Background documents to the Technology and Innovation Report 2023

The Sustainability Transition Requires Extended and Differentiated North-South Cooperation for Innovation

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Abstract

The transition towards a more sustainable world economy is a fact, as the internationally community has realized that business as usual practices will lead to ecological disasters, from global warming, loss of bio-diversity to the contamination of maritime water bodies. Research, development and innovations are powerful tools to align the needs of a growing world population with the necessities of keeping global development within the planetary boundaries. There is, however, a huge and growing - rather than diminishing - divide in both inputs and outputs to the science and innovation systems. Developing countries, which are most severely affected by the multiple ecological crises cannot invest very high financial and human resources to address their specific challenges though research and development. This calls for determined international action and North-South cooperation in science, technology and innovation. The paper analyses the North-South divide in research and development and discusses, how international cooperation may strengthen the capabilities of the Global South to respond to the challenges and, wherever possible, take advantage of new economic opportunities in a world transitioning towards more sustainable growth patterns.

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List of Acronyms

AAAA	Addis Ababa Action Agenda
AMCOST	African Ministerial Council on Science and Technology
BAU	Business As Usual
BRI	Belt and Road Initiative
CCS	Carbon Capture and Storage
FDI	Foreign Direct Investment
GEF	Global Environmental Facility
GWO	Green Window of Opportunity
IDRC	International Research Centre
LIC	Low Income Countries
LIPS	Local Innovative and Productive System
LMIC	Low and Middle Income Countries
MIC	Middle Income Countries
NDCs	Nationally determined contributions
NIS	National Innovation System
ODA	Official Development Assistance
R&D	Research and development
SDGs	Sustainable Development Goals
SIDA	Swedish International Development Agency
SoIS	Sustainability-oriented Innovation System
STI	Science, Technology and Innovation
TA	Technology Assessment
TFM	Technology Facilitation Mechanism
TNA	Technology Needs Assessment
UMIC	Upper Middle Income Countries
UNFCCC	United Nations Framework Convention on Climate Change (
USPTO	United States Patent and Trademark Office

1. Introduction

Among the multiple global divides, the one related to the capacities in science, technology, and innovation STI) is frequently overlooked. However, we may assume that, without addressing it adequately, it might not be possible to achieve many of the Sustainable Development Goals (SDG), enabling poverty reduction and broad-based developmet without further transgressing planetary boundaries (Rockström et al. 2009). Innovation is a key driver of economic growth in a world economy based on competition and market forces and science and technology create the basis for steady innovations. In recent years it has become increasingly clear that economic growth often increases the overall welfare of a society, but it may come at costs, which cannot longer be borne. Climate change, erosion of fertile soils, depletion of fish stocks and eutrophication and contamination of water bodies erode the livelihood of billions of people, most of them living in developing countries.

Thus, a transition towards greener growth patterns is imperative. Green growth may be seen as allowing increasing incomes and growing needs satisfaction (access to clean water and energy, SDG6 and 7), especially for the poorer strata of the world economy, while bringing additional environmental pressures (close) to zero. In a green economy, innovations will remain key drivers of progress, however, the questions of "which kind of innovations" and "innovations for whom" will play an important role. Green innovations decouple economic growth from the depletion of natural resources and sink capacities of the planet. Decoupling occurs when the growth rate of an environmental pressure is less than that of economic growth over a given period. Decoupling can be either absolute or relative. Absolute decoupling occurs when the environmentally relevant variable is stable or decreasing while the driving economic force is growing. Relative decoupling occurs when the growth rate of the environmentally relevant variable is positive, but less than the growth rate of the economic variable (OECD 2001)

The concept of green innovation should also embrace new solutions which may help recovery of some of the highly stressed or damaged elements of eco-systems, e.g., absorbing CO_2 from the atmosphere or bioremediation to restore contaminated soils or water bodies.

In economic history, there have always been cases in which important innovations were triggered through the actions of individual inventors and/or entrepreneurs. However, innovation research since the 1980s has shown that it requires the interaction of several actors from various societal spheres (private sector, academia, state) to make innovation a driver of economic growth beyond single "radical innovations". Focusing on green innovations, the time dimension must be brought into the picture. For instance, the basic principles of the steam engine were already known in France and England around the year 1700. However, it took more than 120 years until the first steam-driven locomotives and steamships started to have impact in the traffic systems, and some additional decades until steam engines became a driver of the industrial revolution in Europe and North America. Such long lead times cannot be accepted for most green innovations, as the time pressure to find solutions to the threats of mankind transgressing several planetary boundaries is high. Innovation research since the 1980s analyzed the importance of knowledge flows and interactions among various actors in the process of generating innovations (for the case of Japan see Freeman 1987) and in 1992 framed the concept of National System of Innovation (Lundvall 1982). More details can be found in section 4.1 of this paper.

All available evidence demonstrates that international cooperation for generating (green) innovations is highly underdeveloped and does not reflect the urgent needs to develop new technological solutions to the environmental challenges the world faces. This chapter collects available evidence about the state of the art and develops some conclusions on possible ways forward to scale up and improve international cooperation in STI.

2. Green Windows of Opportunity: New opportunities for developing countries?

The international community seems to have clearly realized that business as usual (BAU) in production and consumption patterns is no longer a feasible option. Too obvious are the signs that a number of planetary boundaries have been breached which puts into danger the very existence of mankind, if not in today's then in the next few generations (Rockström et al. 2009). This does not only refer to climate change, but also a series of other boundaries, e.g. soil erosion, eutrophication of water bodies, loss of biodiversity. Measures that have been taken include e.g. more stringent environmental regulations and the diffusion of environmental standards in global value chains.

Whether or not developing countries can benefit from this shift towards more sustainable patterns of production and consumption and new "Green Windows of Opportunity" (GWO) cannot yet be answered. On the one hand, incumbent production systems are being disrupted, which may provide space for new entrants to the markets. On the other hand, many big companies on the large markets have recognized the "green" signs of the time and adapted their processes and include core concepts like "climate neutrality" of "zero waste" in their management and public relations. It is crucial that developing countries are supported in adapting their products and processes to more stringent environmental standards. The combination of high standards with relatively cheaper labor costs may indeed open GWOs to developing countries. In addition, not only exporting to the large markets, but also substituting imports by locally produced item can be seen as a GWO, as locally produced goods often have a lower environmental footprint compared to items imported to developing countries from Europe, North America, Japan or China.

3. The decoupling of developing countries from the development of new technologies

Since the 1980s international economic and innovation research studied the dynamics behind the success of countries in technologically advanced industries, such as Japan (Freeman 1987). Several concepts have emerged since the 1990s, to conceptualize the approach. The dominant terms are the "Systems of Innovation" (Lundvall 1992) and the "Triple Helix" (Etzkowitz / Leyesdorff 1995). Much later, Podcameni et al. (2019) adapted the concepts to the specific conditions in Brazil and framed the concept of Local Innovative and Productive

Systems (LIPSs).However, they come to similar conclusions in three aspects. The concepts differ in some respects, which cannot be discussed here in detail. However, they come to similar conclusions in two aspects:

- It is usually not the single creative entrepreneur, nor the lab researcher who develops technological innovations and bring them to markets or applications in society. Rather, innovations emerge as an interplay among various actors, government, universities and other publicly funded research institutions, and private companies, which take new technological knowledge to maturity and bring innovation to the markets.
- The innovation process does not follow a linear approach, in which the sequence would be: basic research, applied research and innovation on the markets. Rather there are feedback loops between several of the steps of the process, e.g. information about the acceptance of a new technology on the markets is fed back to the applied research and development step, leading to adaptions of the product.

The common understanding is that innovations are driven by networks of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.

Whether and how the state should actively shape the direction of the innovation process or leave it to the market forces has for a long time been a matter for very controversial disputes. Public investment in basic research and development (R&D) can, in principle, be justified as overcoming market failure under a liberal approach: Research investment would be far below the socially desirable, if left to the private sector, as the latter cannot expect to recover the research expenditure and gain profits on the markets. Too high the probability that third parties will free-ride on the research outcomes for their own business. This is most relevant for basic R&D which leads to generic knowledge, difficult to convert into protectable intellectual property. Marianna Mazzucato (2011) shows, how important elements of today's ICT industry and arguably the most "shiny" high-tech cluster in the world – Silicon Valley – are to a large extent the outcome of heavy investments and interventions of the US government to promote high-end innovations in the defense industry. Most innovation researchers find empirical evidence that in countries, which have gone through a successful catching-up in knowledge-based development and industrialization (South Korea, Taiwan), the state in certain moments played an active role in guiding the innovation processes towards desired ends.

3.1 Innovation systems refuse to globalize

If we take the publication by Lundvall (1992) as a starting point, we can assume that for around 25 years, innovation system research was mainly dealing with the national level of system configuration and technology and innovation policies. Some transfers have been made to the regional (subnational) and sometimes local level. Interestingly, even in times of accelerated globalization, the question of how innovations are emerging and can be promoted on a global scale has not found very significant attention. Only toward the end of the 2010s, the concept of a Global Innovation System was framed by Binz and Truffer (2017), stressing the fact that in times of globalization, *"IS structure may still respond to "specific territorial contexts, yet in the majority of cases, they depend on actor strategies, networks, and* *institutional dynamics that coevolve between different parts of the world."* (Binz/Truffer 2020: 400).

