because of difficulties in estimating which share of general funding programmes grant funds for environmental concerns or subsidies such as reduced costs of credits for investments, etc. This funding practice enabled Germany to perform a leading role in the international market for EST (18.5 per cent of world trade) and made German industry competitive in this important future market. (BMBF, Report on technological competitiveness of Germany, 1996, p.45)

Funding area "F" of the Federal R&D policy: Research for the environment

The following describes the objectives of the Federal Government´s research and technology policy in the R&D area F: Environmental research and climate research.

The purpose of government-funded environmental research in Germany is to show policy-

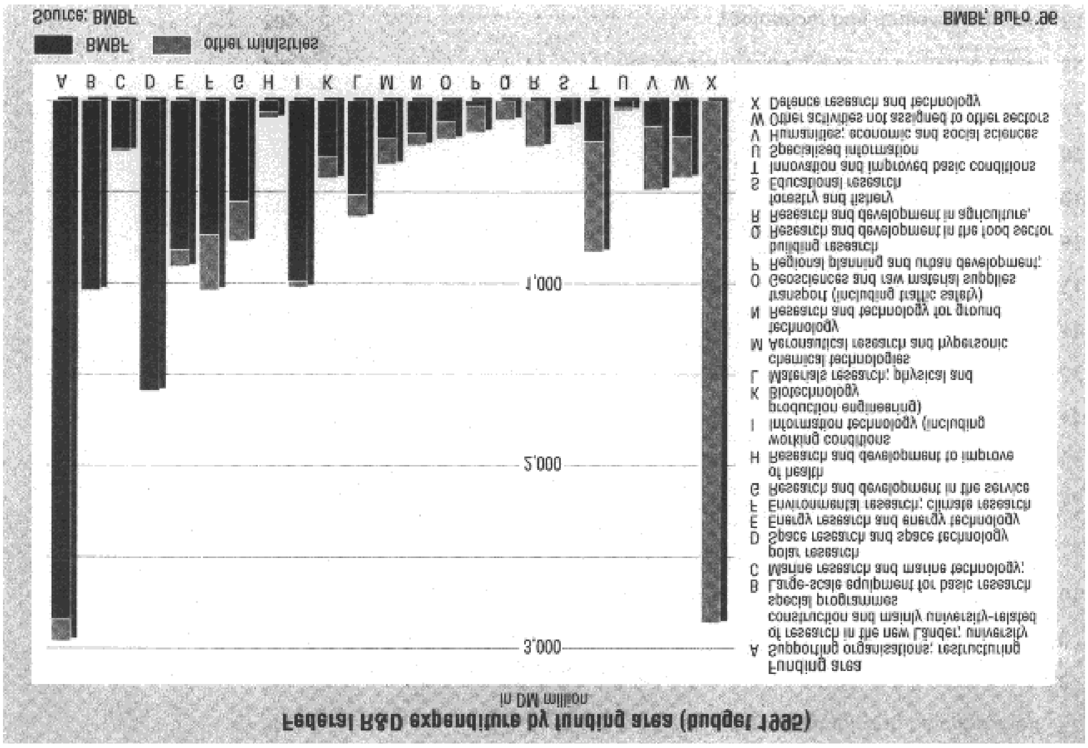
1. G. Angerev et al. (1997). *Wirkungen der Föderung von Umwelttechnologie durch das BMBF*, Berlin.

makers, industry and society, where human interventions in natural ecosystems pose a threat, and how these threats can be avoided. In many cases it has been possible to avoid environmental hazards from the outset and to conserve resources by applying technologies which integrate environmental protection into production processes and products. In the past few years new findings on the environment and more environmentally sound behaviour based on these findings have led to considerable improvements in Germany´s environmental situation.

Since the Rio-Conference in 1992 the government research policy has pursued the objective of "sustainable development". To this end, the German Government considers it necessary to define environmental objectives to create scope for innovation. The Federal Government has created the general framework so as to encourage competition during the search for the best solution in each field to attain these objectives, so as to create incentives for innovations which will foster sustainable development. The use of market economy instruments and the increasing internalization of external costs to enforce the "polluter pays" principle will play an important role in this context. Environmental aspects are major criteria in the German research policy in taking decisions on research funding. When it comes to funding research in the field of environmental technology, the direct primary objective is environmental protection. The purpose of research in this field is to develop and use innovative methods and processes which will help, where possible, to avoid adverse man-made effects on the environment (or at least to curb them) and to avert potential hazards from existing environmental pollution.

The Federal Government´s Environmental Research Programme specifies three key areas of research: participating in defining environmental objectives, creating new technologies and action strategies for sustainable development and, greater emphasis on accelerating the practical application of research findings.

Figure 2
Federal R&D expenditure by funding area, Budget 1995
(in DM million)



3. Funding sources

Figures 1, 2 and 3and Table 2 show the development of R&D-expenditures (funding area F2: EST) of the Federal Government (all federal ministries) on ESTs from 1981 to 1996 (million DM). The share of EST-funding by the Federal Government did not vary much over this period. In addition to funding area F 2, other funding sources (energy research and energy technology (E) or innovation and improved basic conditions (T) etc.) also fund ESTs, but there are no explicit data available.

Table 1
Development of R&D expenditures for EST 1981-1996

	1981	1985	1990	1991	1992	1993	1994	1995*	1996**
R&D expenditures of the Federal Government	10447.8	12834.7	15214.5	16926.5	17338.9	16859.8	16347.6	16938.3	17613.3
Funding area F2: Environmentally Sound Technologies	223.9 2.14 %	266.9 2.08 %	253.5 1.67 %	331.4 1.96 %	364.2 2.10 %	355.7 2.11 %	344.9 2.11 %	372.8 2.20 %	396.2 2.25 %

Notes: * = target
** = expectation of the Federal Government
Source: BMBF; Bundesbericht Forschung 1996, pp.542-543.

Bundesstiftung Umwelt (DBU) is another important source for funding research on the environment. The Deutsche. In 1996 the Deutsche Bundesstiftung Umwelt, which gives detailed information on projects, it funds granted DM 21.26 million for 61 projects on the topic "Future-oriented environmental management, products and technologies" (1995: 61 projects, DM 19.42 million); 48 projects on the area "Innovative process technologies received funds in an amount of DM 11.77 million (1995: 64 projects; DM 18,94 million) and, in the third area,"Rational use of energy and renewable energies", 48 projects were funded with DM 12.57 Million (1995: 57 projects, DM 28.37 Million). The results accruing form funding by the Deutsche Bundessstiftung Umwelt had to be reviewed on a case basis as a general analysis was not available.

4. Funding areas

The above-mentioned FhG-study analysed 1,402 projects funded by the BMBF with research costs of DM. 2,473 Billion. DM 1,264 Billion were granted by public foundations which makes BMBFs funding proportion 51 per cent. (ISI-FhG-study, p.13). The study also found out that the proportion of public funding decreases with the size of the project.

The report on research of the Federal Government does not specify special data on funded projects and types of EST`s. For a more detailed analysis it is necessary to rely on the ISI-FhG-study and on Angerer et.al. (1996), who defined four funding areas and classified the 1569 analysed projects according to this cluster. Some of the projects concerned more than one funding area so they were considered in all related areas.

Table 2
Funding areas and number of projects

Funding area	**Number of projects**	**Funds (million DM)**
Technologies for the prevention of air pollution	368	440
Water balance:		
- prevention of water pollution;	858	669
- preparation of drinking water, water supply; and,	252	209
- purification of sewage, treatment of sludge	606	460
Waste management and dangerous waste from the past:		
- avoidance and exploitation of waste;	431	700
- treatment and depositing of waste;	178	186
- renovation of dangerous waste from the past	253	514
Research on security and safe technology	116	71
Totals	1569*	1547

Note: * = some projects concern to more than one funding area
Source: Angerer et. al., 1996, p.19

The ISI-FhG-study analysed 1,402 projects and divided them into four funding areas:

1. water technology
2. waste
3. prevention of air pollution
4. processes and products containing a low level of harmful substances

Table 3, shows the distribution of funds to the four areas (1980-1992), and Table 4 shows the share of public funding.

Table 3
Distribution of funds in four funding areas 1980-1992

Funding area	**Number of projects (%)**	**BMBF-funds (million DM)**
Water technology	49 %	502
Waste	24 %	421
Prevention of air pollution	7 %	77
Processes and products containing a low level of harmful substances	14 %	187

Note: n = 1,402
Source: ISI-FhG-study, p.19

Table 4
Per centage of public funding

Funding area	Total costs (million DM)	BMBF funds (million DM)	% share of public fundingf
Water technology	904	502	55.53
Waste	1007	421	41.81
Prevention of air pollution	127	77	60.63
Processes and products containing a low level of harmful substances	342	187	54.68

Note: n = 1,402
Source: ISI-FhG-study, p. 21

The DBU mentions every single funded project in its yearly report on funding activities. However, the projects are not classified so that it is difficult to identify ranges or types.

C. Current Developments in the Research System and Implications for the Federal Technology R&D Policy

The declining growth rate of industrial R&D expenditure, German unification and the reconstruction of East German research, have changed the structure of the German research system over the last few years. As a result the share of the business sector fell, while that of the Federal and Länder governments increased as non-university research institutions and especially higher education institutions were built and expanded. Owing to its multiformity, German research can rely on a viable broad-based foundation which-from the government´s perspective - needs to be strengthened. In close consultation with the Länder governments, the science organizations and research institutions the Federal Government has identified the objectives of task specification lean research, networking and internationality, as the so-called future challenges of R&D policy.

1. From research to innovation: integrated research policy approach

The integrated research policy approach of the Federal Government aims to bring together science and industry at the earliest possible stage. It is designed to provide a better framework conducive to innovation. To take better advantage of the research potential in Germany, which is considered generally as excellent, it is necessary for researchers and users to engage in early consultation on priority themes and issues. To this end, pilot projects are being introduced as new instruments of a research funding policy. These pilot projects are designed to promote the development of fundamental innovations in order to:

- Ensure that the best solutions compete for implementing substantial innovations,
- Safeguard and strengthen Germany´s position as a production location,
- Develop innovative networks involving both science and industry,
- Develop innovations in interdisciplinary and cross-sectoral projects,
- Use distributed know-how in a cooperative manner and
- Ensure fast and wide spread dissemination of knowledge.

The function of the pilot projects is to combine exacting tasks with specific application perspectives and bring together different disciplines and applications. The Federal Government expects the national research centres to continue to intensify contacts between science and industry at all levels. One step towards closer cooperation between research institutions and industry could be that the institutions take on service functions in particular with regard to future Cooperation with SMEs. To strengthen these companies´ competitiveness research institutions should be enabled to offer them access to laboratories and pilot facilities and, direct assistance by scientists experienced in the technology areas concerned.

The adequate organization of the *transfer of knowledge and technology* from science and research to industrial application is considered as a key factor in maintaining Germany´s competitiveness. The Federal Government has used various channels to support this transfer of knowledge and technology. Such channels include programmes intended to encourage contract research, and research corporations to establish closer links between research and the practical application of its results. A general trend that can be noted in government policy to improve the transfer of technology, is a gradual shift towards direct transfer between universities/research institutions and businesses. Recent studies have confirmed that technology transfer works better if industry and science are involved in relevant joint projects at a very early stage, rather than passing on technological know-how to future users.

2. “Visions” of the Federal R&D policy

The strategic orientation of the future Federal R&D policy has been laid down in so-called "visions" that should provide overall guidance principles to R&D activities. This strategic re-orientation of the Federal R&D policy was published in June1996. The visions address in particular, the organization of R&D by re organizing the tasks of the public research institutions. The priority areas were developed jointly between industry and the science sector under the guidance of the Government. The idea behind it is to improve the co-ordination of R&D efforts by directing them to certain issues (R&D priority areas). These issues should identify these priority areas where benefits from R&D are expected to be the highest.

The six “Visions”areas are the following:

1. High technology for manufacturing and services
2. Opportunities for Germany offered by biosciences and biotechnology
3. The future of the information society
4. Energy and the environment
5. Mobility - decoupling growth and economic resource consumption
6. Competitiveness through international Cooperation

"Vision" area 4, "Energy and the environment", which is considered as the most relevant in the context of this study, is described in more detail below.

“Visions “Area 4: energy and environment

The guiding principle of sustainable development, which is the basis of the Government´s policy objectives, broadens the horizon of environmental research. The object of research is not the isolated environment system alone, but the interactions between ecological, economic and social developments. There are three major areas within the Government´s research policy where new knowledge needs to be generated, new technologies developed and policy concepts drafted:

- Safeguarding natural resources
- Sustainable management
- General framework for ecologically sound action

The Federal Government considers technical innovations to be the main pillars of sustainable management. Environmental technology must develop and improve the expected technical solutions for waste water and sludge treatment, for reducing soil, water and air pollution, for cleaning up contaminated sites and, for noise reduction, so that immediate effective countermeasures can be taken in those cases where ecological limits have already been exceeded. One of the objectives of environmental research which is focussed on the principle of sustainability will be to integrate environmental protection into production processes and products.

Technical products and services designed to protect the environment are gaining more and more economic importance. Their rating in world markets will increase considerably. It is the very clear target of the German Government to support Germany´s role as a provider of high-quality environmental technologies and, to retake the leading position in the world market. To strengthen German competiveness and, at the same time, reduce environmental pollution further innovation is considered to be needed in the technical, economic and social areas. One of the central objectives of the German Government is "clean production". It is government policy that down-stream end-of-pipe technologies have to be complemented and replaced by integrated solutions which do not give rise to undesirable environmental pollution. In this context, product-integrated and production-integrated environmental protection is playing a key role in the federal research programmes. The objective of this innovative research approach is to cover the entire chain from raw material use to processing, manufacture and use of a product to its return into the product, cycle.

3. The new environmental research programme of the Federal Government

In September 1997, the Federal Government (BMBF) passed the new programme "Research for the Environment" (Forschung für die Umwelt). This programme was initiated under the overall guidance of the Federal Ministry of Research in Cooperation with the Federal Ministry for the Environment. For the first time, this programme embraces all activities in the areas of environmental research including the financing of all activities. The intention of the programme is to contribute more systematically to the future-oriented utilization of world resources and to the other environmental research activities such as climate and atmospheric research. The new Environmental Research Programme is not an academic concept. All scientific stakeholders including industry, trade unions, local authorities, NGO´s and scientific organizations have been involvedin its development. The programme is designed to give incentives to industry and society at large to contribute to a further safeguarding of nature and the living conditions of mankind.

Environmental research that focuses on the development of environmentally sound products, production processes and technologies is considered a key element for sustainable development. At global level, a considerable increase in so-called eco-efficiency is needed, particularly with respect to energy and material use. The Federal Government also believes that to solve global environmental problems, in addition to eco-efficiency, basic innovations are needed in the long run. Such basic innovations should open new basic development paths for environmentally more sustainable technologies and products. In order to reach both targets, new innovative potentials in industry and science must be encouraged, in addition to eco-efficiency and basic renewal of products and production processes that lead to sustainable development

The observance of environmental standards is crucial condition for industry to compete in the global market. To produce at lower costs under the same environmental standards will become more and more important in the near future. Therefore, efforts that lead to cost minimisation in environmentally preferable products and commodities are considered of highest significance by the German Government since this implies a strengthening of German industry in general.

Targets of the programme. The main target of the new environmental research programme is to find incentives for the promotion of new technologies and to develop the appropriate framework with basic conditions for their successful implementation. This target can be reached only with the total involvement of all existing scientific and technological capacities. Hence, this new programme should promote science and research as well as technological development in order to activitate existing potential and, to initiate those R&D efforts in science and industry that reduce unwanted ecological side-effects and promote sustainable development paths.

The approach to involve the complete range of scientific and innovative options into environmental protection policies goes far beyond the previous government programme "Environmental Research And Technologies" that ended in 1994.

The new programme has three main target areas:

1. Ecological research;
2. Research in the field of environmental technology; and
3. Environmental education.

Since in the context of research in the field of environmental technology the role of publicly funded EST should be emphasized, target area 2 which refers also to sustainable consumption and production patterns, way is examined in more detail below. This part of the programme addresses both technical and social innovations and is designed to activate the innovation potential of industry and society. All supporting research activities focus on the following three areas:

1. Supply-side: firstly at company level, with cleaner production through process modifications (Produkt- und produktionsintegrierter Umweltschutz PIUS) and end-of-pipe-technologies; (which are considered to be necessary in the future as well), secondly, industrial sectors and material flow management (recycling technologies).

2. Demand-side the consumer at household level where the consumption patterns demand for food, housing, and transportation might be changing.

3. Regional-level to identify ways and means for regional sustainable strategies under global market conditions.

The programme gives priority to the promotion of environmentally sound technologies that allow cleaner production processes. For industrial sectors priority is given to technological efforts that lead to sound material flow management. It is underlined in the programme that technological solutions alone are not enough to solve the biggest environmental problems. Links with all other scientific, technological and institutional capacities are also needed. Pollution prevention is not only a matter of technology: it involves planning and organization, common sense, an innovative attitude, and good housekeeping - in other words, sound management practices. It is important to minimize waste at all stages of a product´s life cycle so that the overall "environmental content" of a product can be optimized. The transfer of pollutants from one medium to another is not a solution. The new environmental research programme should address all these issues through an integrated and interdisciplinary approach.

In the past few decades environmental protection has been mainly focused on the development and successful use of end-of-the-pipe remedial technology which however, has entailed additional costs. Today´s key impetus comes from the idea of integrating environmental protection into production. In many cases, developing environmental protection measures which are integrated into the production process provides a better opportunity to improve both ecological and economic conditions. This new development was reflected by a new funding programme called PIUS which was initiated in 1994.

- Biotechnology (including genetic engineering) for the remediation of contaminated soils and to reduce the use of pesticides in agriculture.
- Information and communication technology for the reduction of traffic-borne environmental pollution.
- Research for new materials to reduce fuel consumption and noise in airplanes and automobiles.

There is enormous potential to link existing knowledge through interdisciplinary approaches to reach sustainable targets. It is therefore, the target of the Federal Government to promote such approaches much more systematically.
With respect to clean production, low- and non-waste technologies (LNWT) and other ESTs. The focus of the new Environmental Research Programme is in the field of clean production patterns with the following criteria:

- Minimization and rational use of energy and material efficiency in industrial production
- Avoiding or minimizing harmful emissions from production processes
- Material substitution
- Substitution of harmful production processes and products
- Environmental performance of products while in use and after use
- Primarily recycling of solid, liquid and gaseous emissions
- Avoiding waste and reuse of unavoidable waste
- Auditing of all steps of production processes
- Energetic use of waste from non-recyclable production processes
- Recycling of old products in the same or similar production processes (secondary recycling)

Technologies to optimization general waste management, remediation of soil water purification, air quality, noise abatement and safety will also be promoted. This includes end-of-pipe-technologies in all cases where other prevention solutions are not available.

Economic importance of the programme. The Federal Government considers Germany one of the most active countries in the area of environmental protection. More than DM65 billion, are spent for this purpose each year and. today about 956,000 people are employed in environmental fields. According to of the Deutsches Institut für Wirtschaftsforschung, it is likely that this figure will increase to 1.1 million in the year 2000. Therefore, the new Environmental Research Programme also creates opportunities for new jobs and, will strengthen the position of German companies in global markets. Germany still has a strong position in environmental technology. Environmental technology products will become more important, in world markets, a situation for which German industry is well prepared. However, Germany is no longer the largest exporter of products which might be used for environmental protection as it used to be in earlier years. Today it is the United States which is leading, with a world market share of 19 per cent, ahead of Germany (with just under 18.5 per cent) and Japan (13 per cent). The German Government´s clear target is to retake the lead in the world market. This can only be achieved through pioneering innovations and superior technologies on a global scale.

In view of the economic importance of environmental technology, the Federal Government intends to use the new Environmental Research Programme to initiate new partnerships between industry and the scientific community to develop new environmentally sound technologies in the above described areas. The aim is to create new, so-called. "centres of competence", for environmentally sound technologies. These centres would also promote the transfer of these ESTs into practical applications.

Efficient environmental protection policies are costly. Despite the fact that public awareness in Germany for environmental issues is much strong than elsewhere in the world, environmental protection has not been cost-effective for the tax payer: while the cost of living increased about 20 per cent from 1991 to 1995, the cost of drinking water was increased by about 40 per cent, for wastewater treatment about 60 per cent and, waste management 80 per cent. This is due to lack of competition. Therefore, this programme aims to minimize cost and make Germany more competitive.

The Federal Government contributes about one billion DM annually to programme co-ordination and financing programme co-ordination and financing. About three quarters come from the budget of the Federal Research Ministry. Most funds, namely DM 600 million - will go to basic oriented environmental research outside universities. About DM 400 million will be available each year in the future for application oriented research in concrete research projects; some DM 300 million will be provided by the Federal Research Ministry for this purpose.

D. Research Funding Policies at State Level

The 16 states have several programmes for funding EST. Some states have even created special programmes for this purpose, others grant funds from basic programmes for innovation or environmental activities. Not all of the departments in the states responded to the questionnaire so the survey can not provide a complete overview of funding EST by the Länder.

In general, it must be underlined that the funding policy of each state government is very different. The responsibility for funding research on EST is shared by several departments in the Länder (Departments for Science and Education, Departments for Economics and Technology and Departments for Environment).

1. Funding instruments

There are two instruments in the context of public funding of R&D:

- project funding (single projects, cooperative projects)
- institutional funding

According to the 1996 Report on Research of the Federal Government the higher education sector has a share of R&D expenditure of 19 per cent 15 per cent go as to private research institutions and 66 per cent to the business sector. More detailed information about the reasons for project or institutional funding is not given in this report.

Answer to own questionnaire provided farther on this topic. Both institutional and project funding seem to be necessary. According to MUNR, Brandenburg, "Research needs time for the development of technologies. Institutional funding definitely is required because of short budgeting periods and the resulting financial pressure. Project funding makes sense, when funding is possible for more than one year. Otherwise only small and short projects help to improve innovations or the financial situation (cofinancing)." The departments for Science and Education of Lower Saxony and Rhineland Palatinate remarked that the success does not depend on the type on funding; institutional funding can be regarded as a basis, with project funding adding to it.

Funding policies differ from state to state. Some state governments only fund projects (DBU, some departments in the states) other fund both institutions and projects (BMBF, some departments in the states).

II. DIFFUSION AND COMMERCIALIZATION OF PUBLICLY FUNDED ESTs

The FhG-study analyzed the degree of commercially viable projects. About 25 per cent were already marketed, 7 per cent were used for internal use and, 5 per cent could be exploited in the future. In the sample survey, which corresponds to other sources about research on innovation, the reports states that one third of the projects tend to be marketed successfully. Realized exploitation (through external commercialization and application by other users or internal use) of the results of funded projects. (ISI-FhG-study, 1997).

Table 5
Commercially exploited EST Projects

	Projects		**BMFT*foundation**		**Total costs of projects**	
	number	%	Million DM	%	Million DM	%
Project application	436	100	409.4	100	813.6	100
External commercialized results and results used by other users	107	24.5	86.2	21.1	146.3	18
Internal use of the results (ready for application at the end of the project)	29	6.7	47.6	11.6	175	21.5
Total EST projects Exploited	136	31.2	133.8	32.7	321.3	39.5

Source: BMBF previously BMFT

The FhG-study states that two thirds of the projects which were implemented, were commercialized or have starter to enter the market. Nearly three quarters of the users judged the ESTs positively in compared to previously used technologies.

A. Impediments to Commercialization

The main impediments to commercialization are the high costs of the new technologies, the lack of information on these new technologies and, the fact that the products have not yet reached technological maturity. Licencing and a lack of regulations are less important. In the FhGstudy all enterprises and institutions which received funds were asked for the main reasons that prevent new technologies from being commercialized.

The following table shows a summary of the answers. The survey takes only those projects into account which have been, or should be commercialized and, which were considered to be successful from the technical point of view.

Table 6
Survey of commercialized EST Projects

	% business enterprises	**% public enterprises**	**% institutions n=296**
number of projects	**n=257**	**n=94**	
new products too expensive	37	3	27
technology not yet marketable	27	17	35
lack of information on potential users	20	23	41
costly /long licencing period	24	20	23
new technical competitors solutions from	24	13	16
financial problems during commercialization	11	3	25
lack of regulations	12	13	15
lack of infrastructure for ditsribution	11	7	16
Investment cycles slowing down diffusion	9	13	13
lack of market know-how	5	13	14

Source: ISI-FhG-study, p. 71.

B. Regulatory effects

In 1996 Angerer et. al. evaluated 1,569 projects with total funding of DM 1,547 billion (51 per cent) of which was public funding. 567 projects (36 per cent) had regulatory effects; they received funding of DM 690 million (45 per cent). 17 per cent of the projects (25 per cent of public funds) had decisive influence on legal regulations. 20 per cent of the projects gave support to regulatory activities.

The table below shows which funding area the projects with regulatory effects belong to. (Angerer et.al. (1996), p.22)

Table 7
Funding areas and projects with regulatory effects

Area	Projects with regulatory effects			
	Number of projects		Funding	
	Number	Share*	DM Million	Share*
Technologies for the prevention of air pollution	84	23	119	27
Prevention of water pollution, preparation of drinking water, water supply	170	67	69	81
Purification of sewage, treatment of sludge	160	26	205	45
Avoidance and exploitation of waste	83	47	117	63
Treatment and depositing of waste, renovation of dangerous waste from the past	70	28	120	23
Research on security and safe technology	24	21	16	22

Source: * referring to table 8.

Angerer et. al. also come to the conclusion that public funding of ESTs by the BMBF gave major support to environmental legislation and widened the scope of action for environmental policy in general.

C. Technical and Scientific Effects

Public funding of ESTs helps to solve the most important problem of the recipient enterprises and institutions, namely to overcome the lack of financing for R&D. Cooperative research supports the transfer of technology, but implies the possible danger of a too close relationship to industry. Additional multidisciplinary approaches are considered less important with consequent advance effect on innovation.
For research on basic questions Cooperation between different research institutions should be supported. (ISI-FhG-study, p. 168)

D. Patenting and licensing

Applications for patents are an indicator of the scientific and technological success of publicly funded R&D-projects. In spite of some problems in using this indicator (different possibilities of patenting inventions, different patenting behaviour), patents indicate the degree of innovation and the competitiveness of single industries. The technological competitiveness of Germany is determined by patents for the world market and by participation in key technologies, which promise economic growth and employment, such as EST. Using this indicator, the United States and Germany are leading in the field of EST. Today one third of the patents on EST come from Germany, one quarter from the United States and the rest is shared by all other countries.

Tables 8 and 9 show the position of Germany in patenting ESTs. (BMBF, Report of the BMBF on the Technological Competitiveness of Germany (1996), p.45, 72)

Table 8
Average change of application for patents in Germany

	RPA*	Average change of application for patents at EPA** 1989-1994 %	
Areas	**1991-1994**	**Germany**	**Total**
Environment	34	1	-1
Prevention of waterpollution	30	5	-1
Recycling	48	5	3
Waste	33	2	4
Prevention of noise	40	27	7
Prevention of air pollution	35	-8	-6
Measurement technology	-5	-8	-5

Note: *RPA=(relative patententing activities): positive value means that the share of patents in this sector is higher than the share of patents in general; **EPA= Europäisches Patentamt
Source: Germany´s patenting postion in key technologies

As the patenting specialization of selected countries in key technologies shows, Germany has definitely concentrated on its specialization on EST.

Table 9
Germany's patenting position in key-technologies

Country	Microelectronics	Multimedia	Biotechnology	Environment
Germany	-55*	-73	-59	34
United Kingdom	-43	-9	46	12
France	-36	-10	-13	2
Italy	-50	-87	-61	-15
Netherlands	18	10	23	11
Switzerland	-60	-77	-14	21
Sweden	-83	-29	-30	25
Canada	-81	21	60	35
United States	12	44	42	-27
Japan	62	20	-28	-38

Source: *RPA 1991-1994

E. Institutional mechanisms for technology transfer

The states have build a widespread net of agencies and centres for the transfer of technology (transfer of technology serves the exchange of know-how, and helps to ensure that R&D leads to marketable products.). Saxony for example, has built such a network comprising 40 centres and agencies. These centres help entrepreneurs starting a new business with high-technology and innovative products or services, to enter markets. Experience with centres for transfer of technology show that the development of projects accelerates, if the technology is transferred directly. The centres and agencies give advice for establishing new technologies, give information about funding possibilities, help with financing and help to make contact with universities or advisers. Some of the centres are specialized in the transfer of EST, e.g. in Lower Saxony the transfer of EST is coordinated by the FUT (Coordinating centre for EST) in Clausthal-Zellerfeld.

Another special federal initiative for the transfer of technology is supported by the federal department for environment (BMU). The BMU does not grant funds for R&D on EST, but the research plan for environmental concerns in 1997 includes the funding of projects related to transfer of technology in the field of EST. To support this idea, the International Centre for the Transfer of

Technology on EST (ITUT) was established in Leipzig. ITUT´s concern is to ensure Germany´s leading role on ESTs and to strengthen the technical, scientific and political Cooperation on environmental topics between Germany and partner countries.

F. The role of universities

"The university as little-known genius" - this is the typical way the private sector very often thinks of universities. Many companies and industries still consider academic institutions of higher education and research as "ivory tower" in which no earthbound activities take place. This common view is regrettable and wrong. Today it is indispensable for both universities and industries to cooperate closely. Many problems in R&D can be solved only through joint ventures and projects, especially in application-oriented research. But experience shows that it is not possible to solve such problems just by calling the technology transfer agency of a university. Furthermore, the provision of consultancy from universities as a service to companies is not the correct approach. Better to establish long-term research links with mutual benefits for universities and industry. Such close Cooperation can be sustained through joint research projects, the development of prototypes or, the involvement of graduate students into projects carried out by companies.

Another modality for companies to cooperate with universities is the establishment of a so-called “promotion association” to support the university and, through which a steady exchange of information and research contacts can be made. One example of this is at Dortmund University, the FFU e.V., the Förderverein Forschungszentrum Umwelttechnologie e.V. (Environment Technology Research Centre Association). Its aim is to promote Cooperation between the University of Dortmund and companies in the important field of environmental technologies.

III. TECHNICAL COOPERATION WITH DEVELOPING COUNTRIES

The Federal Government’s policy is to improve the capabilities of developing countries and hence their development and prosperity through scientific and technological Cooperation . Total funds appropriated by the BMBF for ongoing projects with developing countries amount to about 330 DM million. These projects, which also have specific research objectives, complement the development schemes of the Federal Ministry for Economic Cooperation which support, among other things, the development and improvement of scientific and technological infrastructure (higher education, technology centres, research institutes) in developing countries.

BMBF activities aim in particular, to extend national research programmes, provide access for German industry and train internationally experienced, skilled manpower by:

- developing and testing new technologies for use in developing countries,
- adapting processes and technologies commonly applied in industrialised countries to the conditions prevailing in the respective partner country,
- transferring scientific and technological knowledge to strengthen the R&D capacities and economic performance and competitiveness of developing countries.

Environmental related funding and support focus on the following priorities:

Energy research and energy technology: most important are the utilization of renewable energies which in fact is the most extensive field of Cooperation with developing countries, and coal technology. Projects relating to the use of solar and wind energy receive priority funding. These projects focus on developing, testing and adapting photovoltaic systems and wind generators for drying, cooling, air-conditioning, for pumping water and for decentralised electricity generation in rural areas.

In environmental research the study of tropical ecosystems is becoming more and more important. Projects aim to deepen the knowledge of the mechanisms of action within ecologically important biosystems and develop concepts for their ecologically sound utilization. In addition, they are intended to improve environmental management strategies and environmental protection in the partner countries.

Cooperation in the field of environmental technologies focuses on developing and adapting low-emission technologies for use in developing countries. Important activities are the development of ecologically sound manufacturing processes, sewage and waste treatment and studies of soil and air pollution

IV. CONCLUSIONS AND LESSONS LEARNT

In Germany, publicly funded R&D for the transfer and diffusion of ESTs can be considered in Germany as a giant programme for promoting the economy. The objective of this policy is to strengthen the competitiveness of German industry. The target is to regain the world market leadership in environmentally sound technologies. This lead position of the German industry should enhance the competitiveness chance of German industry within the globalization process. The development of marketable products can be facilitated through the identification of priority areas for the orientation of R&D activities. Re-oriented R&D policy can be realized by the formulation of pilot projects. Competition in R&D in order to manage scarce resources is a key issue of this policy. The main background is constituted by a partnership between the State, industry and science that should through partnership, come to an agreement on a common R&D policy.

1. Government programmes

The Federal Government has given high priority to supporting research into future needs and implementing its results. Therefore, it.

- Has already developed (September 1997) the new environmental research programme aiming in particular at investigating ecosystems and the conditions of their preservation and development based on the principle of sustainability. It also works, towards the further development of environmental protection technologies and production-integrated environmental techniques to improve the process of protecting the environment in terms of both cost-effectiveness and economic competitiveness

- Will present a new energy research programme designed to achieve the Federal Government´s objective of reducing CO_2 emissions by 25 per cent through tapping additional energy conservation potentials and supporting renewable energies and their commercial uses and,

- Will develop a new concept of mobility to ensure optimum mobility through intelligent transport networks, at the same time substantially reducing resource consumption and environmental pollution.

2. Market-orientation of funding

With regard to future German Government funding of research and technology, major changes are crucial in older structures and mechanisms. This applies both to institutional funding of research institutions and to project funding. The situation is characterized by the scarcity of funding. The BMBF budget is at present stagnant; the same is true for industrial research funding. Major cuts have had to be accommodated, which may however, stimulate the search for new solutions and increase efficiency.

The R&D budget has shrunk by more than the average reduction in public expenditures and is perhaps the most important factor affecting the federal R&D policy. This leads to the idea to `spend the scarce resources in an even more intelligent way. Politically the budget cuts are used for a basic reorientation of federal R&D policy. Leading to the formulation of a so-called “integrated research policy”. This means that all publicly funded research activities will become much more market-oriented and the efficiency of publicly owned research institutions should be increased considerably by introducing market competition.

3. Introducing market mechanisms in R&D

The attempt to bring more competition into research institutions mainly as a response to the increasing scarcity of funding. seems very challenging. The BMBF is currently reducing the basic funding but allowing them, in addition toraising third-party funding, to compete for government funding from a so-called strategy fund. It is also important, that project funding be focused on interdisciplinary pilot projects, which, are considered priorities for research policy reasons.

4. ESTs as driving forces for innovation

The promotion of high-technologies for environmental protection as drivers of innovation is among the focal points of this integrated policy approach, since German industry is coming under increasing international competitive pressure in the field of advanced technology products. The central tasks of science and research are considered as the vital bases for finding answers to urgent questions of our time such as environmental hazards. No global dangers can be solved without scientific and technological progress. The interaction of demographic growth, energy consumption and pollution of the atmosphere alone, shows that scientific and technological progress opens up opportunities for sustainable development.

5. Strengthening of the competitiveness of industry through publicly funded ESTs

German industry intends to concretize the vision of an energy efficient society in the priority area "energy and the environment" through R&D (pilot) projects on fuel cells, new insulation materials and combined-cycle high efficiency power stations. It is clearly understood that all pilot projects are oriented towards global needs and not only to local needs in Germany. Possible examples are the development of environmentally friendly automobiles and traffic management systems for urban areas. Other environment related pilot projects are in the fields of biotechnology for arid areas, the optimization of animal feeding, and water management systems for mega-cities in developing countries. Industry expects to reduce considerably the time frame from the development of a new technology to market penetration through such re-orientation and clear concentration of R&D policy. Focusing on these priority areas should help Germany to fully exploit its comparative advantages in the global market. Therefore, these priority areas focus in general on the R&D areas where Germany is already strong or even in a lead position.

6. Internationality

Finally, the environment related research policy of the Federal Government aims to use German innovation potential as an argument for multilateral negotiations at the international level. International standards established by intergovernment agreements are supported by the Governmnet for that reason enhance to the competitiveness of German industry in the global market.

German industry is encouraged by the Federal Government to adopt the highest environmental protection standards and accordingly develop technical solutions at a high technology level. Although industry sometimes is very reluctant to adopt even more stringent environmental standards as in other countries, the Government argues that adopting the highest environmental standards in Germany would improve the competitive chances of German industry in the global market. The reason for this is because all countries generally tend to adopt the latest state-of-the-art technology for their own industry. The aim of this policy is to offer the world market reference technologies made in Germany.

7. Common R&D policies of the public, private and science sectors

It is considered that, science should be encourage to work with industry in a much closer way. As is the case in other countries. Therefore, industry associations and scientific associations have agreed upon pilot projects to improve the funding of research projects in general. All research projects should be oriented towards these pilot projects. Industry as the implements of new and emerging technologies should be involved in the research process from the very beginning. One consequence should be that universities would cooperate much closer with industry which will also facilitate finding jobs for students.

Through closer collaboration with industry, research institutions could also find better ways for diffusion and market penetration. At the same time, research institutes should compete with each other to obtain scarce research funds. Only the most efficient institutes would get public research funds as a result of this policy.

Despite these intentions there is still the problem that there are no real incentives for public research institutions to diffuse R&D results, broadly. Therefore, under the guidance of the Federal Government, the science sector together with industry has identified priority areas for pilot projects in which R&D funds should be concentrated in the future.

8. The imperative role of the state in R&D

The role of the state is considered imperative for German R&D activities. In Germany publicly funded (civilian) R&D is currently 0.88 per cent of GNP while in Japan it is only 0.47 per cent and in the United States 0.46 per cent. Consequently it is questioned whether the public sector should be involved in R&D. The Federal Government believes that the state is committed to implement R&D policies. According to Mr. Rüttgers, the Federal Minister for Research and Technology, “if the business sector is reducing its efforts in R&D, it would be wrong to reduce the governments efforts as well.” A country with the high salaries of Germany can only compete within globalization through innovations. According to the Federal Government, publicly funded R&D is urgently needed for this. However, publicly funded R&D should be concentrated on application oriented projects.

Germany has lost its leading position with regard to the share of total R&D spending (public and private), and is currently in fourth place among the largest industrial nations. R&D as a percentage of GNP shrank from 4.7 per cent in 1982 to 3.5 per cent in 1996. Public spending on basic research institutions was about DM 5.2 billion. A further DM 4.3 billion was spent on research projects. Public funds for R&D activities cannot be moved easily within the R&D budget because of international commitments by the Federal Government, e.g. for international research programmes in outer space (about DM one billion per year). Consequently publicly funded R&D will be concentrated on certain issues. While such target-oriented research should increase the efficiency of R&D activities and institutions, in fact it is caused by the scarcity resources and competition among research institutions.

Indirect research support measures such as tax incentives or subsidies for the salaries of research personnel no longer plays a role. Until the 1980’s indirect support was important for all R&D activities. Today Germany is the only country among the leading industrialized countries where tax incentives for R&D do not exist. In view of the general situation of the public budgets, this situation is unlikely to change. Only the Innovation Capital Fund for Investment Finance of SMEs of the Kreditanstalt für Wiederaufbau (KfW) will be continued with a total amount of DM one billion per year.

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFUSSION OF ESTs: THE CASE OF THE UNITED KINGDOM

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I. INTRODUCTION

Although the United Kingdom Government publishes detailed statistics of R&D expenditure on Science, Engineering and Technology (SET), it is not easy to separate out the expenditure for purely 'Environmental Technologies'. We have therefore based this report on trends and investment in the general area of SET, highlighting specific references to ESTs where these are available.

Science, Engineering and Technology (SET) R&D in this context includes work described as 'creative' research and development, together with the diffusion and exchange of advanced scientific and technical information, and some postgraduate student support. It does not include the additional scientific, technical, commercial and financial steps that are necessary for the successful development and marketing of new or improved products, processes or services.

The subject areas included in statistics on SET R&D are:

1. medicine, dentistry and allied subjects;
2. engineering and technology;
3. agriculture, fisheries, forestry and veterinary science;
4. biological, mathematical and physical sciences;
5. psychology, geography, economics and social studies;
6. humanities.

The research undertaken in these areas and the statistics derived from it, comply with the key definitions of research and experimental development set out in the OECD Frascati manual. This identifies three main activities;

1. 'basic' research (i.e. not specifically applied to an end use);
2. 'applied' research (research with a specific objective);
3. 'experimental development' (drawing on existing knowledge gained from previous research to produce new materials, products or services).

