Joint Workshop

of the
Secretariat of the United Nations Conference on Trade and Development
and the
International Rubber Study Group
on

Rubber and the Environment.

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Preface

This, the second joint UNCTAD/IRSG Workshop on the internalization of environmental costs of rubber, follows directly from that held at the 101st Group Meeting of the IRSG in Liverpool, UK, in June 1997.

UNCTAD has concluded that natural rubber stands to gain from internalization of environmental costs in the entire rubber industry. The economic variables prevailing in the natural rubber market favour internalization: the supply elasticity is below unity, and the price elasticity for demand is estimated to be significantly less than one. Furthermore, the 70% international market share of Thailand, Indonesia and Malaysia is coupled with intermediate export dependence as rubber accounts for only 3.5 % of their total exports. Unilateral attempts to pass on environmental cost increases appear feasible, although concerted action among the three main producers is desirable and cooperation with producers and manufacturers of synthetic rubber is necessary.

The elastomer market is dominated by renewable natural rubber and non-renewable fossil-fuel-derived synthetic rubber: in some applications they are substitutes and in others, complements. Tyre production accounts for over 50% of elastomer consumption and 60% of natural rubber consumption. The current share of natural rubber in total tyre production is unlikely to change much. Rubber cannot realistically be replaced in tyre production, nor can tyres themselves be replaced by a different product. Many general rubber products also appear very difficult to displace or replace.

Phase 1 of UNCTAD’s programme on internalization prospects in the rubber economy emphasizes identification and measurement of malign and benign environmental effects in the production, manufacturing, and consumption of synthetic *vs* natural rubber to demarcate and appraise environmental costs and benefits. Phase 2 will explore the applicability of various internalization instruments at the country and regional level, considering the scope and the best ways for reflecting internalized environmental costs in international rubber prices. Phase 3 will focus on capacity-building to implement full-cost pricing in countries that may want to make progress. The UNCTAD/IRSG Workshops provide the opportunity to inform and involve producers, manufacturers, traders and consumers of natural and synthetic rubber and enhance transparency among all market agents.

The Liverpool meeting considered generally the internalization of environmental costs, and concluded that the two most important areas of concern were those to be addressed in the present Workshop: (i) scrap tyre disposal and recycling; (ii) the opportunities for and likelihood of international payments for carbon sequestration services to natural rubber producers (ie carbon off-set financing) in the context of global warming. It was agreed to continue the joint Workshops as part of the ongoing investigation by UNCTAD of the factors affecting environmental aspects of commodities.

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Introduction

Dr Ulrich Hoffmann:

Ladies and gentlemen, welcome to this Joint UNCATD/IRSG Workshop on Rubber and the Environment. Most of you will, I suppose, recall that we had the first Workshop last year. At that Workshop we touched upon the general issues of internalization, in particular the opportunities that might arise, but also some of the hurdles that might have to be surmounted or bypassed. I will not try to summarize those discussions last year in Liverpool, which have been published in full by the Secretariat of the International Rubber Study Group, but I would like to refer you to the information leaflet issued with the application form for this Workshop. This summarizes last year's discussion and the points made.

As was suggested at last year's Workshop, we will take the opportunity here in Indonesia to dwell at more length on two specific aspects of the cycle of rubber products. These two problems were regarded as particularly valuable for a further in-depth analysis of the pros and cons of internalization or, in other words, the use of economic instruments for giving the right signals to producers, traders and consumers. Our discussions will fall into two parts. In the first part we will deal with aspects of internalization of scrap tyre management. We have the pleasure of listening first to a paper on the North American experiences and the lessons that can be learned from them, and in the second paper the same theme from the Malaysian point of view. In the second part, we will turn our attention to the opportunities and constraints which might arise from international payments remunerating carbon dioxide sequestration services provided by rubber manufacturers to reduce Greenhouse Gas Emissions and therefore combat climate change.