There are few internationally comparable indicators which may allow us to analyze, whether technological innovations might increasingly be generated on the transnational or even global level. One indicator is the amount of financial resources which are spent on research and development (R&D). The European Union is arguably the most ambitious program of regional integration and it has a joint R&D strategy for the years 2021 to 2024. Thus we might expect the emergence of a regional (transnational), European Innovation System. The main funding line for R&D on the EU level is the ambitious Horizon Europe program. For the seven-year period 2021-2027 a 95.5 billion EUR are earmarked for public spending on the regional level, up 19% from around 80 billion EUR in the preceding program Horizon 2020 (2014-2020). This implies that, on average, EU R&D spending will be around 13 billion EUR over the seven years of the program period. This seems to be a solid basis for an emerging regional innovation system. But it is useful to put it in perspective: For instance, public investment in R&D by the German federal government alone was more than 20 billion EUR in the year 2020 (BMBF 2020).[1]

Still there seems to be a clear hesitancy of national governments to spend money for innovation on a regional, multilateral or international level, even where global challenges are concerned. Stamm/Figueroa/Scordato (2012: 30) attribute this reluctance to complex legitimacy issues national governments face:

> *"A government has to justify to the electorate why it should spend finite financial resources on R&D and not on projects often more highly valued by the electorate, such as infrastructure or social security, and why it makes sense to spend taxpayers' money on international collaboration rather than on national research projects."*

Currently, the topic of sustainably produced, "green hydrogen" raises a lot of expectations for a global sustainability transition. Green hydrogen may provide the basis for decarbonizing important industrial sectors and modes of transport, which cannot be put on a more sustainable basis via conventional technologies, e.g. direct electrification or the usage of bio-energy. Green hydrogen strategies and related R&D funding schemes are mainly on the level of nation states.[2] Most countries try to link their climate commitments related to green hydrogen with the objective to get a head-start into an emerging general purpose technology. The German National Hydrogen Strategy (Nationale Wasserstoffstrategie) speaks of the desire of Germany *"…to position itself as a leading supplier of green hydrogen technologies on the world market."* The US "Hydrogen Shot" launched on June 7, 2021 seeks to reduce the cost of clean hydrogen by 80% to $1 per 1 kilogram in 1 decade ("1 1 1"). With this, the US government wants to "*tackle the toughest remaining barriers to addressing the climate crisis,*

[1] https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/1/687232_BUFI_2022_Datenband.pdf?__blob=publicationFile&v=4

[2] The EU dedicates a special funding line of Horizon Europe to the development of green hydrogen technologies.

and more quickly reach the Biden–Harris Administration's goal of net-zero carbon emissions by 2050 while creating good-paying union jobs and growing the economy."[3]

3.2 North-south divide in STI seems to be widening

In all indicators referring to the input side of national innovation systems (NIS), the gap between the Global South and the North is evident. Gross Economic Spending on Research and Development (GERD) as a percentage of GDP is the most often used indicator for comparing innovation efforts of countries. Here, many countries of the EU strive to reach 3% or achieve this value (Germany, Denmark), while the global top performers invest 5% of GDP in R&D (Israel, South Korea). Few countries in the Global South approach or reach the 1% level (South Africa, Brazil), whereas many range between 0.5% and 1% (e.g. Costa Rica, Kenya) and others stay below, among them even some OECD countries, e.g. Mexico (0.3%) and Colombia (0.2%). In many developing countries the value is not measurable in an adequate way. [4]

In terms of absolute GERD figures, this gives a clear picture. The UNESCO Science Report "Towards 2030", published in 2015, shows that the global divide in R&D spending between High Income countries (HICs) and the other income groups is shifting slightly, with Upper Middle Income countries (UMICs) gaining larger shares at the expense of HICs. This shift is to a large extent related to the fact that GERD has increased very significantly in China and that this country still falls into the category of UMICs. The global position of LICs and LMICs has largely remained stable and on a low level, over the years (see table 1):

Table 1: Strengths of different country groups in global R&D efforts

	Share in global population		Share in global GDP		Share in global GERD	
	2007	2013	2007	2013	2007	2013
High Income Countries	18.9	18.3	57.7	51.0	79.7	69.3
Upper Middle Income Countries	34.8	34.1	27.6	32.1	19.9	25.8
Lower Middle Income Countries	35.1	35.7	13.2	13.7	4.3	4.6
Low Income Countries	11.2	11.9	1.4	1.7	0.2	0.3

[3] https://www.energy.gov/eere/fuelcells/hydrogen-shot
[4] World Bank World Development Indicators, accessed 22.02.2023

Source: UNESCO 2015: 24-27

While the data up to 2013 provided by UNESCO allow a quite precise analysis of the global geography of R&D, for a more recent inquiry, comparable data can mainly refer to the spending on R&D as a percentage of GDP (table 2), which most countries regularly collect and publish. We may assume that during the second half of the decade, the race for leading the global R&D race has increasingly become a "triple fight" between the USA, Europe and China, while Japan as a country traditionally strong in innovation has lost ground.

Table 2: GERD / GDP ratio	2013	2017-2020
World	1.99%	2.63% (2020)
Lower Middle Income Countries	0.44%	0.53% (2017)
High Income Countries	2.4%	2.97% (2020)
European Union	2.1%	2.32 (2020)
USA	2.71%	3.45% (2020)
China	2.0%	2.4% (2020)
Japan	3.28%	3.26% (2020)
Brazil	1.2%	1.2% (2019)
Egypt	0.64%	0.96% (2020)
South Africa	0.66%	0.62% (2019)
Thailand	0.44%	1.14% (2018)
World Development Indicators, online February 2023		

The picture is quite bleak for the developing world. While in the five years from 2013 to 2017 (latest available data for this country group), the GERD/GDP ratio in the group of Lower Middle Income Countries[5] barely rose from 0.44% to 0.53%, while in the world the figures were 1.99% in 2013, 2.14% in 2017 and 2.63% in 2020. Another reason for concern is that relatively advanced developing countries, which have long struggled for keeping up with industrialized countries in science, technology and innovation, have not managed to scale up their innovation-related spending. In Brazil, the GERD/GDP ratio has largely stagnated between 2013 and 2019, in South Africa it decreased. Two exceptions in the chosen sample are Thailand, where the figure was 0.44% in 2013 and 1.14% in 2018 and Egypt, with an increase from 0.64% in 2013 to 0.96% in 2020.

A second important indicator on the input-side of NIS is the percentage of researchers per million inhabitants of a country. The data are not available for most developing countries or are outdated. But in general, also with regard to the human resources, the analyzed trend towards a widening gap in STI performance can be stated (table 3)

[5] No aggregate data are available for the group of Low Income Countries-

Table 3: Researchers per million inhabitants	2010	2018-2020
World	1.282	1.597 (2018)
Middle Income Countries	651	814 (2018)
High Income Countries	3.776	4.670 (2019)
European Union	3.092	4.257 (2020)
USA	3.883	4.822 (2019)
China	885	1.585 (2020)
Japan	5.104	5.455 (2020)
Egypt	492	838 (2020)
South Africa	365	484 (2019)
Thailand	539 (2011)	1.790 (2019)
World Development Indicators online February 2023		

It does not come as a surprise that also at the output side of NIS, the North-South gap is more than evident. Patent indicators is one proxy for measuring the successes generated by joint innovation-related efforts in a society (see the section below on green patents). Another relevant indicator are the numbers of scientific and technical papers annually published in journals. The relevant data are shown in table 4. As in the case of R&D spending it is important to separate China from the statistical group of MICs, as 48% of the total number of publications from the MICs group are from China.

Table 4: Scientific and technical journal articles 2018 by World Bank country group		
Country Group	Absolute number of publications	Publications per 1 Million people
Low Income Countries	5,308	8
Middle Income Countries (MIC)	1,106,517	192
MIC w/o China	580,254	133
China	528,263	377
High Income Countries	1,450,446	1,177
Source: World Development Indicators online April 2021		

One could argue that the global divide in input and output factors of the national innovation systems does not directly reflect differences in capacities of countries to take advantage of green windows of opportunity (GWO) or to develop science-based responses to societal challenges. However, there is evidence that even in fields highly relevant for the Global South and global challenges, most science is carried out and its agenda defined in the North.

Blicharska et al. (2017) analyze the institutional affiliation of authors of scientific publications explicitly dealing with climate change issues and find that during the period 2000–2014, more than 85% of authors of a total of 93,584 publications were from OECD countries, while less than 10% were from other high-income economies or any Southern country income category (only 1.1% in the case of low-income economies). They suggest that the North–South divide in environmental research deprives the scientific community of considerable intellectual capital, influences research priorities and "most likely confines approaches to narrow paradigms from a few cultural settings and perspectives. Similarly, only 10% of funding for health research is spent in the South, where 90% of the world's burden of disease resides (Blicharska et al. 2017: 22).

While publications address the academic outputs of research on environmental topics, green patents give an indication of the practically relevant R&D outcomes of the innovation process related to green technologies. In a 2012 World Bank Paper, Dutz and Sharma find, that the numbers and percentages of green innovations (expressed in the number of granted patents) are increasing over time (admittedly, from a rather small basis). They find the dynamics is mainly driven by developed countries:

> *"Japan, Germany and the US account for 60 percent of total green innovations worldwide between 2000 and 2005, based on key greenhouse gas (GHG)-mitigation technologies." (Dutz/Sharma 2012: 3).*

Whereas high-income countries produced more than 6,000 green technology patents issued in the USA (GHG-reducing technologies only) between 2006–2010, developing and emerging countries combined produced fewer than several hundred (Hultman, Sierra, Eis, Shapiro 2012: 12). In the analyzed five-years period, countries in developing regions were granted patents in the one to two digits range (less than one hundred), while high-income countries were granted nearly 1,500 green patents in 2010 alone (Dutz/Sharma 2012: 4).

More recent data were provided by Nicoletta Corrocher and Andrea Morrison from Bocconi University, Italy to a study of the German Development Institute on the relationship between the green transformation and quality infrastructure (Vidican, Altenburg, Stamm 2020). For a very significant period (1975-2017) patents were extracted from a database of the Cooperative Patent Classification (CPC), referring to green technologies. Green technologies were conceptualized as comprising technologies 1) in climate change mitigation and adaptation and 2) in systems that integrate technologies related to power network operation and ICTs in this area.