While the Frascati convention applies to the type of research being undertaken, it does not identify the primary purpose, i.e. why the R&D is being funded from the public purse.[1]

The socio-economic objectives of government funding of SET R&D are described by the EUROSTAT Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets (NABS). Of the 13 mutually exclusive chapters, the following could contain elements related to ESTs:

1. Exploration and exploitation of the Earth;
2 Control and care of the environment;
3. Protection and improvement of human health;
4. Production, distribution and rational utilisation of energy;
5. Agricultural production and technology;
6. Industrial production and technology.

II. BACKGROUND TO UNITED KINGDOM GOVERNMENT R&D POLICY

The United Kingdom Government’s 1993 White Paper on SET set out a policy framework based on the following principles:

1. The need to make judgements about priorities in allocating finite resources (“no one nation can afford to sustain a significant independent presence in all of the burgeoning fields of scientific research”-SET White Paper, paragraph 1.9), and for these judgements explicitly to take account of the potential to produce exploitable outcomes, as well of intrinsic scientific merit;

2. The agenda for national research priorities should not be imposed top down but should be established through dialogue between the users of research (in industry, commerce, government and the service sector) and the providers of research (in academe and elsewhere);

3. The key to improving the United Kingdom’s effective exploitation of its science and engineering excellence was to bring the business and scientific communities into closer and more systematic contact with each other to improve mutual understanding. The White Paper said that the Government wanted to achieve no less than a change in the culture of

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[1] In the United Kingdom, the categories of primary purposes are described as follows:
1. ppA - general support for basic and applied R&D, including postgraduate support
2. ppB - R&D relevant to a government service (includes all defense research)
3. ppC - R&D in support of government policy (excluding ppB and ppD)
4. ppD - applied R&D that supports advances in technology to underpin the United Kingdom economy, e.g. LINK, (excluding defense)
5. ppE - technology transfer
6. ppF – other SET expenditure including postgraduate taught courses.

the United Kingdom, breaking down barriers in the business and wider community to recognition of the importance of SET, and reorienting the publicly funded research effort into areas relevant to industry's needs and to improvements in quality of life, while continuing to protect the seedcorn of curiosity-driven research;

4. Given the inevitable continuation of tight public expenditure constraints, it was vital to press for public sector SET to be deployed as efficiently as possible, with overheads minimized, and for better co-ordination and collaboration between public sector providers to reduce overlap and maximise synergy;

5. As part of the effort to increase public understanding of the importance of SET and to change the national culture, the Government's use of funds and its efforts in SET should be more explicit and open, as a basis for informing and stimulating debate throughout the scientific and user communities.

Underlying the strategy contained within the White Paper was the intention that in future, decisions on priorities within publicly funded SET should be more clearly related to the nation's needs, and to enhancing the capacity of the United Kingdom to create wealth in the broadest sense. It was therefore geared more to United Kingdom development than necessarily to international development or global issues, although these were not specifically excluded.

III. IMPLEMENTATION OF UNITED KINGDOM GOVERNMENT POLICY ON FUNDING OF SET R&D

The White Paper stressed the need for partnerships - fostering links at all levels between the scientific and engineering communities and users. Central to this is the Foresight Initiative which aims to establish mutual interest networks between science and business, and through these to identify areas of science and technology which will have a key role to play in helping United Kingdom based firms and institutions "to create national wealth and improve

Foresight activities provide a wide range of support and advice in the area of technology transfer and development:

- College-Business Partnerships
- EUREKA-Euroenviron
- Focus Technical
- International Technology Service
- LINK
- Postgraduate Training Partnerships
- Small Firms Merit Award for Science and Technology (SMART)
- The Teaching Company Scheme (TCS)

The Technology Foresight Steering Group report for 1995, highlighted six priority themes having long range potential in terms of markets, strong scientific capabilities in the United Kingdom and pervasive effects across the economy and society. They are:

1. Harnessing the future power of communication and computing technologies;
2. Building new products and processes from the expansion of biological and genetic knowledge;
3. Improving the range, flexibility and quality of materials;
4. Securing high standards of products and services through sensor and automation technologies, business processing and management systems;
5. Securing a cleaner world through the development and application of environmental sciences and technologies for pollution control, clean processing and clean energy and product life cycle analysis;
6. Applying knowledge of social trends and social factors to the better understanding markets, risks perception and the human impact of new technology.

The report noted that “a drive towards more investment in these fields will enable the United Kingdom to build on its strengths and to influence its competitive future rather than having to react to global competition”.

The first phase of the Foresight exercise was undertaken by 15 sector panels with joint academic and business membership which first reported in 1995. In this first phase, panels pursued rigorous schedules of consultation, analysis and network building. Views from over 10,000 people were canvassed in surveys, seminars, workshops, interviews and written submissions. The area of most relevance to this current report on ESTs, namely Natural Resources and the Environment, was represented in this phase on the larger Agriculture, Natural Resources and Environment (ANRE) panel.

These panels have now been extended to 16 and in the second phase, work on reviewing, disseminating and implementing the ANRE recommendations has been taken forward by three separate sector panels - the Natural Resources and Environment panel, the Agriculture, Horticulture and Forestry panel, and the Marine panel. The Energy, Transport, Construction and Chemical panels have also had an interest in the impact of environmental issues on future markets and have made recommendations within the environmental domain.

The first report of the NRE Panel, published in 1996, noted that “The United Kingdom has a high reputation for environmental science, the application of environmental management, and the design and application of certain clean technologies and environmental technologies. The fostering of the underpinning science ‘knowledge’ base and the practical application of science ‘know-how’ is critical for maintaining and restoring our environment at home and in the world at large. In so doing this will generate wealth and maintain or enhance our quality of life in five ways, summarized as follows:

1. Sustain and enhance the wealth that is being created by the industries in the natural resources sector, acknowledged as world leaders, as well as by a healthy environment.

2. Generate income and employment in the environmental management sector by manufacturing and operating plant and equipment which can help manage, reinstate or prevent pollution in the United Kingdom environment.
3. Generate export income and employment by exporting the 'know-how' and environmental goods and services of the environmental management sector to other countries.
4. Provide more environmentally effective and cost-efficient regulatory systems.
5. Inform and enable citizens so that they can play a full part in the sustainable society and in the maintenance of their own and others' quality of life."

The following elements of the report focus on the areas covered by the Natural Resources and Environment panel which has been subdivided into five subgroups as follows:

1. Clean Technologies and Processes
2. Sustainable Resource Utilisation and Environmental management Systems
3. Opportunities for Exploitation - breaking down the barriers to Innovation
4. Young People's Programmes
5. Strategy and Dissemination

Government departments, research councils and higher education funding bodies have taken major steps to implement Foresight recommendations, as have professional and trade bodies. In addition to research funding, over £2 million of United Kingdom government funding goes towards organizing seminars, interactive workshops and encouraging sustainable partnerships between industry and the science and engineering bases.

The Foresight Challenge competition is one of the areas where priority projects identified by the Foresight exercise are developed. The competition boosts partnerships between the science base and industry. In the first round in 1996 it provided £30 million of Government funding and £62 million of funding from industry.

Total budget for the Foresight Challenge Competition is £ 92 million over four years of which £30 million come from public funds. 24 new projects are being supported which focus on priorities identified by the Foresight Programme.

Examples of environmental projects which received funding include:

- Composites from Plants (Positioning the United Kingdom as a World Leader in Innovative Plant Fiber Processing),
- School Children SEE the Sunny Side (The Scholar Programme For Photovoltaics in the United Kingdom),
- Clean Power from Coal (Clean Catalytic Combustion of Nitrogen-Bearing Low Value Gaseous Fuels for Power and Heat Generation),
- United Kingdom Industry Could Save Millions of Pounds (The Centre for Process Analytics and Control Technology),
- Future Looks Congestion Free (Road Traffic Adviser and the Information Superhighway).

A breakdown of the per centage of funds going into environmental projects is not available.

It was considered that the fragmentation of the environmental industry and its linkages with academia/government had in the past inhibited innovation and the exploitation of market opportunities. Recent development of a number of initiatives to foster the necessary partnerships has attempted to address this problem. Prominent among these initiatives are:

The NEST (Network for Exploitation of Science and Technology) project is designed to improve contact between the users and the generators of knowledge by providing an electronic link to enhance existing contact channels. It will facilitate a two-way flow of information about industry needs and research capabilities by providing a user-friendly interface through the Internet.

The principle mechanism for supporting research partnerships between United Kingdom industry and the science and engineering base, is LINK which operates through research programmes again funded 50 per cent by the Government and 50 per cent by industry.

LINK aims to enhance the competitiveness of United Kingdom industry and the quality of people's lives, through support for managed programmes of pre-competitive science and technology in market or technology sectors, and by encouraging industry to invest in further work leading to commercially successful products, processes, systems and services.

Since LINK was refocused in 1995, 12 new programmes have been announced responding to the Foresight priorities which will support innovative research projects involving companies, universities and research council establishments.

Various government departments and research councils currently sponsor 57 LINK programmes covering a wide range of technology, from food and bio-sciences to electronics and communication. Each programme supports a number of collaborative research projects, each lasting around two to three years. Newsletters and seminars disseminate information about each programme.

Since May 1995, £22.8 million were spent on programmes which are likely to include environmentally sound technology, namely:

- waste minimization through recycling, re-use and recovery in industry;
- inland surface transport;
- sustainable livestock production;
- sustainable arable production;
- foresight vehicle.

This compares to the total budget for LINK of £70 million over the same period. While the above programmes include mainly environmentally sound technology next to non-environmental initiatives, other programmes (e.g. crops for industrial use; earth observation) could have environmental implications.

Tables 1 and 2 from the Foresight First Progress Report show the current LINK programmes covered by the Natural Resources and Environmental areas of Foresight.

Under the Foresight Initiative, a number of initiatives have been established to improve the support for infrastructures for innovation and R&D investment in the United Kingdom. These include:

> The Treasury, Department of Trade and Industry (DTI) and the Bank of England have focused directly on the financing of smaller businesses with the introduction of venture capital trusts and enterprise investment scheme to improve the flow of finance to small firms to introduce newer technologies.

> The DTI is jointly sponsoring with (ESRC), a research programme on intellectual property rights (IPR) aimed at improving understanding in Government and among firms, of the relationship between IPR and wealth creation/competitiveness.

It was not considered to be a major role of the Foresight Initiative to encourage directly the take-up of innovative and best technologies/techniques by companies. However, it is seen as the role of Foresight to inform programmes specifically geared to doing this, such as, the Energy Demonstration Programme (ETBPP) and other NGO activities and voluntary/private sector associations, that these can make such information widely available.

IV. ANALYSIS OF R&D FUNDING FOR SET

In 1995, gross domestic expenditure on R&D (GERD) in the United Kingdom was £14.3 billion, just over 2 per cent of GDP. Of this nearly 50 per cent (£6.9 billion) was funded by the private sector, 33 per cent (£4.8 billion) by the Government and the remainder from charities, higher education establishments and overseas organizations. To complete the picture of Government funding for SET it is necessary to add in a further £1.3 billion spent on the wider activities of technology transfer, education and training, and money spent overseas.

The figure of £6.1 billion includes the United Kingdom's indicative contribution to the EU Framework Programme for Research and Technology Development (RTD). It was noted that although exact comparisons are impossible, British researchers gain as much back from EU funding for research as the United Kingdom Government contributes to EU central research finances and thus the flow can be considered 'neutral' for the purposes of this current report.

The detailed statistics taken from ‘Forward Look 1996’ and SET Statistics 1997 are presented in the tables in the Appendices.[2]

V. GOVERNMENT DEPARTMENTS WITH RESPONSIBILITY FOR THE DEVELOPMENT AND DISSEMINATION OF ENVIRONMENTALLY SOUND TECHNOLOGY

Most of the public funding of R&D is administered through government departments. In the following, those with responsibility for environmentally sound technologies are introduced.

1. Ministry of Agriculture, Fisheries and Food (MAFF*)*

The Ministry of Agriculture, Fisheries and Food is responsible for government policies on agriculture, horticulture and fisheries in England and for policies relating to safety and quality of food in the United Kingdom including composition, labelling, additives, contaminants and new production processes.

The Ministry provides scientific, technical and professional services and advice to farmers, growers and ancillary industries, and it commissions research to assist in the formulation and assessment of policy to underpin research and development work done by industry.

2. Department of the Environment, Transport and Regions (DETR, formerly The Department and Environment (DoE)

The Department of the Environment, Transport and Regions is responsible for planning; local government; new towns; housing; construction; inner city matters; environmental protection; water; countryside affairs and conservation.

It manages the Energy Efficiency Best Practice Programme (EEBPP) and the Environmental Technology Best Practice Programme (ETBPP) jointly with the Department of Trade and Industry. The two programmes both aim to stimulate the introduction of cost-effective technologies which have environmental benefits and also lead to cost savings through

[2] The following comments serve as an introduction to those tables:
Annex A shows the gross expenditure of £14.3 billion on civil and defence R&D both in terms of funding providers and recipients.
Annex B shows the trend in government funded SET expenditure.
Annex C shows the socio-economic classification and Appendix E by Frascati type of research.
Annex D shows an international comparison of United Kingdom Government spending by socio-economic objective
Detailed breakdowns of the R&D expenditure by various Government departments, namely Environment, Agriculture, and Overseas Development are given in Annexes E, F and G respectively.
Breakdowns of the expenditure by subject area for the four research councils, namely *Natural Environment (NERC)*, and Engineering and Physical Sciences (EPSRC), are given in Annexes H, and I respectively

reduced use of raw materials and lower waste disposal costs. The ETBPP covers energy use in industry, the services sector and housing, while the ETBPP is confined to industry but addresses a wide range of issues. Both programmes are aimed primarily at persuading their target markets of the benefits of ESTs and showing how they can be applied. Both programmes have provision for supporting collaborative R&D projects with industry partners. However, support for R&D forms only about 10-20 per cent of each programme (EEBPP around £15 million, ETBPP around £5.5 million).

For both programmes, the results of R&D projects are usually the property of the participating companies, although the Department might also have rights to promote generic ideas.

3. Department for International Development (DFID) formerly Overseas Development Administration (ODA)

The Department for International Development is responsible for the Government's overseas aid programmes, including global environmental assistance. It provides humanitarian assistance and promotes sustainable economic and social development. Its purpose is to improve the quality of life of people in poorer countries by contributing to sustainable development and reducing poverty and suffering. To this end the DFID aims to:

- encourage sound developmental policies, efficient markets and good government;
- help people achieve better health, education and opportunities, particularly for women;
- enhance productive capacity and conserve the environment; and
- promote international policies for sustainable development and enhance the effectiveness of multilateral institutions.

DFID strategy with respect to the diffusion of environmentally sound technologies is governed by its strategy papers, especially the Rio strategies, and when issued, the White Paper on International Development. Also their "institutional policy on environmental appraisal should tend to favour the diffusion of ESTs through the implementation of DFID projects".

DFID administers the Know How Fund and the Environmental Know How Fund (EKHF) as well as the Environment Research Programme (ERP) and the Renewable Natural Resources Research Strategy (RNRRS).

The environmental tranche of the United Kingdom's £80 million a year Know How Fund focuses, though not exclusively, on priority projects designed to help countries develop institutional capacity and policy reform where relatively small amounts of funding can have an important catalytic and demonstration effect. The EKHF works broadly within the framework of the Environment for Europe process and actively seeks projects which meet the priorities of the Environmental Action Programme. The EKHF operates in Albania, Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, the Former Yugoslav Republic of Macedonia, Poland, Romania, Slovakia, Slovenia, Belarus, the Russian Federation and the Ukraine. In addition, a contribution of £500,000 has been made to the Aral Sea Programme in the central Asian republics of the former Soviet Union.

Since it was launched in April 1992, EKHF has provided over £7 million for key environmental projects. Some 140 projects have been supported so far. Further projects with significant beneficial effects for the environment, for example in the energy and municipal sectors, are funded under the main Know How Fund.

The EKHF is expected to continue to provide funding for priority projects to transfer British know how, particularly in the areas of capacity building, policy reform and harmonization, and cleaner production. A list of project funded by EKHF are shown in Appendix P

DFID also provides grants, as for example for ‘Intermediate Technology (IT)’. It aims to develop technologies which meet locally defined needs using locally available materials and resources - managed so they are sustainable. IT works in Bangladesh, Kenya, Nepal, Peru, Sri Lanka, Sudan, Zimbabwe and in the United Kingdom. IT received in 1996/97 a core grant of £1.75 million, or 22 per cent of its total income, from DFID.

4. Department of Trade and Industry (DTI*)*

The Department of Trade and Industry aims to help business to compete successfully at home, in the rest of Europe and throughout the world. It has a wide range of responsibilities, including industrial sponsorship, trade policy, export policy, export promotion, energy policy, science and technology, consumer and investor protection, industrial relations and support for small firms. The DTI incorporates the Office of Science and Technology (OST), whose aim is to develop and coordinate, trans-departmentally, Government policy on science, engineering and technology (SET), so as to strengthen the United Kingdom’s SET capability and maximise its contribution to national economic performance and the quality of life.

About half of DTI’s support for industrial R&D is funded through the Innovation and Technology Support (ITS) budget. This includes some support for ESTs. Within the ITS budget, there are no specific financial or institutional policies to govern the diffusion of ESTs or other technologies. However, exploitation and diffusion of the results of ITS funded projects are strongly encouraged. In justifying the need for ITS support, projects have to demonstrate how exploitation and diffusion of the results will take place. This is written into a ROAME statement, which sets out the Rationale, Objectives, Appraisal, Monitoring and Evaluation of each project.

DTI administers a wide range of schemes connected to R&D or dissemination of ESTs.

Relevant schemes include:

- Foresight Directorate (see above)
- LINK (see above)
- EUREKA - Euroenviron

EUREKA is a pan-European network for encouraging near market, collaborative R&D projects which lead to the development of advanced products, processes or services. It involves organizations from 24 European countries and the Commission of the European Union. It is not an EU programme. Funding of up to 50 per cent of eligible costs is available for research projects, which must involve a minimum of two independent organizations from two member countries. A project can be in any technological area chosen by the participants, any United Kingdom-registered company, research organizations and higher education institutions, is eligible.

Other schemes include

- Focus Technical

  Focus Technical provides grants towards the cost of projects which adapt the technological products and services of research and technology organizations to make them more accessible to SMEs.

- Small Firms Merit Award for Research and Technology (SMART)

  The SMART scheme helps small and medium sized enterprises (SMEs) and individuals to research, design and develop technologically innovative products and processes for the national benefit. The scheme provides funding of 75 per cent of project costs up to a maximum of £45,000 to assist in technical and commercial feasibility studies and 30 per cent to help the development of technological products. Companies may apply for SMART at either stage of a project, and the maximum grant available for one applicant is ECU200,000.

  The DTI estimates that there have been 38 environmental projects over the three financial years 1992-1995 that have received between £2.5 million and £5 million from SMART. As some projects involve different technologies, the DTI argues that "the number of environmental projects supported is almost certainly higher than the number indicated".

- Support for Products Under Research (SPUR)

  SPUR is a 'near market' R&D scheme for single companies with up to 250 employees. It gives support to projects that demonstrate a "significant technological advance" for the industrial sector concerned. SPUR applies to process as well as product development. It is a general scheme, but environmental technology projects may be supported. The standard grant is about £165,000 maximum, but under SPUR-PLUS, exceptional projects which have a strategic significance and high R&D costs can get up to £450,000.

SPUR grants of £48 million have been offered between its inception in 1991 and April 1995. The DTI estimates that environmental projects over the three financial years 1992-95 have received between £1.6 million and £3 million from SPUR. As some projects involve different technologies, the DTI estimates that the number of environmental projects supported is higher than the numbers indicated.

Since 1995 the two schemes SMART and SPUR have been combined and received funding of £69 million for the period 1995-1998.

- The Teaching Company Scheme (TCS)

  TCS enables firms to take advantage of the wealth of scientific, engineering, technological and business management skills and knowledge available in British universities. Each TCS programme involves one or more high quality graduates (TCS associates) working in a company for two years on a project which is central to the company's needs. TCS programmes are jointly supervised by academics and company staff.

  Support is available in the form of a government grant to the university partner, the amount of which depends on the detail of the specific Programme and whether or not the company has previously participated in the TCS. The company also contributes to the direct costs of the TCS Programme. An SME participating for the first time will generally contribute about 30 per cent of direct costs (about £10,000 per Associate per year) and a larger company will normally contribute at least 60 per cent (about £20,000 per associate per year).

- Environmental Technology Best Practice Programme

  The Environmental Technology Programme (ETBPP) is a technology transfer programme started by the DTI and DOE in June 1994, with the aim to promote better environmental performance while increasing the competitiveness of United Kingdom industry and commerce. The target is £320 million annual savings to industry by the year 2015 for programme expenditure of £32 million. The technology diffusion activities pursue competitiveness through improved environmental performance, concentrating on priority areas using a range of tools coordinated through one centre of expertise.

The broad themes are waste minimization and cost effective cleaner technology, but it has also given special attention to foundries, metal finishing/surface engineering, volatile organic compounds, glass, paper and board, textile industries, food and drink, speciality chemicals and printing industries. More recently work has begun on the engineering and ceramics industries sectors. While the programme has general themes of clean technologies and waste minimisation, it does not aim at blanket coverage, but targets delivery principally within sectorally specific portfolios, transferring knowledge and techniques between sectors.

There are five main elements of the programme, as well as workshops, seminars, site visits and other events:

i. ‘benchmarking’ activities using environmental performance guides
ii. good existing environmental practice (case studies)
iii. innovative environmental practice (focusing on new technology use)
iv. future environmental practice (limited R&D support)
v. a national centre of expertise for environmental best practice and technology providing a helpline which is a national enquiry service providing free up-to-date information on any environmental issues.

The ETBPP is not a funding programme, although it does have a small element to support R&D for near market technologies that reduce waste at source. Where the programme does support R&D projects, the ownership of technology rests with the developer and the programme promotes the transfer of the technology.

OST also provides funds research councils. The seven councils are non-departmental public bodies, principally funded through the Science Budget by the Department of Trade and Industry via the Office of Science and Technology. Only four of them have a role in the development and dissemination of environmentally sound technologies. They are the councils for:

i. Biotechnology and Biological Science (BBSRC)
ii. Economic and Social Research Council (ESRC)
iii. Engineering and Physical Science Research Council (EPSRC)
iv. Natural Environment Research Council (NERC)

Although detailed funding statistics exist in principle, in the time available for this feasibility study, it was not possible to access them for ESTs apart from the summaries presented in Appendices H and I An estimate provided for the EPSRC indicates that 40 per cent of the £10 million budget would fund R&D for ESTs.

VI. LEGAL FRAMEWORKS AND INTELLECTUAL PROPERTY RIGHTS (IPR)

The details of the DTI’s policy on intellectual property rights are specific to the objectives of the particular scheme under which the research is funded. IPR arrangements are flexible, but ownership of IPR arising from contracts or research grants is normally vested in the contractor or grant recipient, whether private industry, public research organization or higher education institution (HEI), subject only to the rights of any third parties concerned. All contractors are expected to use their best efforts to exploit intellectual property generated in the course of work, pursuing the DTI’s wealth creation objectives, and safeguards are provided against failure by the contractor to exploit the intellectual property within a fixed period.

In collaborative research involving companies and higher education institute, the traditional DTI position has been that IPR should belong to the industrial partner with an appropriate return to the institution in the event of commercialization. This stance has been adopted because the industrial partner has generally been regarded as better placed to seek due protection for the intellectual property and to exploit it. However, the DTI is aware of the developing HEI capability in IPR matters and accepts that a more flexible approach may be required in the future, recognizing the increased commercial exploitation interests and ambitions of many HEIs.

The LINK initiative is an example where IPR arrangements are more complex as more that one government department is involved in funding a given project. LINK is a major government-wide initiative aimed at encouraging firms to work collaboratively with science based on pre-competitive research, and different departments take the lead in individual LINK programmes. Arrangements for IPR are specified by the lead department. For example, for DTI-led LINK projects a formal agreement is made between participants which includes arrangements for the ownership and licensing of IP. All necessary background INTELLECTUAL PROPERTY owned by participants is made freely available but does not affect ownership. The results of the project are made freely available within each consortium, through regular informative reports, and are usually vested in the industrial participants. The collaboration agreement safeguards the interests of non-industrial participants.

The Natural Environment Research Council (NERC) has strong links with government departments/Agencies and many users in the private sector. NERC contributes to the well being of the United Kingdom through training, the creation of new knowledge and its diffusion by publication of scientific papers, carrying out commissioned research and to a lesser extent through commercialization of intellectual property and spin out companies.

The duty to properly manage and exploit intellectual property lies with organizations receiving NERC science budget funds. Recipient organizations are expected to maintain capabilities to identify and carry forward exploitable opportunities (either in partnership with users or alone) where there are significant benefits to the United Kingdom and the organization. To achieve this, ownership of intellectual property arising from the NERC , institutional ownership is vested with NERC as the legal entity. The council is obliged to monitor and report to OST how NERC research outcomes are used for the benefit of the United Kingdom.

Although many initiatives aimed at realising the full potential of NERC results are underway there is no written and approved exploitation policy. The key issues are to provide clear guidance to individual scientists in universities and NERC centres, to encourage partnership between researchers and users and to coordinate, where appropriate, the exploitation of intellectual property.

Any improvements to the legal framework to encourage the transfer of publicly funded ESTs will broadly be the same as those for publicly funded technology in general. IPRs play an important role in encouraging development and commercialization, in particular because they allow for the very effective dissemination of information which otherwise might remain secret or inaccessible, by acting as a reference point for potential users or other interested parties.

VII. PATTERNS OF DIFFUSION OF TECHNOLOGY

United Kingdom Technology Partnership Initiative (TPI)

The aim of this government initiative - administered by the Joint Environmental Marketing Unit (JEMU), through the DTI and the DETR - is to link companies and organizations in industrialising and developing countries with United Kingdom companies and other organizations which provide both technologies and services, as well as the information and advice they need to deal with their environmental problems.The network provides facts and guidance on:

- up-to-date technological solutions to key problems
- best practice by British companies
- new technologies being demonstrated in the United Kingdom

The network includes over 4000 companies and organizations, including commercial sections of the British Embassies and High Commissions, the Commonwealth Development Cooperation, the British Council, chambers of Commerce, and trade associations and organizations in the industrializing countries.

Emphasis is on training and support In collaboration with local organizations the TPI might arrange training seminars, and in partnership with United Kingdom companies, they can help to bring senior business men-and business-women to the United Kingdom to acquire practical experience of modern technology, management and production methods.

TPI will continue at least until March 1999. The DTI states: “Countries in the developing world remain anxious to have access to both proven and developing environmental technology”.

Box 1
Samples of ESTs developed through public funding

Projects funded through the former Clean Technology Unit of the EPSRC:

Immobilized cell reactor for detoxification of industrial wastewaters:
Start Date: 1-10-91
End Date: 31-3-95
Value: £105,255

Quote from the final report: "Clean Technology Aspects of grant: this grant has contributed to cleaner technologies by improving understanding of biofilm systems often used for wastewater treatment. Biofilms allow more intensified, more robust biological systems to be utilized, and a better understanding will hopefully lead to better treatment systems through the new Extractive Membrane Bioreactor. The grant has also led to technology transfer with a DTI SMART award being won by Membrane Extraction Technology, a start-up company, to prove the EB process at an industrial scale and then commercialize it fully."

A study of room temperature direct ethyl formate fuels cells for consumer electronic applications:
Start Date: 1-2-95
End Date: 31-1-97
Value: £75,190

Aims to evaluate Pt/WO_3 catalyst for the direct oxidation of ethyl formate at low temperatures as well as the mechanism of reaction on such electrodes:

1. to optimise the electrode structure and catalyst composition to ensure the most effective utilization of the available catalytic surfaces;
2. to conduct half-cell and full-cell testing on low temperature ethyl formate fuel cells and study the factors governing the life and performance of such cells;
2. to design construct and evaluate prototype cells with the appropriate DC-DC converter circuits to step up the voltage for powering consumer electrical products.

Box 2
Project supported by the ETBPP

Stepping Ahead with Solvent Management

This study demonstrates how Clarks International achieved significant cost savings by reducing its organic solvent consumption through a systematic approach to solvent management. A wide range of measures to reduce the use of organic solvents was implemented. Some measures involved the transfer of 'best practice' between sites; others were identified locally by solvent management representatives and teams. Measures fell into one of two categories:
- substitution of a solvent-free or low-solvent alternative;
- change of practice.

Since 1992 their implementation has reduced solvent use by 163 tones, almost 50 per cent resulting in substantial cost savings.

Normal contribution by ETBPP:
1. a walk-round environmental assessment of the site;
2. advice on specific environmental problems;
3. advice on opportunities for cost-effective waste minimisation;

4. a prioritized action plan for implementing the counsellor's suggestions.

VIII. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK.

In 1995, total expenditure on science, engineering and technology (SET) and R&D in the United Kingdom was £14.3 billion, just over 2 per cent of GDP. Of this £4.3 billion came from public funds. A further £1.3 billion of Government funding was provided in support wider activities including technology transfer, education and training, bringing the total public expenditure in this area to £6.1 billion. The policy behind this expenditure comes from the government's "Foresight" initiative, which includes some objectives specifically aimed at environmental improvement.

Although this SET R&D includes many elements of work directed at what the guidelines for this study termed 'Environmentally Sound Technologies (ESTs)', it has not been possible, nor is it considered appropriate for reasons explained below, to differentiate between research into environmentally 'sound' technologies, and what by inference, might be termed environmentally 'unsound' technologies. Therefore, it has not been possible to provide precise statistics on ESTs in isolation for the following main reasons, already alluded to in the main body of the report:

1. While there are several programmes devoted to supporting environmental improvement in business *per se* (e.g., EEBPP, ETBPP, JEMU, etc.) they are not concerned exclusively with the funding of R&D and/or the dissemination of ESTs. Most of these programmes aim at environmental improvement through a combination of managerial, strategic, design, and education and training approaches. The programmes have been very successful in reducing the environmental and financial costs associated with a given process. First signs are also visible that this kind of improvement is being achieved on a wider scale, (i.e. through the optimization of the life cycle performance of a given product), which evidently requires co-operation between a range of businesses.

2. Environmental R&D and dissemination is carried out and supported within most of the R&D and dissemination schemes presented. Normally no differentiation has been made, and it has been argued that it cannot be made (see main body of the report). The overriding aim of most research and development activities funded through public sources in United Kingdom is as expressed by the Foresight programme, to increase competitiveness of the British business sector. The environment has been recognised as one of the main issues which need to be considered. However, differentiation between mainly environmental and less environmental R&D was seen to lead to projects too specialized to address the complexity of environmental problems. This integration of environmental work into the overall funding can be demonstrated for example through the former Clean Technology Unit of the Engineering and Physical Sciences Research Council. The Clean Technology Unit was aimed especially at the R&D of Clean Technologies or ESTs. When the funding was given back to the main stream budget, it was hoped that most if not all proposals would now have to consider the implications on the environment of the work to be carried out, and thus address environmental improvement in a more holistic way.

3. Within the framework of sustainable development the preventative paradigm becomes prevalent. The minimization of resource throughput for a given process or Product life cycle has been identified as the major criterion for environmental performance. These experiences with environmental problem solving suggest that it depends more on the redesign of technological systems and the adaptation of technology than on the introduction of new and environmentally more sound technology. Thus, combined approaches funding managerial strategic and redesign, as well as those which consider technology adaptation and development, have in many cases proven more effective in environmental terms than research and design of specialist - often “add-on” - technologies. It seems more effective to work in a cross disciplinary way. EEBPP and ETBPP with their 20 per cent funding for environmental R&D might provide the right approach.

In consideration of the foregoing, the authors’ recommendations for future work beyond the current feasibility study, would be to concentrate on all aspects of the design, implementation, operational management etc., currently embraced by the process of Eco-efficiency, for ALL products, processes and services. It would not seek to separate out those technologies which could be defined as environmentally ‘sound’, and which by the current definition as supplied by UNCTAD, would include ‘end-of-pipe’ “fixes” for otherwise environmentally ‘unsound’ processes.

Rather, the approach would be to identify the potential environmental impacts of every technology at the earliest design stage and aim to minimize, or preferably eliminate, these impacts before proceeding further with the development of the technology. Thus, in a truly ‘sustainable’ situation, those products, processes or services for which it was not considered possible adequately to address their potential environmental impacts, would not be developed further until such time as the negative effects could be eliminated at source.

In seeking to disseminate these technologies for use on a world wide scale, the emphasis would then be much more on transferring the know-how and management expertise behind this approach such that the most appropriate technologies could be developed where they are to be implemented by the people who would implement them. Such an approach has implications for those countries which may choose to focus somewhat narrowly on the possibility of high earnings from the export of technologies per se . On the other hand, this approach would have the benefit of eliminating the possibility of the export of inappropriate technologies to developing countries, however environmentally sound they may appear in their country of origin.

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THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ENVIRONMENTALLY SOUND TECHNOLOGIES (ESTs) THE CASE OF JAPAN

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I. INTRODUCTION

Chairing the Third Conference of Parties of the United Nations Framework Convention on Climate Change and presenting the Comprehensive Mitigation Proposals on Global Warming (Green Initiative) at the Special Environmental Session of the United Nations, the Government of Japan has clearly established a policy to make environmental conservation a pillar of its diplomacy. Therefore, the transfers of environmentally sound technologies to developing countries and the domestic diffusion of the results of research and development constitute two of the major policy issues facing Japan today.

The main objective of the Green Initiative is to promote and accelerate the introduction and diffusion of energy-saving technologies and renewable energy technologies to developing countries, under the framework of international cooperation, and for this objective, various programmes for technological transfers and fund assistance have been either implemented or planned. Under the Basic Plan on Science and Technology formulated in 1995, the budget for research and development of science and technology has been increased. In addition, the Government has proposed a Plan of Action, adopted by the cabinet in 1997, which lists environmental conservation as one of 15 new industrial areas expected to grow significantly in the future.

However, despite efforts to enhance research and development, the diffusion and transfer of environmentally sound technologies to both the domestic market and to developing countries have been limited. The reasons vary from those that can be corrected fairly easily by appropriate policies and measures such as inefficient mechanisms for transfer and diffusion and lack of information, to those that involve fundamental problems such as the lack of funds and resources and insufficient development of market demand in developing countries.

In this paper, the discussion will focus on the current situation and future prospects of research and development on ESTs, their diffusion in Japan and transfer to developing countries. Since many of the technologies belong to private companies in Japan, the discussion will centre around the cooperation between the private and public sectors. Although technology transfer to developing countries is still very insufficient, various efforts have been in Japan made to promote such transfers. We hope sincerely that the experiences accumulated and systems developed in Japan will contribute to the sustainable development of the global community.

II. SCOPE OF PUBLICLY FUNDED EST IN JAPAN

A. The current general situation of research and development

The breakdown of research and development expenditures across all fields in Japan for 1995 was Y9,300 billion (75 per cent of the total) by the private sector, Y3,090 billion (25 per cent) by the public sector. In other words, the research fund provided by the Government to universities and institutes consists only 25 per cent of the total, a share that is remarkably lower than that in the United States, Germany, and France, which stands at about 40 per cent. Another significant indicator of the difference between Japan, Europe and the United States is the number of researchers in public research institutes. For every 100 researchers at universities, the number of researchers in public research institutes stands at 47 for the United States, 50 for Germany and 51 for France, whereas it is only 17 for Japan.

In an attempt to improve public funding for R&D in Japan, the new basic plan of science and technology established in 1995 involved an increase in the research and development budget in the public sector. The budget plan for the fiscal year of 1997 set a new and a special budget allowances totalling Y550 billion to promote economic restructuring in environment, science and technologies, and information and telecommunications etc.

The increase in budgets for R&D can also be seen in the private sector as the research and development investment plan of major Japanese business entities increased by 4.3 per cent in 1997, compared with the previous year. Japanese companies are also expanding the number of research and development and manufacturing locations overseas, most notably in electric appliances and chemicals manufacturing, which, according to a recent survey, are being shifted to China and other developing countries.

B. Public AssistPance for Research and Development

The research and development on ESTs with government support can be divided into 1) research and development carried out by all laboratories of national universities and national research institutes, 2) research and development performed by consortia mainly consisting of international research teams or private industry researchers, and 3) research and development for commercialization by private entities.

The major source of budget for these activities is the Special Account for Energy Sector, an account funded by energy-related taxes. Therefore, it is a way of channelling the energy tax back through research and development, technology transfers, and domestic diffusion.

1. Public research and development institutes

This section describes some of the organizations involved in research and development activities dealing with the application and development of environmental conservation technologies under the government initiative.

- New Energy and Industrial Technology Development Organisation (NEDO)

NEDO was established in 1980 immediately following the second oil crisis, as a core governmental institution for technological development in Japan, gathering funds, scientists, and technologies from the national Government and the private sector. NEDO’s project budget for fiscal year 1996 was Y320.6 billion, about 90 per cent of which was for research projects, research and development for universities, public institutes, and domestic and overseas business entities in the fields of new energy technology, industrial technology, environment conservation technology, etc.

- Research Institute of Innovative Technology for the Earth (RITE)

In 1990, the Government of Japan proposed the Earth Renewal plan. RITE was established in the same year for the purpose of resolving global environmental issues such as global warming. Its main themes are "innovative environmental technology development" and "expansion of CO^2 sink sources". It conducts joint research and development at the international level. It is a foundation with 450 employees. The institute conducts research activities with long-term objectives and does not focus on the possibility of transfer to developing countries.

- National research institutes

At present about Y600 million per year go to 16 national institutes for research and development on environmental technologies such as the prediction of environment concentration of greenhouse gases. Funds are also provided to support joint research with developing countries, especially in East Asia. Each institute has a few research programmes it manages through a regional network to promote environmental conservation measures for the long-term. Examples include the East Asia Acid Rain Monitoring Network and Eco-Asia.

- Research works by local public institutes

Environmental institutes belonging to prefectural governments have long experiences in the study of pollution prevention for local industries, and possess many technologies transferable to developing countries. For example, an environment institute in Wakayama Prefecture developed technologies related to the discoloration of waste water by dye, and from 1991 to 1992 conducted a feasibility study on technology transfers to local industries in mid-Java, of Indonesia.

2. Themes of research and development

NEDO, with 27 ongoing projects and a Y10 billion a year budget, is an example of such research and development on ESTs and its themes. The following list includes environmentally sound technology projects that are being implemented by NEDO:

- Development of environment-friendly manufacturing technologies (bio-reactors, hydrogen production);
- Development of technologies for producing less polluting products (bio-degradable plastics, new refrigerants, CFC decomposition, etc);
- Development of technologies for the fixation and effective utilisation of carbon dioxide (microbe fixation, contact hydrogen reaction use, etc.);
- Environmental recovery technology (soil pollution remedy, bio-remediation),
  waste treatment, and recycling technology (waste treatment using melting furnace, and re-resourcing);
- Advanced treatment and utilization of wastes such as those from the residential sector (eco-cement, specific CFC decomposition, bio-treatment of kitchen wastes);
- Environmental technologies such as recycling (recycling PET bottles, recycled paper);
- Emission reduction technologies for carbon dioxides and others (high performance insulating materials, methanol for fuel cells, heat pump);

The following 11 projects are consigned to RITE:

(i) Project for biological CO^2 fixation and utilisation
(ii) Project for chemical CO^2 fixation and utilisation
(iii) Development of biodegradable plastics
(iv) Development of high-performance bioreactor for the production of biochemicals
(v) Biological production of hydrogen by environmentally acceptable technologies
(vi) In situ soil bio-remediation project
(vii) Development of new refrigerant, blowing agent and cleaning solvent for effective use of energy (alternative to chlorofluorocarbon)
(viii) Development of advanced refrigerant for compression heat pumps (alternative to CFC114)
(ix) Comprehensive basic study for the recovery and reuse of metallic materials
(x) Development of environmentally friendly catalysts

(xi) CO^2 fixation in desert area using biological function

Furthermore, there is a plan to commercialize energy-saving lighting equipment using luminance electric diode (LED) that consume only one-eighth the energy used by an incandescent lamp, and half the energy used by a fluorescent light. A Y500 million budget was provided in 1997 for five years to research teams in universities and business entities. This new lighting product is expected to be commercialized by the year 2005.

2. International cooperation in research and development

As part of an international joint study assistance project (international grant), NEDO has offered funds (international grant: yearly budget of about Y300 million) to global environment studies since 1988. The project provides financial assistance for 3 years (Y90 million in total) to an "International Joint Study Team" consisting of selected researchers in Japan and other nations. Applications for this programme are submitted through RITE, and the results of the studies, particularly those involving intellectual property rights, belong to the study team.