Internalization of Scrap Tire Management Costs: A Review of the North American Experience

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Introduction

The pneumatic tire is one of the most common items in the contemporary world. More than 800 million new tires are produced annually, in every region of the world, in a dizzying array of sizes and types, to serve an equally dazzling multiplicity of users on vehicles of every kind and description. More important for our discussion, however, is the countervailing fact that virtually an identical number is removed from service after reaching the end of their useful life as tires. As more and more tires are put into use around the world, so more and more tires are scrapped. Many countries are confronting the problems posed by scrap tires, and are seeking to identify useful economic and regulatory techniques for managing these tires. The main purpose of this paper is to provide examples from the United States and Canada of regulatory and economic instruments, and management and marketing systems that have been used for end of life management of scrap tires.

In economic terms, a waste material can be defined as any discarded material that has negative value: its disposal or reuse costs money. At present, in most of the world, a basic fact of life about scrap tires is that they are a waste material in this economic sense; that is, it costs money to have them removed from the point of generation to a location for processing, use, or disposal. Even though there may be some markets that will value scrap tires positively, this value may not be enough to transport the scrap tire to that market. In addition to these direct management costs, scrap tires can also generate indirect social costs through the consequences of their manner of use. As a result, a major consideration in discussing scrap tire management is the question of who should bear these costs, and how should they be allocated? A fairly pervasive answer, at least with respect to the direct management costs, appears to be that they should be borne by the parties that receive the direct economic benefit from consuming the value of the tire as a tire. These costs then should be internalized to tire ownership and consumption. North American jurisdictions have utilized several different models for this cost internalization and they will be reviewed later in paper.

In addition to discussing these different models for cost internalization, there are also different regulatory and market development techniques that various jurisdictions use to promote ensure disposal and promote positive markets. A discussion will also be provided of the criteria that jurisdictions have used to evaluate both their scrap tire problems and the suitability of various management options.

As an introduction to the US and Canadian scrap tire systems, current generation levels for scrap tires and the various markets that utilize scrap tires will be discussed.

Recycling old tires into new ones

One question that usually needs to be addressed when discussing utilization of scrap tires is why scrap tires are not recycled into new tires, in the same way that scrap paper or metals can be recycled into new paper and metal.

The pneumatic tire is a remarkably elegant device superbly designed to accomplish its main purpose: to work in concert with a wheel to contain the air that supports the weight of the vehicle on which it is mounted. In addition to carrying the vehicle's weight, the tire must transmit various forces that allow the vehicle to accelerate, turn and stop. The tire is a complex composite of many materials including natural and synthetic rubber; reinforcing fabrics, typically polyester, nylon, aramid, or steel; steel wire woven into reinforcing tread belts and beads; carbon black and silica reinforcing and filling agents; and various chemicals, oils and additives that aid in the curing process, help the tire resist oxidation, or serve some other useful purpose in the tire.

Complex physics, chemistry and engineering are used to design and construct the outwardly simple-appearing tire. The process of vulcanization, discovered y Charles Goodyear in 1842, allows rubber to become temperature stable and sets the tire's permanent shape. While making rubber a temperature-stable, thermoset material, vulcanization also modifies the rubber in such a way that it cannot be routinely returned to a virgin state. Because of the inability to return vulcanized rubber to virgin state, it cannot be utilized in new tire construction in place of virgin materials. As a result, its use in new tire manufacture is extremely limited, especially in contemporary radial tires. While research efforts are underway to increase the utilization of recycled rubber in new tires, and at least two U.S. manufacturers have publicly announced that they have original-equipment-qualified tires with recycled content of at least 5%, it will likely be several years before there are significantly greater levels of routine use in new tire manufacture.

About the Scrap Tire Management Council

The Scrap Tire Management Council was established by the Tire Division of the Rubber Manufactures Association in 1990 as the cornerstone of industry efforts to assist in meeting the challenges of scrap tires. The mission of the Council is to assist in promoting scrap tires as a valuable commodity in all ways that are economically and environmentally sound. Its main activity is in the area of market development, where it seeks to expand all sound markets for the utilization of scrap tires and scrap tire-derived materials. It also works to collect and disseminate information on scrap tires, to conduct research necessary to fill in gaps in existing knowledge about scrap tires, to work with legislative and regulatory agencies to develop appropriate laws and regulations dealing with scrap tires, and to maintain liaison with all parties interested and concerned about scrap tires. Its goals are to expand scrap tire markets to consume as many tires as possible, to promote the sound management of all newly generated scrap tires and to promote the remediation of scrap tire in as soon a time period as is practical.