The number of annually recognized patens increased in both analyzed technological classes, and overall, a very sharp take-off is observed after 2005. Looking at the global map of green innovations, it becomes clear that there is a high concentration of green patents in traditional industrial (USA, Japan, Europe) and newly industrialized (South Korea, Taiwan) countries. China is clearly the newcomer in the sphere, with a very fast take-off in green patenting since around the turn of the century.

If we look at table 6, it becomes clear that China clearly leads the group of emerging countries. In the analyzed period, more than 6.200 patents were granted to inventors from China in the USPTO. This office is considered to have very rigorous procedures and, thus, patents granted by here can be seen as a proxy for quality. 2% of all patents granted by USPTO in the analyzed time have gone to inventors in China. This is remarkable as it must be considered that this country has started its technological catching-up only around the year 2000 and a large percentage of the accumulated patents have been granted since then (and not in the 25 years before). All the other emerging economies have very modest shares in the overall numbers of green patents and the gap to the industrialized world does not seem to be narrowing by any means.

Table 5: Top green patenting countries - cumulative number of patents, 1975-2017, World

All patent offices			USPTO		
Country	Patents	% of total patents	Country	Patents	% of total patents
Japan	155,501	18.6%	United States	133,219	42.7%
China	148,032	17.7%	Japan	72,837	23.3%
United States	143,145	17.1%	Germany	21,464	6.9%
South Korea	112,699	13.5%	South Korea	19,490	6.3%
Germany	94,927	11.4%	Taiwan	9,441	3.1%
France	27,764	3.3%	France	7,222	2.3%
Taiwan	22,389	2.7%	China	6,238	2.0%
Russia	21,915	2.6%	Canada	6,191	2.0%
United Kingdom	12,813	1.5%	United Kingdom	5,249	1.7%
Canada	9,477	1.1%	Sweden	3,135	1.0%

Source: Corrocher/Morrison 2020

In most Lower Middle Income Countries and Low Income Countries, patenting activities are hardly measurable. In fact, a study on clean energy patents in Africa over the period between 1980 and 2009 shows that only 1% of all international patents in clean energy were filed in Africa, and 85% of these came from South Africa, pointing to the minor role that developing countries still play in (green) technology development (UNEP/EPO, 2013).

Table 6: Top green patenting emerging countries (number of patents and per cent of total)					
All patent offices			**USPTO**		
Country	**Number**	%	**Country**	**Number**	%
China	148,032	17.70%	China	6,238	2.00%
Russia	21,915	2.62%	India	1,003	0.32%
Brazil	4,676	0.56%	Brazil	277	0.09%
India	1,663	0.20%	Russia	273	0.09%
Mexico	1,130	0.14%	Mexico	209	0.07%
Turkey	875	0.10%	South Africa	202	0.06%
South Africa	437	0.05%	Turkey	79	0.03%
Argentina	363	0.04%	Argentina	75	0.02%
Chile	267	0.03%	Chile	66	0.02%
Egypt	97	0.01%	Egypt	21	0.01%
Indonesia	35	0.00%	Indonesia	9	0.00%
Source: Corrocher/Morrison 2020					

3.3 China as a new technological powerhouse

China has managed to transition very fast from a technology taker to a fast adopter and adapter and today is among the leaders in a series of technologies, among them important green technologies (Altenburg, Schmitz, Stamm 2008). While this technological catching-up was partly triggered by technology transfer from the traditionally industrialized countries, today's China has advanced domestic capacities for steady incremental and also radical innovations, in fields like artificial intelligence, but also renewable energies. Urban (2018) analyses the status of China in three core green technology fields: hydropower, solar and wind energy. She concludes that especially in solar and hydropower, China has left the role of technology follower and is among the technology leaders with partly very high world market shares (50% of the international hydropower market) (Urban 2018: 327). The new role of China has also significantly changed what she calls "geographies of technology transfer and cooperation". China is today engaged both in South-South (China to Asia and Africa) and partly also in South-North (China to Europe) modes of technology transfer.

Chinas interaction with developing nations has indeed increased significantly and led to significant shifts in international cooperation patterns during the past two decades. Parts of Africa are involved in the large-scale infrastructure project Belt and Road Initiative (BRI), which will bring the Chinese and the African markets to closer economic proximity, as times and costs of interaction will significantly decrease. In the same context, large-scale infrastructure projects have been implemented. One example are two important railway projects in Ethiopia, one linking the capital Addis Ababa with the seaport in Djibouti. The second is the Addis Ababa Light Rail System. Both projects were largely financed by China's Export-Import Bank (Exim Bank), China Development Bank and Industrial and Commercial Bank of China. They were implemented by two Chinese companies: China Railway Group Limited and the China Civil Engineering Construction Corporation. Technological learning opportunities in these green technology projects were limited, as no relevant interactions with local companies happened and interactions with universities remained at a level which would not allow significant knowledge and technology transfer (Vidican, Altenburg, Stamm 2020: 155 f).

The expansion of Sino-African trade relations in the last decades has been one of the most remarkable in the developing world. In Sub-Saharan Africa (SSA) alone, imports of manufactured goods from China are more than 50 times larger compared to the moment, when China joined the WTO in the year 2001. While the share of imports from the EU and the US decreased from 10% in 1990 to 3.8% in 2018, China's share of total imports in Sub-Saharan Africa rose from 1.1% to 16.5% over the same period. This has been accompanied by a change in China-SSA trade patterns, shifting from imports of products such as footwear and light manufactured to more sophisticated and capital-intensive goods, making China the largest import partner for machines and electronics for the region (Darko, Ochialli, Vanini 2021). Trade between China and African countries has, for some observers, contributed to innovation through the introduction of new equipment into local markets.

In addition, analysis of firm-level data (Hu et al. 2021) and a meta-study of more than one hundred sources (Calabrese/Tang 2022) suggest a positive role of Chinese investments in Africa on productivity, economic transformation, and innovation. Some studies find that Chinese FDI promotes technological progress in Africa more than FDI from other countries (Hu et al., 2021). One reason for this rather positive effect of Chinese companies compared to FDI from industrialized countries is that their technology gaps with African firms are smaller. In addition, Calabrese/Tang (2022) find that many Chinese investors are very active in transferring technology-related knowledge to their staff, often through on-the-job formats and not in classroom-type trainings. Once this knowledge is transferred successfully, horizontal (e.g. labor mobility) and vertical (backward and forward linkages) spillover effects can happen. This often refers to small Chinese companies operating on Africa's domestic markets. Kirchherr/Matthews (2018) analyze Chinese activities in Europe' and Latin America's hydropower industry. Their analysis finds little evidence of technology transfer to local actors, in spite of relatively frequent interaction with actors from the host countries. Technology transfer is mainly confined to trade. The authors, however, admit that the topic is largely under-researched and that the limited number of cases of Chinese involvement in the hydropower sector of both continents do not really allow very far-reaching conclusions.

Oya (2019) analyses subcontracting of local actors by Chinese FDI: Chinese construction companies regularly hire local subcontractors but tend to give them simple and labor-intensive tasks, whereas work that requires critical technologies is usually commissioned to Chinese subcontractors. This resembles the traditional "Western" style of technology transfer, in which knowledge transfer happens when this is required for a smooth implementation of investment projects and/or where local subcontracting makes the operation cheaper than e.g.

flying in operational staff and technicians from the mother company in the home country. Weng et al. (2019) compare Chinese engagement in three primary sectors in Africa and find significant differences among them with regard to technology transfer. In *forestry*, no relevant technology transfer was found, as the Chinese market demands the timber products to be delivered in log form for highly specialized processing in China. This does not provide value addition opportunities for African producers. In contrast, the *mining* case presented a clear case for beneficial technology diffusion and the introduction of efficient and cheap technology suited to the local context. In the *agriculture* case, some technology transfer was found in the form of new processing technologies and new fertilizer and seeds, *"although our research did not document a transformative impact from these technologies."* (Weng et a. 2019: 98).

The empirical evidence about Chinese technology transfer to developing countries is limited and the results rather mixed. Oya / Schäfer (2019), Weng et al. (2019) and some additional authors warn of a 'Chinese exceptionalism', and state that Chinese companies in Africa are not unique, but rather behave in the same way as other foreign players, or at least, as other 'new entrants' in the market (Calabrese / Tang 2021: 12).

What could additionally be discusses is, whether Chinese approaches to technology transfer today are significantly different from industrialized countries and can indeed be labelled as *South-South innovation cooperation*, implying that it stands for a group of *Southern* countries. Even if China will be classified as a Upper Middle Income Country for some years to come, its economic and technological power is already very strong and the gap to most developing countries very significant. If recent trends continue in the future, China will catch-up with the industrialized world, as South Korea did, starting in the 1960s (Glawe / Wagner 2021). China will soon be a newly industrialized country and belong more to the Global North rather than to the South.

3.4 The incipient South-South cooperation in science and technology

South-south cooperation in science and technology is not happening on a broad scale. An indicator for this might be that in the 817 pages UNESCO Science Report "Towards 2030", the term "South-South cooperation" does not appear at all. It only refers to a limited Biotech project in Southern America as

> *„… an interesting example of subregional co-operation designed to take better advantage of existing research skills to foster competitiveness in productive sectors within the MERCOSUR space." (UNESCO 2015: 200).*

Over past decades, there have been several attempts to foster regional cooperation in STI, e.g. "Africa's Science and Technology Consolidated Plan of Action (CPA)" launched in 2005 by African Ministerial Council on Science and Technology (AMCOST). The CPA involved three areas, namely research and development (R&D); a program for improving policy conditions and building innovation mechanisms; and implementation, governance and funding. The CPA was later followed by a 10-year Science, Technology and Innovation Strategy for Africa (STISA-2024). Evidence about the outcome of both programs cannot be found.