The Institute of International Construction Technology Association, jointly with developing countries, is proceeding with a research cooperation program for construction-related environmental technologies. Building on its 40 years person-to-person contacts, the institute has chosen to drop intellectual property rights for a joint use of installations with its partners. This could be a model for technology transfer. The following are three projects currently underway:

- Technology development to maintain and manage residential buildings of medium height in developing countries, for the purpose of establishing a comfortable residential environment;
- Development of a methodology for reading radar screens that are adapted for tropical regions;
- Demonstration and assessment of sewage treatment facilities using bio-modules.

III. COMMERCIALIZATION AND DOMESTIC DIFFUSION OF ESTs

A. Approaches to promote domestic diffusion

Domestic diffusion support measures of the Government

The "Monitor" subsidizing system for solar power generation equipment. Through the new energy institution management by the Government, a subsidy is offered to family homes wishing to install solar power generation equipment as a "monitor project." In fiscal 1997, the programme would subsidize Y300 thousand per kw (including installation fee) for the equipment of up to four kW capacity per house, available for 9400 houses in total. The subsidy amounted to approximately 30 per cent of the total initial cost born by the user.

The subsidy system for industrial use of solar power generation. This was a new subsidy system planned with a budget of Y3 billion for fiscal year 1998. The programme provides a subsidy for a maximum of one half of the total expense, if factories and other industrial facilities, or public facilities such as a gymnasiums introduce solar power system as an energy source.

The subsidy system for new energy utilization in businesses. Under the Special Act (Announced in April of 1997) to Promote Use of New Energy (solar power generation, wind power generation, co-generation, electric cars or natural gas cars, power generation using temperature differences, and fuel cells), the programme offers a subsidy to those entities which utilize to a certain extent new energy systems. Subsidies include a credit guarantee by NEDO, an interest-free loan by a Prefecture Government under the Act of Subsidies for Modernization Finances of Small to Medium-Scale Enterprises, and a subsidy up to one third of the total cost for the business to install new energy equipment. In the case of small to medium-sized firms, they can apply to the investment fund of the Small to Medium Scale Enterprises Investment Promotion System even if their capital exceeds a Y100 million. The budget for subsidies to new energy use (subsidies for financial assistance groups of local public entities and others) was Y57.3 billion in fiscal 1997. In fiscal 1998, a budget of Y5.4 billion was requested to subsidize one third of the total initial cost needed for entities generating power from new energy sources such as wind power. Local administrations offer a subsidy system to subsidize up to one half of total installation costs for businesses that plan to install large-scale power generation equipment using new energies such as solar power, wind power or solid waste fuel recycling. The request for next year's budget is about Y5.2 billion. The above programme is for domestic businesses only but it is expected to reduce production costs, expand production capacity and provide low cost new energy equipment to developing countries.

Programme of Circumstantial development for rise of new Industry. The Action Plan for the Revolution and Creation of a New Economic Structure adopted by the Cabinet in May 1997 designated the environmental conservation industry as one of 15 new industries for future growth. This indicates that the governmental view emphasises the importance of environmental industries in establishing a sustainable economic society that adds less environmental burden. This Programme of Circumstantial Development for the Rise of a New Industry, an actual plan for implementing the "Action Plan," introduced subsidies for model projects on global warming mitigation measures introduced by local public organizations from fiscal 1997, and the preparation of new energy utilization manual, as a practical measure. The programme also will promote the development of new CFC substituting materials with lower global warming potential, reduce automobile traffic using multimedia, and improve efficiency in manufacturing and distribution activities.

The actual content of the programme of Circumstantial Development for the Rise of a New Industry in the new energy and energy saving area is listed below.
Action Plan. The plan includes the demonstrative purchase of clean energy cars for official fleets, and the construction of infrastructure for their fuel supply. The target is to increase the ratio of clean energy cars up to 10 per cent of total government owned official cars that serve for ordinary administrative purposes, by the year 2000.

Promotion of technological development

Activities include:

- Proceeding with varied applications of thin layered photovoltaic cells, and lowering their cost to realize their common use by the beginning of the 21st century.
- Increasing the functional properties of electric cars and solar power generation by the beginning of the 21st century, and promoting technological development to allow commercialization of high performance Lithium cells for this purpose.
- Developing elemental technologies to efficiently recover, convert, transport, and utilize unused energies such as various waste heat.
- Developing fuel cell power generation technology using molten carbonates that provide the benefits of long product life and high performance.
- Developing hydrogenated coal gasification technology that will be a clean and high calorie substitute for natural gas.

B. The role of intellectual property rights in Japan

Until recently, patent and patent rights have not received much attention and their values have not been fully appreciated. Looking into the results of research and development for the last 10 years (1986-1995), the United States had 990 thousand applications for patents (applications from domestic parties), and produced a surplus of about Y16 trillion in technology trade, whereas Japan had four times more of patent applications (applications by domestic parties) yet recorded a deficit about Y4 trillion in technology trade. Japan, also, showed a higher ratio of unused patents (utilization rate of 33 per cent according to a 1995 survey), and efforts companies in search of licensees have not achieved much success.

Furthermore, Japanese technology exports always produce lower rates of technology licensing fees from overseas subsidiaries or investment firms. United States companies, on the other hand, usually do not make any distinction between licensees and request a determined level of licensing fee even from their own subsidiaries.

Nonetheless, Japanese are increasing their strong awareness today that "Japan should start to roll the cycle of intellectual property creation." Thus, the positive implementation of a pro-patent policy is ongoing in both public and private sectors. Among universities and public research institutes, also, there has been a rising trend to review the role of a patent as a right of the developer. The Patent Agency launched in 1997 a patent data base to promote the diffusion of sleeping patents.

As an effect of a pro-patent policy, the balance of technology trade in patent fees and know-how licensing improved in fiscal 1995, resulting in Y560 billion in exports and Y390 billion in imports. Although the number of overseas patent applications is still limited, there were eight Japanese companies among the ten companies with the highest number of patent applications in United States. Being pro-patent is becoming the latest strategy of Japanese companies.

However, the domestic system to protect intellectual properties such as patents lags far behind those instituted in the United States and Europe. According to the Patent Agency, the amount of compensation fee granted from lawsuits for intellectual property right violations averaged about Y46 million, remarkably lower than the estimated Y11 billion in the United States. Furthermore, the approved compensation fee remains within the limit of a patent fee that can be earned by the use of the patent. This was the ruling in half the cases of lawsuits in Japan. In order to motivate researchers, a consensus is growing in Japan for the need to strengthen the system for intellectual property right protection. The Patent Agency therefore, has scheduled to revise the Patent Law in the near future with a heavier penalty to be imposed on the parties of patent infringement. A central element in the revision will be an increased penalty limit from the conventional Y5 million to Y100 million. The Act to Regulate the Research and Development System for Industrial Technologies stipulates that the handling of patent rights should be a result of international joint research.

Case Study 1

Research and development on global environmental technology

This programme is undertaken as a consignment from NEDO to private entities. Due to the principles of consignment, the intellectual property rights would be shared equally by NEDO and the consignee (private entities). An agreement of both sides is required. However, it is a general practice of NEDO to withhold the transfer of the intellectual property rights to third parties, until the consignee (private entity) requests the use of intellectual property rights.

If the Government of Japan judges that the transfer of some global environmental technology developed under this framework will benefit environmental improvement in developing countries, the government (and NEDO) may encourage the private entity that shares the ownership of the intellectual property right to accept the technology transfer.

In case of delegated research work, the intellectual property rights will be shared evenly between the government (NEDO), consigned research institute and private entities. For patent application, the research institute or private entity shall pay half of the fee to NEDO. Although the fee may vary depending upon the types of intellectual property rights and technologies, many allocate around 1 per cent of the sales amount.

C. Mechanism for Overseas Diffusion

1. Current situation of overseas direct investment by Japanese business entities

According to the status of orders for environmental equipment in July of 1997 published by the Japan Industrial Machinery Society, the total amount of orders received were Y137 billion, an increase of 19.4 per cent over the same month of the previous year. Demand was Y123.4 billion for public and governmental projects, and Y13.3 billion for the private sector. Exports were Y340 million, a decrease of 53.3 per cent over the same month of the previous year. In other words, major customers of environmental conservation equipment are predominantly domestic, and the public sector commands a very large share. For example, in the case of Ebara Manufacturing Co., a major manufacturer of environmental conservation equipment active in overseas markets, sales of environmental engineering equipment was about Y250 billion, or about 60 per cent of total sales, and about 85 per cent of these sales were ordered by the public sector in Japan, 15 per cent by the private sector, and exports hardly reached Y10 billion.

The reasons why Japanese business entities have an extremely small share of overseas direct investment in the environmental conservation field are: 1) insufficient demand in developing countries, 2) lack of information on developing country markets, 3) ineffective and insufficient mechanism of government support for technology transfer, 4) a strategy characteristic of Japanese business entities, 5) the characteristics of environmental conservation technology itself that addresses "domestic" issues mainly, and other factors

Item 4), company strategy, is clearly indicated by the difference of perception between Japanese companies and European and American companies on the role of licensing. According to a recent survey conducted on Japanese companies, on the question "why apply for a patent?", the responses were in the following order, 1) to compete with rival companies, 2) to monopolize market, 3) to raise the technology level within the company (to offer an incentive to employees and to increase patent applications), 4) to get royalty earnings (permit the use of a patent while retaining control over the recipient to prevent any disadvantage to their own company), and 5) to cross-license (technology introduction from other companies at no charge, especially frequent among electric appliance manufacturers).

As described above, Japan places less importance on licensing among many forms of overseas direct investment (local production, product export). Many choose a strategy of joint venture and local production, rather than simple licensing. In other words, they show less enthusiasm to sell production than products produced by the technology. The first reason for this is their desire to retain control and influence over the product manufactured by the technology, and to retain advantages in the market against competition. Furthermore, the export of hardware from Japan is currently not so profitable under the current exchange rate. In the case of Ebara mentioned above, their purposes for overseas sales are: 1) to strengthen competitiveness in the domestic market, and 2) to eventually export to Japan as a mid to long-term target.

2. Organizations and systems for technology transfer

Details of the official system for technology transfer and the actors involved are described below:

- Environmental ODA

In 1992, at the United Nations Conference on Environment and Development in Brazil, the Government of Japan announced its intention to expand and strengthen environmental ODA, aiming to reach Y900 billion to Y1 trillion for five years starting from fiscal year 1992. Since then, the actual expenditure for four years from 1992 to 1995 reached about Y980 billion, reaching the target amount one year ahead of the commitment. Environmental ODA was Y276 billion for fiscal year 1995, 19.9 per cent of total ODA. Among these amounts, about 60 per cent was offered as a form of financial assistance such as Yen credits. A sectoral analysis of bilateral ODA indicated the residential sector, such as water supply and sewage systems, dominated with 60 per cent of the total, and the share of industrial pollution measures was less than 20 per cent. The current Government policy is a dual increase of environmental ODA and industrial pollution measures.

- Green Aid Plan

The plan has been implemented since 1992, as an international cooperation programme (mostly outside the framework of ODA) to provide technological and financial support to efforts to address energy problems in developing countries, such as industrial pollution, recycling, and energy savings.

Target countries were expanded to six namely, China, Thailand, Indonesia, Philippines, Malaysia, and India. The budget for the fiscal year 1996 was Y16.5 billion, and of this about Y2.6 billion were for energy and environment technology cooperation (general account budget, ODA) and Y13.9 billion for the survey and demonstration of technologies (a special account budget separate from ODA). At present, over 20 projects, mainly technology transfer model projects, are either ongoing or under the follow-up and assessment phase. Furthermore, to ensure comprehensive implementation of the Plan, a technology training programme has been instituted. This includes the training of participants from the target countries in Japan, and in their own countries through the provision of Japanese instructors. Such training includes trainee acceptance by the Japan Overseas Technicians Training School (AOTS), the dispatch of experts by the Japan Overseas Development Corporation (JODC), and the extended exchange programme for technological experts instituted by the Japan Export and Trade Reinforcement Organisation (JETRO). A programme with a similar scheme includes the transfer programme for combustion technologies related to coal combustion (Clean Coal Program). It has a budget of about Y4 billion.

Case Study 2

Model project for energy savings under the green aid plan

This is a project to rationalize energy use under the Green Aid Plan, with a key philosophy emphasizing the importance of "joint work" with local people in developing countries. Its implementation is divided into a "demonstration/diffusion phase (Y5.64 billion budget for fiscal year 1997), and a "research and development phase (Y630 million budget for 1997)". It relates closely to actual conditions in the recipient countries. New projects implemented from 1996 were designed to be carried out as projects under the activities implemented jointly for a pilot phase of the Framework Convention on Climate Change.

The following are ongoing projects:

Projects in the demonstration/diffusion phase

- Top pressure recovery turbines (China).
- Waste heat recovery from sintering cooler unit (China).
- Cement waste heat power generation (China).
- Coke dry quenching (China).
- Utilization of paper mill sludge etc.
- Breaking of cement dies.

Projects in the research and development phase

- High efficiency combustion of low quality oil (Thailand).
- Use of waste heat from electric furnaces (for reduced iron).
- Cooling of cement clinker and heat recovery.

Besides these projects, seven projects in demonstration and diffusion phases, and one project in the research and development phase were concluded with successful results.

For energy saving projects overseas, the Government of Japan will ultimately bear about 60 to 70 per cent of total expenses. Japanese accounting principles request the facilities provided by Japan under this programme to become assets of the recipient country only after their book value reaches zero. Therefore, NEDO continues to own the facilities immediately after the completion of the project, and some restrictions may apply for the modification of the facilities. It is the final intention of the Japanese Government to transfer *gratis* the assets built under the programme.

However, the greatest problem until the Green Aid Plan is insufficient follow-up to the projects. This is a common issue in many other assistance programmes. During implementation, problems are due mainly to the financial participation to be borne locally, and the underdeveloped counterpart system these problems have been taken into account during the project design stage. Thus, there is less progress than anticipated in the transfer and diffusion of technologies in the developing countries. Problems seem to arise with the provider and the recipient of technology transfer, and so far there has been no model project that eventually developed into a joint venture project through follow-up work by a participant. As no commercial results have been developed businesses involved are starting to question the benefits of their active participation in the Green Aid Plan. However, technology transfer is an activity with long-term prospects, and should not be judged on short-term results.

- Grant Programme for Comprehensive Promotion of Global Environmental Studies

In fiscal year 1990, the Environment Agency of Japan introduced a grant programme for a comprehensive promotion of global environmental studies, with the objective of extensively promoting research on global environmental issues (Y2.65 billion budget for fiscal year 1997). Major requirements for research funded through this Grand Programme are to participate in an international research programme on global environmental conservation, to undertake research as appropriately allocated, and to realize joint studies and mutual exchanges with research institutes and/or researchers of other countries, especially in developing countries of the Asia-Pacific region. With respect to the latter, the Grant Programme added in 1994 a research classification called "joint research with developing countries". The content of the joint research should include basic studies such as the use of a comprehensive assessment model on global warming measures, and application studies that aim for transfers of environmental conservation technologies. For example, the programme has supported since fiscal 1994, research on the production and enhanced application of bio-Bricket (residential sector fuels produced by solidifying a mixture of biomass and coal powders) at changing, China, to mitigate air pollution. In 1996, Japan shipped only the bio-bricket moulding equipment (production capacity of 10,000 tons/year) and installed it at the site in China. Other than the provision of moulding equipment in anticipation of Chinese efforts, the research calls for the optimum application of technologies and machinery available locally. By October, 1997, trial operation and test production were being implemented with the installed equipment.

In 1995, the Environment Agency also established a programme called Eco-Frontier Fellowship for the purpose of inviting global environmental researchers from other countries (especially from developing countries) to conduct joint studies with researchers at national research institutes in Japan, and thus promote mutual and international exchange between researchers and research institutes. Under this programme, about 20 researchers from eight countries were invited to Japan in fiscal year 1997.

The Agency has an ongoing plan to establish regional networks for North and South America, Europe/Africa, Asia /Pacific. It has become secretariat for the Asia-Pacific Network on Global Change Monitoring, and supports actively joint studies within the region. Today, 18 countries are participating in the Asia Pacific network, and training workshops have been held in cities such as Beijing, China, using a comprehensive assessment model on global warming mitigation developed by the National Environment Research Institute of Japan.

- Trade insurance

The Government offers indirect support to private entities' overseas direct investment in developing countries, through the application of trade insurance to guarantee mid to long-term deferred payments. Examples of exports guaranteed include plants for petrochemicals, electric generation, and steel industries, loans for projects to be carried out in developing countries, and insurance on direct investment in general. Presently, the Government plans to establish a new framework for international cooperation including "Cooperation of Trade Insurance Institutions". The objective is to established a coordination system among insurance institutions of various countries to cover large-scale plant projects. In addition to cooperation among trade insurance institutions, a cooperation framework for the development and management of energies is needed in the Asian region to reduce the transaction costs of technology transfer, and enhance regional security. The trade insurance offered by the Ministry of International Trade and Industry and the Export/Import Bank have been criticized by other OECD countries (especially European countries) as "a means to assist unfair trade". It will be necessary to conclude negotiations at the earliest to seek intergovernmental coordination in the fields of insurance premiums, and their burden on developing countries, guidelines on environmental regulations, as proposed by the United States, and other items of dispute.

- Environmental technology transfer by local administrations

Recently, local administrations have participated increasingly in international cooperation programmes, with a budget totalling Y120 billion in fiscal year 1994, about a six fold increase in six years. Many of them address cooperation in environmental conservation fields, as in the case of Kitakyushu City (environmental cooperation budget of approximately Y50 million a year), Hiroshima City established the Acid Rain Research Centre in Chongqing, China and Yokkaichi City established the International Centre for Technology Transfer). Kitakyushu City (cooperative relationship with I-Chan City of Korea) is undertaking activities on mutual exchange and participation in the formulation of a master plan for environmental conservation of the city of Dalian in China through KITA (Environmental Cooperation Centre of the Kitakyushu International Technology Co-operation Association). 400 companies are members of the association. The International Centre for Technology Transfer (ICETT) is an organization established in Yokkaichi, Mie Prefecture in 1990 for the purpose of promoting technology transfer, and it by December 1996 had already accepted 535 trainees from developing countries. Similarly, it dispatches lecturers to various cities overseas to offer training and guidance. As of December 1996, about 1,044 local personnel attended lectures held in 16 cities in six countries. The Government of Japan supports the activities of local administrations to accept trainees and send experts in technical training by providing subsidies through overseas technological cooperation promotion groups (total budget for fiscal year 1996: Y1230 million).

- Environmental technology transfer by NGOs

The total amount of assistance offered to developing countries by all Japanese NGOs was US$365 million (with government assistance of US$150 million for fiscal year 1995). The "NGO Project Subsidy System" introduced by the Ministry of Foreign Affairs in 1989 increased its budget for subsidies to Y1 billion for fiscal 1996, nine times the initial Y100 million budget. Starting in 1989, the "Grassroots Free Assistance Programme" (Y4.5 billion budget in 1996) generated 707 cases of assistance. 443 of these cases, about 60 per cent, were NGOs' activities in developing countries. The Global Environment Fund (50-50 joint investment by the Government and the private sector) of Environmental Projects Institutes has offered free financial assistance to environmental NGOs from Japan and abroad (Y500-700 million a year) since 1993.

The advantage of NGO activity is their capability to enable the implementation technology transfers with the flexibility needed to adapt to the actual situation of recipient countries. The Japan Recycle Activity Citizens Forum, for example, started the trial production of recycled paper using husks from palm tree wastes generated from the extraction of palm oil. This technology is applicable to jute and, thus transferable to other regions. The transfer of top digging technology for ground water also is achieving positive results.

Case Study 3

Transfer of air pollution monitoring technology to china

Japanese NGOs' activities in China can be divided into 1) ecosystem protection such as the prevention of desertification (this dominates NGO activities), 2) protection of wild animals, 3) survey and building of monitoring networks for air pollution etc., and 4) environmental education and enlightenment. With regard to technology transfer, this section lists actual cases in the survey and monitoring network on air pollution.

The "Committee to Support Environmental Conservation in China", an NGO from Japan, is building model measurement stations throughout China for the constant monitoring of air pollution using recycled automatic measurement equipment, with the support of the Global Environment Fund of the Environmental Project Institutes of Japan. Currently, Chinese local environmental protection agencies obtain their data on air pollution through manual analysis. They have not adopted continuous monitoring, as generally practized in Japan using automatic measurement equipment. The "Committee to Support Environmental Conservation in China" provides local NGOs with technical support for such monitoring systems. The actual procedure is that they purchase air pollution auto-measurement equipment that are taken out of service every seven to ten years by Japanese local administrations; they repair and overhaul the equipment, and give it to private NGOs in China with a one year supply of parts and repair kits. They also send Japanese technicians to the site in China, and offer advice on measurement and data analysis. Such supportive activities have enabled continuous and more precise monitoring of air pollution that is not possible with manual analysis.

D. Public and Private Funding

1. Role of public funding

In Japan, private funding has begun to play an important role in technology transfers. While assistance funding from the Government of Japan was about US$14.7 billion in total for the fiscal year 1995, loans and investments from the private sector recorded about US$23 billion, which is a new record. However, it was the first time in four years that private investment exceed public funding. Among these amounts, government loans such as Yen credits through OECF amounted to about US$4.1 billion, and "OOF" (Other Official Fund) such as loans from the Export Bank (Japan Export/Import Bank) were about US$5.7 billion. However, as discussed earlier, the share of the environmental conservation industry in overseas direct investment is very small. Therefore, regarding funding for environmental conservation b the share private sector investment is relatively small, whereas official aid and funding still plays a significant role.

OECF through overseas investment by which is regarded as public funding, offers loans for a portion of funding or investment necessary (capital investment through stock purchases, as in the case of their Yen credit business), for projects in developing countries executed under the leadership of the private sector. The required conditions for targeted businesses are "being developmental projects of developing countries that have economic cooperation effects (anticipated industry/regional development effect, increased opportunities for employment, effects on earning foreign currencies and on technology transfer) appropriate for the introduction of Japanese public funding, and satisfy the requirement for a project presenting difficulties in its execution solely by private funding, due to various risks in project execution such as lower profits. The forms of their investment are 1) indirect investment through Japanese companies, 2) direct investment into local companies, and 3) capital investment in Japanese owned investment firms. A recent case of a private sector project for natural gas power generation in Pakistan received capital investment through AIMAC, a company that provides investment funds for infrastructure building in Asia, with capital investment by OECF, ADB, C. Itoh Co., Fujutsu, etc.

By the end of fiscal year 1995 OECF had approved investment loans totalling Y503.6 billion in 788 cases. There were 647 loans for a total of Y296.5 billion and 141 investment for a total of Y208 billion. 46 per cent were in Asia, 28 per cent in Central and South America, and 7 per cent in Africa. Sectorally, 47 per cent were for mining and industry, 26 per cent for agriculture, 7 per cent for social services, and 5 per cent for the transport sector.

2. Support to build infrastructure for private sector activities

The support programme to build infrastructure began with the OECF's investment (up to US$30 million through a Japanese investment firm) in 1994 in the Hub thermal power generation project in Pakistan, and projects including the survey fee for a subway system in Jakarta, Indonesia, Y5 billion for infrastructure investment in Singapore, and Y5.7 billion for the industrial use of water in Changchun, China). Besides investment for infrastructure capital investment has been made from the fund to support environmental measures in Mexico, and to offer financial assistance to small and medium scale firms in India. Ongoing projects include a study for the construction of highways and bridges in South-East Asia.

Loans from the Export/Import Bank when compared with Yen credits and investments and loans from OECF, tend to induce private sector investment, rather than public funding. In the fiscal year 1995, its loan provisions and credit guarantee approvals in 324 cases amounted to Y1.72 trillion. Loan conditions of the Export/Import Bank included an interest rate of 0.2 per cent, less than long-term prime rate. Recent loans to Asia Y811.8 billion approved for loans in 1995) directly or indirectly support the trend of privatization, and private sector revitalization under BOT or BOO methods through export financing, untied loans, and credit guarantees.

The Export/Import Bank (Japan Export and Import Bank) loans have more flexibility than onerous loans (Yen credit) from OECF. They are expected to increase further in the future. For example, Export/Import Bank is reviewing applications for 4.2 billion dollars loans to China for power generation and raw material industries. This exceeds the amount of onerous aids offered by OECF. From 1979 to 1992, the Export/Import Bank already provided three resource development loans (energy credits) to China for the total amount of 1.7 trillion yens. The Bank loans can be easily set in dollars, which facilitates the management of currency risks, broadening the selection possibilities to accommodate each particular situation. Furthermore, the general policy on ODA, which requires certain conditions in human rights and military activities, is not applicable to Export Bank loans, reducing the constraints on the political environment. Therefore, it is expected from developing countries to increase their dependency on "Export/Import Bank funds". The latest example is Sanxia Dam Project in China, which will be funded by Export/Import Bank loan. Japanese companies participated in the bidding.

E. A New Mechanism

1. Two-step loans

A two-step loan is a system to enable procurement of funds for small to medium-size companies in developing countries, especially those under-funded but requiring investment for environmental conservation. Currently, OECF is either implementing or planning this type of loans in countries such as Thailand, India, Philippines and Indonesia. The most important factors for the success of a two-step loan include accurate forecasting of financial requirements coordination between the various actors involved in the loans process, and the way the financial sector and legislative systems are organized. In reality, interest rates to end-users are higher than planned, as local banks add their margins and risk costs. In some cases, the loan system does not follow the normal local administrative procedures and Japanese coordinating capacity is often needed.

Case Study 4

Two-step loan in the philippines

A two-step loan was offered to the Development Bank of Philippines to assist the introduction of environmentally sound technologies for private entities in the Manila region. The programme is the first truly financed for industrial pollution prevention measures, and initiated through OECF's work to coordinate three relevant organizations in Philippines: the Department of Environment and Natural Resources (DENR has information on polluting companies), the Development Bank of Philippine (DBP), and the Department o

Finance which provides exchange risk insurance to the Philippine Development Bank. The total loan amount was Y5.158 billion, of which Y158 million cover consultant fees and system introduction expenses. Loan conditions included and interest rate of 2.5 per cent per annum for 30 years (including a 10 years deferment period), with DBP as the borrower. DBP then offered pesos loans to local entities at an interest rate of 11 per cent per annum for periods of three to fifteen years (with a five year deferment period). A preparatory survey conducted by the World Bank indicated that financial demand totalled Y170 billion in the city of Manila alone. Two-step loans are used actively by NGOs in environmental monitoring in the Philippines.

2. Super low-interest rates for environmental ODA

The Government of Japan provide favourable loan conditions for Yen credits for pollution control measures (air pollution, water pollution, and waste treatment) and global environmental problems (reforestation as a measure to reduce global warming, new energies and energy savings, etc.) by reducing the interest rate to 0.75 per cent per annum and extending redemption periods to 40 years (including 10 years of deferment). The improvement in Yen credit conditions will bring them down to a level equivalent to no-interest loans (interest rate 0 per cent, handling fee 0.75 per cent, and a redemption period 40 years (with 10 years deferment) implemented by the International Development Association (IDA: a member of the World Bank group, and an organization that provides loans on preferable conditions to developing countries). Similar Yen credits to the moderately developed countries will be provided at an interest rate of 2.5 per cent (25 years redemption period with 7 years deferred period). Furthermore, for other credit applications, the interest rate will be 0.75 per cent and a 40 years redemption period (10 years deferred). For similar cases in moderately developed countries, the interest rate will be 2.5 per cent with 25 years redemption period and 7 years of deferment.

This super low-interest programme was announced by Prime Minister Hashimoto upon his visit to China in August 1997. It underlined Japan's policy to give priority to environmental elements in its ODA.

3. APEC Virtual Centre (Technology Dissemination Centre)

Providing information on environmental conservation in general, and on measures and technologies in particular, plays an important role in the promotion of technology transfers. During the APEC Summit meeting held in Osaka, the Government of Japan took the opportunity to launch a database called the APEC Virtual Centre on Environmental Technology Exchange. It has been operating since 1996, in cooperation with private sector. The annual budget of the centre is about Y100 million, 40 per cent provided by the Government and 60 per cent by member companies and local administrations. The main objective of the data base is to match seeds and needs, with a home-page accessible on the internet (http://www.apec-vc.or.jp). The home page allows queries on technologies as well as on policies/measures. It provides responses on available environmentally sound technologies, on Japanese companies' know-how on pollution measures, both in English and Japanese, in a database format. In the future, the centre plans to add links to servers in other APEC countries and other regions, keyword query function, and the capacity to offer other information related to environmental issues.

The challenges of the APEC Virtual Centre Environmental Technology Exchange are: 1) configuration of the relationship with other existing data bases of environmental information and technologies (UNEP/IETC, and the Green Tie of IEA); 2) how to display difficult-to-show information such as company know-how, and success stories; 3) how to provide information to countries and regions with less or no internet infrastructure. Information on item 2), current "on-site" information provided by companies, would be extremely beneficial to developing countries. Yet companies loose the opportunity to communicate their experiences as time passes. Therefore, a timely and organized collection of information is needed. Case Study 5 should be considered as a case of inter-company transfer of technologies.

4. Acid rain monitoring network in East Asia

The Government of Japan has been proposing the establishment of an acid rain monitoring network in East Asia as part of a regional cooperation system for transboundary acid rain problems. At the expert meeting held in Hiroshima in February, 1997, fundamental agreement was reached on the networks establishment. It was scheduled to hold a government level meeting in early 1998.

The purpose of the network is to clarify quantitatively the actual situation regarding acid rain the mechanism of its occurrence and effects, by collecting and analysing data collected with standardized methods, then formulating a framework of regional cooperation acid rain measures based on scientific knowledge. The network calls for strong support, technologically and financially, from the Government of Japan, which applied for a Y280 million budget for fiscal 1998.

Case Study 5

Environmental technology database at obayashi construction Co.

Obayashi Co. created a database on environmentally sound technologies accumulated throughout the company and developed a system, on a trial basis, that would allow real-time query for application purposes. The trial system was completed in October 1997. The system enables the selection of appropriate technologies that respond to actual needs in urban development planning, such as "lessening the environmental burden" and "harmony with nature". Such a system can help in choosing environmental conservation measures at the planning stage of urban development projects. The system includes a database of over 100 cases of environmental measures and technologies. Items such as summary description, characteristics, utilization experiences and cost, relevant laws and regulations, and the contact address of the technical engineer in charge, are easily accessible and can be accessed from personal computers. The menu display classifies the technologies into six areas required for urban development, such as "reduced environmental burden" and "making a healthy town". Subdivisions include, energy, wastes, plants, soil, water, landscape, etc.; the menu enables further narrowing of relevant technologies to select the technology that conforms to the needs. If reduced environmental burden" then "waste" are included in a query for example, the system will display the list of technologies for waste disposal measures to reduce the environmental burden, such as "system of sorting, collecting, and transporting wastes".

On the issue of transboundary acid rain, Europe is ten to 20 years ahead of Asia in terms of both "scientific infrastructure" and "political infrastructure". Should the current pattern of fossil fuel consumption continue in Asia for the coming years, acid rain damage to the ecosystem will certainly increase. In other words, the Asian region needs a scheme similar to that adopted in Europe, e.g., the Sulfur Emission Reduction Convention. Current issues may include the clarification of a correlation between the impact of each country on the anthropogenic emission and the sink of sulfur. In future, however, it will be desirable to build a framework for acid rain mitigation throughout Asia to address the issue of cost-effectiveness by calculating the marginal cost of sulfur emission reduction.

IV. THOUGHTS AND PROPOSALS ON THE PROMOTION OF TECHNOLOGY TRANSFERS

A. Intellectual property rights as a means to strengthen competitiveness

There is an argument that environmentally sound technologies should be made, "international public properties" and to deny private ownership of intellectual property rights associated with such technologies, thereby allowing any company to use the technologies at no charge. Let us, however, examine the possibility of such companies effectively utilizing such intellectual property rights acquired at no cost. The company that owns the environmentally sound technologies may either apply such technology, or may sell it to others. In the case of commercialization of the technology and the equipment that embodies such technologies, it will be the primary strategy of a private entity to reduce the cost of raw materials, processing, management and other costs as well as intellectual property rights. At the same time, however, the management will base its judgement on commercializing such products on the possibility to secure the market for the equipment, the degree to which it may dominate the market, and the possible level of profit. For entrepreneurs, it may be more natural for intellectual property rights on competitive environmental technology to gain an advantageous position in competition with other companies. For instance, a company in Indonesia (P. T. Bukaka) that manufactures and sells electric dust collectors, bases its competitiveness on differentiating itself from other companies by the licence it obtained. Such a trend in entrepreneurship seems to be spreading to other companies, and is being adopted in countries with rapid economic growth.

B. Elements of an EST bank

For developing countries to be able to use intellectual property rights on environmental technologies that are mostly owned by developed countries, one idea is to introduce a government policy to support the purchase of such property rights at no or low cost (a so-called EST bank). The two essential elements of an EST bank are, first to facilitate the transfer of environmentally sound technologies to developing countries, and secondly to make them cheap. The fees to use intellectual property rights constitute part of the price for the technology or the resultant product. In order for the technology to be transferred and diffused, it is essential to maintain the price at a low level. In this case, an EST bank can be provide incentives to maintain a lower prices. Consequently, an EST bank may need to make pricing guidance a precondition for approval of assistance. In such a case, there should not be any differentiation between public financial assistance or that of private funding. The principle of equal treatment of public aid and private funding should be part of the basic concept of an EST bank, and could be supported from the defensive view of preventing a shift of intellectual property rights towards, and more preferable treatment, for those receiving public assistance.

C. Relationship between overseas direct investment and intellectual property rights

Many Japanese companies (such as Mitsubishi Heavy Industries, Toshiba, NEC, Ricoh, etc.) apply first for a patent in China, the Republic of Korea, Indonesia, and the United States. This year Mitsubishi Heavy Industry will apply for more than 1300 patents overseas for about 190 inventions in ship-building and environmental equipment (about twice as much as last year), taking advantage of applications under the Patent Co-operation Treaty which allows a discount in application fees if patents are applied about in 10 countries at once for the patent on one invention. Such increase in patent applications along with the policy of global companies policy to encourage investment, will benefit the commercialization of environmentally sound technologies.

However, Japanese companies tend to market products (including OEM) manufactured with such technology, rather than marketing the technology itself. As they consider this as the most effective method of applying technologies, they enter into almost no contracts for the licensing of patent. The core of technology transfer is not the licensing of the patent, but the transfer of the know-how which is at the sole discretion of a company. In many cases, the practical transfer of technology does not start until experts from the transferring party provide a direct training service to the recipient.

Although developing countries frequently demand "the revelation of the know-how on production technology rather than the products", the reality in business is not to allow the copying of a company patent. In principle, private entities allow only their own subsidiaries to use the transferred technologies and thereby dominate the market. In other words, technology transfer hardly materializes in the surrounding region, (its transfer to a third party in the region is not allowed). Such a trend is found also in the case of European and American companies, thus indicating the limit of technology transfer by private entities.

Very often environmentally sound technologies consist mainly of engineering know-how that cannot be patented. In most cases, environmentally sound technologies for developing countries are a "blend" of conventional patent-expired technologies. Therefore, in many cases, the (legislative) establishment of intellectual property rights will not be associated directly with the promotion of technology transfer.

D. Review of the ODA Mechanism

Japan's overseas development aid to developing countries constantly receives criticism domestically and internationally, expressed through such statements as "have no faces", "amount is big but not contents", and "purposeless spending". Its budget for fiscal 1997 experienced the least growth in the history of ODA (the actual Yen credit amount in fiscal 1996 was 35 per cent less than in the previous year.) Pressure to review the quality and content of development aid will certainly increase.

One of the main themes of any aid review is the elimination of vested interests. The budget for technology cooperation expenditure managed by each relevant ministry or agency, other than the Ministry of Foreign Affairs and JICA (Japan International Co-operation Association) amounts to Y130 billion (fiscal 1996) or 34 per cent of total ODA, but its increase merely reflects the overall growth of the ODA's total budget since 1989. In developing countries, also, one cannot deny the presence of vested interests for Japanese ODA. It is inevitable, as a part of administrative restructuring, to have a total review of the system which provides aid to developing countries.

There has been a reduction in the demand for yen credits due to exchange rate fluctuations as well as the trend away from the yen. There is a need to reorganize Japan's aid to make it more attractive to developing countries. As part of this, a further review of various preferential treatments in the environmental conservation field is inevitable.

In terms of preferential treatment, companies that offer technologies require public assistance in risk sharing as a priority. For example, environmental infrastructure projects in developing countries are generally carried out by local authorities, and so the national government of the recipient country will not provide currency indemnity directly. Instead, the executor (the company) must bear the currency risk. A policy for strengthening the system of risk sharing is an extremely important issue.

Furthermore, many companies are experiencing difficulties in introducing environmental investment in developing countries because they are small to medium size companies. Many companies in environmental industries are also small to medium size (whether in Japan or in developing countries). Aid to these companies is especially needed from the international community, including Japan. In addition, remote areas, where overseas funds hardly penetrate, and economic growth progresses slowly, have serious environmental degradation problems. "Small to medium companies", remote areas", and "risk sharing", will be key elements in future reviews of ODA.

E. Capacity required from Japanese companies and their personnel

Private sector aid is starting to go into the field of water supply infrastructure, which is in the scope of the environmental sector, in addition to power generation and road construction. Despite this expanded scope, Japanese companies lag behind European and American companies in the fields of environmental conservation and infrastructure construction. In these fields, not only is the cost performance of products important but the executing companies must have the risk management ability to oversee a whole project. Japanese companies, including banks, have less experience in these fields. Their capacities are not as large as those in other developed countries. Both companies and their personnel beside sharing risks must participate actively in communicating their environmental experience and business success stories to other countries.

It is well known that Asian countries have strong feelings of discontent and criticism as "Japan is reluctant to disclose technology know-how." An explanation of this "reluctance", however is the problem of communication. Japanese companies use oral training methods by technicians who train engineers of recipient countries. With the language barrier, it is difficult to measure objectively the impact of communication, thus creating situation where know-how is not fully transferred to the recipient. In contrast, American companies, upon signing a technology contract, usually prepare a manual describing the technology know-how, sell it to recipient engineers and finally give lectures using that manual. Should recipients want more information, a revised manual will be sold to them. Therefore, they seldom give the impression that there is some hidden know-how. Although there are various methods to transfer know-how from supplier to recipient, Japanese companies have much to learn. This, of course, calls for an improvement in communication abilities by the Japanese people in general.

F. Capacity required from developing countries

Japan has contributed a great deal towards building infrastructure for developing countries. The need for Japan's contribution will remain important in many areas including energy resource development, building of industrial complexes, health maintenance and hygiene. Under conventional Japanese methods, utmost efforts were made to develop teams that could be relied upon to execute these projects (for the construction industry, establishing sub-contract systems), and to secure project sustainability. In these cases, projects were designed to provide benefits to a wide range of business. They focused on gaining long-lasting trust, and avoided concluding monetary deal on intellectual property rights alone. Recipient countries should consider the significance and the benefit of this system, while Japanese companies need to develop a more comprehensive cooperation system, with increased appointments of local employees to management and executive levels.

It is expected that there will be more cases where the transfer of the latest technologies and systems, as in power generation and traffic systems, will become most effective in terms of global environmental conservation. Recipient countries should consider applying BOT or BOO methods more positively to actual projects. Through these, they can increase the number of cases where the transfer of intellectual property rights results in actual benefit for environmental improvement. Indemnities can allow flexible measures like the exchange of assets such as land, or instalment payments from income earned in the operation of systems for a designated period.

Despite the difference in technological levels, developing countries need to participate in joint studies to raise their technological capacities, by providing them with opportunities in application. It is also necessary to increase the number of operator training sites, and to set up a system to supply the necessary personnel, despite the somewhat excessive mobility of such personnel. To depart from conventional restrictions that training can be done in Japan only, there should be strong efforts to develop manufacturing industry in developing countries, including the construction of model plants, and to transfer assembly industries where assembly can proceed with a moderate level of technology. It is essential to conduct the methodical development of industrial technology infrastructure until engineers will be no longer the elite.