To date, regional STI cooperation is not gaining sufficient traction in any of the developing regions to build a strong joint basis for using GWO for sustainable development. Some of the reasons to explain this may be the overall low levels of R&D spending and the lack of incentives for researchers and research institutions to cooperate with their peers in the region. Both for institutions and for researchers, it is more attractive to enter into research projects with developed countries and emerging economies. The opportunities to get access to world-class research and related hardware (laboratories, computing power) are better. In addition, for the individual researcher it is attractive to be able to publish in international refereed journals: Also for this purpose cooperation with researchers from well-known universities in the North is a better "entry ticket" (see, for instance, Blicharska, Malgorzata et al. (2017).

3.5 Summary and preliminary conclusions

The North-South divide in innovation performance is very pronounced, both regarding input and output indicators to the innovation systems. There are no indications that it might get narrower over time, if we leave the rapid rise of China as global technology hub out of the equation. The possibilities that the Global South will manage to catch-up with the industrialized countries are not promising. The COVID 19 pandemic has affected severely some of the technologically rather good performers of the Global South, such as Chile, Colombia, Peru or South Africa. In the near future, governments will have to address urgent social needs (such as youth unemployment, which has reached e.g. 40% in Namibia. 45% in Costa Rica and 64% in South Africa in the year 2021)[6]. These necessities limit the financial leeway for public investment in research and development, which generally only pays off in the medium to long term. The impacts of the war of Russia against Ukraine, such as serious weakening of food security due to reductions in grain exports from Ukraine and soaring fertilizer prices is another factor requiring emergency responses by national governments.

It cannot be expected that in the near future they will have the financial resources for a broad-based strategy of catching-up in STI. This implies that many developing countries will need strong support from the global North in identifying and implementing innovations to tackle global challenges, and, here, assuring food security for a growing population under conditions of climate change. This happens in a time when impacts of climate change are also hitting many developing countries, which would need scaling up research to understand the impact chains related to global warming and science and technology to develop mitigation options and take advantage of GWO.

Thus, there is an urgent need to address the question, how STI can be embedded into concepts of a fair globalization, implying that the needs of developing countries receive adequate attention in international agenda and priority setting and can benefit adequately from knowledge and benefit sharing. This is more urgent than ever in times of worsening climate change and its impacts in the developing world, e.g. exposition to natural disasters and deteriorated food security. Another element of fair globalization has to be that developing countries receive a decent share of opportunities to take advantages of opening GWOs as a basis for sustainable development.

[6] World Bank, World Development Indicators, accessed 20.02.2023

Developing countries might take advantage of the emerging competition between traditional industrialized countries and China for influence in developing countries. For instance, the G7 recently announced a large-scale cooperation project for infrastructure in Africa, obviously to counteract the influence of the BRI. Developing countries might consider negotiating with their cooperation partners intelligent approaches to combine the implementation of infrastructure hardware with best possible approaches of transfer of knowledge and technology.

4 From technology transfer to international innovation cooperation for the green transformation

The problem that countries of the Global South lack advanced technologies and the related capabilities to use them both effectively and efficiently has been seen as a core reason for the lack of socio-economic dynamics in developing countries since a long time. Proponents of endogenous growth theories (e.g. Paul Romer) link economic growth directly with advancements in technological capabilities. Spectacular examples of industrial catching-up (South Korea, and more recently China, e.g. Urban 2018) are directly connected to rapid advancements in adapting and developing technologies.

Raúl Prebisch, UNCTADs first Secretary General (1964-1969), in his Center-Periphery Model saw differences in access to technologies and in abilities to manage them properly, as core elements of an unequal economic world order and declining terms of trade to the detriment of developing countries. Few years later, in 1972 the *United Nations Conference on the Human Environment* in Stockholm adopted the first global set of principles to help preserve and enhance the human environment. Principle 12 of the "Stockholm Declaration" recognizes that additional international technical and financial resources should be made available to developing countries "to preserve and improve the environment." Access to technology became an element of concepts for an environmentally sustainable world. Commitments in this direction have been repeated several time, e.g. on the Earth Summit in Rio de Janeiro (1992) and in the Paris Agreement of 2015 (Kosolapova 2020: 2).

The question, how the deployment of sustainable technologies can be accelerated not only in the most advanced but also in developing countries has gained momentum in view of the urgent climate and environmental crises of the present. Scientific research on the topic is, however, not new either. Already in 1990, Martin Bell from the Science and Policy Research Unit SPRU of Sussex University published a report discussing the interrelations between *industrialization, climate change and technology transfer* (Bell 1990). Innovation research made clear since early on, that technology transfer cannot be conceptualized as moving physical "hardware" from one geographical and societal context to another, e.g. through the selling of industrial machinery or Foreign Direct Investment (FDI). Bell and other authors embedded the question of technology transfer in the more complex issue of building-up innovative capabilities, the capacities to adopt, adapt, develop, deploy and operate technologies under varying societal and environmental contexts (Ockwell/Mallett 2012: 9). Araújo and Teixeira (2014) stress that successful technology transfer does not only require willingness and abilities by the providers of a technology, but also, at the side of technology receivers, *"… absorptive capacity, human capital, trust, social connectedness, prior experience with partnerships, and international experience."*

Bell (1990) introduced the concepts of "hardware" and "software" in technology transfer, which is still used today. *Hardware* refers to the capital goods and equipment which are needed to establish physical assets and directly related services, such as engineering services. *Software* are the skills needed to make the hardware running (know-how) and understand, why it is running (know-why). Both types of skills are required for making technology transfer effective beyond single "events":

> *"A successful technology transfer and cooperation is one that does not only provide hardware to a recipient country, but that also enables it to operate, maintain, replicate and innovate this technology." (Kirchherr / Urban 2018: 601).*

Only if local actors acquire certain "know-why" capabilities, a country can be able to adapt a given set of technologies to varying framework conditions and apply it beyond the usage for which it was transferred initially. Regarding green technologies, these capabilities are of crucial importance, as very often their deployment within and across countries needs adaptations to specific conditions on the ground. In addition, some green innovations have still not reached complete technological maturity and require significant adaptive research to allow a large-scale roll-out, envisaged and required to achieve real impact in terms of mitigating climate change and other environmental degradation.

Enabling and empowering developing countries to take advantage of GWO requires, thus, broad and comprehensive development strategies of support to national innovation systems of eco-systems. IN the subsequent chapter we will briefly discuss main activities by three sectors in international cooperation for green innovation.

4.1 Actors in the transfer of green technologies to developing countries

Over past decades three different sectors have been engaged in transferring (green) technologies to developing countries:

- Governments channel funds and give technical assistance to countries in the global South in the context of Official Development Assistance (ODA) and in the form of financial and technical cooperation.
- The private sector trades goods and services and invests in developing countries, transferring technology and related knowledge, most of the time for business interests.

The "third sector" relevant in the context of technology transfer to developing countries consists of non-governmental organizations and other non-profit organizations, like foundations or charities. They played and play a role specifically in the development of so-called appropriate technologies, often containing a "green innovation" component. Arguably the most widely diffused green technology are "Improved Cooking Stoves" (see below) with important environmental and health benefits.

4.1.1 Governments: Official Development Assistance to support STI for green innovations

It is not easy to assess the contribution of ODA to the capacities of developing countries to handle technologies and generate innovations, as a pre-condition for their abilities to identify and use GWOs. Important progress in reporting and monitoring of ODA flows allows at least to get a rough understanding. The rather sophisticated methodology of OECD-DAC to collect and disseminate aid data permits to estimate the percentage of ODA, addressing international environment goals, written down in Conventions on Climate Change, Biodiversity, Desertification, etc. (OECD 2019). No reliable time series are available, but it can be assumed that "green" ODA has been increasing over time in most countries, following international agreements, like the Paris Agreement of 2015. In 2016/2017 many of the large international donors committed at least 40% of their development assistance as "green ODA" (see table 7).

Table 7: Green ODA as a percentage of all ODA in leading donor countries (2016/2017)

Canada	41%
EU institutions	34%
France	67%
Germany	42%
Japan	48%
Sweden	47%
United Kingdom	42%
Korea	9%
United States	7%

Source: Rijsberman (2021)

The European Union institutions green ODA share was already above average in 2016/2017 (34%). With the EU Green Deal becoming the backbone of the green recovery for Europe and the "green growth strategy" across all EU policies, this is expected to increase. The formal target for the green share of the EU's ODA has not been set yet, but European development partners are arguing that it should be at least 50% green, for both environment and climate finance combined (Rijberman 2021). The OECD Development Assistance Committee (DAC) issued a declaration on a "new approach to align development co-operation with the goals of the Paris Agreement on Climate Change". It was adopted by DAC members on 27 October 2021.

The DAC offers data which allow a sector breakdown of international ODA flows. Regarding the field of science, technology and innovation, Eriksson / Mealy (2019) stress important methodological constraints, as STI is not a "marker" in the DAC Reporting System. Looking exclusively at the concessional finance to STI, the annual amounts are relatively stable, with around USD 10.5 billion per year, representing 5.9 % of total concessional finance by DAC members, multilateral organizations and other countries. (Eriksson/Mealy 2019: 46). Due to the mentioned methodological problems, it is not completely clear, which sub-categories are summarized under "ODA for STI" and whether all donors report it in a similar way. UNDESA comes to much lower figures, when it comes to ODA specifically targeting the development of STI capacities in developing countries, which they find to have more than doubled between 2014 and 2019, but starting on a rather low level (2014: US$ 0.9 billion, 2019: US$2.4 billion). This implies that only a very small percentage of international aid flows target the STI capacities. In addition, ODA for STI capacity development in LDCs, landlocked developing countries, small island developing states (SIDS), and Africa has not grown over the past decade and remained on a rather low level (United Nations & Department of Economic and Social Affairs, 2019).

There might be changes in the future, as it is becoming clear, that developing countries need more advanced capacities in technology development to enable the transition to renewable energy sources and long-term low-emission development. Developing countries are increasingly raising this issue in international negotiations. Kosolapova (2020) mentions that Mongolia has committed to increase its emissions reduction goal from 22.7 to 27.2% by 2030, if it receives assistance with carbon capture and storage (CCS) and waste-to-energy technologies. Similarly, Thailand has promised to raise its emissions reduction target from 20 to 25% from the projected business as usual level by 2030, with *"adequate and enhanced access to technology development and transfer,"* and financial and capacity-building support.

On the individual country level, the highest ODA flows (in absolute terms) to support science and innovation come from the USA, UK, Germany, Canada, Australia, France, Sweden, Netherlands, Norway and Switzerland. The ranking regarding "ODA for technology" is different and sees Korea at the top, however, with a rather huge proportion of non-concessional loans (Eriksson/Mealy 2019: 53). The priorities that different donors set for their STI support vary significantly:

- The United States is the largest provider of concessional finance to STI, with a large share of its funding directed towards research, capacity building and innovative approaches to fight the spread of infectious and tropical diseases and prevent maternal and child deaths. The USAID Global Health Research and Development
- The United Kingdom is heavily scaling up support to research. In 2013, the UK Government announced its pledge to provide 0.7% of its gross national income (GNI) as ODA. The following three years, new research funds were set up to support research activities tackling challenges faced by developing countries (Newton Fund, Ross Fund, Global Challenges Research Fund). A second aim of the research funds were also to make developing countries benefit from the high quality standard of research conducted in the United Kingdom.
- Sweden's research co-operation programme focusses on both strengthening the research capacity of developing countries and financing research projects. It is grounded in the government's Strategy for research co-operation and research in development co-operation 2015-2021. The aim of the strategy is *"to contribute to strengthened research of high quality and of relevance to poverty reduction and sustainable development, with a primary focus on low-income countries and regions."*
- Canada funds international STI cooperation mainly though the Ottawa based International Research Centre (IDRC). The centre champions and funds research and

innovation within and alongside developing regions to drive global change. It invests in high-quality research in developing countries, share knowledge with researchers and policymakers for greater uptake and use, and *"mobilizes global alliances to build a more sustainable and inclusive world"*.

- Germany has a long tradition of supporting technical and vocational education and training systems in developing countries, which can pave the way for implementing green technologies in businesses and society. In addition, organizations as the German Academic Exchange Service (DAAD) and Alexander von Humboldt Stiftung (AvH) provide scholarships for students from developing countries on the postgraduate and post-doctorate level.

4.1.2 United Nations Actions for green STI

Already before the United Nations Framework Convention on Climate Change (UNFCCC) was agreed upon in 1992, the **Global Environmental Facility (GEF)** came into being. Since its inception in 1991, the GEF has been facilitating technology transfer to help developing countries address the global climate change challenge. It later received the mandate from UNFCCC to finance the transfer of Environmentally Sound Technologies, and has evolved into the largest public-sector funding source in this area. These technologies have the potential for significantly improved environmental performance. They include know-how, goods and services, and equipment, as well as organizational and managerial procedures. The GEF supports innovation and technology transfer at key early and middle stages, focusing on the demonstration and early deployment of innovative options. The GEF support aims at addressing elevated risks associated with innovation, mitigating the barriers of technology transfer, and piloting promising approaches.

Since its inception in 1992, technology has played an important role in the context of **UNFCCC**. In the founding text of the convention, specific provisions on technology were included. These form the basis for all technology efforts under the Convention and read like this[7]

Article 4, paragraph 1

> *"All parties…shall: (c) Promote and cooperate in the development, application and diffusion, including transfer, of technologies…that control, reduce or prevent anthropogenic emissions of greenhouse gases…"*

Article 4, paragraph 5

> *"The developed country Parties…shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention…"*

[7] Climate Technology Negotiations (unfccc.int)

After a consultation process, UNFCCC member countries, in 2001 created the technology transfer framework. They also established the expert group on technology transfer (EGTT) to analyze technology development and transfer issues. The technology transfer framework covers five key technology topics:

- Technology needs and needs assessments
- Technology information
- Enabling environments for technology transfer
- Capacity-building for technology transfer
- Mechanisms for technology transfer

Between 2001 and 2010, the technology transfer framework with support from the EGTT supported developing countries to address technology transfer issues and implement technology activities. Through these institutions, countries established and consolidated the technology needs assessment (TNA) process. Since 2001, more than 90 developing countries have conducted TNAs to address climate change, addressing both technologies for adapting to climate change and for reducing greenhouse gas (GHG) emissions. More recently, many countries have identified climate technology needs in their nationally determined contributions (NDCs).

Since 2008, the Global Environmental Facility (GEF) has supported climate technology activities under the Poznan strategic program on technology transfer. This program aims to scale up the level of investment for technology transfer, helping developing countries to address their needs for climate technologies. The GEF initially created the program with three windows: supporting technology needs assessments (TNAs); supporting pilot projects linked to TNAs; and disseminating experience on climate technology activities.

In 2010 countries scaled up efforts on climate technology by establishing the Technology Mechanism. The Technology Mechanism consists of two complementary bodies, the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). With the creation of the Technology Mechanism, the mandate of the EGTT ended.

The 2015 Paris Agreement also refers to technologies and technology transfer as a means of keeping global warming at controllable levels and helping developing countries adapt to climate change. Article 10, paragraph 1 of the Agreement reads like this:

> *"Parties share a long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions."*

On the 2018 UNFCCC conference in Katowice (COP 24), parties adopted the technology framework under the Paris Agreement. The technology framework shall improve effectiveness and efficiency of the work of the Technology Mechanism by addressing the transformational changes envisioned in the Paris Agreement and the long-term vision for technology development and transfer.

Outside the UNFCCC, financial and technological support for climate action draws from a variety of sources, including ODA, the multilateral development banks, and multilateral climate funds, such as Climate Investment Funds (CIF) and the Nordic Development Fund

(NDF). Over the last 12 years, the CIF mobilized over USD 8 billion for climate action. With the five Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) providing the capital base, the NDF has to be considered a rather smaller fund. In 2020, it offered EUR 350 million for climate financing. The Global Environment Facility has dispersed some USD 20.5 billion in grants in addition to USD 112 billion in co-financing for over 4800 initiatives focusing on environmentally sound technologies in developing countries since its conception in 1992 (GEF, 2020).

The Addis Ababa Action Agenda (AAAA) provides a global framework for financing development aligned with the 2030 Agenda and its Sustainable Development Goals (SDGs). The AAAA outlines action areas to guide global Financing for Development efforts, including:

- domestic and international resources;
- public and private resources;
- international development cooperation;
- science, technology, and innovation (STI); and
- capacity building.

The AAAA established a **Technology Facilitation Mechanism (TFM)** to support the SDGs by encouraging the development, adaptation, dissemination, and diffusion and transfer of environmentally sound technologies to developing countries. The TFM has facilitated collaboration and partnerships on STI for sustainable development through four components: (1) the United Nations interagency task team on STI for the SDGs (IATT); (2) the United Nations 10-Member-Group of High-level Representatives of Civil Society, Private Sector and Scientific Community to support the TFM (10-Member-Group); (3) an online platform for the TFM—"2030 Connect"; and (4) an annual Multi-stakeholder Forum on STI for the Sustainable Development Goals (STI Forum), which also provides formal inputs to the High-level Political Forum on Sustainable Development (HLPF). The STI Forum's main strength lies in its convening power. While it cannot compel stakeholders to share their know-how with others, it provides the space to discuss developing countries' needs and gaps, showcase technologies for the SDGs, and promote networking.

In 2021, **UNCTAD and CSTD** launched a pilot project in cooperation with three countries in Sub-Sahara Africa to establish a methodology for Technology Assessment (TA) and create capacities for TA. TA is an established methodology and practice in industrialized countries to inform policy makers about the potentials and risks related to new technologies. Being able to assess technologies at an early stage is of crucial importance for developing countries, as only that way it will be possible to take political action and/or implement measures to help maximize benefits and mitigate risks associated with new technologies. The pilot project in Zambia, Seychelles and South Africa will last from 2021 to 2023.

4.1.3 Multilateral research cooperation for the green transformation

As explained in section 2.1, most research and development efforts are financed and governed on the level of nation states, even when it comes to addressing global challenges through STI. The examples of multilateral modes of research and research cooperation are few. In this section we briefly present three of these cases, which have been analyzed in more detail in an international research project under the umbrella of the OECD (2012).

Consultative Group on International Agricultural Research (CGIAR)

CGIAR was formally launched in May 1971 by the World Bank and 16 donors, including governments of industrialized countries and other organizations. CGIAR has, since then, become a major player for world agricultural research and a reference in terms of how scientific research can help develop agricultural solutions for the poor (Fabre/Wang 2012: 45). CGIAR is the largest global partnership focusing on “agricultural research for development” particularly in developing countries with a vision to create a “world free of poverty, hunger and environmental degradation”. It operates globally through its 15 research centers in close association with “hundreds of partners, including national and regional research institutes (NARIs), civil society organizations, academia, development organizations and the private sector.” (Pardey / de Conink / Sagar 2020:7). CGIAR’s mandate is to contribute to regional or global public goods and, thus, technologies and knowledge generated are in principle freely transferred of shared (Fabre / Wang 2012: 50).