For real effects of environmentally sound technologies to materialize, there should be a system to confirm the results objectively, and to evaluate improvements through the actual operation of equipment. In addition, the system could evaluate the technology effects of the trade in intellectual property rights, thereby allowing a better perspective on the need for the re-transfer of technology. Various methods can achieve these goals. One such method, the European environmental control system has been adopted by the International Standard Organization (ISO). Its application to developing countries will assist in better technology diffusion.

For developing countries the establishment of a system to allow production and maintenance of necessary equipment is required to implement call for environmental conservation measures. To achieve this, they may be allowed to impose higher tariffs on such machinery imports as a necessary policy to achieve environmental goals. As an incentive to entrepreneurs it will be essential to provide abundant information on environmental conservation measures. Governments of developing countries and technology-owning countries should offer maximum support to such information exchanges. For example, internet access should be made free of charge as soon as possible.

To confirm the effects of drugs, administered drugs effects are compared with those of placebos. For a comparison study of the effectiveness of environmental technology transfer, it might be interesting to conduct a demonstrative comparison between, on one hand the method of government intervention on the supply side through permit and approval and, on the other hand, the method of less intervention in technology introduction and reliance on business-oriented assessment of the results.

G. Possibility of joint implementation

All of the eleven projects the Government of Japan plan to implement jointly have not been approved by the recipient countries (as of September, 1997). In addition, the projects offer almost no incentives for participating companies. The bottleneck is the problem of lack of emission credit, and it will be extremely difficult to have a consensus of the relevant parties on this point. The situation will change, should legally binding emission budget and emission credit be introduced at the Third Conference of Parties for the Framework Convention of Climate Change to be held in December, 1997 in Kyoto. However, if the emission budget and carbon tax do not materialize domestically, there will be no incentives for companies.

The ideal scenario is for international cooperation to establish an environmental security system in an organized and systematic way. Such a scheme should use the market mechanism. To establish a joint implementation system, it will be necessary to develop academic community cooperation in conducting the cost-benefit analysis based on a unified format. An international monitoring organization also will be needed. Furthermore, more extensive exchanges between companies should be encouraged. Such expansion of joint activities and communication will nurture trust and strengthen regional unity. If technology transfer intensifies as a result of joint implementation, both suppliers and recipients of technology will benefit. For developing countries, it will have a significant meaning if advanced technology that was not transferable without joint implementation can now be transferred. Joint studies on cost benefits will clarify complexities such as the energy savings effects attainable domestically and internationally through air pollutant emission reduction. This may encourage developing countries to value highly the scheme and environmentally sound technology itself.

There are many problems in the joint implementation scheme. The most important one is the possibility of a slow-down in technological development in the fields of energy savings. However, it is certain that joint implementation can act as a trigger to jump-start technology transfer. Furthermore, it is possible to develop regional cooperation resulting from joint implementation and a more organized scheme. If the objective is to establish a security system such as stocks of oil and food, with risk management of nuclear energy in view, the merit of joint implementation will far exceed its drawbacks.

PART III

LEGAL AND SECTORAL CASE STUDIES

Studies of legal regimes
Sectoral study

THE ROLE OF PUBLICLY FUNDED RESEARCH AND PUBLICLY OWNED TECHNOLOGIES IN THE TRANSFER AND DIFFUSION OF ESTs: THE CASE OF MERCOSUR

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I. THE SETTING: THE OVERALL ROLE, SCOPE AND RELATIVE IMPORTANCE OF PUBLICLY FUNDED R&D IN MERCOSUR

A. R&D Expenditures

1. Some indicators

Mercosur countries, like other Latin American countries, have traditionally invested a relatively minor proportion of their GNP in science and technology. As a result of the patterns of industialization that prevailed untill the 1980's, and the application of a "linear model" of development in S&T, R&D expenditures have focused on basic and applied science and have been mainly funded and executed by the public sector. Most R&D is undertaken in isolation from productive needs and never reaches the market.

The private sector, relatively isolated from competition during the import-substitution phase, has relied extensively on the importation of technology and on the use of relatively mature technologies consequently. The private sector's participation in total R&D has been quite low compared to that observed in industrialized countries.

Total S&T expenditure in Mercosur amounted to around US$ 7 billion in 1996. Important differences exist with regard to the levels of expenditure and to the participation of the public and private sectors in each country (see table 1).

Table 1
S&T expenditures in MERCOSUR*

Country	Total expenditures (US$ million)	S&T expenditures (1995) Percentage spent by enterprises
Argentina	1 030	11 5
Brazil	5 888	30 2
Uruguay	5 524	----

Source: For Argentina and Uruguay, S&T indicators produced by: La Universidad de Quilmes (1997); for Uruguay, data communicated by: La Universidad de la República.
* No information is available on Paraguay

As indicated in table 1, Brazil possesses the largest S&T infrastructure in the subregion, with total S&T expenditures that are almost six times higher than those of the second largest country, Argentina. The participation of enterprises in total expenditures on S&T is greater in Brazil (30 per cent of total R&D) than in Argentina (11.5 per cent of total R&D).

Most R&D undertaken in the Mercosur countries is funded by the public sector. This is reflected in the types of R&D undertaken. In Argentina for instance, only a minor proportion of R&D is devoted to "experimental development", that is, R&D activities that are closest to industrial application (see table 2)[1].

Table 2

Argentina: percentage distribution of R&D by activities (1988)

Basic research	**Applied research**	**Experimental development**
34.5	58.4	6.1

Source: UNESCO, 1991.

Only a small proportion of S&T expenditure goes to projects relating to the control and protection of the environment. In 1995, their shares of total S&T expenditures for Argentina and Brazil were 3.8 per cent and 1.6 per cent, respectively.[2]. In Uruguay, 11 per cent of the resources available under the CONICYT-BID programme were devoted to the environment (16 projects with a total funding of US$ 1.7 million)[3].

2. The changing paradigm of R&D

The initial elements of an institutional framework for the public support and promotion of S&T activities were established in the Mercosur countries at the end of the 1950's. Since then while universities expanded their role in basic and applied science, the governments set up national "councils" for the promotion of science (CONICET in Argentina; CNPq in Brazil; CONICYT in Uruguay). In some cases, these councils created their own scientific institutes, or operated them jointly with the universities.

In addition, various "technology institutes" were set up, to provide technical services and assistance to a number of industrial sectors (e.g. Instituto Nacional de Tecnología

[1] For purposes of comparison, according to the same source (UNESCO, 1991) experimental development accounted for more than 60 per cent of total R&D expenditures in the United States and Japan, against a meager 6 per cent in Argentina.
[2] Data elaborated by the University of Quilmes, 1997.
[3] Data as of 31.5.96, supplied by *CONICYT*, Departamento de Proyectos de Investigación.

Industrial -INTI- in Argentina; Instituto Nacional de Tecnología y Normalización -INTN- in Paraguay) and to farmers and breeders (Instituto Nacional de Tecnología Agropecuaria -INTA- in Argentina, Instituto Nacional de Investigaciones Agropecuarias -INIA- in Uruguay).

R&D activities in public institutions were undertaken under a paradigm of open access to their results. The role of scientific and technological institutions was conceived as the creation of public, non-proprietary knowledge. R&D results were diffused and made available without restrictions. Intellectual property rights were claimed only exceptionally, even with regard to technological applications.

This approach started to change during the 1980's, as a result of the convergence of several factors:

Firstly, a reduction in public budgets for S&T activities stimulated some institutions to try to recover their R&D expenditures by commercializing R&D results. In some cases (e.g. INTA in Argentina), authorities perceived that while their funding was insufficient and declining, private companies (mainly foreign firms) were able to benefit from publicly funded R&D results (Jacobs and Gutiérrez, 1986, p. 33).

Secondly, public institutions deliberately defined policies aimed at increasing their relationships with the productive sector. Several mechanisms were set up for that purpose, including specialized units for the transfer of technology. While implementing these policies, it became apparent that the protection of results by intellectual property rights not only facilitated their commercialization, but it was in some cases a necessary condition for the in transfer. Many firms are not interested in acquiring technologies without exclusivity (Correa, 1997,p. 68).

Thirdly, difficult working conditions and the deteriorating salaries of researchers, prompted demands to participate in the profits eventually gained from the commercialization of R&D results. The latter started to be regarded not as a simple output of a "public service", but as a contribution for which the researcher should receive additional compensation (Delpiazzo, 1995, p. 54).

This change in the conception of public R&D reflects, as in developed countries, an attack on the values of the paradigm of technological research in the area of science (Dasgupta and David, 1994). However, the transition towards a new paradigm has found, , many obstacles, notably[4]:

- the lack of consensus within the scientific community with regard to the new paradigm of appropriation of results;
- the practices of evaluation maintained by research institutions, based mainly on the publication of papers and the little or no academic recognition given to applied work;

[4] For a review of Latin American literature on the university-enterprise relationship, see Correa et al., 1996.

- the lack of familiarity of researchers and institutions with regard to the acquisition and management of IPRs.

Most importantly, the shift in the R&D paradigm is ongoing, and so far limited by the lack of a strong demand for R&D results from the private sector (Weiss, 1994, p. 232). In fact, although the number of agreements between R&D institutions and private firms has steadily grown since the 1980's, most of these agreements relate to the provision of services rather than research. Moreover, enterprises consider "informal" relationships with R&D institutions more effective rather than "formal"[5] (Correa et al, 1996).

B. General Legal Regime

The appropriation and transfer of the results of publicly funded R&D are subject in Mercosur countries to different national legislation. No Mercosur country has specific legislation on the matter. Therefore, the rules that govern the appropriation and transfer of such results are found in various legal fields:

- intellectual property legislation
- constitutional and civil law
- contract law
- labour law and,
- administrative law as applied to contracts by public entities.

These regimes, as applied at the national level in each country, determine the general conditions for the appropriation and transfer of publicly funded R&D results. Legislation on intellectual property rights (IPRs) is reviewed in section IV. The following paragraphs briefly illustrate how the other legal fields affect some aspects of the transfer of publicly funded R&D results.

1. Constitutional and civil law

Constitutional and civil law determines the basic rights involved in the appropriation of R&D results. An important aspect regulated by this component of legislation is the concept of "State property". A distinction should be made between the "public" and "private" property of the State. The category of "public" property involves land and other goods that by their nature, are of common use to citizens, or are outside commerce for other reasons. The State can not dispose of this property.

[5] “Informal” relationships channel the transfer of information based on personal contacts with researchers, participation in seminars and other activities that do not require agreements with the R&D institution. When such agreements are entered into relationships are deemed “formal”.

The "private" property of the State includes goods that the State uses for the execution of its responsibilities (buildings, vehicles, etc.). Such goods may be rented or disposed of. This is the category that in principle, applies where a State holds intellectual property rights. Hence, when reference is made to "publicly owned IPRs" in the sense of IPRs held by public institutions, it is a kind of property that may be disposed of through assignment or licenced to third parties. Another problem, in federal countries, relates to the attribution of property to Provinces or individual States, as distinct from the property that belongs to the Federal State[6].

2. Contract law

Contract law also is relevant to the appropriation and transfer of R&D results. An important aspect is for instance, how arrangements for the transfer of R&D results are categorized. The application of different legal categories (sales, services, licences, etc) may lead to very different effects, particularly with regard to property rights and responsibility. Thus, research arrangements may be deemed to be service agreements (whereby the supplier undertakes only to provide certain professional services, but not to deliver a given result), or agreements involving the delivery of a specific result (Reboul, 1978, p. 125). Agreements may involve the assignment of rights (that is, the transfer of total or partial ownership), or just the authorization to use research results (licences).

Similarly, contract law determines the extent of rights and obligations of parties in agreements for the transfer of R&D results. The principle of freedom to enter into and define the terms and conditions of such agreements is recognized in the Mercosur countries.[7] However, contract law applies with regard to any aspect not specifically dealt with by the parties, and may also limit such freedom in some respects[8].

3. Labour law

Labour law is relevant to the determination of the rights and obligations of employers and research personnel with regard to R&D results. Thus, inventions of employees may belong to the employer or to the employee, depending upon the circumstances. In some cases, the employee may not have title to the invention, but the right to claim compensation. In Paraguay and Uruguay, existing IPR laws do not include specific provisions on this issue. Hence, the allocation of intellectual property rights is regulated by labour law.

In Argentina and Brazil the patent laws include special regimes for employees' inventions, which equally apply to employees in the private sector as well as to university professors and other research personnel in public R&D institutions[9]. If an invention has been developed by an employee who has not been engaged to undertake research or an inventive activity, and who has not used a knowledge or other resources of the employer, the invention

[6] This distinction has become particularly relevant in certain areas, such as with regard to jurisdiction and property in genetic resources.

[7] In accordance with the *Argentine Civil Code*, the contract is "the law for the parties".

[8] For instance, the *Brazilian Industrial Property Code* (article 63), determines that the improvements made to a licenced patent shall belong to the person who has made them.

[9] Brazilian law specifically extends the application of these provisions to federal, state and municipal entities (article 93).

belongs to the employee both under Argentine and Brazilian law. However, in Argentina, when the employee has used the resources of the employer to develop an invention, the employer may claim property rights or the right to exploit the invention, while in Brazil such an invention is the joint property of the employer and employee, except if otherwise agreed upon. In any case, and despite the specificity of these provisions, their application is subject to the general rules and principles of domestic labour law.

4. Administrative law

Public institutions are subject in Mercosur to a variety of legal regimes with respect to their contracting activities. In some cases, they operate as if they were private parties, that is, their acts are subject to common legislation. In other cases, however, the administrative law applies, which may limit among other things:

- the process for selecting contractors (bidding, direct contacting, etc) ;
- the admissibility of certain conditions with regard to the property and use of R&D results (e.g. non assignability of rights);
- the freedom to choose the mechanisms for dispute settlement.

C. Specific Regimes

In addition to the general regimes indicated above, many public institutions including universities, have adopted regulations for dealing with the appropriation and transfer of R&D results. This means that both the creation and application of such regulations are largely decentralized in Mercosur countries. Such decentralization is particularly significant in the cases of Argentina and Brazil, since both are federal States, and many Provinces and States have established institutions for the promotion of R&D, which apply their own regulations to R&D results.

Furthermore, universities enjoy a certain degree of autonomy and the in right to determine the conditions for the protection and transfer of the R&D results that they generate has been generally recognized. It should be noted in this regard, that most basic and applied research within Mercosur is done by universities, from their own budgets or the financial support of other local or foreign institutions.

Hence, in order to define the legal status of a particular set of results of publicly funded R&D, it is necessary to determine the extent to which the general legal regimes mentioned above and/or specific institutional regulations are applicable.

It should be noted that under the law in force in Mercosur countries, any legal person, including research institutions and universities, may be the original title-holder of R&D results if protected by industrial property rights, but not in the case of copyright.[10] The State, as mentioned above, may own IPRs, as part of its "private" property.

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[10] Universities account for around 15 per cent of the national budget for S&T. They are the main locus for basic research in the country

A few examples on how universities and other R&D institutions, and some funding agencies deal with the appropriation of R&D results, are given in the following subsections.

1. Regulations of R&D institutions. Some examples:

A study on the regulations of some universities show important differences regarding to the type of results and activities considered under such regulations, and the way in which property rights are allocated. In many universities -including some with significant links with the productive sector- the issue of appropriation and use of IPRs has not been regulated yet and, therefore, each situation is solved on a case-by-case basis (Fracasso and Balbinot, 1996, p. 639).

As indicated in table 3, in a number of Argentine universities[11] the type of results covered is widely defined, though in one case the regulation is limited to patentable inventions. The type of activities and projects covered also differ.

In some cases regulations only apply to research executed and financed by the university, that is, R&D undertaken by the researchers and/or universities without a request. In other cases (the majority in the sample) they apply also to cases where a project has been supported by a third party. Unlike many universities in developed countries, Argentine universities seem open to admit that IPRs belong to the contractor solely or jointly with the university.

This flexible position seems appropriate for two main reasons. On one hand, the relationship of universities with the productive sector is weak, and they are not generally in a strong bargaining position vis-a-vis potential clients. On the other, Argentine universities (like most universities in Mercosur) lack the infrastructure and resources to manage IPRs adequately especially if the registration of titles abroad is required.

According to the regulations of one university, joint ownership between the university and its researchers has been established. In all other cases, the universities retain an exclusive title to the R&D results obtained, but they guarantee the researchers some form of participation in the profits derived from the commercial exploitation of the results. The distribution of such profits is an internal issue that does not affect in principle the relationship with contractors.

The Universidad de la República (Uruguay) is one of the institutions in the subregion with the most elaborate regime for the allocation of IPRs relating to R&D results. The University's Ordinance of 8/3/94, applies to knowledge protected by intellectual property rights (including breeders' rights) and copyright relating to computer programmes. It covers any knowledge developed as a result of projects executed or financed by the University, implemented by professors, students or any person working in the University. IPRs obtained belong to the University. Unlike other regulations mentioned above, the Ordinance specifically requests the inventor/author to assign his rights to the University.

[11] Universities account for around 15 per cent of the national budget for S&T. They are the main locus for basic research in the country

In Brazil,[12] the paradigm shift mentioned above is taking place in many institutions. The issue of IPRs is however, quite new for Brazilian universities. Each university defines its own policy for the appropriation and transfer of results. The general approach is that such results belong in exclusivity to the universities themselves. If they are exploited through a licence by a third party, the researchers may generally claim participation in the profits.

2. Funding institutions

The Consejo Nacional de Investigaciones Científicas y Técnicas (Conicet) was created in Argentina in 1957, with the purpose of promoting, co-ordinating and carrying out research in applied and basic sciences. CONICET is the most important institution in terms of budget and human resources in the area of science in Argentina. It accounts for about one third of the national budget for S&T. According to CONICET Resolution 243/89, the results of R&D undertaken by CONICET personnel or with subsidies conferred by it, are a "joint property of CONICET and the involved personnel" (article 2). If such results are commercialized, personnel who participated in the research are entitled to 50 per cent of the income obtained.

A new agency for funding scientific and technological activities was created in Argentina in 1997, to administer federal funds available (from different sources) for the promotion of scientific and technological activities. The "Agencia Nacional de Promoción Científica y Tecnológica" does not execute R&D but is only in charge of the allocation of resources for R&D undertaken by other institutions or private parties. In accordance with the contracts established by the Agency with research institutions and the adopting parties,[13] R&D results shall be confidential. Before publishing them in any form, authorization has to be obtained from the Agency. The lack of reply from the Agency may be interpreted as an authorization to publish. In cases when the results may be patented, the parties should jointly agree how to proceed.

The Consejo Nacional de Investigaciones Científicas y Técnicas (CONICYT) of Uruguay was created in 1961, with the objective of promoting scientific activities. In 1991, with the support of the Interamerican Development Bank, it initiated a programme to support technological projects. Under this programme, CONICYT has financed about 200 projects with a total budget of US$ 17 million. In addition, the FINTEC programme[14] provides loans at low interest rates for the implementation of innovation projects. Contracts established between CONICYT and the beneficiaries of the FINTEC programme stipulate that the intellectual property rights of the R&D results of the financed projects, shall belong jointly to the parties to the contract.

The allocation of IPRs for employees' innovations has also been regulated in Uruguay by the Instituto Nacional de Investigación Agropecuaria (INIA). Under INIA's regulations, all knowledge obtained as a result of a research activity which may be implicitly or explicitly deemed a part of the object of the employment contract, shall belong to INIA.

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[12] The analysis relating to Brazil is mainly based on a communication by Eva Stal, Universidad de San Pablo.
[13] These are the firms or other entities that agree to use the results of a R&D project, if successfully concluded.
[14] *FINTEC* (Financiamiento para la Innovación Tecnológica) is a programme of CONICYT.

In the case of the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) of Brazil, the conditions for the allocation of R&D results are established according to the type of project and funding granted. CNPq is currently reviewing its policy on the matter, in the light of the new patent law, in order to ensure that researchers obtain some benefits from the R&D results. CNPq does not seek IPRs for the results of R&D that it has financed, and allows the funded institutions to apply for such rights, if appropriate, in their own names. The only obligation imposed is to inform CNPq that a patent or other IPR has been obtained. Similar conditions apply to R&D financed by Financiadora de Estudos e Projetos (FINEP) and by the Ministerio de Ciencia e Tecnologia.

The Fundaçao Oswaldo Cruz (FIOCRUZ), the most important public institution in the field of health R&D in Brazil, adopted in 1996 a regulation for the allocation of IPRs for "inventions and improvements". All patentable inventions are allocated to FIOCRUZ. The same applies when the inventions are the result of activities exclusively financed by and developed in FIOCRUZ. If the invention was partially developed outside the institution, it will be jointly owned with the other parties participating in the project.

D. The appropriation and diffusion of publicly funded R&D results

To define the legal status of R&D results, they should first be classified under the appropriate IPRs. If it cannot be patented or classified under an IPR, it belongs to the public domain. If however, these is potential to classify it under IPRs, its legal status will be determined by the title applicable to the type of knowledge involved (patents, utility models, copyrights, etc.).

The concept of "public domain" used here is different from "publicly owned", since the former means that the knowledge is freely accessible and usable, i.e. anybody can use it without authorization or payment. In contrast, the concept of "publicly owned" technology indicates that there exists some form of appropriation based on IPRs held by a public entity. In other words, this latter concept does not allude to the legal status of the technology as such which is not freely available- but only indicates that the title-holder is a public entity.

1. Legal regimes governing ownership

IPRs legislation defines the types of property rights obtainable with regard to the results of publicly funded R&D. The main type of IPRs relevant for the protection of ESTs are patents. The protection of undisclosed information (trade secrets), as well as of utility models may also be relevant.

The Mercosur countries have initiated negotiations to harmonize certain aspects of intellectual property rights. So far, only a protocol on trademarks and other distinctive signs has been approved by the representatives of the Governments, but approval by the respective Parliaments is still pending. Discussions on protocols on copyright and industrial designs have also led to the preparation of draft texts which are now being considered.

2. Patents

Argentina and Brazil have recently amended their patent laws (1995 and 1996, respectively) in line with the requirements of the Trade Related Intellectual Property Agreement. Paraguay and Uruguay also confer patent protection under existing laws, but are considering a substantial revision of their legal regimes on the matter.

Generally ESTs can be patented in Mercosur countries. However, Argentine law excludes -in line with the TRIPs Agreement- the patenting of inventions that may cause serious prejudice to the environment (article 7 a). The inventor has the right to obtain a patent. Priority is given on the basis of the date of the filing of an application. While in Argentina and Brazil, the allocation of patent rights for employees' inventions is specifically dealt with, this is not at present the case in Paraguay and Uruguay[15].

It should be noted that Argentine patent law incorporates three of the conditions for compulsory licences explicitly referred to by article 31 of the TRIPs Agreement (national emergency, anti-competitive practices, dependent patents), plus compulsory licences based on the concept of “non-working” and "refusal to deal."[16] The conditions set forth in article 31 of the Agreement for the granting of compulsory licences are almost literally reproduced in the Argentine law.

The 1996 Brazilian law (No. 9.279) provides also for several types of compulsory licences for a number of reasons including lack of local industrial use for the invention, dependent patents, national emergency or public interest, and abuses of patent rights.

The patent laws of Paraguay (law 773 of 1925) and Uruguay (law 10.089 of 1941) contain provisions on compulsory licences, in the case of lack of exploitation of the patented invention

The trend of innovation in Mercosur is characterized by the development of "minor" innovations, i.e. the adaptation or improvement of existing technologies. It is not surprising therefore, that the number of patents applied for by residents of Mercosur countries is very low, compared to applications made by foreigners (see table 4). In Argentina, patents applied for and granted to residents are about one quarter of those granted to foreigners. The same applies to Brazil with respect to patents granted, where the participation of residents is even lower (12 per cent) in terms of patent applications. There is little information about patents obtained by public R&D institutions in Mercosur countries. Anecdotal information indicates that the number of patents applied for by universities and other R&D institutions in Argentina is growing, but remains very small[17].

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[15] However, draft legislation under consideration in these countries, provides for the regulation of employees' inventions.

[16] Argentine law considers article 31 a) of the TRIPs Agreement, both as an autonomous ground for granting compulsory licences, and as a condition to be applied to compulsory licences conferred on the basis of other grounds.

[17] For instance, the University of Buenos Aires, one of the largest (with 170.000 students) in Latin America, has only applied for ten patents so far.

In the case of Brazil, between 1988 and 1991, universities and R&D institutions applied for 222 patents, less than 1 per cent of patent applications made by residents of Brazil With some exceptions, the productivity of such institutions in terms of patents per researcher has been extremely low (less than one per year)(Fernandes, 1992, p. 416).

3. Undisclosed information

The obligation to keep undisclosed information secret is provided for under labour law in some countries, as well as under the regulations of some institutions. In December 1996, Argentina passed legislation on "confidential information", which literally reproduces article 39.2 of the TRIPs Agreement. Protection is given under the framework of unfair competition law. Data submitted for the approval of patents for agrochemical and pharmaceutical products are protected against disclosure, in conformity with the Agreement (article 39.3).

In Brazil, under article 195 of the Code on Industrial Property (1996) the unauthorised disclosure or use of confidential information, excluding information publicly known or "evident" to an appropriate technical person is illegal. The article also condemns the disclosure of the results of tests and other data submitted to government authorities to obtain approval for commercializing a product, provided that the production of such data involved a considerable effort. There are no special rules on the matter in Paraguay and Uruguay.

Publicly funded R&D results may be protected as undisclosed information, either provisionally until a patent is applied for, or on a more permanent basis. Public institutions in Mercosur are paying growing attention to this type of protection, although an important conflict has arisen in many institutions -particularly universities- where the tradition of open access to knowledge prevailed until the 1980's.

E. Rules governing the licencing and assignment of R&D results

Publicly financed licencing and assignment agreements related to R&D are governed by a variety of regulations including, as mentioned above, civil and contractual law and, in the case of public institutions administrative law.

Licensing agreements relating to publicly funded R&D results can in general be negotiated with considerable freedom. The parties can define the scope of the agreement, the price to be charged, the duration, and the conditions for use of the technology, including obligations of confidentiality. While public institutions have considerable flexibility in this regard, many of them, particularly public universities, have sought greater room of manoeuvre by establishing independent agencies (generally under the form of foundations).[18] These agencies are not subject to administrative regulations and have greater freedom than universities´ administrations to negotiate the conditions of contracts with third parties.

[18] In the case of The University of Buenos Aires, a private company (UBATEC S.A) has been established

In general, there are no restrictions on granting exclusive licences, even for publicly funded R&D results. As indicated above, with regard to a number of R&D institutions and universities, if the contracting party has financed or co-financed a research project, many regulations stipulate that such a party may get an exclusive licence or even the property of the R&D results, either exclusively or jointly with the University. Thus, in the case of Brazil, the contractor of a project with a State research centre is entitled to any IPRs that may arise even if the results do not correspond to those specified when the contract was made (Borges Barbosa, 1997, p. 59).

However, the agreements for the assignment of IPRs that belong to a public institution are subject to more stringent rules than licencing agreements. In Brazil for instance, the University of Sao Paulo can only transfer the ownership of IPRs through bidding procedures governed by administrative law. The universities that have set up foundations or other entities (which operate as private parties) may bypass these kinds of requirements and negotiate directly the transfer of rights.

No different treatment has been found neither in legislation nor in the institutional regulations reviewed, of the owners of the enterprises that contract with R&D institutions based on size or nationality. This means that any enterprise, national or foreign may in principle, negotiate and obtain a licence or the assignment of IPRs relating to publicly funded R&D results.

F. Institutional mechanisms for diffusion and utilisation of publicly funded R&D results

Several mechanisms have been established to promote the diffusion and use of publicly funded R&D, which are applicable -albeit not solely- to ESTs.

1. General instruments

In Argentina, a federal law ("Law on the Promotion of Technological Innovation" (Law No. 23.877) was enacted in 1990 with the objective of improving firms' performance in technological innovation. The law provides financing for the operation of "linkage units" between public institutions and private parties. The units had to be able to identify, select and formulate research and development projects, to transfer technology, and to provide technical assistance.

The law allows different types of financing, notably:

- Loans for undertaking research and development projects, technology transfer and technical assistance. Funds may cover as much as 80 per cent of the cost of a project; they must be refunded in four years (payments can be postponed up to three years). The interest rate is half the lowest interest rate available from the Banco de la Nación.

- Subsidies, only available to "linkage units" and firms that acquire the technology resulting from an approved project. The amount received must be reimbursed only if the project is successful[19].

A number of instruments available in Brazil for the promotion of innovation may be used by firms to finance the acquisition of technology from public institutions, or the cost involved in the execution of R&D projects agreed upon with such institutions (Galvao et al, 1993, p. 63).

2. Transfer of technology offices and agencies

A second type of institutional mechanism for the transfer of R&D results has been the establishment, within universities and other R&D institutions, of specific offices for the transfer of technology to the private sector. In many universities in Mercosur, such offices have been established since the 1980's, in many cases following the model of the Spanish "Offices for the Transfer of Technology". For instance, the University of Buenos Aires set up in 1987 a Technology Transfer Office. Its duties included not only work on technology transfer, but also on the promotion of broader linkages between enterprises and the academic environment.

Since 1987, the number of contracts between the University of Buenos Aires and third parties has increased sharply. The overwhelming majority of such contracts however, were entered into with public institutions and aimed at the provision of technical assistance and services, rather than the development and transfer of technology. Between 1990 and 1994, less than 50 contracts were signed by the University with private enterprises and associations.

As mentioned above, some universities have gone a step further and created private independent agencies, to foster relationships with the private sector. For instance, UBATEC S.A, with a turnover of around US$ 4 million annually, promotes the transfer of R&D results achieved by the University of Buenos Aires, and different kinds of consultancy and technical assistance complemented by the University's staff.

Another example is provided by CONICET, Argentina. From its foundation, it focused on basic sciences such as chemistry, physics and biomedics, and did not pay too much attention to technological development. Linkages with the productive sector were regarded as unimportant or even ignored by scientists: between 1971 and 1983 CONICET had an average of only ten agreements per year for the transfer of technology or services. In 1984, CONICET created a Technology Transfer Office. The number of agreements increased significantly: between 1984 and 1989 it climbed to 229 of which 65 per cent were signed with firms. Most of the contracts related to technical assistance and services, rather than to the transfer of R&D results as such or the undertaking of new research.

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[19] The law also provides for non-reimbursable subsidies to support the development of technology - based firms and for the development of technical services and training for small and medium enterprises.

This office was closed down in 1989 and reopened in 1994 as the "Office for Relationships with the Productive Sector". The number of agreements entered into with third parties fell drastically again (only 25 contracts between 1990 and September 1995).

G. Mechanisms for accessing publicly funded ESTs by firms in third countries

A review of legislation and regulations adopted by some R&D institutions and universities in Mercosur, does not reveal the existence of legal mechanisms specifically aimed at dealing with the transfer of ESTs. No special obstacles for their transfer has been observed either.

Public funding mechanisms for R&D generation and transfer, where available, are applied in Mercosur countries without differentiating the sectors to which the incentive is to be given. No special incentives for the transfer and diffusion of ESTs were identified in the countries considered in this study.

Due to the profound North-South asymmetry in the capability to generate new technologies[20] including ESTs, and the different scope and impact of environmental policies applied in developed and developing countries, ESTs have been developed and held predominantly by companies and institutions in industrialized countries. The important role played by the private sector in the development of ESTs in industrialized countries, has been examined elsewhere (see OECD, 1992, Chapter 9), and has been recognized by the international community (see Agenda 21, article 34.18).

Publicly funded institutions in industrialized countries are working enthusiastically under the influence of a paradigm of appropriation of R&D results (Dasgupta and David, 1994). Hence, in a framework of increasing "privatization" of public research "publicly funded R&D" does not generally mean "publicly available" R&D results, but results which are subject to appropriation under patents or other titles held by the entities that developed them. (Cohen and Noll, 1994, p. 72).

ESTs are not an exception. Despite the benefits that a wide diffusion of some ESTs may entail, there are restrictions to their access by third parties, including enterprises and institutions in developing countries. The strengthening of IPRs as a result of the implementation of the TRIPs Agreement, is likely to have an ambivalent effect on the transfer of ESTs to developing countries.

Stronger and broader IPRs will enhance the bargaining position of technology holders with potential licensees, who may face higher royalties or more stringent terms for acquiring ESTs, if the technology holders are willing to transfer them at all. These effects may however, be mitigated if measures are adopted at the national level to promote the transfer of technology through voluntary and compulsory licences.

The TRIPs Agreement does not limit the grounds under which a compulsory licence may be granted. It allows any WTO Member, to introduce compulsory licencing to facilitate

[20] Developing countries account for only 6 per cent of world R&D expenditures (Kumar (1997), p. 10).

access to ESTs, provided that such licences are conferred in accordance with the conditions set forth in article 31 of the Agreement. It should be noted that Article 34.18.e) of Agenda 21 specifically recommended the adoption of compulsory licences with respect to ESTs, to prevent the abuse of IPRs in this area, subject to the relevant international conventions and to "equitable and adequate compensation".

Another measure that may be established under national law to promote the use of patented ESTs is a "licence of rights". Under this system, as provided for by some national legislation [21], the patentee may voluntarily offer to licence its patent to any interested party. The offer is registered with the Patent Office, which can confer licences upon request, and determine the compensation to be paid in case of disagreement between the potential licensee and the patentee. The Patent Office can publish the offer generally and provide for a discount in maintenance fees. This system provides incentives for the diffusion of patented technology by reducing the transaction costs for the patentee.

However, the implementation of an enhanced system of protection of IPRs in developing countries may be a necessary condition for a transfer of technology to take place. Technology holders seem to be increasingly sensitive to the level and effectiveness of IPRs protection when considering the transfer of technology to a foreign country (Correa, 1994, p. 373).

ESTs Bank

The establishment of an "ESTs Bank" may be an important and useful initiative. There are examples of international cooperation for the diffusion of ESTs[22] protection (ICOLP), for instance with Northern Telecom and the United States Environmental Protection Agency, that the establishment of such a bank may further encourage. However, at least two problems may be encountered.

Firstly, to be successful, the "ESTs Bank" should be able to hold technologies that are proven and efficient. R&D results that are of an experimental nature will be of low interest, except when other alternatives are not available and somebody is willing to bear the (generally substantial) costs necessary to operationalize them. If this is the case, an additional problem is that the firm or institution that undertook the development work, may seek protection by IPRs and thereby limit accessibility to the technology by other parties.

Secondly, a major constraint to the transfer of ESTs to developing countries may not be on the supply side, but on the lack of incentives for potential licences to adopt ESTs, particularly when their adoption implies significant changes in production equipment and processes, or other important costs. Likewise, the capability of potential recipients to select adequately the appropriate ESTs, negotiate the terms for their transfer and most importantly, absorb the technology, is crucial for successful technology transfer.

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[21] See, for instance, articles 64 to 67 of *Brazilian law No. 9.279* (1996).

[22] Such as the training and demonstration project on CFC solvent conservation and elimination in Mexican electronics industry, executed by the Industry Cooperative for the Ozone Layer

Domestic policies may address these two latter issues and promote the use of ESTs by providing information, training and other kinds of support for the adoption of ESTs. In terms of the implementation of an "ESTs Bank", it should be borne in mind, however, that the success of the initiative will be dependent to a large extent, on the strength and quality of the demand for ESTs. An integrated approach that considers both the supply of and the demand for ESTs is therefore highly recommended.

Finally, with regard to the legal mechanisms necessary to facilitate the transfer of publicly funded ESTs to developing countries, an important aspect would seem to be the full implementation in due time, of the obligations under the TRIPs Agreement, including measures that ensure a reasonable level of competition. These measures may include the regulation of restrictive practices in voluntary licence agreements along the lines permitted by Part I, Section 8 of the TRIPs Agreement.

ANNEX

Table 3
Appropriation and transfer of R&D results in selected institutions

Institutions	Type of R&D results	Type of R&D activities	Title-holders
National. University of Córdoba (Argentina)	Knowledge useful in production		University and researchers involved; titles may be partially attributed to contractors.
National University of Buenos Aires (Argentina)	Knowledge useful in production	Contracted R&D	University, contractors; joint property of university/contractors
National University of Entre Rios (Argentina)	Patentable	Financed by the University	University
National University of Litoral (Argentina)	Knowledge useful in production	Financed by the University or contracted R&D	University, contractors; joint property of university/contractors
National University of Mar del Plata (Argentina)	Not specified	Contracted R&D	As agreed upon with the contractor

Source: Based on the regulations adopted by the institutions shown in the table.

Table 4
*Patents applied for and granted in Mercosur**
(1995)

Country	Patent applications Residents	Patent applications Non- residents	Patents granted Residents	Patents granted Non-residents
Argentina	700	2 854	209	795
Brazil	2 757	23 040	525	2 134
Uruguay	34	221	12	24

Source: WIPO, Statistics 1995.
* No information is available on Paraguay

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OWNERSHIP, COMMERCIAL DEVELOPMENT, TRANSFER AND USE OF PUBLICLY FUNDED RESEARCH RESULTS: THE UNITED STATES LEGAL REGIME

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I. INTRODUCTION

This report summarizes key provisions of the United States. legal regime concerning ownership, dissemination and commercialization of the results of publicly funded research as background for a study on the feasibility of improving access by developing countries and economies in transition to environmentally sound technologies (ESTs) developed in other parts of the world.

A. History of Current Policy

The current legislative framework for United States government policy toward intellectual property and technology transfer for the results of government-sponsored research has its origins in two 1980 statutes. Prior to that time, Congress had only addressed these issues in specific contexts involving particular agencies or programmes. On these limited forays into the field, Congress typically had encouraged or required federal agencies sponsoring research to make the results widely available to the public through government ownership or assuagement to the public domain.[1] However, in two statutes passed in 1980,[2] Congress endorsed a new vision of how best to put publicly-sponsored research results to practical use. In this new vision, public ownership of research results was equivalent to

[1] See, e.g., Research and Marketing Act of 1946, Pub. L. No. 79-733, 60 Stat. 1082, 1085 and 1090, codified at 7 U.S.C. § 427i and 1624; Atomic Energy Act of 1954, Pub. L. No. 83-703, 68 Stat. 919, codified at 42 U.S.C. § 2011 et seq., at § 2182; National Aeronautics and Space Act of 1958, Pub. L. No. 85-568, 72 Stat. 435, codified at 42 U.S.C. 2451 et seq., at 2457; Coal Research Act, codified at 30 U.S.C. 666; Arms Control and Disarmament Act of 1961, Pub. L. No. 87-297, title III, § 32, 70 Stat. 634, codified at 22 U.S.C. § 2572; Helium Act Amendments of 1960, § 4, Pub. L. No. 86-777, 74 Stat. 920, codified at 50 U.S.C. § 167b; Saline Water Conversion Act of 1961, § 4b, Pub. L. No. 87-295, 75 Stat. 628, codified at 42 U.S.C. § 1954(b); Water Resources Research Act of 1964, Pub. L. No. 88-379, 78 Stat. 330, codified at 42 U.S.C. § 1961c-3; Appalachian Regional Development Act of 1965, Pub. L. No. 89-4, as amended, 79 Stat. 5, as amended, codified at 40 U.S.C. App. § 302(e); Solid Waste Disposal Act of 1965, Pub. L. No. 89-272, 79 Stat. 997, as amended by the Resources Recovery Act, Pub. L. No. 91-512, codified at 42 U.S.C. § 3253(c); National Traffic & Motor Vehicle Safety Act of 1966, 80 Stat. 721, codified at 15 U.S.C. § 1395(c); Federal Coal Mines Health and Safety Act of 1969, Pub. L. No. 91-173, 83 Stat. 742 § 501(c), codified at 30 U.S.C. § 951(c); Foreign Assistance Act of 1969, 22 U.S.C. 217(b); Federal Non-nuclear Energy Research and Development Act of 1974, Pub. L. No. 93-577, 88 Stat. 1887, codified at 42 U.S.C. § 5908. *Cf.* National Science Foundation Act of 1950, Pub. L. No. S1-507, 76 Stat. 1253, codified at 42 U.S.C. § 1871(a) (providing for the disposition of rights in inventions "in a manner calculated to protect the public interest and the equities of the individual or organization with which the contract or other arrangement is executed").

[2] Pub. L. No. 96-480, 94 Stat. 2311 (1980) (commonly known as the *Stevenson-Wydler Technology Innovation Act*) and Pub. L. No. 96-517, 94 Stat. 3015 (1980) (commonly known as the Bayh-Dole Act).

"dead-hand control",[3] and assignment of research results to the public domain threatened to destroy their attractiveness to the private sector. If the results of federally-sponsored research were to be rescued from oblivion and successfully developed into commercial products, they would have to be patented and offered for appropriation by private firms.