Global Carbon Capture and Storage Institute

When the Global CCS Institute was launched in 2009 it had 15 governments and more than 40 companies and industry groups as foundation members. By 2010 membership had increased to 263 members, including 26 national governments. The mission of the Global CCS Institute is to accelerate the roll-out of commercial CCS for a low-carbon future. To achieve this objective, a set of CCS demonstration projects shall be rolled out and capacity building and knowledge sharing is crucial. The role of Intellectual Property Rights (IPR) has intensely been discussed since the formation of the institute. While on the one hand, IPR of partners are respected, the goals are, 1) to gather and package non-proprietary information on CCS and make it accessible to all stakeholders, 2) to make knowledge generated through programme activities as widely accessible to members as practical and to make intellectual property jointly generated by the Institute and its partners through Institute activities available in reasonable terms to other Institute activities. (Delegation 2012: 237).

International Energy Agency (IEA) Implementing Agreements

The IEA, an intergovernmental organization, acts as an energy policy advisor to is member countries. Through its work, IEA supports their efforts to ensure reliable, affordable and clean energy for their citizens. The triple goals are energy security, economic development and environmental protection (Figueroa 2012: 132-133). IEA also provides opportunities for exploring alternative sources of energy and energy conservation through long-term cooperation. One important mode of multilateral cooperation is the IEA Implementation Agreements (IA). By IEA rules and regulations, participation in an IA is to be based on equitable sharing of obligations, contributions, rights and benefits. Patents resulting from work within an IA may be filed in countries, as appropriate by the inventing participant, and participants may be required not to disclose information related to these patents for a fixed period.

4.2 Technology transfer by private companies: trade and foreign investments

There is a long discussion about the role that ***trade*** plays for transferring technologies from industrialized to developing countries. The findings from conceptual and empirical work are never very straightforward but depend, mostly, on the type of technologies in question and the specificities of the host country. Research still has to provide findings specifically on the question, what trade in environmental goods and FDI contributes to the opportunities of developing countries to benefit from GWO. In general, it can be stated, that an increased trade in green technology products opens opportunities to learn by observation and by reverse engineering, two documented modes of technology transfer via trade. This does not imply, that developing countries will be able to use this technological learning in the short term for import-substitution of green technology products or building up an own export sector, which would be two modes of utilizing GWO. Some green technology items, such as solar PV modules, are globally traded commodities and the competition is not based on simple learning of its key features, but on a highly efficient industrial value chain. For developing countries without a strong manufacturing sector, there are important barriers to entering this market. Even if we have a look at a rather "low tech" green innovation with high relevance for the environment and public health we observe similar patterns and challenges. Improved Cooking Stoves (ICS) are an important tool to reduce deforestation, black carbon emissions and indoor air pollution from which a large number of people (mainly women and kids) die each year. From global diffusion figures we might say that it is one of the most successful green innovation in the past decades. In 2012/13 an estimated 200 million ICS were used (ESMAP 2015). Beyond the environmental and health benefits, one of the key advantages in their diffusion is that it can, in general, be produced with locally available materials and employing local workers. However, over the years, the market started to differentiate. ESMAP (2015) differentiates artisanal, semi-industrial ad industrial manufacturing.

> *"The industrial model involves a highly mechanized production process, a high degree of centralization, and large scale. This model is growing significantly within the sector, with several variants identified" (ESMAP 2015: 106).*

This does not imply that developing countries should abstain from looking at technological learning opportunities from trade. Rather, it should be done strategically to acquire knowledge about the technologies and the business models and how they evolve. There might be opportunities to build up facilities to adapt internationally traded goods to local conditions and to build up green value chains in selected items. Where the markets are small, South-South cooperation could be seen as a way forward.

Foreign Direct Investment (FDI) can contribute to technological learning by various ways: A foreign company which builds up production facilities in a developing country will usually require specialized inputs from domestic firms. In order to assure effective and efficient supply chains, a transfer of knowledge through these backward linkages is in the interest of the international company. This implies **vertical technology transfer** from the home country to the host country and from the FDI to local companies. Horizontal technology transfer may be induced, when domestic companies are facing competition by better and/or cheaper production and upgrade their production.

> *"These productive linkages, in particular, can provide a direct channel for a diffusion of knowledge, which in turn can help local companies to carry out a technological and capacity upgrade with transshipment effects for an entire economy". (Fernandes da Silva/ Mourão 2019)*

Another mode of horizontal technology transfer happens through labor migration, when workers and managers trained on the job in a foreign enterprise switch to local companies or institutions. These positive effects are well documented for conventional goods. However, the picture is not completely clear about the effectiveness of this mode of technology transfer (Glass and Saggi 2002/ Saggi 2002).

The empirical relevance of FDI as a mode of technology transfer to use GWO still has to materialize and is not covered yet by development research. Currently, global value chains related to green technology items (e.g. solar PV and wind energy) are mainly based on North-North relations, involving China, Europe, USA and Japan. No significant modes of industrial division of labor involving developing countries are documented in the literature. This might, however, change soon. The envisaged transition towards a green hydrogen economy requires very significant upscaling of key components of this emerging industry, e.g. electrolysers. Considering the increasing problem of labor shortage in some of the traditional hotspots of industrial production (Europe, Japan) it is more than likely that big companies will outsource parts of the manufacturing to developing countries and emerging economies. Developing countries' governments should prepare for this GWO and not only struggle to attract FDI, but also, design policies to assure a solid contribution of FDI to the innovation systems in their countries.

The literature is divided on whether **intellectual property rights** are inhibitors or drivers of technology transfer to the Global South (Kirchherr / Urban 2018).

> *„The "traditional" view is that strong patent rights promote technology transfer to firms in developing countries, by giving patent owners more control over who gains access, and under what conditions, thus making them more willing to enter into licensing agreements. On the other hand, stronger intellectual property (IP) protection consolidates the monopoly power of patent holders, which makes it costlier for firms in developing countries to license foreign technology, ultimately reducing follow-on innovation in the developing world. " (Gentile 2017: 1).*

EPC companies in the field of renewable energies: a new form of FDI

International investments by industrialized countries' firms in developing countries are not always implemented by very large companies, traditionally discussed as FDI. When it comes to the implementation of complex projects, a second type pf private actors plays a role, which has not yet been studied sufficiently. Gunn / Salter (2000: 956) analyze the role of project-based and service-enhanced forms of enterprises mainly in the construction sector and come to the conclusions, that these enterprises are not adequately addressed in innovation literature.

The main focus of their paper and related studies on large technical systems are the challenges which enterprises have to manage when they bring together complex technologies from a variety of different disciplines.

When it comes to utility-scale renewable energy projects in developing countries as a contribution to climate change mitigation, project developers, or Engineering, Procurement and Construction (EPC) companies, play an important role in carrying out the siting of projects, identify the best possible technical solutions and establish the projects until it is up and running (see below). A large n-study by Bjarne et al (2018) is probably the first serious piece of research which takes a closer look at project developers (EPC companies) in the implementation of renewable energy projects in developing countries. The authors analyze a total of 863 utility-scale RE projects (>1 MW) implemented between 2007 and 2017 in eighty countries. They find that international project developers play an important role in opening new markets in the field of RE s, including solar PV, wind and biomass-based energy generation. While Wind and Biomass have developed rather continuously over time, Solar PV "virtually exploded after 2009". The authors see the main reason for this kick-start in a very significant drop in international prices for PV systems around 2010 (Bjarne et al 2018: 564). A "peak" in the diffusion of biomass project in 2008 is related to the fact that this technology was often used in the context of the international Clean Development Mechanism which could be used to offset emissions in countries with emissions-reduction obligations under the Kyoto Protocol. The EU emission trading system, as a large buyer, accepted CDM credits since 2008.

A closer look at the available data show that international private project developers have been crucial for first projects in solar PV (61%) and wind (58%) and less in biomass (33%). While both Solar PV and Wind have been "new to the market" innovations in all cases, utilizing available biomass for generating energy has a longer history in many developing countries. For instance, already towards the end of last century, the Brazilian sugar sector was self-sufficient in its electricity provision for its industries, combusting sub-products (bagasse) of sugar cane processing (Coelho / Bolignini 1999). In the same time Sharma / Sharma (1999) see a potential surplus electricity co-generation potential of 3500 MW in the Indian sugar sector. This means, that in wind and solar PV, "the whole value chain of competencies often needed to realize wind and solar PV projects are being brought to the country the by international developer" (Bjarne et al. 2018: 571). In biomass, more local competencies have been present in many developing countries.

For the present context, an important observation in the study by Bjarne et al. is that participation of international project developers was significantly lower in follow-on projects: 37% in Wind, 36% in Solar PV and 12% in Biomass.

> *"This effect could be due to "spillovers" from international firms into the local market. While initially, international developers may bring competencies completely from abroad, there is often a natural transfer and buildup of local capabilities in the process of project development." (Bjarne et al. 2018: 572).*

What is important is that EPC companies are often “medium-sized” companies, which only have a limited presence in the host country, and sometimes only as a transitory solution, depending on their business model, which can either follow the Build-Operate-Operate(BOO) mode or the Build-Operate-Transfer (BOT) mode. Under BOO, EPC companies most often sign a long term power purchasing agreement with a utility of the host country, and will continue to operate and maintain infrastructure and equipment for a pre-defined time. Under BOT, the project is handed over to national entities after it has been successfully built and proven to operate properly. In both cases it can be assumed that the project developer has an intrinsic motivation to transfer technical knowledge to the host country, e.g. by training local technicians or advising national institutions. Under BOO, the revenue of the project developer comes from selling electricity over a longer period, which means that a clear business-case exists for building up local capabilities to assure a smooth operation and maintenance under best possible cost conditions. In most cases, the costs will be lower, if operation and maintenance can be done by national technicians and not by experts which have to be flown in from the project developer’s home country or from other international project sites. Under BOT, the formal responsibility of the project may end with the handing-over of the project to national entities. However, the project developer may take serious reputation risks, if a project handed over, does not fulfill the expectations. Vidican / Altenburg / Stamm (2020: 157-159), for instance, document the case of the “Reppie”-project, meant to be the first modern waste-to-energy facility in Africa. After the project was handed over to the national utility Ethiopian Electric Power (EEP) in 2018, the outcomes stayed far below expectations, in terms of waste that could be processed, energy that was generated and local emissions of potentially harmful substances. In a market like climate mitigation technologies, with high amounts of international money which will be invested in the future, international project developers have to do what they can, to avoid such disappointing outcomes. One way of assuring satisfactory performance is transferring technological knowledge to local companies. The role of EPC companies in the building up of national innovation systems is still awaiting a more in-depth research.

5. The way forward: Five action lines to foster international cooperation for green innovation

In chapter 4 it became clear, that many actors are contributing to the uptake of green innovations in developing countries. They do this with varying logics and following different objectives, from pure business cases, through contributing to global public goods and to philanthropy. One could argue that this fragmented support structures hinder faster progress in green innovations in developing countries. But there are important counterarguments. Pandey/Coninck/Sagar (2021) study international experiences of technology transfer in the fields of health, agriculture and climate/energy. They see diversity of actors in functional and geographical terms not as a barrier to international technology transfer but, rather, as an asset:

> *“Each actor has specific strengths and constraints and thus has a complementary role in the overall frame, and the complexities and scale of the problem far exceed the capabilities and resources of singular*

> *stakeholders. Cooperative alliances for technology innovation and implementation are resource-efficient (as they capitalize on resources from multiple agents), build capacities of engaging partners (through cross-fertilization and coevolution), maximize value-creation and appropriation in due course, and can result in better SD {Sustainable Development} outcomes (by representing divergent interests and managing trade-offs" (Pandey, Connick, Sagar (2021: 15).*

On a more conceptual level, one could argue that creating a green innovation ecosystem in developing countries and emerging economies is not a linear process and that diversity of support is a necessary feature. Successful innovations in developing countries, like the mobile payment system M-Pesa, developed in Kenya around 2005, are usually not the outcome of a coherent long-term strategy with different actors working together in a planned way. They always have elements of luck and chance.

A more substantive issue is that most actors and lines of support in the field of (green) innovations focus on the outputs and possible outcomes of green innovation processes, e.g. the implementation of energy efficient modes of transport or production or the diffusion of fuel-saving improved cooking stoves. Much less attention is being paid to strengthening the capacities of developing countries to develop own innovative solutions to sustainability issues and being able to actively take advantage of GWO. As we saw, less than 6% of concessional development finance is assigned to the field of promoting research for development. And from this, only a fraction goes to strengthening innovative capacities and national innovation systems. Among bilateral donors mainly Sweden, Canada are clearly committed to promoting *research and innovation systems* in the partner countries, others like UK and Germany are supporting qualification of researchers from developing countries and their exchange with their peers in Europe.

Focusing on outputs and outcomes of green innovation processes is understandable considering the time pressure under which the global sustainability transition must happen, as the world is transgressing and approaching several of the planetary boundaries (Rockström et al.2009). However, there are direct correlations between the abilities of societies to adopt and adapt green technologies and the level of development of innovative capacities on the ground. Many authors writing on the fate of technology transfer processes assign a very important role to host country policies and efforts, mainly in building local technological capabilities / absorptive capacity and creating a conducive framework and a good balance between competition and collaboration.

5.1 Promoting sustainability-oriented innovation systems in developing countries

Many green innovations must be adapted to local conditions, in order to be effective and fulfil their economic, social and ecological functions. One important example are utility scale renewable energy projects, such as solar and wind farm. They cannot be bought "off the shelf" but require in-situ activities to ensure that the technology is compatible with local conditions. They must be adapted to the geography of the specific sites, solar radiation, wind speed and in the case of biomass, to the specific fuels used (Bjarne et al. 2018: 560). The better the local research capacities, the faster and more cost-efficient can these activities be carried out. If important elements of these complementary activities must be carried out by international experts, the costs will increase significantly, and implementation times will be longer. Thus, from a mere sustainability transition perspective, a higher level of domestic innovation capabilities in Low and Middle Income Countries is very important.

In addition, from a sustainable development which combines economic, social and ecological dimensions it is important that developing countries benefit from green growth and can take advantage of GWO. This additionally emphasizes the need to interiorize as large parts as possible of value addition in innovative green projects – and not only the low-tech and standardized elements.

Technological learning is a cumulative process. Successful implementation of knowledge-intensive and innovative projects provides the basis for learning processes and, thus, of further technological upgrading. In addition, whether a country can use trade as a vehicle for technological upgrading largely depends on local capabilities to understand how imported items work, either by mere observation of by more complex processes of reverse engineering, which have been used successfully in important technological catch-up processes of the past:

> *"The basis for the Korean model was the use of rigid policies to achieve a process of technological accumulation through imitation and the use of reverse engineering." (Quiero 2021: 33)*

As with technology transfer through trade, similar functional relations can be found for FDI as a very important channel of technology transfer. In his influential paper, Kamal (2002) concludes:

> *"Several studies (both theoretical and empirical) indicate that absorptive capacity in the host country is crucial for obtaining significant benefits from FDI. Without adequate human capital or investments in R&D, spillovers from FDI may simply be infeasible. In fact, this may be the most robust finding of the literature discussed in the paper." (Kamal 2002: 39).*

The conducive national framework for a strategy to maximize technology transfer and local adoption of technological knowledge can be captured by the concept of national innovation system, as it captures the core complementarities required for a significant number of successful green innovations emerging in a developing country. Innovation research during past 40 years has shown, that innovations develop in the form of a "chain-linked" model (Kline / Rosenberg 1986) and with important public-private interactions in each of the links of the chain. This is the basic concept of the National Innovation System Approach (NIS) as framed by Lundvall (1992).

Foxon et al. (2005), Stamm et al. (2008) and Altenburg / Pegels (2012) analyze the specificities of innovation systems that are geared towards the normative approach of contributing to the sustainability transition. While the basic features of sustainability-oriented innovation systems (SoIS) are mainly the same as in conventional NIS, SoIS have same specific characteristics:

- They often operate under conditions of ***market failures***, because environmental costs are still not (fully) internalized and green technologies might economically not be feasible, relying exclusively on market force. Financing new green technologies is a challenge, mainly at the "Valley of Death", when a technological invention leaves the labs and substantive funding must be mobilized for demonstration and pre-commercial projects (Etzkowitz 2006: 314). Today, many complementarities in NIS may be partially mobilized through international cooperation, like international climate finance substituting financing by national banks.

- Often, a green innovation cannot unfold on a white map ***but must compete successfully against incumbent technologies***. This is not only a challenge for techno-economic reasons, but often also for reasons of political economy. Incumbent technologies often have well-established and strong strategic interest groups on their side, while alternative, green technologies might not have a significant political backing in the beginning.
- SoIS operate under conditions of high ***time pressure and high degrees of uncertainty***. Many countries have committed to become carbon neutral in the next two to three decades, which implies serious technological challenges (see the case of the global green hydrogen economy in textbox 1). This implies that green technologies must be made technological mature and rolled out on large scale in a much shorter time than has been the case in economic history. For instance, the principle of operation of the steam engine were well-known in England and France around the year 1700, but it took more than 120 years, before they were first used for the propulsion of ships and locomotives and still several decades longer until they became a major driver of the industrial revolution.

Considering the strategic importance of green innovations to assure a safe operating space for humanity (Rockström et al. 2009) there is time for a *paradigm shift in international cooperation* from the support of single green innovations (be it fuel-saving cooking stoves, be it hydrogen-powered busses) to a determined international action to assist developing countries in the building up and strengthening of their SoIS. Here we agree with Pandey/Coninck/Sagar (2021) who propose to replace the term of "international technology transfer" with "innovation cooperation", in order to cover the whole cycle from development of a technology to its implementation, and the involved actors. Cooperation is also seen as a more appropriate term compared to "transfer", as all partners are working together for common objectives and that achieving sustainable development requires mutual efforts. Hultman et al. (2016) also stress the needs to come to international partnerships and to follow creative approaches to tackle the challenges of the required sustainability transition by developing and rolling out green technologies.

Most elements of such a systemic international cooperation are well-known and often applied by governments, private and third sector, but most often fragmented and not consistent over time. The core of such a cooperation must be, supporting countries of the Gloal South in developing their own strategy for establishing an innovation system which empowers them to contribute to global climate efforts, and to tackle additional sustainability challenges. Based on such a strategy and a related gap analysis, international actors may decide, for instance, to contribute to human resource development (technical and vocational training, higher education), physical research infrastructure and incubators for innovative "green" start-ups, linking mechanisms between research and businesses or financing mechanisms for green innovations. Following the OECD principles of aid and development effectiveness, national governments of the host countries must coordinate the contributions.