This new strategy was promoted as serving a number of converging goals. It would ensure effective transfer and commercial development of discoveries that would otherwise languish in government and university archives. It would reinvigorate United States industry by giving it a fresh infusion of new ideas that would enhance productivity and create new jobs. It would ensure also that United States-sponsored research discoveries were developed by American firms rather than by foreign competitors who had too often be enable to dominate world markets for products based on technologies pioneered in the United States.

The first of the 1980 statutes, the Stevenson-Wydler Technology Innovation Act,[4] made technology transfer an integral part of the research and development responsibilities of federal laboratories and their employees. The Stevenson-Wydler Act explicitly directed federal agencies to "strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector", and to set aside funds from their research and development budgets to support technology transfer functions.[5] While some agencies had previously viewed technology transfer as an inherent by-product of making discoveries widely available to anyone who wanted them, it was now designated as a purposive task for agencies to pursue conscientiously and deliberately.

The second statute, commonly known as the Bayh-Dole Act,[6] encouraged small businesses and non-profit organizations to patent the results of government-sponsored research by allowing them to retain patent ownership themselves, provided they were diligent about getting patent applications on file and promoting commercial development of the inventions. At the same time, the Bayh-Dole Act clarified the authority of federal agencies to apply for and hold patents and to license their patents to the private sector on an exclusive or non-exclusive basis. In 1983, President Reagan significantly extended the reach of the new policy by directing the heads of executive departments and agencies to extend the more generous title provisions that the Bayh-Dole Act had provided only for small businesses and nonprofit organizations, to all government contractors, including large businesses, so that now they too could own patents on inventions made in their laboratories with federal funds.[7]

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[3] See Hearings before the Subcommission. on Courts, Civil Liberties, and the Administration of Justice of the Comm. on the Judiciary, House of Representatives, 96th Congress., 2d Session., *on H.R. 6033, H.R. 6934, H.R. 3806, H.R. 2414*, President's Industrial Innovation Programme, April 3, 15, 17, 22, 25, May 8, and June 9, 1980, at 286, citing *United States v. Dubilier Condenser Corp.* (testimony of Howard W. Bremer, Patent Counsel, Wisconsin Alumni Research Foundation).

[4] *Pub. L. 96-480, 94 Stat. 2311* (1980).

[5] 15 U.S.C. §§ 3701, 3710(a),(b). The Stevenson-Wydler Act also created Offices of Research and Technology Applications in the larger laboratories to evaluate new technologies and promote transfer of technologies with commercial potential, *id.* § 11(b), codified at 15 U.S.C. § 3710(b), and created a Centre for the Utilization of Federal Technology in the Department of Commerce to function as a clearinghouse for information on Federal inventions and patents. *Id.* § 11(d), codified at 15 U.S.C. § 3710(d).

[6] *Pub. L. No. 96-517, 94 Stat. 3015* (1980).

[7] Presidential Memorandum to the Heads of Executive Departments and Agencies, Subject: Government Patent Policy, 1983 Pub. Papers 248 (Feb. 18, 1983), 36 Fed. Reg. 16887.

Subsequent legislation has continued to broaden and fortify the emerging policy in favour of private appropriation of research results. Efforts to promote active federal involvement in technology transfer took a major step forward with passage of the Federal Technology Transfer Act of 1986.[8] That Act amended the Stevenson-Wydler Act to authorize government-operated laboratories to enter into cooperative research and development agreements (CRADAs) with industry, to agree in advance to assign patents on inventions made by federal employees to the collaborating firm, and to waive any federal claims to inventions made by the collaborating firm or its employees.[9] It also provided for the sharing of royalties with inventors [10] in federal employ and directed agencies that did not elect to file patent applications or otherwise to promote commercialization of inventions they owned to allow government employee-inventors to retain title.[11] Three years later Congress moved to promote active technology transfer from the national laboratories with the passage of the National Competitiveness Technology Transfer Act of 1989,[12] which amended the Stevenson-Wydler Act to include government-owned, contractor-operated laboratories. The National Technology Transfer and Advancement Act of 1995[13] further expanded the rights of private sector CRADA partners to obtain exclusive licences, provided for the sharing of

[8] Pub. L. No. 99-502, 100 Stat. 1785.

[9] *Idem* § 2, 100 Stat. 1785-87, codified at 15 U.S.C. § 3710a(a)(1), (b)(2),(3). That Act also established the Federal Laboratory Consortium for Technology Transfer to promote technology transfer activities within the federal laboratories, *id.* § 3, 100 Stat. 1787-89. See also Technology Competitiveness Act, enacted as part of the *Omnibus Trade and Competitiveness Act of 1988*, Pub. L. No. 100-418, Title V, Subtitle B, §§ 5101-5184, 102 Stat. 1107, 1426 (renaming and upgrading the National Bureau of Standards as the National Institute of Standards and Technology with a mission to enhance the competitiveness of American industry and creating the Advanced Technology Programme to assist industry-led, pre-competitive research and development projects to develop new generic technologies); National Technical Information Act of 1988, Pub. L. No. 100-519, Title II, Subtitle B, 102 Stat. 2589, 2594-96 (amending the Stevenson-Wydler Act to permit the National Technical Information Service to take actions to disseminate technical information to the private sector*); National Competitiveness Technology Transfer Act of 1989*, Pub. L. No. 101-189, Division C, Title XXXI, Part C, §§ 3131-3133, 103 Stat. 1352, 1674-79 (amending the Stevenson-Wydler Act to include government-owned, contractor-operated laboratories; to provide for inclusion of provisions establishing technology transfer as a mission for the laboratory and requiring the laboratory to widely disseminate information on technology transfer and cooperative research and development agreements in contracts with non-federal entities for the operation of a government-owned laboratory; and to revoke federal agencies' authority to waive technology transfer funding requirements); *National Defense Authorization Act for Fiscal Year 1991*, Pub. L. No. 101-510, Title VIII, Part C, §§ 827-828, 104 Stat. 1485, 1606-07 (1990) (allowing federal agencies to use partnership intermediaries to conduct collaborative research and establishing a model programme to study the commercial use of collaborative research); *American Technology Preeminence Act of 1991*, Pub. L. No. 102-245, 106 Stat. 7 *National Defense Authorization Act for Fiscal Year 1993*, Pub. L. No. 102-484, Division C, Title XXXI, Subtitle C, § 3135(b), 106 Stat. 2315, 2640-41 (1992) (requiring the Secretary of Energy to establish a programme to facilitate and encourage the transfer of technology to small businesses).

[10] Codified at 15 U.S.C. § 3710c.

[11] Codified at 15 U.S.C. § 3710d. President Reagan promptly followed with an executive order directing the heads of executive departments and agencies to "promote the commercialization of patentable results of federally funded research by granting to all contractors, regardless of size, the title to patents made in whole or in part with Federal funds…." Exec. Order No. 12,591, 52 Fed. Reg. 13,414, *reprinted in 15 U.S.C.A. § 3710 app. at 298-99* (West 1995).

[12] Pub. L. No. 101-189, Division C, Title XXXI, Part C, §§ 3131-3133, 103 Stat. 1352, 1674-79. That Act also provided for inclusion in contracts with non-federal entities for the operation of a government-owned laboratory of provisions establishing technology transfer as a mission for the laboratory and requiring the laboratory to disseminate information on technology transfer and CRADAs, and revoked the authority of federal agencies to waive technology transfer funding requirements.

[13] Pub. L. No. 104-113, § 4.

federal royalty income with laboratory scientists, and clarified the rights of federal employees to own inventions that their agencies chose not to patent.

Through these and other measures, Congress has gradually expanded the private appropriation policy that the Bayh-Dole Act endorsed for research in non-profit organizations and small businesses to cover government-sponsored research in a wide range of settings, including intramural research in government laboratories and collaborative research involving government, university, and private laboratories. While on the extramural side of federally-sponsored research, Congress has urged sponsoring agencies to forbear from asserting patent rights in favour of contractors who might be more effective in getting the underlying technologies developed in the private sector, on the intramural side Congress has urged the same agencies to become more active in patenting their discoveries and licensing them to industry.

B. Motivations for Current Policy

Two primary strategic motivations emerge from a review of legislative provisions governing technology transfer for government-sponsored research. First is a desire to motivate the private sector to pick up where government funding leaves off so that research advances will be developed into useful new technologies. Thus, the findings set forth at the beginning of the Stevenson-Wydler Act state that:

> "Many new discoveries and advances in science occur in universities and federal laboratories, while the application of this new knowledge to commercial and useful public purposes depends largely upon actions by business and labour. Cooperation among academia, federal laboratories, labour, and industry, in such forms as technology transfer, personnel exchange, joint research projects, and others, should be renewed, expanded, and strengthened."[14]

The Bayh-Dole Act states that:

> "It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development…"[15]

Second, and closely related to the goal of promoting commercial development to achieve practical applications for new research discoveries, is a palpable desire to leverage United States government spending on research into a competitive advantage in world markets for American firms and workers. Thus the Bayh-Dole Act's opening statement of Congressional policy objectives specifies a targeted aim "to promote the commercialization and public availability of inventions *made in the* United States by United States industry and labour…"[16] The Stevenson-Wydler Act's introductory list of Congressional findings laments that "industrial and technological innovation in the United States may be lagging when

[14] *15 U.S.C.A. § 3701(3).*
[15] *35 U.S.C.A. § 200.*
[16] *Idem,* emphasis added.

compared to historical patterns and other industrialized nations”,[17] and claims that technology and industrial innovation promise “creation of new industries and employment opportunities and enhanced competitiveness of United States products in world markets”,[18] and will “reduce trade deficits, stabilize the dollar, increase productivity gains, increase employment, and stabilize prices.”[19]

Specific provisions aim to ensure that the benefits of the new policy remain in the United States rather than accruing to foreign institutions. For example, although as a general rule government contractors may elect to retain title to inventions made with federal funds, the statute recognizes an exception “when the contractor is not located in the United States or does not have a place of business located in the United States or is subject to the control of a foreign government ….”[20] Moreover, although contractors that receive title to inventions are generally permitted to grant exclusive licences, they may not “grant to any person the exclusive right to use or sell any subject invention in the United States unless such person agrees that any products embodying the subject invention or produced through the use of the subject invention will be manufactured substantially in the United States.”[21]

C. Principal Features of Current Policy

The law governing patent rights and technology transfer for inventions made with federal assistance is set forth primarily in Title 35 of the Unite States Code at §§ 200-212 and in Title 15 of the U.S. Code at §§ 3701-3717. These provisions supply a unified set of legal rules applicable to all federal government agencies. The principle features of this statutory scheme include the promotion of patenting, ownership by research performers, qualified discretion in the deployment of patent rights (with preferences for small firms and American manufacturers), encouragement of collaboration across sectors, and an active role for government in disseminating technical information.

1. Encouragement of patenting

United States policy pervasively promotes the patenting of federally-sponsored inventions wherever they are made, whether in government, university, or private laboratories or in the course of collaborative research across these sectors. The current statutory scheme generally permits anyone involved in the research project who wants the discovery to be patented to prevail over anyone who thinks the discovery should not be patented. Thus for example, if a contractor fails to make a timely election to retain title to the invention, the funding agency may seek a patent,[22] and if neither the agency nor the contractor has an interest in pursuing patent rights, the individual investigator who made the discovery may

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[17] *15 U.S.C.A. § 3701 (5)*, emphasis added.
[18] *15 U.S.C.A. § 3701 (2).*
[19] *15 U.S.C.A. § 3701(6).*
[20] *35 U.S.C.A. § 202(a)(i).*
[21] *35 U.S.C.A. § 204*. This requirement may be waived by the federal agency if the contractor shows that it made reasonable but unsuccessful efforts to find a licensee that would manufacture in the U.S. on similar terms or that domestic manufacture is not commercially feasible. *Id.*
[22] *35 U.S.C. § 202(c)(2).*

claim them.[23] Resource constraints prohibit patenting many discoveries that emerge from government-sponsored research. The discoveries that enter the public domain today are those that slip through the net of present policy, whether through oversight or through a deliberate choice to allocate resources to more promising commercial prospects, rather than those that a funding agency selects as suitable for widespread availability to the public.

Several features of the statutory scheme affirmatively promote patenting, including provisions for the initial allocation of ownership rights to institutions that perform research under a contract or grant,[24] the loss of ownership rights by institutions that delay too long in filing patent applications,[25] and directives to non-profit institutions to share royalties with inventors.[26] These features provide financial incentives for researchers to disclose inventions to their institutions and for the institutions to file timely patent applications. The statute also directs federal agencies to share royalties with their employee-inventors for inventions made in the course of intramural research.[27] Funding agencies may pursue patent rights in the United States and any other countries in which contractors have failed to file within reasonable times.[28]

Finally, when neither the institution in which the research is performed nor the funding agency is interested in pursuing patent rights, the statute permits the inventor to file a patent application.[29]

2. Ownership by research performers

United States law generally permits the institutions that perform government-sponsored research to retain title to the inventions that they choose to patent. Although from the statutory language it appears that this policy is limited to non-profit organizations and small business firms,[30] the policy has in fact been applied to all government contractors, including large businesses, under the terms of a 1983 Presidential Memorandum to the Heads of Executive Departments and Agencies.[31] The approach outlined in this memorandum was quietly endorsed by Congress in what appeared to be an inconsequential housekeeping provision to a 1984 change in the law.[32]35 U.S.C.A. § 210(c).

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[23] *35 U.S.C.A. § 202(d); 15 U.S.C. § 3710d.*
[24] *35 U.S.C.A. § 202(a).*
[25] *35 U.S.C.A. § 202(c)(3).*
[26] *35 U.S.C.A. § 202(c)(7)(B).*
[27] *15 U.S.C.A § 3710c.*
[28] *35 U.S.C.A. § 202(c)(3).*
[29] *35 U.S.C.A. § 203(d); 15 U.S.C.A. § 3710d(a).*
[30] *35 U.S.C.A. § 202(a)* thus begins "Each nonprofit organization or small business firm may, within a reasonable time after disclosure as required by paragraph (c)(1) of this section, elect to retain title to any subject invention ...."
[31] Presidential Memorandum to the Heads of Executive Departments and Agencies, Subject: Government Patent Policy, *supra* note ("To the extent permitted by law, agency policy with respect to the disposition of any invention made in the performance of a federally-funded research and development contract, grant or cooperative agreement award shall be the same or substantially the same as applied to small business firms and non-profit organizations under Chapter 38 of Title 35 of the United States Code.").
[32] The provisions as codified read:
"Nothing in this chapter is intended to limit the authority of agencies to agree to the disposition of rights in inventions made in the performance of work under funding agreements with persons other than non-profit

The statute recognizes four exceptions to the general rule that a contractor may elect to retain title to an invention. The first exception, mentioned above, arises "when the contractor is not located in the United States or does not have a place of business located in the United States or is subject to the control of a foreign government."[33] The second exception permits the agency to withhold title from the contractor "in exceptional circumstances when it is determined by the agency that restriction or elimination of the right to retain title to any subject invention will better promote the policy and objectives of this chapter."[34] Other provisions ensure that this exception is parsimoniously administered. Determinations of exceptional circumstances must be documented in a statement filed with the Secretary of Commerce that includes an analysis justifying the determination.[35] If the Secretary of Commerce believes that the determination is not justified, the Secretary is directed to so advise the head of the agency and the Administrator of the Office of Federal Procurement Policy and to recommend corrective actions.[36] If the Administrator of the Office of Federal Procurement Policy believes the exceptions to the general rule of leaving title in the contractor are being abused, the Administrator may issue regulations describing classes of situations in which agencies should not withhold title.[37] The third exception concerns restrictions imposed to maintain the security of foreign intelligence or counter-intelligence activities,[38] and the fourth concerns government-owned, contractor-operated facilities of the Department of Energy dedicated to naval nuclear propulsion or weapons related programmes.[39]

In all cases, however, the federal agency sponsoring the research retains "a non-exclusive, non-transferable, irrevocable, paid-up licence to practice or have practiced for or on behalf of the United States any subject invention throughout the world."[40] When the United States is a major customer for the patented technology-as is the case for example, for some technologies for cleaning up radioactive wastes-this retained non-exclusive licence may be a significant limitation on the ownership rights of the contractor. Although the original contractor owns the patent, the Government may choose another contractor to put the technology to use for government purposes without any obligation to the patent owner.

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organizations or small business firms in accordance with the Statement of Government Patent Policy issued on February 18, 1983 ...."

[33] *35 U.S.C.A. § 202(a)(i).*

[34] *35 U.S.C.A. § 202(a)(ii).* Although the statute makes it difficult for agencies to invoke this authority without circumstances that are truly extraordinary, agencies may sometimes be able to discourage contractors from patenting without making an explicit finding of exceptional circumstances. For example, the National Human Genome Research Institute has issued a statement urging its grantees to make human genomic DNA sequence information freely available in the public domain, warning that it intends to "monitor grantee activity in this area to learn whether or not attempts are being made to patent large blocks of primary human genomic DNA sequence," and that it will consider making a determination of exceptional circumstances if sequence information generated under grants is not made maximally useful to the research and commercial sectors. National Human Genome Research Institute, Policy on Availability and Patenting of Human Genomic DNA Sequence Produced by NHGRI Pilot Projects (Apr. 9 1996) <http://www.nhgri.nih.gov/Grant info/Funding/Statements/patenting.html>.

[35] *35 U.S.C.A. § 202(b)(1).*

[36] *Idem.*

[37] *35 U.S.C.A. § 202(b)(2).*

[38] *35 U.S.C.A. § 202(a)(iii).*

[39] *35 U.S.C.A. § 202(a)(iv).*

[40] *35 U.S.C.A. § 202(c)(4).*

The statute further authorizes federal agencies to provide in the terms of a funding agreement, for the retention such additional rights as the agency determines are necessary to comply with obligations of the United States under a treaty or similar arrangement.[41] The wording of this provision suggests not only a grant of power, but also a limitation on the power of the funding agency. It permits agencies to retain the right to license or even assign foreign patents as needed to comply with international obligations of the United States. But it requires that such rights be explicitly retained in the terms of the funding agreement, and suggests that something more specific is required in the language of the contract than the standard provision for a "non-exclusive, non-transferable, irrevocable, paid-up licence to practice or have practiced for or on behalf of the United States any subject invention throughout the world." 37 C.F.R. § 401.5(d). The evident implication is that the funding agency does not otherwise normally retain such a right.

This construction of the statutory language suggests that developing countries might be able to preserve future options to acquire licences from government agencies to use patented environmentally sound technologies emerging from future United States-sponsored research by negotiating for access to such technologies in the terms of treaties with the United States Government. United States agencies would thereafter cite these treaties in research funding agreements and explicitly retain the right to convey licences to foreign governments or firms to use technologies developed under the agreements to comply with the Government's treaty obligations. In the absence of such explicit agreements however, funding agencies would not seem to have the right to convey such licences under patents arising from previously funded research.

3. Deployment of patent rights with preferences for small firms and United States manufacturers

United States. law gives substantial discretion to both contractors and agencies concerning how best to license their patents to achieve commercial development.[42] The principal constraints are that preference be given to small business firms,[43] that preference be given to licensees that agree to manufacture in the U.S.,[44] and that federal agencies may only grant exclusive or partially exclusive licences after public notice and opportunity for filing written objections.[45]

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[41] *Idem:* "The funding agreement may provide for such additional rights; including the right to assign or have assigned foreign patent rights in the subject inventions, as are determined by the agency as necessary for meeting the obligations of the United States under any treaty, international agreement, arrangement of cooperation, memorandum of understanding, or similar arrangement ...."

[42] *35 U.S.C.A. § 207(a)* authorizes Federal agencies to "grant nonexclusive, exclusive, or partially exclusive licenses under federally owned patent applications, patents, or other forms of protection obtained, royalty-free or for royalties or other consideration, and on such terms and conditions ... as determined appropriate in the public interest."

[43] *35 U.S.C.A. § 202(7)(D)* (governing licensing by nonprofit organizations); 35 U.S.C.A. § 209(c)(3) (governing exclusive or partially exclusive licensing by Federal agencies). See also 15 U.S.C.A. § 3710a(c)(4)(A) (in deciding what cooperative research and development agreements to enter into laboratory directors should give special consideration to small business firms.).

[44] *35 U.S.C.A. §§ 204, 209(b).* See also 15 U.S.C.A. § 3710a(c)(4)(B) (in deciding what cooperative research and development agreements to enter into, laboratory directors should give preference to business units located in the U.S. that agree to manufacture products substantially in the U.S.).

[45] *35 U.S.C.A. § 209(d).*

This discretion is contingent upon active efforts to develop the technology and make it available commercially through an appropriate licensee. The funding agency may exercise "march-in rights" to grant licences to responsible applicants if it determines that the contractor is not taking "effective steps to achieve practical application" of the invention, that the contractor or its licensees are not satisfying health or safety needs, that the contractor or its licensees are not satisfying requirements for public use of the invention, or that the contractor or licensee has not agreed to, or is in breach of, an agreement to manufacture substantially in the U.S.[46] In fact, agencies rarely exercise these "march-in" rights, but they could do so in an appropriate case.

4. Encouragement of collaboration across sectors

A number of statutory provisions seek to promote public-private and university-industry collaboration and to remove regulatory barriers that make industry wary of projects involving government-sponsored research. For example, the statute explicitly grants authority to federal agencies to enter into collaborative research and development agreements (CRADAs) with research partners in other agencies, State or local government, private firms, foundations, and non-profit organizations, and to agree in advance to grant patent licences or assignments to collaborating parties.[47] This legislative grant of authority was promptly fortified by an executive order from the President affirmatively directing the heads of executive departments and agencies to "encourage and facilitate" the permitted collaborations "in order to assist in the transfer of technology to the marketplace," and to disregard limitations on licensing found in earlier versions of the statute or prior institutional patent agreements.[48]

The Secretary of Commerce is also explicitly directed to "propose and encourage cooperative research involving appropriate federal entities, State or local governments, regional organizations, colleges or universities, non-profit organizations or private industry, to promote the common use of resources, to improve training programmes and curricula, to stimulate interest in high technology careers, and to encourage the effective dissemination of technology skills within the wider community."[49]

Statutory provisions governing the Advanced Technology Programme (ATP) managed by the National Institute of Standards and Technology (NIST) within the Department of Commerce promote collaborative research initiatives across sectors. ATP was established in 1988[50] to provide assistance to business in joint research and development ventures (which might include universities and independent research organizations) aimed at creating and applying pre-competitive, generic technologies, to commercialize significant new scientific discoveries, and to refine manufacturing technologies.[51]

[46] *35 U.S.C.A. § 203(1).*
[47] *15 U.S.C.A. § 3710a.*
[48] Exec. Order No. 12591, 52 Fed. Reg. 13414, as amended, Exec. Order No. 12618, 52 Fed. Reg. 48661 (1987).
[49] *15 U.S.C.A. § 3704(c)(12).*
[50] ATP was created by passage of the Technology Competitiveness Act as part of the Omnibus Trade and Competitiveness Act of 1988, Pub. L. No. 100-418, §§ 5101-5164, 102 Stat. 1107, 1426-1451 (codified as amended at 15 U.S.C. §§ 271 et seq.).
[51] *Idem* § 5131, 102 Stat. 1439, current version codified at *35 U.S.C. § 278n.*

Less obviously to the same effect is the allocation of ownership rights in discoveries made in universities to the universities themselves, rather than to the sponsoring agency. Ownership of patent rights free of government claims makes it easier for universities to find partners in industry to fund additional research within the university, or to take inchoate discoveries out of the laboratory and into the market, by removing uncertainty and potential bureaucratic impediments that might otherwise inhibit private firms from investing in a technology, for fear that the Government would undermine their patent position in potential products.

Statutory provisions promoting collaborations reflect the same preference for U.S. industry as the provisions for licensing patents. Thus, for example, laboratory directors selecting cooperative research and development agreements are told to "give preference to business units located in the United States which agree that products embodying inventions made under the cooperative research and development agreement or produced through the use of such inventions will be manufactured substantially in the United States ...."[52]

The result of this overall strategy is to promote the combining of research funds from multiple sources, while permitting American firms to acquire the value of resulting intellectual property rights, either through direct ownership of patents or through exclusive licences.

5. Active role for government in disseminating technical information

Another important avenue for promoting technology transfer is through government initiatives to disseminate technical information directly to prospective users. In addition to directing agencies involved in research to take an active role in promoting technology transfer,[53] United States law allocates responsibility for information dissemination to the Department of Commerce through the National Technical Information Service (NTIS).[54] The statute directs agencies to transfer information resulting from federally funded research and development to NTIS,[55] and directs NTIS to "establish and maintain a permanent repository of non-classified scientific, technical, and engineering information,"[56] to disseminate bibliographic information,[57] to translate and disseminate unclassified foreign information,[58] and to implement new methods or media for dissemination of information.[59]

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[52] *15 U.S.C.A. § 3710a(c)(4)(B).* This provision goes on to state that "in the case of any industrial organization or other person subject to the control of a foreign company or government" the laboratory director shall "take into consideration whether or not such foreign government permits United States agencies, organizations, or other persons to enter into cooperative research and development agreements and licensing agreements." *Id.*
[53] *15 U.S.C.A. § 3710.*
[54] *15 U.S.C.A. §§ 3704b(e), 3710(d).*
[55] *15 U.S.C.A. § 3704b-2(a).*
[56] *15 U.S.C.A. § 3704b(e)(1).*
[57] *15 U.S.C.A. § 3704b(e)(3).*
[58] *15 U.S.C.A. § 3704b(e)(4).*
[59] *15 U.S.C.A. § 3704b(e)(5).*

II. SPECIFIC PROVISIONS CONCERNING ENVIRONMENTALLY SOUND TECHNOLOGIES

In addition to the foregoing provisions of general application to all federally-sponsored research, there are a number of statutory provisions addressed more narrowly to the transfer of environmentally sound technologies. These more specialized provisions are, for the most part, broadly consistent with the general approach described above, although they often show an enhanced concern for promoting exports of United States products and technologies. The study does not attempt to provide an exhaustive catalogue of the statutory provisions governing all such programs.

The United States Congress acted to promote the commercial development of renewable energy technologies in passing the Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989.[60] This statute directs the Secretary of Energy to foster collaborative efforts involving the private sector to commercialize renewable energy and energy efficiency technologies.[61] It requires that supported activities "shall be performed in the United States" and that selected projects "shall require the manufacture and reproduction substantially within the United States for commercial sale of any invention or product that may result from the project."[62] The Secretary is further explicitly directed to consider the export potential of the technology in the selection of projects[63] and to develop a strategy for assisting the private sector "in meeting competition from foreign suppliers of products derived from renewable energy and energy efficiency technologies."[64]

The goal of promoting the competitive position of United States firms in world markets looms even larger in provisions enacted as part of the Energy Policy Act of 1992.[65] The provisions begin by announcing a goal of promoting exports of renewable energy technologies and services[66] and specifically targeting markets in developing countries.[67] Selection criteria for funded projects include export potential,[68] and awards may be made "only to individuals who are United States nationals or permanent resident aliens, or to non-Federal organizations that are organized under the laws of the United States or the laws of a State of the United States."[69] To assist in marketing such technologies abroad, the Secretary of Commerce is directed to develop a database of information on the energy technology needs of foreign countries and U.S. technologies available to meet those needs and to make the information available among others to industry and lending agencies.[70]

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[60] *Pub. L. No. 101-218, 103 Stat. 1859* (1989), codified at 42 U.S.C.A. §§ 12001 et seq.
[61] *42 U.S.C.A. § 12001(b).*
[62] *42 U.S.C.A. § 12005(b)(1)(B).*
[63] *42 U.S.C.A. § 12005(c)(1)(C)(v).*
[64] *42 U.S.C.A. § 12006(b)(3)(B).*
[65] *Pub. L. No. 102-474, 106 Stat. 2956* (1992), codified at 42 U.S.C.A. §§ 13311 et seq.
[66] *42 U.S.C.A. § 13311(3).*
[67] *42 U.S.C.A. § 13312(a)* directs the Secretary of Energy, through the Agency for International Development, to "establish a programme for the training of individuals from developing countries in the operation and maintenance of renewable energy and energy efficiency technologies" and subsection (b) goes on to specify that the goal of this programme is to train appropriate persons in the use of "renewable energy and energy efficiency equipment *manufactured in the United States*." 42 U.S.C.A. § 13312(b) (emphasis added).
[68] *42 U.S.C.A. § 13313(b)(4).*
[69] *42 U.S.C.A. § 13314(d).*
[70] *42 U.S.C.A. § 13315.*

The Secretary of Energy is also given the mission, through the Agency for International Development, to establish a renewable energy technology transfer programme[71] to serve a long list of purposes related to competitiveness, including reducing trade deficits, retaining jobs, encouraging the export of American renewable energy technologies, and developing markets for renewable energy technologies in foreign countries. He should ensure also the participation of United States firms and technologies in energy-related projects in foreign countries, ensuring the introduction of American firms and expertise in foreign countries, and assisting United States firms to obtain opportunities to undertake projects in foreign countries.[72] Once again, proposals must involve the participation of United States firms,[73] and in selecting among proposals the Secretary is directed to consider "the degree to which the equipment to be included in the project is designed and manufactured in the United States"[74] and "the ability of the United States firm to compete in the development of additional energy projects using such technology in the host country and in other foreign countries."[75]

In the same Act, Congress established a "Clean Coal Technology Subgroup" with a mission to expand the export and use of U.S. clean coal technologies.[76] The clean coal provisions of the Act parallel the renewable energy provisions outlined above in many respects. They direct the establishment and dissemination of a database of information on available technologies and potential needs for such technologies, "particularly in developing countries and countries making the transition from non-market to market economies."[77] They direct also the establishment of a clean coal technology transfer program to increase exports by United States firms and protect American jobs,[78] they set requirements for participation by American firms,[79] and they specify selection criteria that stress the use of American manufactured equipment and prospects for development of additional markets for American firms using American technologies in foreign countries.[80]

[71] *42 U.S.C.A. § 13316(a).*
[72] *42 U.S.C.A. § 13316(b).*
[73] *42 U.S.C.A. § 13316(e)(3).*
[74] *42 U.S.C.A. § 13316(h)(2)(B).* The statute further directs the Secretary to ensure that "the maximum percentage, but in no case less than 50 percent, of the cost of any equipment furnished in connection with a project authorized under this section shall be attributable to the manufactured United States components of such equipment" and "the maximum participation of United States firms." 42 U.S.C.A. § 13316(j).
[75] *42 U.S.C.A. § 13316(h)(2)(C).*
[76] *42 U.S.C.A. § 13361(a).*
[77] *42 U.S.C.A. § 13361(e).*
[78] *42 U.S.C.A. §§ 13362(a), (b).*
[79] *42 U.S.C.A. §§ 13362(e)(1), (3).*
[80] *42 U.S.C.A. §§ 13362(h)(2), (j).*

III. OTHER MODELS

A. Government ownership

Although the foregoing discussion describes the predominant model of technology transfer for the results of United States government-sponsored research, United States Code occasionally reveals another model for ownership and dissemination of the results of federally-sponsored research which, while largely overriden by the statutory provisions outlined above, still remains on the books. This other model appears to be followed in certain limited circumstances involving some environmentally sound technologies.

Prior to passage of the Bayh-Dole Act, Congress provided for title to inventions made in the course of non-nuclear energy research to be vested in the United States and for patents on such inventions to be ssued to the United States.[81] These rights could be waived by the Secretary of Energy in the interest of promoting commercial utilization, encouraging participation by private firms in the research programme, and fostering competition.[82]

Congress appears to have intended to override this earlier provision with passage of the Bayh-Dole Act, which explicitly states:

"This chapter shall take precedence over any other Act which would require a disposition of rights in subject inventions of small business firms or non-profit organizations contractors [sic] in a manner that is inconsistent with this chapter, including but not necessarily limited to...section 9 of the Federal Non-nuclear Energy Research and Development Act of 1974 … "[83]

Nonetheless, the earlier provision remains in the code books, and Department of Energy regulations, while acknowledging the Bayh-Dole Act, seem to contemplate that the old provision will continue to apply in at least some circumstances.[84]

Whatever its continuing legal force within the realm of non-nuclear energy research, this provision has been explicitly adopted by Congress in at least two Acts passed since the Bayh-Dole Act. The Water Resources Research Act of 1984[85] explicitly adopts the old title and patent provisions for federal non-nuclear energy research by reference:

"Notwithstanding any other provision of law, the Secretary shall be governed by the provisions set forth above] with respect to patent policy and to the definition of title to and licensing of inventions made or conceived in the course of work performed, or under any contract or grant made, pursuant to this chapter."[86]

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[81] *42 U.S.C.A. § 5908(a).*
[82] *42 U.S.C.A. § 5908(c).*
[83] *35 U.S.C.A. § 210(12).* The statute goes on to give what appears to be an erroneous citation *of 42 U.S.C. § 5901* for this provision, but the evident intent was to override the provision on patents and inventions codified at *42 U.S.C. § 5908* rather than the Congressional statement of findings codified at *42 U.S.C. § 5901*.
[84] *10 C.F.R. §§ 784.1-784.13*.
[85] *Pub. L. No. 98-242 § 102* et seq., codified at *42 U.S.C.A. § 10301* et seq.
[86] *42 U.S.C.A. § 10308*.

The statutory language continues in a strikingly different tone from that found in the provisions applicable to renewable energy and clean coal, emphasizing the importance of accessibility in place of competitiveness:

"Subject to such patent policy, all research or development contracted for, sponsored, co-sponsored, or authorized under authority of this chapter shall be provided in such manner that all information, data, and know-how, regardless of their nature or mediums, resulting from such research and development shall ... be usefully available for practice by the general public."[87]

A similar provision governs proprietary rights in the Steel and Aluminum Energy Conservation and Technology Competitiveness Act of 1988.[88] The statute provides that:

"All patent rights from inventions developed under the management plan or the research plan implemented pursuant to this Act shall be vested in accordance with section 9 of the Federal Non-nuclear Energy Research and Development Act of 1974."

This provision is particularly interesting in the context of an act that in other respects echoes the emphasis on United States competitiveness found in other statutes governing technology transfer of the results of federally-sponsored research in the post-Bayh-Dole era.

It should be recognized however, that although these acts presumptively allocate title to the Government rather than to the contractor in the first instance, the agency has the authority to vary these rules. Moreover, even if the agency chooses to retain title, licensing of the invention will still be governed by the post-1980 rules concerning technology transfer for inventions owned by the Government, including the required preferences for firms that manufacture in the United States.

B. Mandatory Licensing

The underlying logic of United States policy focuses on the creation of private incentives for innovation, trusting the market to impel private patent holders to market their products as widely as possible. But the way patents improve incentives for innovation is by creating monopolies that can have the effect of increasing the price and reducing the availability of the inventions they cover. In the ordinary case it may be reasonable to expect the patent owner to be willing to license the technology on reasonable terms in order to increase profits. But there may be circumstances in which the patent holder chooses instead to withhold licences from business competitors. The social cost of strategic withholding of patent licences by private patent owners could be quite high in the case of environmentally sound technologies for which there is a strong public interest in widespread access.

Although the primary safeguard against suppression of patented technologies under United States law is the private incentive of patent holders to maximize profits during the patent term, there are some additional safeguards in this law that further minimize this risk.

[87] *Idem.*
[88] *Pub. L. No. 100-680*, 102 Stat. 4073 (1988), codified at *15 U.S.C.A. § 5101* et seq.

First, the United States government and its contractors have a right to use any patented technology for the Government upon payment of a reasonable royalty.[89] In effect, this provision allows the Government to obtain a compulsory licence, for a price, under any patent that it needs to use for the public good, regardless of who owns the patent and who paid for the research.

Second, as discussed above, further restrictions apply in cases where the Government sponsored the research that yielded the patented invention. The funding agency retains a "non-exclusive, non-transferable, irrevocable, paid-up licence" to use the invention or have others use it on behalf of the United States Government throughout the world.[90] The statute permits the funding agency to retain additional rights to sublicense foreign governments or international organizations to use these discoveries pursuant to international treaties.[91] This can be a significant restraint on the patent owner's monopoly if the United States Government is a principal customer for the patented technology. Moreover, as discussed above, the Government retains "march-in" rights to grant licences to responsible applicants on reasonable terms if (a) the contractor fails to take effective steps to achieve practical application of the invention, (b) such action is necessary to alleviate health or safety needs, (c) such action is necessary to meet requirements for public use specified by federal regulations, or (d) the contractor or its exclusive licensee has either failed to agree to manufacture substantially in the United States or is in breach of such an agreement.[92]

Third, although highly unusual in the United States, a small number of statutes call for mandatory licensing of some types of patented technologies in cases of compelling public interest. For example, the Clean Air Act of 1970 established a procedure for seeking a district court order requiring the issuance of licences on reasonable terms if the Attorney General certifies to a district court that such a licence is necessary to comply with the act, that there are no alternative methods to accomplish the same purpose, and that the absence of such a licence threatens to lessen competition in commerce.[93] The Atomic Energy Act also includes a provision for administrative issuance of mandatory licences under patents on discoveries that the Atomic Energy Commission deems to be "of primary importance in the production or utilization of special nuclear material or atomic energy" if "the licensing of such invention or discovery under this section is of primary importance to effectuate the policies and purposes of this Act."[94]

In both of these settings, the statutory provisions and implementing regulations make clear that mandatory licences are a remedy of last resort. Those who seek mandatory licences must first demonstrate that they have been unable after reasonable efforts to obtain a license

[89] *28 U.S.C.A. § 1498*
[90] *35 U.S.C.A. § 202(c)(4)*
[91] *Idem.*
[92] *35 U.S.C.A. § 203(1).*
[93] *42 U.S.C.A. § 7608.*
[94] *42 U.S.C.A. § 2183.*

from the owner of the patent on reasonable terms.[95] Even these limited provisions for mandatory licences are extraordinary in the United States patent system, which as a general rule entrusts patent licensing to the realm of private bargaining.

IV. CLINTON ADMINISTRATION ENVIRONMENTAL TECHNOLOGY STRATEGY

The statutory provisions reviewed above have been enacted by different Congresses over at least two decades, and are the subject of ongoing refinement. Yet for the most part they reflect a consistent strategy, unlikely to change in the near term, of using United States. government funding and intellectual property rights to enhance the competitive position of American. firms in international markets for new technologies, including environmental technologies. This strategy is entirely consistent with the policy of the Clinton administration as reflected in a 1995 report entitled "Bridge to a Sustainable Future -- National Environmental Technology Strategy."[96]

This document urges strengthening private incentives for innovation and commercialization of new technologies as a means to achieve the twin goals of improving the environment and economic growth. Toward these ends, it proposes collaborative research and development involving the private sector as well as federal, state and local governments.[97] It emphasizes the importance of exports of environmental technologies as a means of creating new, high-paying jobs.[98] It expresses considerable interest in helping other nations to address environmental concerns, but these other nations are pictured as customers[99] as much as they are pictured as partners.[100]

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[95] *42 U.S.C.A. § 7608*; *40 C.F.R. §§ 95.2(b)(4)(v), (viii), 95.3(b), (e)* (petitioner seeking mandatory licence to use patented technology necessary for compliance with Clean Air Act must show, and Administrator must find, that a mandatory licence is necessary, that the technology is not otherwise available, and that the petitioner tried and failed to obtain a licence from the patent owner on reasonable terms); *42 U.S.C.A. § 2183(c), (e)(4)(*prior to issuance of mandatory licence under Atomic Energy Act for patents affected with the public interest, Commission must find that applicant cannot otherwise obtain a licence from the patent owner on reasonable terms).

[96] National Science and Technology Council, Bridge to a Sustainable Future - National Environmental Technology Strategy (1995)<http://192.188.119.21/envstrat.txt>.

[97] *Idem* at 26-30.

[98] *Idem* at 34-39.

[99] *Idem* at 39 ("The Initiative for Environmental Technologies of the United Nations Agency for International Development] will help create markets for environmental technologies and eliminate barriers to the flow of technology through partnerships with the private sector.").

[100] See *idem* at 50:

> "Demand for environmental technologies will increasingly be found outside the United States in countries with growing populations, rapid industrialization, and rising incomes. Thus, the international dimension of the national environmental technology strategy must encourage U.S. partnerships with these nations to adopt sustainable development practices and employ appropriate technologies to meet challenges."

V. IMPLICATIONS FOR ACQUISITION OF U.S. ENVIRONMENTALLY SOUND TECHNOLOGIES

Plainly, United States law welcomes the dissemination of American technologies to foreign countries through the sale of American-manufactured products in foreign markets. Toward this end, statutes governing ownership and dissemination of the results of United States-government-sponsored research typically encourage private contractors to patent their discoveries in the United States and abroad and encourage non-profit institutions and federal agencies to patent their discoveries and license them to American firms. The Unites States government is so eager to promote technology transfer in this manner that it will sometimes provide funding to help American firms introduce their technologies into foreign markets.

This is not, however, the only avenue available for technology transfer. It may sometimes be possible to implement new technologies locally at less cost by avoiding collaboration with foreign firms. Despite strong encouragement and incentives to patent the results of government-sponsored research, not all such results are patented, and even when a discovery is patented in the Unite States, it may not be patented throughout the world. In cases where there are no local patent rights covering the technology, it may be possible to obtain the necessary technical information from publications, foreign patent documents, or government agencies such as the NTIS, and put it directly to use.

It may well be however, that for technologies that have been developed to the point of commercial feasibility, the advantages of collaborating with an experienced firm that knows the technology well are considerable. This suggests that the starting point for acquiring United States technologies is to identify the firms that are developing the technologies and pursue collaboration with them. In addition to controlling the relevant patent rights, these firms may offer considerable experience with and understanding of the technology and cost advantages, over other firms that have not yet established enough of a market for the technology to achieve economies of scale.

The choice of strategy may vary from one technology to the next depending on the existence of local patent rights, the cost of the technology, the existence of local expertise for implementing the technology, and the value of technical assistance and experience offered by foreign firms.

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THE ROLE OF US UNIVERSITIES IN ENVIRONMENTALLY SOUND TECHNOLOGY (EST) TRANSFER

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I. OVERVIEW OF THE UNITES STATES' INVESTMENT IN THE RESEARCH AND DEVELOPMENT OF TECHNOLOGY

Investment in science and technology research fuels a strong economy and improves the competitiveness of United States industry in the world market. The federal government plays an important role in science and technology research and development (S&T, R&D). First, it funds universities and national laboratories to pursue basic scientific research. Private companies, on the other hand, are reluctant to conduct basic scientific research because of the substantial capital investments involved and uncertain profitability. Second, the Federal Government coordinates R&D activities among federal agencies, industry, and universities in order to avoid redundant pursuits and efficiently share human and financial resources.

Table 1
Research and Development Investments*
(US$ millions)

	1993 Actual	**1997 Estimate**	**1998 Proposed Dollar**	**Change: 1997- 998**	**Per cent Change: 1997- 1998**

By Agency					
Defence	38,898	37,461	36,780	-681	-2
Health and Human Services	10,472	12,933	13,478	+545	+4
National Aeronautics and Space Administration	8,873	9,314	9,603	+289	+3
Energy	6,896	6,186	7,312	+1,126	+18
National Science Foundation	2,012	2,458	2,553	+95	+4
Agriculture	1,467	1,545	1,485	-60	-4
Commerce	793	1,050	1,115	+65	+6
Interior	649	581	605	+24	+4
Transportation	613	639	754	+115	+18
Energy Protection Agency	511	504	555	+51	+10
Other	1,308	1,150	1,229	+79	+7
Total	**72,492**	**73,821**	**75,469**	**+1,648**	**+2**

	1993 Actual	**1997 Estimate**	**1998 Proposed Dollar**	**Change: 1997-1998**	**Per cent Change: 1997 - 1998**
By R&D Theme					
Basic Research	13,362	14,885	15,303	+418	+3
Applied Research	13,608	14,529	15,159	+630	+4
Development	42,795	42,153	41,636	-517	-1
Equipment	NA	937	960	+23	+2
Facilities	2,727	1,317	2,411	+1,094	+83
Total	**72,492**	**73,821**	**75,496**	**+1,648**	**+2**
R&D Support to Universities	**11,674**	**12,979**	**13,268**	**+289**	**+2**
Merit (Peer) Reviewed R&D Programmes	**NA**	**22,220**	**22,717**	**+497**	**0.02**

Source: The Budget of the United States; Fiscal Year 1998, Page 78.
*This table is modified from the Budget of the United States Government Fiscal Year 1998.
NA = Not Applicable

Note: 1998 estimates reflect an extra US$1 billion for Department of Energy (DOE) facilities acquisition (primarily in defence) as a part of DOE's move to fully funding acquisitions up front.

Equipment and Facilities were mpt collectes separately in 1993.

The commitment of the Federal Government to promote S&T research can be measured by the budget dedicated to these activities. Table 1 shows the proposed budget for R&D in the fiscal year 1998, which is US$75.47 billion and has increased 2 per cent (US$1.65 billion dollars) from the previous year. With the exception of the Department of Defence and Department of Agriculture, all other agencies have increased allocations in the fiscal year 1998. The three largest increases (in per cent) were to the Department of Energy (DOE), the Department of Transportation (DOT), and the Environmental Protection Agency (EPA), who are dealing with major environmental problems. According to the estimated budget for the next five years (Table 2), no significant changes in budget allocations are apparent except for DOT.

Table 2
Budget authority by agency* (US$ Billion)

Agency	1996 Actual	Estimate					
		1997	**1998**	**1999**	**2000**	**2001**	**2002**
Agriculture	58.7	60.6	60.3	60.3	62.3	62.7	65.6
Commerce	3.6	3.7	4.2	4.8	6.1	4.0	39.0
Defence military	254.4	250.0	250.7	256.3	262.8	269.6	277.5
Defence civil	32.4	33.8	35.2	35.9	37.0	38.0	39.0
Energy	14.1	14.2	17.0	15.5	14.6	14.0	11.4
Health and human Services	318.5	357.3	370.0	396.3	414.3	439.2	463.1
Transportation	35.7	43.0	43.3	42.1	42.2	42.5	42.2
EPA	6.3	6.6	7.7	7.8	7.2	7.2	7.3
NASA	13.9	13.7	13.5	13.4	13.2	13.2	13.2

Source: The budget of the United States; Fiscal Year 1998, Page 325
*Table is modified from the original by the author.

The United States is one of the leading countries in S&T R&D. According to the World Bank, the United States spends the most in R&D expenditure in gross and is second to Japan in R&D expenditure measured as a percentage of GDP. Most developed countries spend much more than developing countries in terms of gross investment as well as percentage of GDP (see Table 3). This trend indicates that investment in R&D of science and technology is an essential component for the economic growth of countries. For example, investment in R&D by Taiwan and the Republic of Korea is one major reason for the surge in their high-tech industries, (e.g. semiconductor manufacturing). It is not surprising that Taiwan and the Republic of Korea have similar percentages of GDP allocated for R&D expenditures as many of the developed nations.

Table 3
GDP and R&D Expenditure by Countries

Country	GDP 1994 US$million	GDP Percentage Growth Rate	R&D Expenditures as per cent of GDP
USA	6,648,013	2.5	2.54
Japan	4,590,971	1.2	2.90
Germany	2,045,991	1.1	2.33
France	1,330,381	0.8	2.38
United Kingdom	1,071,306	5.7	2.54
Canada	639,900	5.7	2.54
Brazil	554,587	2.2	0.70
China	522,172	12.9	0.60

Country	GDP 1994 US$million	GDP Percentage Growth Rate	R&D Expenditures as per cent of GDP
Mexico	377,115	2.5	0.31
Republic of Korea	*376,900	6.6	**2.6
Australia	331,990	3.4	1.56
India	***267,070	3.8	***0.73
Argentina	281,922	7.6	NA
Taiwan	234,000	6.5	1.82
Indonesia	174,640	7.6	0.26
Thailand	143,209	8.2	0.12
South Africa	121,888	-0.1	0.96
Poland	92,580	1.6	0.80
Malaysia	70,626	8.4	0.37
Chile	51,957	7.5	0.78
Hungary	41,374	-2.0	0.80
Czech Republic	36,024	-4.7	0.42

Source: World Bank, From plan to market: World Development Report 1996; and Science and Engineering Indicator, 1996

* GNP; ** Based on GNP; *** 1992-1993

II. INVESTMENT IN ENVIRONMENTAL TECHNOLOGY

Allocations for EST R&D are not easily distinguished from S&T R&D because the classification of a technology as 'environmentally sound' is often difficult. Much scientific research can be applied to many different applications, including environmental ones.

The majority of the environmental programmes funded by federal government are remediation-oriented programmes, rather than prevention-oriented ones. For example, the Environmental Protection Agency (EPA), the Department of Energy (DOE), and the Department of Defence (DOD) have budgets allocated for cleanup activities of polluted sites. EPA administers the Superfund programme that is responsible for cleaning up the most polluted sites resulting from industrial activities, and the DOE has federal facilities cleanup programmes that are responsible for dealing with the pollution caused by nuclear activities and military activities. The DOD has one of the largest budgets among federal agencies and has a wealth of technological know-how in various scientific disciplines. See annex II for a detailed description of applications of military technology being pursued in the environmental field.

As today's environmental problems become more complex and global, collaboration among federal and state agencies has increased. For example, the US Global Change Research Programme draws participation from NASA, DOE, NSF, DOC, and other agencies with a budget of US$1.81 billion for the 1997 fiscal year (Table 4). Similarly, environmental issues like global warming and acid rain have led to increase international collaboration.

Table 4

Environmental/Natural Resource Investments and Other High Priority Programmes*
(Discretionary budget authority unless otherwise noted US$ million

	1993 Actual	**1997 Estimate**	**1998 Proposed**	**Per cent Change: 1993 - 1997**	**Per cent Change: 1997 - 1998**
Environmental Protection Agency (EPA)					
Operating programme	2,767	3,109	3,402	+12%	+9%
State Revolving Funds (SRFs)					
Clean Water[1]	1,928	625	1,075	-68%	+72%
Drinking water[1]	NA	1,275	725	NA	-43%
Superfund	1,589	1,394	2,094	-12%	+50%
Other	639	396	349	-38%	-12%
Subtotal, EPA	6,923	6,799	7,645	-2%	+12%
Department of Interior (DOI)					
National Park Service operating Programme	984	1,155	1,220	+17%	+6%
Bureau of Land Management operating Programme	638	673	688	+5%	+2%
Fish and Wildlife Service operating Programme	531	524	562	-1%	+7%
Subtotal, DOI (Selected Programmes)	2,153	2,352	2,470	+9%	+5%
Department of Energy (DOE)					
Energy conservation and efficiency	592	550	688	-7%	+25%
Solar and renewable energy R&D	257	270	330	+5%	+22%
Federal facilities cleanup	6,396	6,027	7,246	-6%	+20%
Subtotal, DOE (Selected Programmes)	7,245	6,847	8,264	-5%	+21%
Department of Defence (DOD)					
Cleanup	1,604	2,043	2,114	+27%	+3%
Env.compliance/pollution prevention/conserv.	2,227	2,411	2,486	+8%	+3%
Environmental Technology	393	182	171	-54%	-6%
Subtotal, DOD (Selected Programmes)	4,224	4,636	4,771	+10%	+3%
Partnership for a new generation of vehicles (DOE, DOC, NSF, EPA, DOT)	NA	263	281	NA	+7%
US Global Change Research (NASA, DOE, NSF, DOC, Others)	1,464	1,810	1,878	+24%	+4%
Montreal Protocol (State/EPA)	25	40	49	+60%	+23%

Source: The Budget of United States Government; Fiscal Year 1998, Page 86
*This table is modified from the original
1, Reflects a one time transfer of clean water funds to drinking water in 1997

III. CURRENT LEGAL ASPECTS OF TRANSFERRING PUBLICLY OWNED ESTs

The seminal report on technology transfer by the universities is entitled "Science - The Endless frontier" by Vannevar Bush after the success of the Manhattan Project. It became the basis of governmental funding policy and eventually led to the establishment of agencies like the National Institute of Health (NIH) and the National Science Foundation (NSF). However, in the 1960s and 1970s, government policy regarding the ownership of inventions derived from federally funded research did not exist. The United States government did not want to give the ownership of inventions to universities directly and instead issued non-exclusive licences to anyone interested. The philosophy behind this policy was that since the inventions were made possible by federal funding, the resulting technology must be available to the public, and corporations alone should be prevented from reaping the benefits through exclusive licences. At the same time, small businesses were very reluctant to develop the inventions because competitors could manufacture and market the same products through a non-exclusive license from the government.

A. The Bayh-Dole Act

Inefficient policy governing publicly funded technology transfer propelled the enactment of Bayh-Dole Act of 1980. After numerous amendments, the regulations and guidelines were finalized and codified by the Department of Commerce in 1987 (37 CFR 401). See annex I for the excerpts of 37 CFR 401.14.

Two points of the Bayh-Dole Act help to clarify the United States policy regarding the transfer of publicly funded technology to foreign countries. First, it creates strong incentives for increased research activity, clearly stating that the rights of publicly funded patents belong to the inventor and grantee institution and streamlines the regulations and guidelines for patent application. 37 CFR 401.14 (b) Allocation of Principal Rights states:

"The grantee institution may retain the entire right, title, and interest throughout the world to each subject invention subject to the provisions of this clause and 35 USC. 203. With respect to any subject invention in which the grantee institution retains title, the Federal Government shall have a nonexclusive, nontransferable, irrevocable, paid-up licence to practice or have practised for or on behalf of the United States the subject invention throughout the world".

Second, the Bayh-Dole Act discourages the transfer of publicly funded technology to foreign nations. It specifies that preference must be given to United States industry or to institutions that manufacture products substantially in the United States. In order to waive this requirement, the grantee institution must show that it has tried to commercialize the invention domestically, but cannot feasibly do so. 37 CFR 401.14 (i) Preference for United States industry states:

"Notwithstanding any other provision of this clause, the grantee institution agrees that neither it nor any assignee will grant to any person the exclusive right to use or sell any subject inventions in the United States unless such person agrees that any products embodying the subject invention or produced through the use of the subject invention will be manufactured substantially in the United States. However, in individual cases, the requirement for such an agreement may be waived by the federal agency upon a showing by the grantee institution or its assignee that reasonable but unsuccessful efforts have been made to grant licences on similar terms to potential licensees that would be likely to manufacture substantially in the United States or that under the circumstances domestic manufacture is not commercially feasible".

Unless the United States government makes an exception for EST by legislation, it is difficult to envision the transfer of any inventions. Systematic approaches and mechanisms to promote the sharing of EST with developing nations need to be formulated, or else developing nations will repeat the environmental mistakes that developed nations have made in the past. Although the predominant policy interest of United States Government under the current regime is to assist United States industry to maintain their technical prowess and their distinct advantage in global competition, universities may be able to participate more freely in training and transferring EST to developing nations with an amendment to the Bayh-Dole Act.

B. Evaluating the Potential Role of Universities in Developing and Diffusing ESTs

Universities exist to develop and disseminate information of one kind or another. They are where professors, scholars, researchers, and their students congregate to better themselves through intellectual pursuits. Removed from both government and industry, although not completely independent from either, universities tend to be insulated from the demands of the public and from the controlling need to make a profit, and thus occupy unique and advantageous positions to lend assistance to the UN in establishing an EST transfer programme.

The primary objectives of university research is to generate new knowledge and to train technical specialists in various fields. The US universities have been training and will continue to train a large number of international students, scholars and visiting scientists from virtually every nation in the world. In that regard, the role of US universities in developing a knowledge base for the diffusion of EST to developing countries will remain intact in the foreseeable future regardless of changes in political and legal frame work governing transfer of ESTs.

University researchers developing a particular EST are likely to be doing so not for personal gain in terms of money or intellectual property rights (else they would be doing their research elsewhere) but instead for addressing the application or problem to which the EST are inherently aimed, and are therefore more likely than their industry counterparts to support and be willing to participate in the EST transfer. If Universities are directly incorporated into the EST transfer system, then their human resources networks may be utilised as well, minimising administrative costs that would otherwise be placed on the United Nations.

However, many universities lack sufficient financial resources. The suggested funding mechanism is as follows: Institutes are established at various universities throughout the world. Each institute is responsible for collecting and analysing EST information and for reporting their findings and analysis to the UN agency. Governments provide direct financial support to the institutes and are compensated as a part of ODA for those countries.

According to the financial year of 1998 budget, the R&D support to universities increased by 2 per cent over the financial year 1997. Likewise, peer reviewed R&D programmes increased by 2 per cent to US$22.72 billion. Note that 22.72 billion for peer reviewed R&D programmes include support to both universities and to industry (see Table 1). A gradual increase in the budget for the support of R&D activities in US universities is evident.

There are over 3,000 universities and colleges in the United States and the number is increasing. However, not all universities participate in scientific and engineering research. According to the Association of University Technology Managers (AUTM), approximately 230 universities and non-profit organisations have a technology transfer office.

Table 5
Federal R&D in Science and Engineering to United States Universities
(Thousands of dollars)

Rank	1994		1995	
	Institutions	**Amount**	**Institutions**	**Amount**
1	Johns Hopkins University	612 681	Johns Hopkins University	569 329
2	University of Washington	275 905	University of Washington	299 631
3	MA Inst. of Technology	267 404	MA Inst. of Technology	282 120
4	Stanford University	262 438	Stanford University	266 744
5	University of Michigan	240 390	University of Michigan	243 126
6	University California Los Angeles	221 820	University California San Diego	239 078
7	University California San Diego	218 272	University California Los Angeles	216 423
8	University WI Madison	207 625	University WI Madison	207 504
9	University California S. Francisco	204 404	University of Minnesota	202 354
10	Cornell University	194 482	Cornell University	202 077
11	University of Pennsylvania	190 296	University California S. Francisco	201 770
12	Harvard University	190 125	University of PA	197 229
13	Columbia University	187 308	Harvard University	191 499
14	Penn State University	184 376	Columbia University	186 179
15	Yale University	182 754	Yale University	179 542
Total	**All Institutions**	**11 768 416**	**All Institutions**	**12 068 442**

Source: NSF, **http://www.nsf.gov/sbe/srs/fedspt95/htmstart.htm** and http://www.nsf.gov/sbe/srs/fedsut/pubs/dst94/tab/b21.htm.

According to Table 5, Johns Hopkins University received the most federal R&D funds in the financial year 1994 and 1995. The rankings of the years, 1994 and 1995, are very similar. The top fifteen schools received similar amounts in consecutive financial years, 1994 and 1995. The four universities, Columbia, Harvard, Yale, and Stanford, are selected for a further investigation in this study. Their research activities not only represent active collaboration between Government and academia, but also represent specialised fields of interest. For example, Columbia University undertakes a great deal of research activities in geosciences due to its world-renown Lamont-Doherty Earth Observatory. On the other hand, Stanford University has active research projects in engineering fields. Table 6 shows the breakdown of federal R&D funds by disciplines and schools in the years of 1993, 1994, and 1995.

Although each school has its specialities in different fields, their patent, copyright and other intellectual property policies are similar. Their policies is based on the Bayh-Dole Act of 1980, Public Law 96-517. The procedure for the issuance of a patent generally comprises four steps.

First, the conception of invention by an inventor is the starting point of the process. Second, an inventor must disclose patentable inventions to the appropriate offices in his or her university. Third, the universities must make a decision whether they would pursue a patent for an invention and notify the inventor of the decision. If they choose not to pursue a patent, the ownership usually goes back to an inventor. If they choose to pursue a patent, the university will file for a patent, even foreign patents if necessary. Fourth, the appropriate offices in respective universities with the consent of inventors seek to give either exclusive or non-exclusive licences to companies for commercialisation. Although the patent process and the necessary procedures are similar, the internal mechanisms and royalty sharing policies differ among schools. Table 6 shows the comparison of differences among schools.

Table 6
Federally financed R&D expenditures in science and engineering for selected universities
(Thousands of dollars)

Academic Discipline	93	93	93	93	94	94	94	94	95	95	95	95
	Columbia	Harvard	Stanford	Yale	Columbia	Harvard	Stanford	Yale	Columbia	Harvard	Stanford	Yale
ENGINEERING	12 251	4 054	78 061	5 805	12 036	4 186	81 762	4 946	10 314	2 643	80 298	5 167
Aerospace Engineering		292	4 793				4 685				4704	
Chemical Engineering	1 754	306	2 456	1 461	705		3 564	1 239	396		3 758	1 317
Civil Engineering	258	304	4 914		350		5 209		108		6 253	
Electrical Engineering	5 931	1 064	25 377	1 304	5 619		25 096	1 209	3 813		20 613	1 492
Mechanical Engineering	470	790	7 799	2 038	137		8 326	1 493	263		10 186	1 503
Materials Engineering	717		1 346		1 007		1 145		1 474		956	
Other Engineering	3 121	1 298	31 376	1 002	4 218	4 186	33 737	1 005	4 260	2 643	33 828	855
PHYSICAL SCIENCES	16 822	24 155	42 174	16 600	18 702	27 062	40 075	17 009	20 180	26 698	44 652	16 828
Astronomy	2 559	4 107		881	2 608	4 192		783	2 268	4 072		711
Chemistry	6 496	11 600	9 018	7 017	6 956	13 080	9 686	6 027	7 334	12 347	10 857	5 620
Physics	1 864	8 448	3 523	8 626	2 615	9 790	3 100	10 199	2 952	10 259	3 760	10 497
Other Physical Sciences	5 903		29 633	76	6 523		27 289		7 626	20	30 035	
GEOSCIENCES	28 197	6 631	4 745	1 762	38 467	6 754	5 085	1 878	38 525	7 383	6 299	1 527
Atmospheric Sciences				810				677				519
Earth Sciences		6 631	3 361	670		6 754	3 512	1 089		7 383	4 862	886
Oceanography	28 197		1 384	211			1 573	75			1 437	15
Other Geosciences				71	38 467			37	38 525			107
MATH AND COMPUTER. SCIENCES	3 071	3 802	12 266	5 517	3 927	3 752	13 304	4 649	4 432	3 800	16 768	3 770
Mathematics and Statistics	669	2 035	3 072	1 560	664	2 170	2 752	1 739	676	2 221	2 730	1 584
Computer Science	2 402	1 767	9 194	3 957	3 263	1 582	10 552	2 910	3 756	1 579	14 038	2 186
LIFE SCIENCES	116 106	123 020	113 245	136 069	123 331	122 176	124 208	139 449	126 387	130 755	121 744	144 180
Agricultural Sciences		11		411				447				694
Biological Sciences	49 074	65 549	8 362	50 540	48 680	65 373	9 985	52 049	46 933	69 578	9 433	54 693
Medical Sciences	67 032	57 460	104 675	85 118	74 454	56 803	114 002	86 953	78 833	61 177	111 924	88 793
Other Life Sciences			208		197		221		621		387	

Source: NSF http://caspar.nsf.gov/cgi-bin/WebIC.exe

A. Columbia University New York, NY

Columbia Innovation Enterprise (CIE) is the main office that assists research activities of Columbia University. CIE helps researchers and professors of Columbia University to obtain patents and copyrights or rights to any intellectual properties. In addition it helps to commercialise patents by issuing licences to industry and manages the profits and expenditures from research activities.

The main legislation that guides the policy of CIE is the Bayh-Dole Act of 1980. Because of the Bayh-Dole Act, the university owns numerous publicly funded technologies and has greatly benefited from them. One interesting aspect of CIE policy is the distribution of net income (gross income minus expenses) from an invention. Net income is distributed amongst five recipients:

1. The inventor
2. The inventor's research activities
3. The university
4. The inventor's department
5. The faculty in which unit applicable under 4 is a component.

The inventor receives 50 per cent of net income if the net income is under US$100 000. If over $100 000 the inventor receives 50 per cent of first US$100 000 and 25 per cent of the excess. The inventor's research activities will receive 25 per cent of the net income. If the amount exceeds $500 000 the excess will be transferred to the university. If the net income is less than US$100 000 the University will receive 25 per cent of the net income. If over US$100 000 the University's share is 25 per cent of the first $100 000 and 33 per cent of the excess. If there are any remaining funds after the first three recipients they will be equally divided between the inventor's department and the faculty.

B. Harvard University, Cambridge MA

The Office for Technology and Trademark Licensing co-ordinates technology transfer in Harvard University. As in the case of Columbia University the Bayh-Dole Act is the major basis for legal policy. One interesting aspect is that if an inventor elects to pursue public use of his/her invention without the help from the University he does so and is entitled to all income resulting from the decision.

The royalty sharing policy for Harvard University is as follows: the net income from any Harvard-owned inventions is distributed to four recipients, the inventor, the inventor's department the faculty, and the university. The Dean's Office or Office of the Vice President represents the faculty and President and fellows of Harvard College represent the university. The Inventor receives 35 per cent of the net income unless it exceeds US$50 000. If it does the inventor receives 35 per cent of first US$50 000 and 25 per cent of the excess. Inventor's department receives 30 per cent of the net income unless it is exceeds US$50 000. If it is over US$50 000, it receives 30 per cent of first US$50 000 and 40 per cent of the excess. However the inventor may direct the usage of a half of the department's share. In addition the faculty receives 20 per cent and the university receives 15 per cent regardless of the amount of net income.

C. Stanford University, Stanford CA

The Office of Technology Licensing (OTL) is the main office to help and facilitate researchers and professors to protect and further develop their inventions. Stanford University also give inventors an option of placing their inventions in the public domain. The Sponsored Projects Office (SPO) also helps the process by reviewing contracts for their compliance with the university's policies.

The royalty sharing policy is rather simple in Stanford University. First, 15 per cent of gross income is deducted to cover the overheads of OTL. Then, all the expenses used in the process are deducted from 85 per cent of the gross income. After the deductions, one third goes to the inventor, one third to the inventor's department, and one third to the inventor's school regardless of the amount of the income.

D. Yale University, New Haven CT

The University's Office of Corporate Research is the main office to evaluate the patentability of inventions and to help commercialise them. It was also established to help technology transfer for the public interest. The royalty sharing policy is as follows: for net income under US$100 000, one goes to the inventor and the other half goes to the general support of university research activities. For net income between US$100 000 and US$200 000, 40 per cent go to the inventor and 60 per cent goes to the general support of the university's research activities. For net income exceeding US$200 000, 30 per cent goes to the inventor and 70 per cent goes to the general support of the University as research activities.

V. CONCLUSIONS AND RECOMMENDATIONS

The United States Federal Government granted over US$13 billion in science and technology research and development (S&T R&D) to universities in the financial year 1998. In addition, the universities receive substantial financial resources from state and local governments, charitable foundations and industry. A significant portion of these resources is dedicated to EST R&D. Despite funding from these various sources, they have maintained their integrity and neutral position between government and industry, making them valuable tools in the transfer of EST. Furthermore, because most EST are system-oriented requiring extensive training and education, universities are ideally suited for facilitating EST transfer. Another noteworthy aspect of United States universities with regard to EST transfer is the extensive participation of international students and scholars.

United States universities and affiliated national laboratories have established unique capabilities and advantageous positions to enable the effective transfer of EST to the global community. However, there are significant impediments. Most importantly, current regulations discourage the transfer of technologies to anyone, particularly foreign nations without appropriate compensation to the inventors. With regard to patents arising from publicly funded research, the Bayh-Dole Act of 1980 (Public Law 96-517) gives intellectual property rights to the inventors and the grantee institution (e.g. university). As a result United States universities have benefited greatly from rapidly increasing revenues generated through licensing and commercialization of these inventions.

The transfer of EST under the current system would require a significant investment on the part of the recipient developing nations under licensing agreements if use and development were permitted outside of the United States (see the Bayh-Dole Act). Such investment is beyond their means and is clearly a disincentive for their participation in environmentally sound development. However, changing the current intellectual property rights system in favour of technology transfer would put the burden of R&D costs (and possibly compensation costs to inventors and grantee institutions) onto taxpayers and this is not likely to be supported by the American people. An exception to the current system might be created to allow the low cost transfer of EST to developing nations if other benefits, such as reductions in greenhouse gas emissions, are valued highly enough by the American people; in other words if they recognise and value the significant non-monetary benefits (environmental protection/preservation health and safety etc...) to be realised through the use of EST globally then support for legislative change might be possible.

Thus, effective EST transfer mechanisms must be developed despite the current non-conducive United States regulations. Additional incentives to conduct and fund research other than financial gain may be created for a donor nation through EST transfer mechanisms where the donor nation (or its institutions and inventors) has a supervisory and educational role during technology transfer and also gains protected rights concerning new inventions that grow out of continued 'testing' of proven yet still advancing technologies. Similar tangible incentives must be incorporated into EST transfer mechanisms to overcome the projectionist policy interests seen in the Bayh-Dole Act.

Furthermore, a form of public financing through ODA can be an effective means to sustain technology transfer. For example, a funding mechanism similar to the UNDP Revolving Funds for Natural Resources Exploration (UNDP-RFNRE) could be considered. The UNDP-RFNRE was established in 1973 to provide assistance to developing countries to enhance their ability to produce mineral and energy resources. RFNRE provides initial technical and financial assistance to recipient nations during the exploration stage and recovers a part of the profit when successful projects start generating revenues. As mentioned above, similar roles may be developed through the university system for educational and training components of EST transfer, and intellectual property rights provide a currency of sorts to recompense the donor nation.

A United Nations agency should be established to coordinate EST transfer amongst donor nations and developing nations. When possible, environmentally sound technologies should be marketed at fair prices to recipient nations with proper financial credits to the donor nations in a form of ODA. If the agency can establish a pool of EST to which donor nations can contribute and for which compensation mechanisms are provided for the nations in need can use EST at a reasonable cost. Furthermore, unrecognised or undervalued incentives for donor countries to participate need to be developed by the agency in cases where 'fair market prices' are too high for developing nations. The agency should work closely with a set of participating universities. A feasibility study could be undertaken by establishing EST Transfer Centres at such universities.

It is also important to explore the possibility to utilise technologies developed by government agencies (e.g. the Department of Defence) for purposes other than those they were originally developed for (i.e. environmental protection). For example the Government instituted the Dual Use Applications Programme (DUAP) to facilitate the diffusion of useful technologies, that were developed during the Cold War, for alternative non-military public applications. In the financial year 1998, US$225 million were proposed for DUAP. Other United States Government agencies and many other governments have attempted to develop similar programmes and many have been successful in adapting various technologies for environmental purposes. Unlike technologies developed by universities, the Government owns significant interests in the technologies and can make decisions regarding their transfer with fewer regulatory and financial obstacles. Universities have been involved in the various stages of the development of such technologies and will be in a position to help disseminate such technologies to the global community. It should be noted that applications of military technology have a great potential to have a significant impact on the improvement of the environment. Among the anticipated areas to benefit from military technology are hazardous waste management, environmental monitoring, the use of environmentally benign materials and site remediation (see annex II).

ANNEX I

37CFR 401.14 Standard Patent Rights Clause

(a) Patent Rights (Small Business Firms and Nonprofit Organisations)
Definitions

(a.1) "Invention" means any invention or discovery which is or may be patentable or otherwise protectable under Title 35 of the United States Code or any novel variety of plant which is or may be protected under the Plant Variety Protection Act (7 USC. 2321 et seq.).

(a.2) "Subject invention" means any invention of the grantee institution conceived or first actually reduced to practice in the performance of work under this grant provided that in the case of a variety of plant the date of determination (as defined in section 41 (d) of the Plant Variety Protection Act 7 USC. 2401 (d)) must also occur during the period of grant performance.

(a.3) "Practical Application" means to manufacture in the case of a composition or product to practice in the case of a process or method or to operate in the case of a machine or system; and in each case under such conditions as to establish that the invention is being utilised and that its benefits are to the extent permitted by law or government regulations available to the public on reasonable terms.

(a.4) "Made" when used in relation to any invention means the conception or first actual reduction to practice of such invention.

(a.5) "Small Business Firm" means a small business concern as defined at section 2 of Pub. L. 85-536 (15 USC. 632) and implementing regulations of the Administrator of the Small Business Administration. For the purpose of this clause the size standards for small business concerns involved in government procurement and subcontracting at 13CFR 121.3-8 and 13CFR 121.3-12 respectively will be used.

(a.6) "Nonprofit Organisation" means a university or other institution of higher education or an organisation of the type described in section 501 (c)(3) of the Internal Revenue Code of 1954 (26 USC. 501 (c) and exempt from taxation under section 501 (a) of the Internal Revenue Code (25 USC. 501 (a)) or any nonprofit scientific or educational organisation qualified under a state nonprofit organisation statute.

(b) Allocation of Principal Rights

The grantee institution may retain the entire right title and interest throughout the world to each subject invention subject to the provisions of this clause and 35 USC. 203. With respect to any subject invention in which the grantee institution retains title the Federal government shall have a nonexclusive nontransferable irrevocable paid-up license to practice or have practised for or on behalf of the United States the subject invention throughout the world.

(c) Invention disclosure Election of Title and Filing of Patent Application by Grantee Institution

(c.1) The grantee institution will disclose each subject invention to the Federal Agency within two months after the inventor discloses it in writing to grantee institution personnel responsible for patent matters. The disclosure to the agency shall be in the form of a written report and shall identify the grant under which the invention was made and the inventor(s). It shall be sufficiently complete in technical detail to convey a clear understanding to the extent known at the time of the disclosure of the nature purpose operation and the physical chemical biological or electrical characteristics of the invention. The disclosure shall also identify any publication on sale or public use of the invention and whether a manuscript describing the invention has been submitted for publication and if so whether it has been accepted for publication at the time of disclosure. In addition after disclosure to the agency the grantee institution will promptly notify the agency of the acceptance of any manuscript describing the invention for publication or of any on sale or public use planned by the grantee institution.

(c.2) The grantee institution will elect in writing whether or not to retain title to any such invention by notifying the Federal agency within two years of disclosure to the Federal agency. However in any case where publication on sale or public use has initiated the one year statutory period wherein valid patent protection can still be obtained in the United States the period for election of title may be shortened by the agency to a date that is no more than 60 days prior to the end of the statutory period.

(c.3) The grantee institution will file its initial patent application on a subject invention to which it elects to retain title within one year after election of title or if earlier prior to the end of any statutory period wherein valid patent protection can be obtained in the United States after a publication on sale or public use. The grantee institution will file patent applications in additional countries or international patent offices within either ten months of the corresponding initial patent application or six months from the date permission is granted by the Commissioner of Patents and Trademarks to file foreign patent applications where such filing has been prohibited by a Secrecy Order.

(c.4) Requests for extension of the time for disclosure election and filing under subparagraphs (1) (2) and (3) may at the discretion of the agency be granted.

(d) Conditions When the Government May Obtain Title

The grantee institution will convey to the Federal agency upon written request title to any subject invention-

(d.1) If the grantee institution fails to disclose or elect title to the subject invention within the times specified in (c) above or elects not to retain title; provided that the agency may only request title within 60 days after learning of the failure of the grantee institution to disclose or elect within the specified times.

(d.2) In those countries in which the grantee institution fails to file patent applications within the times specified in (c) above; provided however that if the grantee institution has filed a patent application in a country after the times specified in (c) above but prior to its receipt of the written request of the Federal agency the grantee institution shall continue to retain title in that country.

(d.3) In any country in which the grantee institution decides not to continue the prosecution of any application for to pay the maintenance fees on or defend in reexamination or opposition proceeding on a patent on a subject invention.

(e) Minimum Rights to Grantee Institution and Protection of the Grantee Institution Right to File

(e.1) The grantee institution will retain a nonexclusive royalty-free license throughout the world in each subject invention to which the government obtains title except if the grantee institution fails to disclose the invention within the times specified in (c) above. The grantee institution's license extends to its domestic subsidiary and affiliates if any within the corporate structure of which the grantee institution is a party and includes the right to grant sublicenses of the same scope to the extent the grantee institution was legally obligated to do so at the time the grant was awarded. The license is transferable only with the approval of the Federal agency except when transferred to the successor of that party of the grantee institution's business to which the invention pertains.

(e.2) The grantee institution's domestic license may be revoked or modified by the funding federal agency to the extent necessary to achieve expeditious practical application of the subject invention pursuant to an application for an exclusive license submitted in accordance with applicable provisions at 37CFR Part 404 and agency licensing regulations (if any). This license will not be revoked in that field of use or the geographical areas in which the grantee institution has achieved practical application and continues to make the benefits of the invention reasonably accessible to the public. The license in any foreign country may be revoked or modified at the discretion of the funding federal agency to the extent the grantee institution its licensees or the domestic subsidiaries or affiliates have failed to achieve practical application in that foreign country.

(e.3) Before revocation or modification of the license the funding federal agency will furnish the grantee institution a written notice of its intention to revoke or modify the license and the grantee institution will be allowed thirty days (or such other time as may be authorised by the funding federal agency for good cause shown by the grantee institution) after the notice to show cause why the license should not be revoked or modified. The grantee institution has the right to appeal in accordance with applicable regulations in 37CFR Part 404 and agency regulations (if any) concerning the licensing of government-owned inventions any decision concerning the revocation or modification of the license

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(f) Grantee Institution Action to Protect the Government's Interest

(f.1) The grantee institution agrees to execute or to have executed and promptly deliver to the Federal agency all instruments necessary to (i) establish or confirm the rights the government has throughout the world in those subject inventions to which the grantee institution elects to retain title and (ii) convey title to the Federal agency when requested under paragraph (d) above and to enable the government to obtain patent protection throughout the world in that subject invention.

(f.2) The grantee institution agrees to require by written agreement its employees other than clerical and nontechnical employees to disclose promptly in writing to personnel identified as responsible for the administration of patent matters and in a format suggested by the grantee institution each subject invention made under grant in order that the grantee institution can comply with the disclosure provisions of paragraph (c) above and to execute all papers necessary to file patent applications on subject inventions and to establish the government's rights in the subject inventions. This disclosure format should require as a minimum the information required by (c)(1) above. The grantee institution shall instruct such employees through employee agreements or other suitable educational programmes on the importance of reporting inventions in sufficient time to permit the filing of patent applications prior to US or foreign statutory bars.

(f.3) The grantee institution will notify the Federal agency of any decisions not to continue the prosecution of a patent application pay maintenance fees or defend in a reexamination or opposition proceeding on a patent in any country not less than thirty days before the expiration of the response period required by the relevant patent office.

(f.4) The grantee institution agrees to include within the specification of any United States patent applications and any patent issuing thereon covering a subject invention the following statement "This invention was made with government support under (identify the grant) awarded by (identify the federal agency). The government has certain rights in the invention."

(f.5) The grantee institution agrees to provide a final invention statement and certification prior to the closeout of a grant listing all subject inventions or stating that there were none.

(f.6) The grantee institution will provide the patent application filing date serial number and title; copy of the page of the patent application with the statement identified in (4) above (and upon request a copy of the patent application); and patent number and issue date for any subject invention in any country in which the grantee institution has applied for patent.

(g) Subcontracts

(g.1) The grantee institution will include this clause suitably modified to identify the parties in all subcontracts regardless of tier for experimental developmental or research work to be performed by a small business firm or domestic nonprofit organisation. The subcontractor will retain all rights provided for the grantee institution in this clause and the grantee institution will not as part of the consideration for awarding the subcontract obtain rights in the subcontractor's subject inventions.

(g.2) In the case of subcontracts at any tier when the prime award with the federal agency was a contract (but not a grant or a co-operative agreement) the agency subcontractor and contractor agree that the mutual obligations of the parties created by this clause constitutes a contract between the subcontractor and the Federal agency with respect to matters covered by the clause; provided however that nothing in this paragraph is intended to confer any jurisdiction under the Contract Disputes Act in connection with proceedings under paragraph (j) of this clause.

(h) Reporting on Utilisation of Subject Inventions

The grantee institution agrees to submit on request periodic reports no more frequently than annually on the utilisation of a subject invention or on efforts at obtaining such utilisation that are being made by the grantee institution or its licensees or assignees. Such reports shall include information regarding the status of development date of first commercial sale or use gross royalties received by the grantee institution and such other data and information as the agency may reasonably specify. The grantee institution also agrees to provide additional reports as may be requested by the agency in connection with any march-in proceeding undertaken by the agency in accordance with paragraph (j) of this clause. As required by 35 USC. 202(c)(5) the agency agrees it will not disclose such information to persons outside the government without permission of the grantee institution.