5.2 Towards a more partnership-oriented approach to green innovations

The relationships between making green innovations work for the sustainability transition on the one hand, and empowering developing countries to take advantage of GWO is complex and not always reflected appropriately in current literature. Considering the urgency to shift global production and consumption patterns towards a future-proof, climate-smart and resilient future definitely calls for global efforts to accelerate the development and deployment of green technologies under the philosophy of common contributions to common goods (see Pandey, Connick, Sagar 2021). The groundbreaking work of the Intergovernmental Panel on Climate Change (IPCC) might serve as a role model for such an approach, even if it has been criticized that IPCC's governance could not avoid certain North-South divide in knowledge management and that developing countries views and priorities have not been considered equitably (Blicharska, Malgorzata et al. 2017, Stamm 2022). A global partnership is also the main philosophy of the Paris Agreement of 2015 and the Sustainable Development Goals (SDGs), especially SDG 17 "Partnership for the Goals". As Paris Agreement and SDGs have been approved by nearly all governments, this should also be a guiding principle for public promotion of green innovations, by politics and funding.

A general focus on partnership and common goods orientation does not mean absence of conflicting views and diverging interests. This can be shown by the current discussion about a global transition towards a "green hydrogen economy". The recent debate about the EU energy "taxonomy" made clear that countries have different views on what a clean energy as the basis for a green hydrogen production should be. For Germany, the term "clean energy" should be exclusively reserved for renewables (wind, solar), while France opted for an inclusion of nuclear energy among the clean energy sources.

More fundamental in the context of North-South relations is the fact that there are clear tensions between public and private goods and between national and global interests. Green innovations are often the outcome of significant R&D investments by private actors who strive to protect their intellectual property through patents and link its usage by third parties to the payment of royalties. National societies hosting inventors and innovators expect social benefits, e.g. in the form of employment. This contradicts the rapid and widespread diffusion of innovations, for example, to reduce emissions and save energy, necessary to protect the environmental fundaments for the survival of future generations.

The calls for cooperative and partnership approaches to green technology development make a lot of sense for the reasons explained but it has to be factored in that private and national interest shape international cooperation for green innovations. It is more the case as the green transformations implies not only GWO, but also disruptive changes and tensions for many societies, e.g. loss of employment in fossil fuel sectors or rising prices for energy and mobility. Under such conditions policy makers, in the search for keeping legitimacy and ownership for the green transformation will be keen to assure that national companies can benefit from emerging GWO and employment will be built up at home. International and national governance of green innovation has to be able to deal with these tensions.

5.3 Shifting research for green innovations from the national to the multilateral level

By far the largest parts of global STI efforts are governed at the national level. This means that agendas and priorities of research are defined by national stakeholders, financing comes from public and private sources of the country, and in most cases, national companies and societal groups are first addressed when it comes to designing pathways to impact (Stamm, Figueroa, Scordato 2012). To some extent, research and innovation have been reluctant to follow the train towards globalization. We have to include into the analysis the fact, that there still is a huge North-South divide in STI performance (see 2.1) and that to some extent the countries which are especially affected by climate change and other environmental crises (e.g. depleted fish stocks, loss of biodiversity) are those that have least resources available for STI. A structural problem has to be identified, which starts with the identification of the STI agenda and priorities. Countries with different levels of socio-economic development and ecological conditions necessarily will set diverse priorities in their R&D agenda and priority setting. Pardey et al. observe, for instance, that in high-income countries, R&D in the agricultural sector declines, reflecting the fact that availability of food is no longer an issue and overall consumption patterns are changing towards processed food and eating out. Middle income countries face very different challenges in the food sector, such as swelling populations and an increase in prosperity. They focus, thus, aggressively on R&D to increase agricultural productivity (Pardey et. al 2016). While much energy research focusses on decarbonizing grid-connected energy systems in industrialized countries (which is good from a global common goods perspective), very little is done, for instance, to develop easy to roll out mini grids, fed by renewable energies, which is a topic mainly relevant for Low Income Countries in Africa and Southern Asia. In the current green hydrogen debate the main focus is on hydrogen to decarbonize the steel industry, while a developing countries' perspective would, most likely, focus on using green hydrogen to produce clean ammonium and, thus, green nitrogen fertilizer, to avoid an extended food security crisis.

Shifting research for green innovations from the national to the multilateral level could be an important step forward. The CGIAR (see 3.1.4) could serve as an important role model. Internationally financed, located mainly in developing countries intensively embedded in multi-stakeholder network and with a clear common goods approach the group has proven to contribute to innovative solutions for a climate-smart, innovative and socially inclusive agriculture. International organizations and donors could replicate the CGIAR model in adaptive ways to other sectors, in order to shift research towards the needs and conditions of developing countries. What would require a closer analysis is, whether multilateral research should cover the whole STI value chain. One approach could be bringing research and development close to technology maturity and inviting private companies to take care of a rapid deployment. An alternative would be to focus much more on earlystage research and bring a technological concept to the laboratory stage and perhaps early demonstration projects. Both approaches make sense, but would require differing institutional set-ups and funding.

What could be conceptualized as an element of modern modes of multilateral research are open innovations. The research questions developed and intermediate results could be made available to international experts and epistemic communities, inviting them to contribute to finding the best solutions in the shortest time possible.

What would be important is to combine the strength of multilateral and publicly funded research with the creativity and endeavors of the private sector. The outputs of the multilateral R&D efforts could be made available to interested stakeholders who commit to bringing them to societal practice in short time.

5.4 Multilateral approaches to technology assessment

Technology Assessment (TA) is a well-established inter-disciplinary methodology for assessing opportunities and risks of new technologies. To date is has been applied nearly exclusively in the Global North and often with a rather skeptical or concerned attitude towards technologies, with possibly far-reaching impacts, for instance of using nuclear energy for generating electricity. Many technologies, however, have important potentials, may have both positive and negative consequences, depending how their progress is framed and which accompanying measures are taken. Artificial intelligence in agriculture, for instance, may empower farmers in developing countries to radically reduce applications of fertilizer and pesticides through precision IT-enabled farming. Or it can lead to the loss of jobs for agricultural workers (often women), when IT-powered robots are applied in harvesting of fruits and vegetables (Stamm 2022). How technologies are assessed regarding their opportunities and risks is often related to the specific value systems of a society and the challenges it faces. One example is CRISPR-CAS, a new technology for using genome editing in agriculture and medicine with potentially good impacts in food security but a series of risks and ethical issues involved. A 2018 ruling by the EU court of justice made progress in Genome Editing technologies depending on bureaucratic procedures and, thus, slowed down the innovation processes. Thus, a decision based on normative considerations from one world region potentially has significant global impact (Stamm 2022).

There is, currently, no institution which would allow that new technologies are assessed based on the challenges, which the different world regions face and weigh opportunities and risks based on a global discourse. UNCTAD-CSTD is currently carrying out a pilot projects involving three African countries with the objective to build up capacities for technology assessment in Africa. Based on the outcomes of this project, a discussion could be started, how developing countries can be systematically supported in their capacities to implement TA. In addition, it could be discussed, how to assess new technologies on the multilateral level, bundling international expert knowledge to answer questions that – due their complexity - cannot be dealt with at the level of nation states. Artificial intelligence in agriculture or gene editing technologies (e.g. CRISP CAS9) could be mentioned as examples (Stamm 2022).

5.5 Support South-south STI cooperation for green innovations

South-South cooperation in STI is still incipient (see above). This implies a loss of opportunities to tackle climate and other environmental challenges, which are often similar across countries in a certain region, e.g. sea level rising in the Caribbean or changing precipitation patterns in large parts of Sub-Sahara-Africa. In addition, regional approaches to green innovation may improve the possibility to make use of opening GWO. Relatively small and poor countries may not provide a sufficiently interesting home market to attract FDI in green technologies and/or build up an own manufacturing of related items. There are, however, good reasons, why regional STI cooperation in developing regions have had difficulties to "take off". International cooperation should provide solid incentives to overcome cooperation barriers, e.g. by supporting regional centers of excellence for green technologies and innovation. Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) and West African Science Service Centre on Climate Change and Adapted Land Use could mentioned as possible examples.

5.6 A multilateral challenge fund "Innovations for Our Common Future"

Our recommendations in sub-chapter 1 focus on strengthening sustainability-oriented innovation (SoIS) systems in developing countries. It would, however, be short-sighted to see innovation systems as stable structures over time. Rather, successful innovation systems create multiple incentives for companies and entrepreneurs to develop their own ideas and transfer them to practice. Business Plan competitions or competition-based incentives for regional networks of innovation actors (e.g. "Hydrogen valleys" in Europe, USA, Chile etc.) are just two of such incentives, implemented in many industrialized countries. They bring dynamism to the business sectors of their countries and, thus, also change the configuration of the innovation systems. Most developing countries lack the financial resource and partly also the management capacities of their public administrations to develop similar challenges. In addition, in the spirit of this chapter, innovation challenges should best be implemented, not on the national level, but internationally.

We propose to develop and launch a multilateral challenge fund „Innovations for our common future". The proposed name deliberately refers to the 1987 report of the World Commission on Environment and Development (WCED), also known as the Brundtland Commission. „Our Common Future" placed environmental issues firmly on the political agenda; it aimed to discuss the environment and development as one single issue. The report coined the definition of sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The challenge fund would have to be endowed with financial means from international organizations (e.g. GEF), donors and international philanthropy. The objective of this challenge fund would be to mobilize, at the international level, creative thinking and innovations to find responses to the multiple global challenges the world is facing. It could work with an own governance mechanism, with, for instance, UNCTAD having the secretariat function. It might be framed similar to the Intergovernmental Panel on Climate Change (IPCC) with its own executive committee, technical support units and with a secretariat hosted by World Metrological Organization (WMO).

The concrete design of such a global green innovation competition would have to be developed in a next step. It could draw, for instance, on the experience and expertise of international donors, which have worked on research for sustainable development and/or on strengthening research and innovation systems in developing countries, e.g. the Canadian IDRC. The rules of "Innovation for Our Common Future" should be such, that both North-South and South-South STI cooperation for green innovations would be core elements to be positively assessed. The outcomes of the challenges could be either open innovations or protected intellectual property, this would have to be discussed and defined.

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