(i) Preference for United States Industry

Notwithstanding any other provision of this clause the grantee institution agrees that neither it nor any assignee will grant to any person the exclusive right to use or sell any subject inventions in the United States unless such person agrees that any products embodying the subject invention or produced through the use of the subject invention will be manufactured substantially in the United States. However in individual cases the requirement for such an agreement may be waived by the federal agency upon a showing by the grantee institution or its assignee that reasonable but unsuccessful efforts have been made to grant licences on similar terms to potential licensees that would be likely to manufacture substantially in the United States or that under the circumstances domestic manufacture is not commercially feasible

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(j) March-in Rights

The grantee institution agrees that with respect to any subject invention in which it has acquired title the Federal agency has the right in accordance with the procedures in 37CFR 401.6 and any supplemental regulations of the agency to require the grantee institution an assignee or exclusive licensee of a subject invention to grant a nonexclusive partially exclusive or exclusive license in any field of use to a responsible applicant or applicants upon terms that are reasonable under the circumstances and if the grantee institution assignee or exclusive licensee refuses such a request the federal agency has the right to grant such a license itself if the federal agency determines that:

(j.1) Such action is necessary because the grantee institution or assignee has not taken or is not expected to take within a reasonable time effective steps to achieve practical application of the subject invention in such field of use.

(j.2) Such action is necessary to alleviate health or safety needs which are not reasonably satisfied by the grantee institution assignee or their licensees;

(j.3) Such action is necessary to meet requirements for federal regulations and such requirements are not reasonably satisfied by the grantee institution assignee or licensees; or

(j.4) Such action is necessary because the agreement required by paragraph (i) of this clause has not been obtained or waived or because a licensee of the exclusive right to use or sell any subject invention in the United States is in breach of such agreement.

(k) Special Provisions for grants with Non-profit organisations

If the grantee institution is a nonprofit organisation it agrees that:

(k.1) Rights to a subject invention in the United States may not be assigned without the approval of the federal agency except where such assignment is made to an organisation which has as one of its primary functions the management of inventions provided that such assignee will be subject to the same provisions as the grantee institution;

(k.2) The grantee institution will share royalties collected on a subject invention with the inventor including federal employee co-inventors (when the agency deems it appropriate) when the subject invention is assigned in accordance with 35 USC. 202(e) and 37CFR 401.10

(k.3) The balance of any royalties or income earned by the grantee institution with respect to subject inventions after payment of expenses (including payments to inventors) incidental to the administration of subject inventions will be utilised for the support of scientific research or education; and

(k.4) It will make efforts that are reasonable under the circumstances to attract licensees of subject invention that are small business firms and that it will give a preference to a small business firm when licensing a subject invention if the grantee institution determines that the small business firm has a plan or proposal for marketing the invention which if executed is equally as likely to bring the invention to practical application as any plans or proposals from applicants that are not small business firms; provided that the grantee institution is also satisfied that the small business firm has the capability and resources to carry out its plan or proposal. The decision whether to give a preference in any specific case will be at the discretion of the grantee institution. However the grantee institution agrees that the Secretary may review the grantee institution's licensing programme and decisions regarding small business applicants and the grantee institution will negotiate changes to its licensing policies procedures or practices with the Secretary when the Secretary's review discloses that the grantee institution could take reasonable steps to implement more effectively the requirements of this paragraph (k)(4).

(l) Communication

All disclosures elections confirmatory licences to the government face page of the patent applications waivers and other routine communications should be sent to the Director Office of Policy for Extramural Research Administration Building 31 Room 5B62 31 Centre Drive MSC2190 Bethesda MD 20892-2190.

ANNEX II

This list is from Potential Uses of Military-Related Resources for Protection of the Environment published by United Nations Office for Disarmament Affairs in 1993.

Technological capabilities of waste management Erreur! Signet non défini.

Supercritical carbon dioxide

Organics are soluble in supercritical carbon dioxide thus a selective extraction process for solid phases can be developed which concentrates the organics while the solvent is recycled. The process is a possible pretreatment for extraction of organics by concentration to be followed by a destructive treatment such as supercritical water oxidation.

Supercritical water oxidation

Destructive oxidation of hazardous wastes to carbon dioxide water and other small molecules can minimise waste volume and detoxify many hazardous compounds. Supercritical water is a unique solvent medium in which oxidation can take place at lower temperatures than those of the most common oxidation technique of incineration in air at atmospheric pressure. Possible applications include propellants munitions gunpowder flares explosive wastes groundwater contaminated with pesticides or animal wastes nitrates from fertilisers and industrial wastes.

Electrochemical oxidation

Two technologies are involved: (1) electrochemical oxidation of liquid and solid wastes at low temperatures and pressures and (2) use of advanced membranes in conjunction with electrochemical cells to remove organics from water.

Robotics

Robotics is used to produce automated systems for remotely analysing the chemical content of hazardous and radioactive materials. This work has been underway for several years as a basic need and use for the defence effort.

Magnetic separation of waste

With the development of high-field strength superconducting magnets it is possible to magnetically separate a wide variety of compounds including actinides from liquid solid or gaseous wastes.

Plant cell (jimsonweed) clean-up

Development of cell cultivators and engineering methods for using jimsonweed cells for sequestering plutonium barium and other metals from aqueous solutions and for cleaning up the "pink water" the results from machining explosives.

Performance assessment data interpretation and models

Efforts in support of performance assessments and data interpretation include atmospheric pathways surface water contaminant transport sub-surface migration site characterisation data interpretation waste characterisation and predicted behaviour and application of isotopic tracers for model verification. Future directions may apply to neural networks and uncertainty analysis to the suite of computational tools.

Environmental biotechnology

Biological processes are an attractive option for degrading organic wastes. Microorganisms will metabolise an impressive variety of organic substrates. During metabolism the organics are chemically transformed into metabolic intermediates which the microbes use for production of energy and biosynthesis to cellular material. Consequently the organic substrates are chemically converted into harmless products: carbon dioxide water minerals and biomass. Many hazardous chemicals including the chemical classes found in mixed waste e.g. hydrocarbons halogenated aliphatics and polychlorinated biphenyls have been shown to be degraded by microorganisms. Natural microorganisms have been isolated that will use explosives as a food source. Currently organisms have been isolated that are capable of destruction of TNT and nitroglycerin Organisms to digest HMX PBX and nitrocellulose are being selected.

Closure and containment of waste sites

Defence-related waste site closure technologies that are directly transferable to mixed and hazardous waste sites with some changes to meet the close-in-place requirements. An integrated cover design for such closures that addresses water balance on the surface and subsurface biotic intrusion effects and seasonal effects is one technology. For faster regulatory acceptance a demonstration of the design on a semi-arid and humid site containing mixed wastes could complete the full utilisation of the technology.

Chemical sensors

For use in the remote determination of radionuclides and hazardous organics. The use of electrochemical piezoelectric oscillators and spectroscopic technology with selective polymers supports or encapsulants protective coatings and attachment of polymers to substrates with an emphasis on selectivity durability and repeatability.

Optical Diagnostics for real-time remote in-situ-monitoring of environmental contaminants

The technology includes the selection and integration of optical diagnostic methods for a range of contaminants i.e. organics inorganics radionuclides and mixtures. Included are phytothermal spectroscopy and laser-induced fluorescence near- and mid-infrared absorbance/luminescence vibrational Ramen spectroscopy laser photoionization spectrometry and laser light detection and ranging (lidar).

Destructive technologies for waste

Under investigation in this category are plasmas microwaves and Accelerator Transmutation of Waste (ATW). The latter technology uses an accelerator to generate a high flux of neutrons by directing a beam of subatomic particles into a lead-bismuth target. The interaction of beam and target releases neutrons from the target; these neutrons then enter a surrounding heavy-water moderator which slows them down. The system is designed so that the neutrons then interact with radioactive waste into short-lived radioactive or stable (nonradioactive) substances. The transformed refuse would in many cases still require isolation from human contact but demands upon storage would be reduced from tens of thousands of years to only hundreds of years or less.

Sensor fundamentals and applications

Sensors are the physical transducers by means of which specific environmental attributes are converted into information usually in the form of a quantitative electronic signals. The principal indices of sensor performance are its spatial resolution or accuracy and its ability to discriminate between the object's signal and random variations in the object a threshold called the signal-to noise ratio (SNR). Overall performance is a compromise between resolution and area covered. Sensors can react to physical chemical or biological phenomena often in combination. Depending on the basic physical principles used for measurement one can distinguish between seismic-acoustic sensors which react to mechanical pressure (e.g. sonars) magnetic sensors which measure disturbances in the earth magnetic field detectors measuring radioactivity and electromagnetic sensors which are sensitive to different regions of the electromagnetic spectrum. In the last mentioned category most important are radar wave sensors and sensors operating in the visible and infrared (IR) parts of the spectrum (generally called opto-electronic sensors). Remote sensing as its name implies means the detection of (environmental or military) changes at a distance from the sensor and is now almost synonymous with the use of airborne and space platforms.

1. Passive sensors

Passive sensors consist of a receiver that detects some attribute of the object (e.g. the amount of heat emitted from different landforms or an enemy tank). Some illustrations of their environmental use are given below:

(a) Photographic: visible and near infrared

Under optimum conditions aircraft photography can provide spatial resolution in the range of approximately 1 cm. Military reconnaissance satellites are reported to provide resolutions down to 10 cm and civilian satellites down to 10 metres. This disparity suggests that non-military applications could benefit from military technology and data. Photography from both aircraft and satellites is a major tool for remote sensing of the lithosphere being particularly useful in the assessment of landforms and how they change (basic geomorphology land cover water resource assessment ice cover vulcanology etc.) and provides quantification of distance areas volumes height and directions. High resolution photography coupled with photogrammetry and computerised image enhancement (digitisation of the density data) is extremely versatile.

(b) Vidicon camera: visible and near infrared

The vidicon camera is the electrical analogue of the conventional camera in which an optical image is formed on the photo-sensitive surface of an electron gun which then converts the image into an electrical signal. Vidicon TV cameras are deployed on a number of meteorological satellites and the Landsat series has an improved version called the Return Beam Vidicon (REV).

(c) Thermal infrared scanner

In thermal infrared radiation the detector converts intensity to electrical signals which are input to a single-line cathode ray tube (CRT) which records a line on film. As the sensor moves successive new lines are swept and an image perpendicular to the direction of movement is formed. Thermal infrared sensing is particularly effective in the study of secondary volcanic activity (fumaroles gas vents that follow an eruption); ocean and coastal currents; forest fires; and ground water discharges. Thermal inertia mapping is also able to study near surface conductive heat transfer.

(d) Optical-mechanical multispectral scanner

Optical-mechanical multispectral scanners (MSS) using detectors calibrated or designed for specific spectral bands of radiation can collect simultaneous data over a range of wavelengths. For example the MSS on the Landsat series of satellites provides simultaneous data on the Earth's surface at four different bands. The Computer Compatible Tape (CCT) from the Landsat MSS allows advanced methods of pre-processing enhancement and classification of information. Because clear water transmits energy in the blue-green range and absorbs in the near infrared MSS can detect turbid sediment laden waters and has proven valuable in studies of river flooding.

(e) Microwave sensors

Passive microwave sensors (PMS) detect emitted reflected and transmitted radiation in the microwave part of the radio spectrum. Compared with optical (visible and infrared) sensors PMS are effective at night in poor weather and can penetrate clouds. However their resolution is poor (several metres) and the strength of the signal is determined by the temperature and dielectric properties of the Earth's surface. An Electrically Scanning Microwave Radiometer (ESMR) is fitted to the Nimbus-5 satellite. Passive microwave sensing is particularly effective in monitoring water resources.

2. Active sensors

Active sensors comprise a transmitter which scans the object usually with some type of electromagnetic radiation (e.g. microwaves infrared radiation radio waves) and a receiver which detects how the beam interacts with the target object (e.g. how the radar beam is reflected back from an aircraft sea surface or landform).

(a) Radio detection and ranging (radar)

Radar systems were developed for military uses primarily to detect targets (typically aircraft). In addition to measuring distance radar can be used to measure the velocity of moving targets (Moving Target Indication MTI) by determining the frequency difference between the emitted and received radio waves (the Doppler effect). Of greater relevance to environmental sensing is the ability of Side-Looking Airborne Radar (SLAR) which uses short pulses of radio waves emitted perpendicular to the flight path of an airborne platform to generate two-dimensional images of the terrain from the reflected signal.

Phased Array Radars (PARs) use a static (i.e. non-scanning) antenna which enables greater scan rates multi-target tracking reliability and accuracy to be achieved. Synthetic Aperture Radars (SARs) are able to simulate the performance of a very large antenna by computation to provide a very high resolution. Radars working at the short wavelengths (millimetre-wave) provide greater accuracy and are less susceptible to disturbances. Electronic miniaturization has resulted in the development of very small radar units that can be mounted on unmanned platforms.

Radars particularly SAR can be used to monitor floods ocean oil spills sea-ice and soil moisture to measure wind speed and the intensity of rain and snow. In recent years Doppler radars have been developed specifically to detect tornadoes and other forms of storm.

(b) Light detection and ranging (lidar)

The complement to radar in the visible and infrared region of the spectrum is called lidar (light detection and ranging). It finds military and civilian applications in the location of objects in the atmosphere and in space. The differential absorption lidar (DIAL) provides range-resolved measurements of the concentration of chemical pollutants by reflecting pulses of laser light at two wavelengths. As a pulsed laser is used the time-resolved recording of the backscattered photons gives information on the altitude.

Lidar systems have been tested on balloons and aircraft and designed for space applications. Commonly spaceborne lidar technology is focused on temperature profile estimation determination of minor atmospheric constituents like ozone (mainly in the upper atmosphere) and aerosol determination.b Applicable pulsed lasers which are tuneable in the appropriate wavelength region may be selected from semiconductor diode lasers spin-flip Ramen lasers optical parametric oscillators high pressure gas lasers and others. Some of these laser types are developed in the military field. Their main differences relates to spectral resolution which is best for the semiconductor diode lasers and output energy which is best for the gas lasers. The main disadvantages are the high costs of such systems and/or their weight (especially for high-energy lasers). There are limitations in detecting chemicals which are covered by clouds.

(c) Sonar

Sonar (sound navigation and ranging) is a technique for detecting and determining the distance and direction to underwater objects by acoustic means. In the military sonar is used in submarine detection and applied to acoustic homing torpedoes acoustic mines and mine detection. For environmental purposes sonar can be used for detecting icebergs fish finding depth sounding mapping of the sea bottom and Doppler navigation. Small sonobuoys can be air-launched by helicopter.

(d) Isotope tracing

Natural variation in stable isotopes of carbon nitrogen and sulphur can be used to trace the flow of energy through aquatic food webs. Tritium deuterium and oxygen-18 content in precipitation has been monitored monthly since the early 1960s by the global network of stations jointly operated by the International Atomic Energy Agency (IAEA) and the World Meteorological Organisation (WMO). Observation data show that the concentration in air of some trace constituents such as carbon dioxide methane carbon monoxide ozone CFCs nitrogen and sulphur oxides is changing as a result of anthropogenic emissions. In the Chernobyl area investigations are directed at the migration of radionuclides released as a result of the nuclear power plant accident in 1986. In the future it is necessary to develop more adequate interpretative and prognostic models and to establish databases on typical characteristics of pollutant migration under typical geological and thermodynamical conditions.

3. Platforms

Scout tanks

The German scout tank "Fox" is based on the TM-170 already in production and service. Instruments on board the tank essentially include gamma detectors for the detection of nuclear radiation and mass spectrometers for identifying organic substances like chemical warfare agents. A database stores up to 900 substances and print-outs are provided. Meteorological sensors on-board can measure temperature humidity wind speed and direction and barometric pressure. A military land navigation system is used to determine the exact position. The mobile mass spectrometer can work under extreme conditions of temperature and humidity and is totally controlled by microprocessors. Environmental applications include water and fire analysis determination of pesticide and pollution measurement after an accident.

US Reconnaissance satellites

The most advanced military photo-reconnaissance satellites like the US "keyhole" satellites (KH-11 KH-12) consist of an array with millions of small pixels and a reported spatial resolution of 15-30 cm which would be much better than for civilian photo-satellites. Images at night can be made through the use of infrared detectors and photomultipliers which have a substantially lower resolution than the visible-light images. Lacrosse is a cloud-penetrating all-weather radar in space with a number of sensors specially designed for long life. Its resolution is assumed to be in the range of 2:3 m. Depending on the frequency used the Synthetic Aperture Radar (SAR) of Lacrosse is estimated to be capable of penetrating one to several meters of mature green crops. Reconnaissance satellites are important for crisis monitoring early-warning and disarmament verification but could principally perform functions for environmental monitoring with very high resolution.

The US Defence Support Programme (DSP) provides a satellite surveillance system for early warning of a ballistic missile attack. It consists of three geostationary satellites several ground processing stations and a communications network. The primary sensor is a large telescope which consists of an array of infrared detectors each of which sees a terrestrial area less than two miles square. [g] Besides detecting a missile's heat plume it is able to locate large heat sources (fires) either from natural or man-made disasters.

The US Defence Meteorological Satellite System (DMSP) collects data with a number of different sensors: high resolution sensors (scanning radiometers) in the visible and the thermal infrared channels which are used to analyse cloud patterns in support of military operations (e.g. storm warning); passive microwave and infrared temperature sounders; a microwave imager that penetrates cloud cover to obtain a variety of environmental data; an electron spectrometer measuring Earth's charged-particle activity; a TV camera. A lidar is planned to measure the three-dimensional wind field of the atmosphere a vacuum ultraviolet sensor to determine the height of cloud tops and aerosol content of clouds and an ionosonde that measures the high-frequency radio reflection heights of the atmosphere.

4. Environmental applications of remote sensing

(a) The atmosphere

The collection of meteorological data has been traditionally ground-based with the use of such standard instruments as barometers thermometers anemometers rain-gauges and sunshine recorders distributed in a dense network of stations over a country. Specialised sounding rockets have been employed to obtain pressure temperature density and wind data of the uppermost layers of the atmosphere for meteorological and geophysical studies. Remote-sensing satellites are particularly useful in the measurement of temperature structures; surface radiation studies; cloud classification; rainfall estimation; water vapour analysis; wind field analysis; production of severe storms; weather analysis and forecasts; assessment of ozone depletion; and monitoring the greenhouse effect.

(b) The lithosphere

Major environmental applications of remote sensing of the lithosphere from aircraft and satellites are to detect identify and map earth features on the surface and sub-surface and to infer the processes at work. Aerial photography has been used to record volcanic eruptions e.g. the eruption of Mount St. Helens. The thermal infrared scanner is suited to monitor secondary volcanic activity such as fumaroles gas vents etc. In the coastal environment aerial photography reveals details of macroscopic coastal features and circulation patterns of the sea water. Other lithospheric uses of satellite remote sensing include: geological reconnaissance of concealed terrains in harsh environments; floodplain delineation and groundwater flow system detection; mapping of geothermal phenomena; thermal inertia mapping; detection of silicate rocks; determination of terrain slope; detection of structural linear features; extraction of drainage network parameters; geological mapping in heavily forested terrain; snowfield and cryosphere mapping; mapping of surface deposits in desert regions; assessment of grass and forest fire damage; landform analysis; and mapping of surface structures .

(c) The organic biosphere

In the study of vegetation crops and soils there is invariably the need to carry out surveys with a view to discover their spatial distribution structure and type. This information is indispensable for the purpose of management in agriculture and forestry for informed decision-making in planning for feasibility in land development projects and many engineering works. Biospheric use of satellites is well established for vegetation damage assessment; crop identification and discrimination; detection of crop conditions; soil mapping; forest inventory; wetland vegetation; soil moisture determination; crop temperature and crop yield prediction; estimation of the amount of green vegetation. Other missions have been undertaken as for example to rescue a crashed aircraft or a sinking ship by detecting its emergency signals from space.

(d) The hydrosphere

The importance of remote sensing satellites in collecting data concerning the physical biological geological and chemical characteristics of the sea is obvious. Both aerial and satellite photography can be used to track the drift and dispersion of industrial wastes in the sea for instance of heavy metals and organic chemical compounds. Aerial observation is essential to investigate and gather evidence of violation for: illegal and permitted dumping of chemicals incineration of chemicals surveillance of sea traffic fishing protection off-shore activities search and rescue ship traffic control sea ice mapping smuggling activities and general environmental investigation. To detect oil slicks ultraviolet thermal infrared and microwave sensors are potentially suited. The laser fluorosensor gives a coarse-type classification of oil. Passive microwave radiometers have been used in detecting sea-surface temperature sea ice and salinity. Radar has been employed in mapping sea ice measuring wave heights detecting aquatic plants and fish stock determining water depths and sensing oil slicks.

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PART IV

RESPONSES, STRATEGIES AND COOPERATION POLICY OPTIONS

Partnering, alliances and networking

SHAPING THE DEMAND SIDES FOR ENVIRONMENTALLY SOUND TECHNOLOGIES: INTER-FIRM COOPERATION, INTERNATIONAL PARTNERING AND TECHNICAL ASSISTANCE

by
Jörg Meyer-Stamer

I. INTRODUCTION

Making environmentally sound technologies available to firms, especially in developing countries, is a necessary but not sufficient precondition to reduce the ecological burden caused by industrial production. The key challenge to stimulate demand for environmentally sound technologies is the subject of this chapter.

There is little dispute today that it is not adequate to describe technology as just another product that can be purchased off-the-shelf. Apart from tangible technology, such as a machine tool, there is also intangible technology, such as management and organization, and there is tacit knowledge, i.e. non-codifyable knowledge on how to fine-tune a machine or how to make an organization work efficiently. In other words, it is important to conceptualize technology in a broad sense, i.e. not just as technical hardware but also organization and knowledge.

It is quite obvious that technology in the broad sense is not easily transferable – not within an economy and even less between countries. At the same time, it is quite obvious that international technology transfer has worked marvelously on many occasions. Such occasions were those where the competence of the donor and the recipient of a technology fit, not only in terms of mastering a given technology but also in terms of mastering the transfer process as such. In many other cases, international technology transfer has failed–often due to the insufficient capacity of the donor and/or the recipient.

The purpose of this chapter is to look more closely at the recipient side. In particular, two issues will be addressed. Firstly, there is the question of why firms should try to acquire environmentally sound technologies in the first place. There seems to be a typical trajectory in the way firms deal with environmental issues and technology. Initially, they tend to see environmental protection only as a burden, adding cost without measurable benefit. It is only later on that firms start to acknowledge that environmental measures may also have a positive economic impact, and that more than just a few businesspeople have environmental consciousness. In some cases, firms are forced to reduce their environmental impact by government agencies, but it would be an exaggeration to claim that in the developing world environmental agencies are consistently in a position to strictly enforce environmental legislation. Therefore, it is essential to consider further means to stimulate firms to implement environmental measures.

Secondly, there is the question of how international transfer of environmentally sound technologies can be stimulated and supported. Creating a demand and leaving the rest to the market would be one option. However, given the peculiarities of economically good "technology", it makes sense to consider specific support measures to create the preconditions for the market mechanism to work.

The structure of this chapter is as follows: section B presents six case studies where firms in Brazil for one reason or another started to articulate demand for environmentally-sound technologies, often within the context of an overall effort to reduce the environmental burden; this is why the term "environmental management" occurs more often than "environmentally sound technology". It focuses specifically on cases where inter-firm cooperation played an important role. The case studies are then evaluated in a comparative perspective, and a number of policy conclusions are drawn. Section C discusses instruments to stimulate international partnering as a precondition for successful international transfer of environmentally sound technologies.

The evidence presented in this paper is based on research and policy advisory work conducted on behalf of two pilot projects of the German Agency for Technical Cooperation, GTZ, namely the "Pilot Programme for the Promotion of Environmental Management (P3U)" (http://www.gtz.de/p3u) and the "Pilot Project for Strengthening Environmental Competence in Developing Countries (ETC)" (http://www.gtz.de/utk).

II. STIMULATING THE DEMAND FOR ENVIRONMENTALLY-SOUND TECHNOLOGY (WITH SPECIAL REFERENCE TO INTER-FIRM COOPERATION): EXPERIENCES FROM BRAZIL

Brazil has been implementing an environmental policy since the 1970s, mainly as a response to growing environmental damage caused by dynamic industrial development. Brazil has created a federal environmental agency, IBAMA, States have created their own environmental agencies, and even some municipalities have active environmental agencies of their own. The division of responsibilities between these agencies is often not clearly defined, and their modes of action are extremely diverse. A large firm in an urban agglomeration is likely to be controlled strictly, whereas small firms in small towns may not have suffered any control so far even if they are highly polluting. In any case, there is not only legislation but also implementation so that firms are under pressure to reduce their environmental impact. An important instrument in this context is the certification formal sector firms have to obtain from the environmental agency. The need to get a licence first arises when building a new plant (licença prévia/provisional licence at the initiation of a project, licença de construção/construction licence before the start of construction). A licence for operation (licença de operação) is less required and usually has to be renewed on a fixed-term basis (with differences in actual practice; firms in Joinville complain that they have to renew the licence annually, at a substantial cost).

A. *Case Studies*

The following six case studies describe experiences in inter-firm cooperation in environmental technology and management in Brazil. They cover a wide spectrum regarding types of cooperation, of firms involved, and of the role of business associations and government. They are all from the industrially more advanced South and Southeast of the country (although no case is included from the state of São Paulo, the most important state in terms of industrial production). They cover different types of business structures: mostly domestic firms in the cases of Santa Catarina and Rio de Janeiro, and production systems that include domestic suppliers and foreign-owned final producers in Paraná.

1. Núcleo do Meio AmbienteJoinville

The *Núcleo do Meio Ambiente* (NMA) of the *Associação Comercial Industrial de Joinville* (Association of Commerce and Industry, ACIJ) was established in March 1993. It is essential to know three factors to understand its creation.

First, firms in Joinville were under pressure to improve their environmental performance. Joinville is the largest city and the most important industrial town in Santa Catarina; it is the location of a number of large, well-known firms, from four main branches: electromechanical industry (Embraco, Multibrás, Schulz, Wayne-Wetzel), the metal-engineering industry (Fundição Tupy, Carrocerias Nielson, Fundição Wetzel, Embraco Fundição, Docol), the plastics industry (Tigre, Akros), and the textile industry (Döhler, Lepper). The state environmental agency, FATMA, at that time followed the principle that large firms are the main polluters and thus the main targets of controls. In the specific case of the Joinville firms, this particularly meant intense controls of their waste-water effluents and pressure to build waste-water treatment stations. This was motivated by the high level of pollution of local rivers and the high water-intensity of many firms (particularly in sectors like textiles).

Second, a number of medium-sized and large firms had an – albeit brief – history of cooperation on a concrete environmental problem. In 1989, they created the "Group of 19", consisting of the owners or CEOs of 19 leading local firms, to find a solution to the problem of disposing of solid waste, as the municipal landfill site did not offer adequate installations for the disposal of industrial waste.[1]

Third, ACIJ was a partner in a German technical cooperation project that had started in 1991. It involved several ACIs from the northeastern part of Santa Catarina and the Chamber of Arts and Crafts of Munich and Upper Bavaria. A key contribution of this project was to induce the creation of working groups within ACIs ("núcleos"), not just by suggesting the possibility and referring to successful experiences in Germany but also by organizing the process of starting and sustaining them. Thus, even though the notion that it might be

1 It took no less than eight years until the industrial landfill site finally went into operation. The delay was mainly due to problems acquiring a piece of real estate, although all participants involved had in 1991 agreed to use a certain area.

possible to set up a working group ran against the predominant local business paradigm,[2] there were already a few cases which proved that there was an alternative.

2. The working modus of the Núcleo do Meio Ambiente**.**

The structure of the NMA is as follows. It had 31 member firms at the end of 1997. Each member firm is represented by an employee (i.e. not the owner or CEO), typically the manager/engineer in charge of waste-water treatment, environmental management, or utility issues. It meets every fortnight. The work is facilitated by a consultant employed by the ACIJ[3] who has long experience in the environmental field, both in the public and the private sectors, something that gives him a high standing with the firms' representatives. He sees to the administrative work, convenes the participants, prepares material for the meetings, moderates the meetings, and takes care of the follow-up. A typical meeting lasts about three hours and is attended by 15 firm representatives (although deviation is very high, from as few as six participants to as many as 34, i.e. including representatives from firms which are not member of the núcleo).

3. Results of the work of the NMA.

Initially the NMA addressed mostly the issue of waste-water treatment. Over time, there has been both a broadening and a deepening of the focus of the work. The NMA has started to address new issues, such as environmental management or the Local Agenda 21. The NMA has produced also a manual for waste-water treatment in industrial firms, 5,000 copies of which have been distributed to local firms, particularly SMEs.

Participants point out that apart from the issues raised in the meetings, the NMA has played a crucial role in creating a culture of easy information exchange between firms' professionals. This is an important aspect as this runs contrary to the local business culture. Firms just did not have informal exchanges of information and experiences (Meyer-Stamer et al 1996, Meyer-Stamer 1998), particularly not among employees. Owners and CEOs met at the ACI and socially (but they did not discuss firm issues there), but employees hardly met at all (there are also no professional associations which might stimulate information exchange). In this context, participants point out that it is an important feature of the NMA that it consists exclusively of employees. The presence of owners/CEOs would make frank communication much more complicated.

A further contribution of the NMA's work has been a profound change in the firms' relationship with FATMA, the state environmental agency, which used to be highly conflicting in the past. The NMA routinely invited FATMA officials to its meetings. This gave rise to a mutual learning process where firm representatives started to understand the

2 The local proverb to describe this paradigm is "cada um por si e deus por todos", i.e. everybody for himself and God for everybody.

3 This at least, is the prevailing notion and the usual pattern regarding persons who accompany work with núcleos. In fact, the consultant in charge of NMA is technically not an employee of ACIJ but of a cooperative that was founded by the "Club of 19". However, he has his office at the ACIJ like everybody else, and he acts as if he were an employee of ACIJ.

logic, necessities, and pressures behind FATMAs actions, and vice versa. As result a certain level of trust evolved between FATMA and the NMA member firms.

The change in the relationship can be illustrated by two examples. Firstly, it sometimes happens that a technical defect disables a firm's waste-water treatment station. The firm will then get in contact with FATMA to inform it about the problem and the plans to solve it. FATMA normally accepts this and refrains from fining the firm. Secondly, firms and FATMA are in the process of setting up a system of self-monitoring where firms will constantly control the composition of their effluents to assure that they comply with legally established standards. At the time of the field research for this paper, firms and FATMA were in conflict about the number of substances to be controlled. FATMA proposed a comprehensive list to be applied to all firms, that included various substances that were not used at all by some of the firms, whereas firms suggested checking only a limited number of substances, thus reducing the monthly cost of the tests from about R$ 6 000 to about R$ 2 000 Participants in the dispute were optimistic about the resolution of this conflict and the possibility to have an arrangement that counting on the responsible behavior of firms.

Another impact of the NMA's work is increased awareness of environmental issues in member firms and in the business community as a whole. The NMA is locally well-known, among other things because it received an environmental prize established by a business magazine.[4]

The future work of the NMA will probably focus on two issues the First being environmental management. So far, technical discussions have mostly been focused at end-of-pipe-technologies, particularly in waste-water treatment. Firms have started only recently to move beyond this towards environmental management systems. This is the obvious next step on the typical trajectory of firms' dealings with environmental issues. At the same time, some firms are under pressure from their customers to become active in this field and to seek a certification according to QS-9000[5] or ISO-14000. There is general agreement among participants that the NMA will be a highly useful forum to organize information exchange on environmental management, thus accelerating and leveraging the learning process in each firm.

Secondly, the NMA will become more involved with the community **(***comunidade*). Participants, perceive that community involvement has already been one of the tarjets of the NMA, especially regarding the production and dissemination of the waste-water treatment manual and the involvement of NMA members in discussions on a Local Agenda 21. In future the NMA participants are keen to support local micro and small firms. They are also interested in stimulating a broader dialogue on environmental issues, and as a first step they have invited a number of local environmentalist groups for a joint discussion.

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4 This magazine, Expressão, thus highlights each year the environmental effort of several individual firms. The NMA's activities gave rise to a special prize for collective action.

5 QS-9000 is a quality standard used by United .States. car manufacturers. It builds on ISO 9000 but goes beyond it; among other features it includes certain environmental features. European car manufacturers use a similar system.

In explaining the success of the NMA it is important not to forget the emotional aspect. Being the person in charge of environmental affairs meant mostly being responsible for waste-water treatment and solid waste, and making sure that the firm was fined as little as possible by the environmental authorities. In their respective firms, the NMA participants were often in a marginal position, tolerated but associated with one of the unpleasant sides of the firm, a side that mostly caused costs and conflicts with authorities. Thus, the level of emotional stress was quite high. Sharing their problems and experiences with colleagues suffering from the same problem helped professionals to deal with this stress.

4. Grupo de Aterro Industrial, Blumenau

In 1995, the local administration in Blumenau noticed that it was running out of space in the municipal landfill site. In order to delay the closure of the site, it notified firms that it planned to reserve it for domestic waste. Thus, the question arose of how to dispose of 3,000 tons per month industrial sludge which made up the largest part of the solid waste generated by firms. The massive generation of sludge was the result of high investment in waste-water treatment stations; essentially all large firms in Blumenau, most of them in the textiles industry, had their own stations. They were built mostly in the second half of the 1980's in response to pressures from FATMA and foreign customers.

Within the local Chamber of Industry and Commerce (ACIB), a working group of ten industrial firms was formed to deal with the problem.[6] Among the options study by the group was the installation of a sludge incinerator. This idea was not feasible, mostly for financial reasons (it would have involved an investment of some R$ 60 million) but also because of the toxic content of its emissions. The most realistic option, it turned out, was a two-track-approach: reducing the generation of sludge and initiating the construction of an industrial landfill site.

In order to reduce sludge, the firms contracted a small local engineering firm specialized in waste-water treatment, Resíduo Zero (RZ). It suggested a different biological treatment process which reduced the generation of sludge by 80 per cent at 20 per cent less cost (compared to the established process). However, the process was difficult as it required a roughly stable consistency of the effluent entering the station. Currently, the firm is refining the process to make it more stable, for example resilient against vast oscillations in the pH value of the effluent (which are due for instance, to the practice of some textile firms to conduct certain types of finishing activities, like mercerizing, only once a week).

Regarding the industrial landfill site, the group identified a local firm in the waste business which was willing to invest in its construction. The firm visited installations elsewhere in Brazil and abroad in order to make sure that its installation would reflect the current best practice in this field. The new landfill site has been completed recently.

6 ACIB is taking part in the same technical assistance project as ACIJ, but the working group preferred not to employ the núcleo methodology, apparently because nobody at ACIB believed that this might have been a good idea.

During the process, ACIB professionals repeatedly pointed out to the firms that the disposal of waste in the new installation was bound to be much more expensive than the R$ 6 per ton firms had to pay at the municipal landfill site. In fact, the waste firm is going to charge according to the water content of the waste. Whereas waste with a water content of less than 20 per cent per ton will cost R$ 20, and waste with a water content of more than 80 per cent will cost R$ 75 per ton. Depositing humid waste involves high costs since it has to be mixed with concrete and lime. This has created a further incentive for firms to generate less sludge.

Reducing the generation of sludge is ecologically desirable, but it may compromise the economic viability of the landfill site. To counter this, the Chamber has informally encouraged the waste firm to identify, within a circle of 100 km around Blumenau, firms which do not dispose of their sludge adequately and to notify the authorities. As the firm is responsible for disposing of industrial waste in the region, it is in a position to observe irregular behavior by such companies.

Cooperation among the firms so far has been restricted to the issues mentioned above, i.e. reducing the generation of sludge and discussing the sludge issue with the waste firm. A culture of intense communication, as in the NMA in Joinville, has not emerged so far. Possible explanations for this are a local business culture that is perhaps hostile to cooperation, and the fact that the group did not establish a clear distinction between the participation of owners and employees. However, on learning of the Joinville experience the firms' representatives liked the idea of continuing to work in a group, but with a broader focus such as environmental management. It is probable that it. Whether this materializes will depend largely on ACIB. If it invites firms and facilitates the work of the group, an experience similar to the one in Joinville may result.

5. Small Printing Shops, Blumenau.

In 1996, the local environmental protection agency in Blumenau, FAEMA, started to control more intensively local micro-firms in the textile printing industry. The existing several dozen firms were estimated to generate 1,200 cubic meters of effluent with high dye-content and high pH-values without any attempt to clean it. Being threatened to be shut down, the micro-firms contacted the ACIB and asked for support in identifying a technically and financially feasible solution; some workshops consisted of just one self-employed person, earning about US$ 300 per month from this activity.

Commercially available small waste-water treatment stations proved to be too expensive. A commercial firm proposed a central treatment station for the micro-firms; but transport would have been too expensive.

ACIB again got in contact with Resíduo Zero (RZ) which developed a tailor-made, cheap solution. It consisted of building a tank where the waste-water was deposited. RZ identified a chemical substance which, at a cost of R$ 10-20 per month, binds the dyestuff and reduces the pH-value, thus generating water clean enough to be reused in the production process and a sand-like sludge which can be disposed of as ordinary waste. The cost of the construction material for a new tank was about R$ 400, but RZ reduced this to R$ 250 by using recycled construction material. RZ visited 60 to 70 firms which might have used this process. It also assisted firms in constructing the tank and understanding the process without charging for this service; part of the cost was covered by ACIB, and part was written off as investment in establishing RZ as a competent and credible service provider. In the end the process was installed at about 30 firms. In the meantime, many of the other firms had gone out of business due to economic reasons. The project involved no direct cooperation between the micro-firms except for visits of their managers to the sites of pilot installations.

6. Projeto Ecogoman, SC.

The project Ecogoman involved Brazilian and German textile and starch firms, government, and research organizations. It aimed at adapting a process to recycle starch used in the finishing of textiles fabric to specific Brazilian circumstances. The starch content in effluents poses significant problems for waste-water treatment as it causes a high demand for oxygen. GTV, a German machine building firm, had developed an equipment which not only recycled 85 per cent of the starch but also reduced the use of water and electricity and allowed the recycling of other inputs such as dyes and caustic soda. This equipment however, had been developed to deal with synthetic starch whereas Brazilian firms commonly use natural starch based on manioc.

The project was launched in 1995 on the initiative of the textiles research institute in Denkendorf, Germany (ITV), which had been working previously with firms in Brazil. It persuaded a group of Brazilian firms to lobby for a joint project under the umbrella of scientific-technological cooperation between Germany (BMFT/BMBF) and Brazil (Ministry of Foreign Affairs). A group of six Brazilian firms was formed: four home textiles firms (Artex, Döhler, and Karsten from Santa Catarina, and Alpargatas Santista from São Paulo) and two starch producers (Inpal, Inquil). They joined a project with a group of seven German manufacturers of equipment starch, and textiles. The project is governed by a steering committee that consists of CNPq (Brazil's national science council), IEL/SC,[7] BMBF and DLR (as executive agency of BMBF). The costs of the project, which have been estimated at R$ 6 million, were divided between the Governments of Germany, Brazil, and the State of Santa Catarina, and the firms involved.

The first phase of the project involved training Brazilian engineers in Germany, started in November 1995. The first months of 1996 saw the testing of starches, conducted by Brazilian researchers in Brazil. In June 1996 the equipment from Germany arrived. Clearing it through customs and avoiding paying import duties which would have amounted to about R$ 1.5 million, was no easy task. It was mainly due to IEL's effort that both aims were achieved. Most spectacularly, IEL succeeded in persuading the State Government to waive import duties. It pointed out that this was first of all, a research project and not a commercial

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7 IEL (Institutio Euvaldo Lodi) is a branch of the Federation of Industries. Its traditional task was to organize internships for university students in firms. In the specific case of Santa Catarina, IEL has widened its scope of activity, starting to offer real services to firms. Apart from the Ecogoman project this included information dissemination on ISO 14000, the coordination of a benchmarking study with firms, and the creation of a venture capital fund.

venture. When the equipment arrived by mistake in Santos in the state of São Paulo rather than a port in Santa Catarina, IEL persuaded the secretary of finance of Santa Catarina to seek a waiver from CONFAZ, the council of the state secretaries of finance. This may have positive implications for future projects of this kind which may also count on import duty exemption.

Practical tests started in August 1996 at a plant of Alpargatas Santista in São Paulo. They were conducted by a team of five Brazilian engineers who were employed on a full-time basis, German engineers who repeatedly stayed in Brazil for several weeks, and firm's engineers who worked with the project as a part of their regular workload. It soon became obvious that adapting the equipment to natural starch would be more complicated than expected; at the end of the test phase at Alpargatas the expected recycling ratio was not reached by far. However, there was a learning process, and things improved after the equipment was transferred to Döhler in Joinville in March 1997. In November 1997 the equipment was transferred to Karsten in Blumenau. By March 1998, the recycling ratio had got close to the desired level of 85 per cent, and recycling ratios for other inputs were above expectations.

The Ecogoman project does not involve direct technical cooperation between the participating Brazilian textile firms. Nevertheless, persuading firms to accept technological development, and share their learning processes with engineers external to the firm, is seen locally as quite an achievement. Previously, firms were unwilling to let anybody look into their production technology due to secrecy considerations.

The Ecogoman project will probably lead to sustained capacity building. The Brazilian engineers involved in the project are going to be employed at the Environmental Center of SENAI in Blumenau; the idea is to use their know-how to offer support to firms for further upgrading in environmental technology. At the time of the field research, there was still one firm left where the equipment was to be tested. The future of the equipment afterwards was unclear.

7. Associação Paranaense de Empresas de Tratamento de Superfície, Curitiba, Paraná

The formation of the Paraná Association of Surface Treatment Firms (Paranaense de Empresas de Tratamento de Superfície, APETS) was the result of an initiative started by a technical cooperation project between CITPAR and GTZ. CITPAR, the technology integration center, is an entity that aims to give technological support to firms in Paraná; it is attached to the Federation of Industries of Paraná. The German technical cooperation project supports parts of its activities. It is part of GTZ's IBD programme (integrated advisory service for the private sector); it was started in 1992 and will terminate at the end of 1998.

To understand the APETS story it is important to look at the evolution of the IBD project. Initially, its main goal was to generate exports by upgrading SMEs in Paraná. However, it soon became obvious that the overwhelming number of SMEs in Paraná were so utterly uncompetitive that exports were a remote possibility. The project thus changed its focus towards improving the survival conditions of firms which were struggling fiercely to cope with the new framework after the opening of the market, and more so after the end of inflation. Among other things, it focused on small garment firms which together employed tens of thousands of workers and where failiure rates were very high.

The problem was that the project's activities were not very visible. Therefore, it decided to create a success story, i.e. some activity that would yield a quick and visible impact. In order to identify possible points of departure, project personnel contacted various organizations including the association of the metal-engineering industry (Sindicato da Indústria Metalmecânica). CITPAR organized a first workshop in 1995 where it was suggested that the galvanic industry might be an interesting target group. On the one hand, it consisted mainly of small firms with all sorts of technical and management deficiencies, including severe environmental problems. On the other hand, it had good growth perspectives, especially due to new foreign direct investment in the passenger car industry (Renault, Audi, Chrysler).

The first step in addressing the galvanic industry was to prepare a diagnosis of the sector, which was based on visits to 51 formal-sector firms (altogether, it was estimated that the sector consisted of about 80 formal and maybe 200 informal firms). CITPAR then organized another workshop to present the results and to define actions. Apart from the firms, it invited a number of representatives from other agencies: the Federal University of Paraná (UFPR), the local technology institute TECPAR which in fact, is mostly an MSTQ organization, the local technical school of SENAI, the CEFET technical college, the Association for Surface Treatment (ABTS), which is dominated apparently by the suppliers of chemical inputs. Is also invited, the metal-engineering industry association, banks, the SME support organization SEBRAE, the State Government, and the state environmental agency IAP. The output of this workshop was a plan of action which defined the responsibilities of several agencies.

An important consecutive activity was to invite a technical expert from Germany (a professor from Fachhochschule Aalen, a polytechnic, who specializes in surface treatment) to visit, during 15 days, five firms as well as the laboratories at TECPAR and UFPR. He suggested a number of improvements which could be implemented in firms with little investment, and he started to train a UFPR professor to identify and implement such measures. The most obvious improvements were the implementation of the Lancy cleaning process for parts which had been treated with cyanide (a relatively cheap and easy process which is however, not used by technologically more advanced European firms), the introduction of cascades (i.e. a small basin with three chambers instead of the usual one, a measure that dramatically reduces water consumption), the change of the zinc treatment from cyanide to acid, changes in factory layout, and other measures. For instance, in one firm the installation of the cascade bath reduced the water consumption in the phosphatizing process from 240,000 to 10,500 liters/month. Another firm reduced its overall water consumption by 80 per cent, thus saving about R$ 800 per month with an investment in cascade tanks of about R$ 2000. The implementation of the improvements was accompanied and supported by a student of FH Aalen who stayed for five months and wrote his diploma thesis on the experience; the thesis is now being translated and adapted to create a manual for firms.

The creation of APETS, which has about 40 member firms, took the whole process one step further. The idea behind this initiative was to create a forum for the ongoing cooperation between firms, and to create the conditions for a sustainable solution to the waste-water problem. APETS is a forum where firms discuss their problems and possible solutions. This includes ongoing cooperation with UFPR in terms of upgrading processes and training employees, inviting (at the cost of the firms) external specialists for seminars, and joint visits to fairs. A further incentive for firms to participate in APETS is that its members receive electrical energy at a lower rate than non-members, a benefit that was negotiated between CITPAR and the local electricity utility COPEL.

In order to tackle the waste-water problem, about ten of the member firms decided to form a cooperative to set up a waste-water treatment station; another eleven firms have joined since. They defined, together with the UFPR professor, a technically and economically viable solution which requires an investment of about R$ 150,000. It will probably be financed mainly with funds from the Ministry of Science and Technology which has a special line of support for joint university-industry projects. It will be decided in June 1998 whether funds will be allocated to this project. Firms who take part in this venture will for one to two years not be fined by IAP for not disposing of sludge (provided that the sludge gets stored adequately, without causing a health hazard).

A further effect of the initiative was that TECPAR trained an engineer and set up a special laboratory for testing firm's galvanization baths. This is an important activity because the quality of galvanizing baths deteriorates over time, and there are two possible options in dealing with this: add more chemicals or replace the whole bath. In the past, galvanizing baths were usually tested by technicians of the firms which supplied them. There is little doubt that they had a certain bias to declare baths unusable prematurely as this increased their sales. The TECPAR laboratory gives firms another option. If the results of a given galvanizing process are no longer satisfactory, they can send a sample of a given bath to TECPAR for testing to identify the exact cause of the problem, and to suggest possible solutions like filtration or adding a precise dose of a specific chemical. A similar laboratory is being established at UFPR to make sure that there is no monopoly, i.e. to exert performance pressure on providers of testing services.

There was a series of less obvious factors which convinced firms to undertake these efforts.

- Firms were aware of their environmental problems and were willing to do something about them.

- There was little immediate pressure from IAP, the state environmental agency, but as firms were aware of their problems they perceived that they might come under intense pressure at any given time. Moreover, as the certificate for operation has to be renewed every two years, problems with IAP were foreseeable. However, 60 per cent of APETS member firms so far prefer not to be registered with IAP.

- There was little immediate pressure from customers, although this has changed in the meantime. For instance, first-tier suppliers of firms like Volvo are under pressure to implement the QS-9000 system or its equivalents, and they pass this pressure on to their subcontractors. Moreover, as some of them are running just-in-time inventory schemes, they do not want to run the risk that a supplier suddenly is closed down by the environmental agencies.

- Firms that did something to improve their environmental records also hoped that this might in the end lead to a situation where competitors who have not made this effort, and consequently have lower costs and prices, might be squeezed out of the market, either by customers or by the environmental agencies.

- Overall awareness of environmental issues increased to the extent that Curitiba began to present itself as a showcase of urban environmental policy.

8. Pilot Plants in Energy Efficiency, Rio de Janeiro

In 1996 SEBRAE-RJ, the branch of Brazil's parastatal SME-support organization responsible for the state of Rio de Janeiro, started a joint project with GTZ to stimulate a move towards efficient use of energy in industry, especially in SMEs. One of the motivating factors was the observation that, whereas energy intensity in industry had been reduced substantially in industrially advanced countries, in some cases by more than 50 per cent, it remained stable in Brazil between 1970 and 1990, and in 1990 the energy efficiency of Brazilian industry was low. This is shown in table 1

Table 1

Energy efficiency in industry (energy consumption in industry in MJ/US$ GDP 1985)

Country	**1970**	**1980**	**1990**	**% change 90/70**
USA	6.7	5.3	4.0	-40.3
Canada	7.7	8.0	6.1	-20.8
France	5.6	4.3	3.0	-46.4
Germany	7.9	6.0	4.1	-48.1
Italy	6.2	4.5	3.7	-40.3
UK	10.4	6.4	4.5	-56.7
Japan	7.7	4.9	3.5	-51.4
Spain	6.0	6.1	5.0	-16.7
Brazil	7.3	7.1	7.1	-2.7

The first step towards enhancing every efficiency twas to establish cooperation with other organizations with interest in this field; these were the vocational training system (SENAI) and a government-funded MSTQ and technological research institute (Instituto Nacional de Tecnologia, INT). The second step was to identify particularly energy-intensive industries, namely manufacturing of bricks, refurbishing of tyres, coffee roasting, manufacturing of sausages, and baking. The third step was to identify firms who would be willing to take part in an exercise to examine energy efficiency potentials.

The basic idea was to identify firms which for some reason were open to change, and to take them as pilot plants for energy efficiency measures. Such firms had to commit themselves to permit visitors from other firms to visit their factory. This was one of the conditions in a contract that included fines if a firm did not permit visitors to its factory. The hope was that success in the pilot plants would convince other entrepreneurs not only of the viability of but also of the economic potential of energy efficiency measures, particularly in terms of improved competitiveness.

The project has been cooperating with ten firms so far (four brick manufacturers, two firms in the tyre refurbishing business, two coffee roasters, one sausage producer, and one bakery). The energy efficiency potential in these firms has exceeded expectations. The following table gives an overview of possible measures in the brick industry. To assess these data it is important to know that Brazilian brick manufacturers tend to be far behind best practice; they usually employ circle ovens or Hoffmann ovens, i.e. 19th century technology. The first of the pilot firms is only now setting up a tunnel oven, a technology developed in the early 20th century in industrialized countries. With an investment of about R$ 310,000 it will have a payback period, based on energy savings alone, of about one year. Apart from that, it will improve the quality of the bricks and reduce scrap from 7 per cent to 1.5 per cent.

Table 2

Energy efficiency potentials in the traditional brick industry

	Investment (R$)	**Annual savings (R$)**	**Life cycle of equipment (years)**
Electrical			
Correction of power factors	1 800	3 600	5 - 10
Installation of high-efficiency motors	5 693	7 420	10 - 15
Thermicl			
Reuse of heat from circle ovens	31 000	29 440	5 - 10
Reduce the heat stores in circle ovens	96 000	13 380	2 - 6
Equipment to dry bricks before burning	50 000	102 000	10 - 15
Improve burning in Hoffmann oven	5 000	4 581	5 - 10

In the particular case of the brick industry the project could build on an existing initiative of brick manufacturers in the northern part of the state. They started to upgrade in the 1980s, stimulated both by increasing demands, especially in terms of quality, from their main customers (large civil construction firms), and by visits to fairs and brick factories in Europe, which revealed the gap with best practice. In 1991, these firms set up their own association (Sindicato de Cerâmica para Construção e Olaria do Médio Vale do Paraiba, Sincovap) as they were frustrated with the lack of support and services offered by the existing association that was organized on a statewide basis.

Firms were already looking for energy efficiency potentials when they contacted the SEBRAE/GTZ-project. As they had been in contact with consultants who specialized only in isolated parts of the production process, the efficiency potentials revealed by the SEBRAE/GTZ-project consultants far exceeded their expectations. These efficiency potentials were discovered by engineers at INT and a professor from the Federal University of Rio de Janeiro; they amounted to 22 per cent of electrical and 53 per cent of thermic energy inputs. An indirect effect of the project is a change in the attitudes of the representatives of equipment vendors who often exaggerated potential benefits of new equipment but now that the firms are better informed due to close contact with SEBRAE, SENAI, and INT. are now more honest and modest.

Apart from working directly with firms, the project aims to set up a database and produce information material on energy efficiency (at SEBRAE), train numerous entrepreneurs, employees, consultants, and teachers and produce teaching material to be used in distance learning for firms' employees (at SENAI). In fact, one of the main effects of the project has been to establish cooperation between firms, SEBRAE, SENAI, and INT. A further contribution of the project has been to encourage firms and banks to be in contact with each other. This is because improving energy efficiency often requires investment in new equipment, and SMEs find it difficult to have access to credit for equipment purchases, a phenomenon that reflects the poor development of Brazil's finance system. While it was brilliant in dealing with hyperinflation, it was unable to develop (for the same reasons) a practice of conceding medium-term credits to private firms, especially SMEs.

B. Comparison of the experiences

1. Point of departure

When looking at the different experiences it is useful to distinguish supply- and demand-driven cases. NMA and the two cases in Blumenau are clearly demand-driven: firms were under acute pressure to resolve a well-defined environmental problem. The Ecogoman project fits also into this pattern as firms were determined to do something about starch-rich effluents due to general pressure from the environmental agency. In this case a certain element of supply-drive was involved due to the acquisition activities of ITV. The experiences in Paraná and Rio de Janeiro were both supply-driven, i.e. they were initiated by German technical assistance projects. However, both could count on a target group that was already motivated to initial action. A typical problem of technical assistance, namely convincing the target group of its own deficiencies, was not an issue. Apparently, it is not difficult for an agency seeking to assist the private sector in Brazil to identify groups of firms which are open to change. The pressure on firms to improve their performance has increased tremendously with the opening of the market and the stabilization of the macro-economic framework, even though this does not necessarily mean that firms most in need of assistance are most open to change and support.

2. Type of firms involved

A broad spectrum of types of firms was involved in the experiences – from world-class large-scale firms (some of the participants of NMA) to one-person-workshops in the case of printing shops in Blumenau. Nevertheless, the observations do not support the preconception of a clear correlation between size, competitiveness and environmental awareness. It is more complicated for the following reasons:

- Although mostly small, the galvanic firms in Paraná were fully aware of the environmental problems they caused, and were seriously seeking a resolution. If one assumes that there is a "natural" trajectory for a firm (from end-of-pipe treatment to process-integrated measures to environmental management), the small galvanic firms were more or less on par with some large firms in Joinville, which are leaders and global players in their respective industries but because they are in the metal-engineering and electromechanical industry and intensive assembly, rather than transformation – are less likely targets of environmental control. Experience in Brazil thus indicates that a firm’s level of environmental activity is more correlated with the type and intensity of environmental impacts created than with the size of the firm.

- There is also no clear pattern regarding the role of multinational firms. Some of the galvanic firms in Paraná are second or third-tier suppliers to firms like Volvo and Siemens. First tier suppliers to Volvo report that the company has so far not defined a strategy towards ISO 14000, and that their pressure on galvanic firms is rather due to the fact that they fear a disruption of their just-in-time delivery schedule with Volvo if a galvanic firm is closed due to environmental violations. In Blumenau, the participants in the landfill site group include a subsidiary of an United States cardboard manufacturer and the local franchise of Coca-Cola. The cardboard firm recently received instructions from headquarters, to conduct an environmental audit. Support from headquarters, however, meant nothing more than sending a checklist and an auditor; there was no further support such as instruction manuals describing the reasons for the exercise, the philosophy behind it, and the practical procedures. On the other hand, Coca-Cola Inc. has clearly defined that its franchises have to be certified according to ISO 14000 by 1999. Assistance to franchises includes providing printed material and workshops, and also creative measures including support for recycling campains. The Blumenau franchise is involved in a campaign whereby pupils are encouraged to collect empty Coca-Cola cans. If they collect a given quantity, their school receives a free PC.

3. Incentives for firms to participate

Firms participate in various environmental activities for different reasons. Immediate pressure was important in the cases of Joinville and Blumenau. This pressure arose mostly from the state environmental agency. In the cases of the Ecogoman project and in Paraná and Rio de Janeiro it was imminent rather than immediate pressure that convinced firms to do something about the environmental burden they caused.

Pressure from customers played a lesser role. Textile firms in Santa Catarina used to suffer from this pressure in the past. Since, investing in waste-water treatment and substituting hazardous inputs in their production process, this pressure is now less relevant.. Moreover, it is restricted to manufacturers of home textiles since clothing producers have largely stopped their exports to Europe where pressure from customers is most intense. It has already been noted that multinationals in Paraná like Volvo or Siemens so far do not exert much pressure for the introduction of environmental management.

It should be noted that: being under pressure is a relative notion. If a given firm feels under pressure at a given point in time, it is still possible that pressure will become more intense in the future. In other words, if a firm explains that it pursues a given activity because it feels under pressure it is important to discuss the quality of the pressure.

4. Mode of organization, formal work modus, informal aspects, and develop-ment trajectory

The intensity of cooperation among firms varied vastly. It was most intense in the case of the NMA, and also quite intense in the cases in Paraná and Rio de Janeiro; in the latter, close cooperation had started before the firms become involved in the SEBRAE/GTZ-project.

Environment-related cooperation among firms reflects a broader trend in Brazilian industry. In the past, there was very little cooperation among firms, a feature that reflected the specific circumstances not so much of late industrialization but mostly of the economically unstable high-inflation environment. We have hypothesized that environmental issues are a promising point of entry for inter-firm cooperation, as firms do not perceive it as a core activity (at least as long as environmental activities mainly refer to end-of-pipe-measures) and have thus less misgivings regarding the possible loss of business secrets (Meyer-Stamer et al 1996). The experiences documented in this paper support this hypothesis, although certain modifications are in order:

- There is not a "natural" trajectory from a single-issue activity to a broader focus not even in the environmental field. In certain cases, the focus of cooperation has constantly widened; this is most prominent in the cases of NMA Joinville and Paraná galvanic firms. This has not occurred in the two cases in Blumenau. In the case of Paraná, the widening scope of cooperation increasingly touches on the key activities of firms and involves collective technological learning processes. In the case of the NMA, it is likely that something similar will happen if the núcleo becomes the focal point for information exchange on environmental management. The Ecogoman experience may give rise to further technology cooperation projects among leading textile manufacturers, although only little enthusiasm can be detected in this regard at the level of executive boards.

- The Rio de Janeiro energy efficiency experience illustrates that other points of entry to inter-firm cooperation exist. In the case of the association of brick manufacturers, three points apparently have been crucial: strong pressure from customers regarding product quality, strong local leadership, and a we-against-them attitude of firms in the northern part of the state and less competitive firms (and a not-too-active association) elsewhere.

5. Organizing agent

A further essential point regarding inter-firm cooperation regards the role of business associations. All the cases documented in this paper involved business associations. More precisely, they involved business associations that are in a profound transformation process. Brazilian business associations were created by law as part of a state corporate system in the 1930's. This legal framework still exists, and many business associations still reflect the corporatist heritage – as membership is mandatory. They show little inclination to do anything to secure the credibility of their organizations with their members apart from ad-hoc lobbying efforts. It is interesting to note that things were not much different at associations with voluntary membership, i.e. the ACIs. The situation changes to the extent that internal democratization processes occur within corporate business associations, allowing frustrated members to take over their association and to start restructuring it so that it offers real services. The alternative is to found new associations. as in the cases in Paraná and Rio de Janeiro.

There is strong evidence that business associations do play an essential role in organizing inter-firm cooperation. To do this on a sustained basis, it is critical that they have a minimum number of professional staff, at the very least to take care of the administrative work involved in cooperation projects. ACIs in Joinville and Blumenau as well as IEL-SC have this staff. In the cases of Paraná and Rio, associations so far are maintained through the voluntary work of members. This however, is only feasible because administrative capacity is available elsewhere – at CITPAR in the case of Paraná, and at SEBRAE in the case of Rio de Janeiro.

6. The role of German technical assistance

All the projects examined involved some kind of cooperation with Germany (technical assistance in five cases, scientific-technological cooperation in the case of Ecogoman). In the case of the technical assistance projects, two different patterns can be identified:

- indirect, facilitating activities,
- issue-oriented, stimulating activities.

The cooperation project with ACIs in Santa Catarina exemplifies the first type. It aimed at organizational development in ACIs, i.e. reshaping ACIs in such a way that they react flexibly to new challenges and opportunities, or are even able to create new opportunities. Organizing núcleos was instrumental towards achieving this goal. Neither of the three cases in Joinville and Blumenau was the direct result of the technical assistance project. They reflect a more responsive mode of action by the ACIs, something that according to local sources has to a significant degree been stimulated by the technical assistance project.

The projects in Paraná and Rio de Janeiro exemplify the second type, i.e. issue-oriented, stimulating activities. The project in Rio was introduced to address energy efficiency issues in industry. The project in Paraná perceived the environmental problems of the galvanic industry as an opportunity to implement another of its main objectives, namely to find a way to contribute to firms' quest for competitiveness in an environment where there was little tradition and experience of interaction between firms and institutions at the intermediate level. The project in Rio de Janeiro was not designed to contribute to organizational development in any of the organizations involved (SEBRAE, SENAI, INT), whereas it does stimulate much closer cooperation between these organizations. The project in Paraná has stimulated organizational development within CITPAR, an institution that has existed since the mid-1980s which according to local observers, is now much more dynamic and firm-oriented than it was before the project started.

7. Competition aspects

Many Brazilian businesspeople are not convinced by the notion that firms should cooperate on any issue. In their view firms are competitors, and consequently there are no areas where they might cooperate. Moreover, cooperation may have had a negative meaning in the past. One of the ABETS member firms mentioned that it had once tried to organize an association. The immediate effect was that it was blacklisted by one of its main customers who suspected that the firm was trying to organize a cartel.

At the same time, it is largely undisputed that, especially in industrialized countries, competition and cooperation not only go hand in hand but that cooperation is actually a necessary prerequisite to survive in a highly competitive environment; neologisms like "coopetition" have been created to address this observation. This includes both formal cooperation, as in strategic alliances, and informal cooperation through various means of communication (e.g. communication with suppliers and customers, and with competitors in fora like conferences and professional associations). "Learning by interaction" is an essential means of coping with the increasing velocity of technical change and surviving in competitive markets.

All this means that stimulating cooperation among firms, even with respect to environmental issues, is by no means an easy task. It involves much effort by leaders in the business sector, by business associations, and by other agents like SME support organizations. The experiences presented in this paper show that cooperation is possible, even in activities that are close to technological core competences and among firms who are direct rivals, as in the case of the Ecogoman project. It appears that once cooperation has started to work well, it is a self-reinforcing mechanism. For instance, representatives from the NMA firms are quite enthusiastic about their núcleo and find it extremely complicated to explain why such cooperation takes place so rarely. After a certain period, firms find it quite natural to balance cooperation and competition concerns.

C. *Inter-firm cooperation and environmental technology and management*

The purpose of this section is to draw a number of conclusions from the case studies. It addresses two main issues. First, is combining two difficult tasks, namely stimulating inter-firm cooperation and environmental management, a promising venture? Second, how can different types of target and partner groups be addressed?

1. Trajectories in inter-firm cooperation and in environmental management

An effort to stimulate inter-firm cooperation in environmental management faces an enormous challenge as it tries to combine two extremely complex issues:

- Convincing firms to cooperate is a difficult task, especially if they do not have previous experience with cooperation and hence view the idea of inter-firm cooperation with suspicion and reluctance.
- Convincing firms to deal with environmental management, which normally is perceived as just adding costs to production, is no less complicated.

At the same time, the above cases illustrate that cooperation is possible, even in an environment where inter-firm cooperation hardly existed in the past, and in which trust among firms is low. In fact, some of the cases seem to indicate that combining the two difficult tasks – stimulating cooperation and environmental management – does not multiply the problems but actually reduces them. In order to understand this point, it is useful to take a look at the process, i.e. to understand typical trajectories in both inter-firm cooperation and environmental management.

Inter-firm cooperation follows the normal logic of cooperation (Axelrod 1984), i.e. it is strongly path-dependent. If there is little or no cooperation, there will probably be little trust between firms, and firms will be unwilling to disclose information. The preconditions for any attempt to involve firms in cooperation are unfavorable. If one participant tries to break through this negative circle of non-cooperation and the others do not see positive results this will reinforce their reluctance to cooperate with each other. If the outcome is positive, this will over time lead to intense cooperation. If asked by an external observer why they cooperate, company representatives will claim that inter-firm cooperation is perfectly normal. Hence, cooperation is often a self-reinforcing process in which trust is continuously being strengthened.

This desirable process of change from reluctance to cooperation, towards a positive experience stimulated by a change agent and a self-reinforcing tendency towards further and closer cooperation between firms, requires:

- a careful selection of the change agent,
- an equally careful selection of the issue to be addressed by the initial cooperation,
- the facilitation of the subsequent steps of cooperation.

A move from non-cooperation to cooperation will hardly occur without a major change in the mindset of entrepreneurs, something that is often induced by crisis or external shocks. In order to sustain cooperation it is necessary to accompany, facilitate, and evaluate at least one whole cycle of cooperation, with a view to creating organizational conditions for a repeatable process, rather than concentrating on one specific single output.

Stimulating cooperation, i.e. inducing the very profound change from a non-cooperative to a cooperative situation, is a demanding task. In the case of Brazil we documented certain cases where change took place during a serious crisis which revealed the disfunctionality of traditional un-cooperative behavior (Meyer-Stamer 1998). Clearly identifiable individual local change agents played a crucial role in these changes. In the case of ACIs in Santa Catarina, a German technical assistance project played a major role.

Stimulating cooperation is time-consuming since it involves the fragile process of accumulating trust. It is more promising in fields with little incentive to default. Therefore trying to start cooperation in a field like the marketing of technology is not promisingThe situation is different when it comes to environmental issues.

- They are often seen as secondary issues inside the firm.
- There is often an environmental agency or an important client who is expected to put pressure on firms to comply with environmental requirements, i.e. there is an external "enemy" that helps to convince the "victims" of the value added of joint action.

Firms in Brazil seem to follow the same trajectory regarding environmental management that has been observed in industrialized countries (Porter and Linde 1995), as Brazilian environmental policy has been applying the same patterns as in Europe and the United States. It began with the enforcement of environmental legislation and/or the demands of customers, which typically led firms to implement end-of-pipe measures and to substitute certain inputs (e.g. hazardous dyestuffs in the textile industry). Subsequently, firms examined their production processes from a different angle, e.g. they reduced the generation of sludge (which is costly to dispose of) or substituted certain inputs altogether, by modifying their production process. This sequence often included the identification of so-far undiscovered potentials to increase productivity or quality. In innovation economics terminology it challenged path dependency and thus changed the innovation trajectory, leading to a new search pattern to optimize production processes and implement organizational changes.

Once firms have reached the latter stage, they begin to understand that environmental issues are not just a nuisance and an additional cost-factor, but may actually reveal competitiveness potentials by identifying winning-options. This is reinforced when new equipment becomes available that increases both productivity and product quality, and in most cases leads to improved environmental performance. Firms then develop a real interest in environmental management systems as these are helpful to comply both with environmental legislation and to improve business performance. Leading companies in Santa

Catarina have reached the stage where they prepare for ISO 14000 certification (one textile firm in Blumenau was the first national firm to be certified), and they go on to examine how to integrate environmental management in a more systematic and consistent way into their overall management system.

The case of the NMA Joinville shows how these two trajectories can reinforce each other. At the outset, there was very little cooperation and no environmental management. The NMA initially was a rather strange association that involved individuals from the fringes of firms to deal with just one specific problem. Then two things happened:

- Ongoing work in the núcleo created trust and the focus of the group widened to include new and broader issues.
- Environmental issues became more important as firms followed the previosly described learning trajectory in environmental management.

At present, it seems very likely that the NMA may become the main forum for joint learning on environmental management, an issue that has become a high priority in many of the participating firms. Environmental management is becoming an important element of creating a competitive advantage. Some years ago, firms would have found the idea of a joint learning process on a key management issue ridiculous. Today it seems perfectly obvious, thanks to the experience of the NMA.

It is however, essential to acknowledge that several factors coincided which made this case of inter-firm cooperation in environmental management possible, and that some or all of them would also be required in other cases:

- external pressure, which may be acute or imminent (as in the case of Paraná),
- clearly defined, measurable goals of cooperation at the outset (to avoid the impression of futility among the participants),
- professional facilitation of the cooperation process by an agent external to the firms,
- a certain consistency in the composition of the group which helps to create trust and commitment (in the case of the NMA all participants repeatedly pointed out how important it was that only professionals, and not owners, be in the group).

2. Addressing different types of firms and constellations

There are four basic considerations for the introduction of environmental management in firms. Firms may or may not be under pressure to comply with environmental legislation, eco-standards, etc., and firms may or may not have established detailed cost accounting and embarked on a continuous and systematic search for efficiency potentials.

The importance of environmental pressure on firms has been stressed repeatedly in this paper; in nearly all of the cases (except energy efficiency, Rio de Janeiro) it was the most important or at least a crucial factor. The issue of cost accounting and the search for efficiency has not been addressed so far. Reducing a complex reality to a simple dichotomy, two types of firms can be distinguished in relation to these issues. On the one hand, there are firms which have introduced detailed cost accounting and are searching systematically for potentials to raise efficiency. Contrary to popular perceptions they are a minority, even in industrialized countries. The popularity and wide application of concepts like lean manufacturing, re-engineering, and total cost management illustrates this observation. In the specific case of Brazil, very few firms even among the leading ones, actually had detailed cost accounting systems until the early 1990s (Fleury and Humphrey 1993). This was not a high priority at that time because limited efficiency was no problem in the closed market. The success of a firm was not determined by productive efficiency but effective financial management, i.e. keeping liquidity high and indebtedness low and understanding quickly the new rules of the game after the frequent macroeconomic stabilization plans.

On the other hand, there is a huge majority of firms, mostly micro, small and medium-sized firms, which do not have sophisticated cost accounting systems and pursue at best, idiosyncratic efforts to raise efficiency. The latter feature has been acknowledged by economists as an ubiquitous phenomenon; they have been described and explained by terms like "satisfycing", "bounded rationality", and "path dependence". “ refers to the observation that firms may not seek to maximize their profit but rather be content with stabilizing a certain level of profitability, especially if seeking higher profit implies much higher risks. “Bounded rationality” refers to the observation that it may actually be inefficient or even impossible for an economic agent to check all possible alternatives when he makes a decision so that he prefer to bases his decisions on recent experiences and rules of thumb. “Path dependence” refers to the observation that past decisions limit current options: for instance, if a firm has opted for a given cost accounting software package it will not easily switch to another one, even if major flaws become visible after some months of operation.

Combining these features leads to the following matrix:

Table 3

	Detailed cost accounting, systematic effort to raise efficiency	**No or only general cost accounting; idiosyncratic effort to raise efficiency**
Pressure to comply with environmental legislation/eco-standards	(1)	(3)
No pressure	(2)	(4)

There may be good prospects for measures to stimulate environmental management in fields 1, 2, and 3, whereas they do not appear promising in field 4. From the perspective of a technical cooperation pilot programme like P3U, the problem is that probably the majority of firms in a country like Brazil do belong to field 4. Field 1 typically refers to well organized, competitive firms like those participating in the NMA Joinville and the Ecogoman project.

There were no obvious field 2 examples involved in the research for this paper, except for a few participants in the landfill group in Blumenau. Field 3 refers to firms like the small printing shops in Blumenau and the galvanic firms in Paraná. The important point is that it cannot be predicted when such firms will move from field 4 to field 3. Environmental agencies admit that they cannot systematically control all firms, i.e. a large number of micro, small, and medium-sized firms in their jurisdiction is never visited by inspectors, and many are not even known to the authorities. The selection of firms that are actually being controlled is mainly based on complaints, for instance by neighbors noticing and reporting odors or colourful effluents.

Firms in fields 3 and 4 are the typical target group of technical assistance projects in both the private sector development and environmental management areas. There are several possible ways to bring the message of environmental management to these firms:

- The first and easiest option is to wait until these firms come under environmental pressure. The drawback is that it may take years for this to happen. However, this may be acceptable to support organizations that can deal only with a limited number of customers, and one may suppose that the number of industries and firms coming under environmental pressure will continuously grow, especially as large firms environmental establish management systems and become effective, and as environmental agencies shift their focus to micro, small and medium-sized firms. Therefore, just dealing with firms under pressure may employ all the resources available to existing support organizations.

- A second option is to team up with environmental agencies to pursue a carrot-and-stick approach. The idea is to formulate sectoral programmes for certain heavily polluting industries, where environmental agencies implement existing legislation (preferably in a cooperative way and without a bias for end-of-pipe measures), and SME support organizations come in to help firms to cope with this pressure. The drawback is that pressure from the environmental agency will probably create a hostile atmosphere which will hamper interaction with the SME support institution, especially if business owners perceive the latter as another government agency, thus deterring the use of voluntary instruments of environmental management at the company level.

- A third alternative is a “carrot-and-carrot” approach. The idea is that environmental agencies give preferential treatment to pro-active firms which are seriously engaged in the introduction of environmental management, as in the case of Paraná where galvanic firms participating in the treatment station project are exempted from fines for storing their galvanic sludge. It is important to understand that in the past things often worked the other way around. Firms with established environmental procedures were more visible and hence inspected more intensely, and consequently often were fined more than firms without any such procedures. Inspectors from environmental agencies found it easier to check on well organized firms with transparent processes, whereas for instance, controlling a disorganized firm with a multitude of emission sources was much more complicated. It is obvious that this created perverse "incentives": Firms with well-established environment-related activities and environmental management systems are more vulnerable to government enforcement. Even in a well organized firm some things will go wrong sometimes, and it is easier to detect such occurrences. Moreover, environmental legislation may be inconsistent or establish unrealistic standards. While the performance of inspectors is implicitly or explicitly measured against the number of fines they impose, it will be complicated to move from perverse to sound incentives. The cases both of Santa Catarina and Paraná show that some environmental agencies are moving from conflictive towards cautiously cooperative relations with firms. Under such conditions a “carrot-and-carrot” approach may work. At the same time, it is important to note that, as long as perverse incentives prevail, firms may hesitate to implement techniques such as environmental cost management, even if they promise substantial savings in costs and materials, if this increases their vulnerability to enforcement.

- A fourth option is to cooperate with large companies in their efforts to support smaller firms. In the environmental field especially large firms play a crucial role, as certification according to the ISO 14000 system of standards implies the extension of environmental management towards suppliers, mostly small and medium-sized firms. It is by no means certain that large firms have the means and willingness to support their suppliers in introducing environmental management, especially if foreign firms do not receive adequate support from headquarters. Partnership with SME support organizations, which are typical partners for international technical cooperation, appears to be a promising option. The problem is that a substantial part of the small business sector would not be targeted as it is not part of supply chains.

- A fifth option is to identify a group of firms under high competitive pressure with substantial potential for eco-efficiency (e.g. brick manufacturing was chosen in Rio de Janeiro due to its enormous potential for energy efficiency). However, this approach is unreliable as firms may perceive that other measures (cheap credit for modern equipment, training of employees, or lobbying for protection against pressure) appear more promising than addressing the competitiveness issue from an eco-efficiency angle. It also ignores the typical learning trajectory outlined above. If firms have occasional conflicts with environmental enforcement, and even more if they have never had such contact and rely on hearsay, they tend to have a highly developed skepticism regarding anything related to the environment.

None of these alternatives seems to be a first or best option. Each of them may be appropriate under specific conditions.

3. Learning to cooperate

When firms actually start to deal with environmental management and are willing to do this collectively, it is crucial to understand that cooperation is an evolutionary process. The first step in stimulating a group-centered approach is to identify a group of firms that for some reason, is under pressure to do something about its environmental impact and its competitiveness. Firms which have been under immediate pressure by an environmental agency or by customers, have clear incentives and are the easier target group for support in environmental management. Additional pressure resulting from the need to reduce costs of resource consumption in order to stay in the market or become more competitive is helpful. Such firms may find the idea of forming a group to react collectively instead of individually to external pressure immediately convincing, so that it is easier to overcome their unfriendly predisposition towards cooperation.

The second step is to identify an organization or a person that can organize and facilitate the work of the group, i.e. who is both credible and competent (with respect to technical issues as well as the moderation of group processes). The experiences from Santa Catarina and Paraná indicate that business associations are promising candidates, provided that they have professionals who are able to perform this task. In order to motivate the group, it is useful to refer to proven methodologies such as the one refined by Fundação Empreender (see http://www.fe.org.br). It is however, essential to understand that business associations are in a complicated situation when it comes to environmental issues. On the one hand, an association with a minimum of strategic capacity will stimulate environmental learning processes among its member firms since experience shows that environmental pressure does increase sooner or later. On the other hand, member firms will expect the association to delay this process as much as possible, i.e. to lobby against strict environmental measures. This means that officials of business associations may have to develop a somewhat schizophrenic attitude. To overcome this, a business association may try to push a proposal for the "carrot-and-carrot" approach outlined above.

In order to facilitate the work of the group it is important to accept that it takes some time for learning processes to occur. It is unlikely that a short-track can be found to circumvent the typical sequence outlined above (although supporting agents may succeed in creating a learning curve steeper than usual). It is important to consider the psychology of firm owners in this context. Businesspeople seem to have a kind of natural tendency to perceive environmental concerns as a middle-class luxury, something they cannot afford, especially if they own micro or small firms. They tend to see themselves as heroic entrepreneurs fighting for survival in a hostile environment anyway, and environmental concerns appear to be just other obstacles to making survival more complicated.

Regarding environmental management, there are specific obstacles in micro, small and medium-sized firms. In their case convincing businessowners to adopt environmental management is all the more complicated as, in the first place they often do not really have a management system worthy of the name. In other words, the introduction of environmental management is a synonym for a transition from improvised to systematic management, which in turn, means that the introduction of environmental management offers the opportunity to upgrade the overall management system. In addition, it can make an important contribution to economic dynamism. This process however, involves much training and learning, and thus will take time.

4. Consequences for the work of development agencies.

There are two implications for agencies that try to disseminate environmental management tools. On the one hand, it is unlikely that recipient firms will immediately adopt environmental management. On the other hand, they may be promising candidates for no-cost and low-cost instruments like good housekeeping (GTZ-P3U 1998). It will be essential at least initially, to emphasize cost reduction potentials and to keep the environmental issue in the background, perhaps even to avoid environmental terminology altogether.

In the case of medium-sized firms in which a certain degree of division of labor exists, the situation is different since owners tend to delegate environmental issues, like managing waste-water treatment or solid waste, to specialized employees. In this case, moving along the trajectory from end-of-pipe measures to environmental management involves profound changes in the internal power structures of the firm as the environmental person moves from a fringe to a core position. It is unrealistic to expect the process to be quick and smooth. However it can be expected that support from technical cooperation reduces some of the pain and the time needed for this process.

A further important conclusion is that it is useful to involve environmental agencies in stimulating eco-efficiency. Their pressure is an important reason why firms do something about the environment. Combining carrot and stick, i.e. not only puting pressure on firms but also supporting them in complying with ecological requirements, appears to be a plausible approach. However, the degree to which an environmental agency can support firms is necessarily limited. At the same time, it is important to acknowledge that the learning trajectory mentioned above includes important learning processes inside environmental agencies. They tend to have a profoundly hostile view of firms as they perceive them, often correctly, as major environmental hazards. In dealing with firms, they tend to think that the stronger the enforcement is, the better. The problem is that their officials often have no hands-on experience inside firms and therefore do not understand easily how business people think and act. The understanding of each others mode of activity and incentives was an important outcome of contacts between the NMA Joinville and FATMA. As soon as firms deal systematically with environmental issues, they tend to develop environmental consciousness, a tendency that environmental agencies do not always appreciate. Agency officials continue to believe in aggressive approach, which often leads them to enforce implementation of environmental measures in an inflexible and dysfunctional way, namely by insisting on certain methods and technologies rather than stimulating firms' creativity to not only come up with the most efficient solution for a given problem, but also to embark on a new trajectory of continuous improvement to minimize environmental impact.

Support is mostly required from other intermediate-level organizations, which can also help to moderate interaction between the environmental agency and the firms. It has been mentioned above that government agencies including SME support agencies, may not be the most promising candidates to support companies in the environmental field because firms see them as potential Trojan Horses, (i.e. fear that they disclose information on environmental impact to their colleagues at the environmental agency).

In order to stimulate group-centered approaches to the diffusion of eco-efficient production practices, it is useful to propagate positive experiences – both of environmental management within firms and of successful group activities, like those documented in this paper. Based on the experiences of Fundação Empreender, the organization that accompanies the organizational development process in ACIs in Santa Catarina, it is particularly useful to organize workshops on environmental management and group-centered approaches, including visits to factory sites, with the participation of successful businessowners, managers and engineers since they have much more credibility in dealing with other businesspeople than technical cooperation experts or SME support organization officials.

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READERSHIP SURVEY ON

"ATAS XII – The Role of Publicly Funded Research and Publicly Owned Technologies in the Transfer and Diffusion of ESTs."

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