The Council does not represent nor have any vested interest in any product derived from scrap tires or used in the processing of scrap tires. The Scrap Tire Management

Council promotes the concept that scrap tires can be a resource that can be used in a wide array of applications.

Magnitude of scrap tyre volumes in US and Canada

Calculating scrap tire generation rates

The methods used to calculate scrap tire generation rates in the United States and Canada are similar to methods used elsewhere in the world. Scrap tires are generated either when new replacement tires are purchased, or when the vehicle is scrapped.

In the United States, scrap tire generation rates have usually been given in terms of individual tire units. Only occasionally have those units been translated either into 'passenger tire equivalents' at the rate of 20lbs per passenger tire, or translated into total weight. Market utilization figures also generally use a simple calculation of units. For 1997, an estimated 270 million scrap tires were generated in the United States. Canada has similar experience and in 1997 generated approximately 25 million scrap tires.

The majority of the scrap tires that have markets are passenger, light truck and bias ply truck tires. The majority of medium and heavy truck radial tires, off-road tires and agricultural tires are only slowly coming into market applications.

The differential between the percentage of the total number of scrap tires generated *versus* the weight of those tires, are set forth in the following table.

Tire generation/weight differential

Type of tire	Percentage of units in the market	Percentage of total weight
Passenger/Light truck	84	65
Medium/Heavy truck	15	20
All other tires	1	15

In practice, many worn tires initially removed from vehicles continue to be used as tires. There are extensive national and international markets for used tires and for sound casings that are retreaded and returned to service. The retread market is especially strong in the medium truck market segment. Light truck retread markets are also expanding. With the used tire and retreaded tire markets, the assumption is that for each used or retreaded tire put into service, there is another tire which goes to the scrap pile. Ultimately, however, tires diverted to the used tire or retread market do end up in the scrap stream, and it is assumed there is a tire going to the scrap stream when the retreaded or reused tire is mounted. Thus, the replacement tire market figure remains the best estimate of the volume of discarded tires.

Individual state generation estimates range from less than 700,000 per year in less populated areas such as North Dakota and Wyoming, to more that 30 million per year in California.

Scrap Tire Generation, units

	1990	1997
Passenger replacement	152,251,000	179,487,000
Light truck replacement	22,832,000	28,035,000
Medium, wide-base, heavy and large off-the-road	10,687,000	11,908,000
Farm	1,549,000	2,460,000
Tires from scrapped vehicles	44,296,000	48,076,000
Total scrapped tires	231,615,000	269,966,000
US population	248,718,301	267,100,000
Rate of scrappage	0.93 per person	1.00 per person

Figures from *Tire Industry Facts, 1997*, published by the Rubber Manufacturers Association and from *Statistical Abstract of the United States*, published by the U.S. Department of Commerce

Scrap tires stockpiles

In the United States and Canada, there are actually two separate but interrelated scrap tire management issues: the first is dealing with newly generated scrap tires; the second is dealing with legal and illegal stockpiles of tires which are the residue of past (and some current) methods of handling scrap tires.

Stockpiles were created as a means of disposing of tires outside the normal landfill destination for most solid waste. In some locations, many tires went to landfills, and some states still allow the practice, at least for shredded or cut tires. Stockpiles were an alternate disposal option. Stockpile operators thought they were collecting 'black gold,' that the stockpiles contained highly valuable potential energy that would someday be of great value. With the threat to oil availability and rising oil prices in the 1970's and 1980's, many operators though they would eventually be wealthy. In the meantime, tip fees collected for the dumped tires provided a current income. Stockpiles also resulted from cost avoidance: where landfills sought to exclude tires, the tire jockeys found other, illegal and cost-free sites to deposit tires. Out of the way ravines and woods became the sites of illegal dumping, often without the property owner's knowledge. In time these illegal dumps could contain upwards of several thousand tires each.

Based on surveys taken by the Scrap Tire Management Council, it is estimated that US tire stockpiles contain between 700–800 million scrap tires.

Individual state estimates of the volume of stockpiled tires in their borders range from 100,000 in Minnesota to 100,000,000 in Ohio. Individual stockpile size also varies considerably. Although the largest single stockpile is estimated to contain up to 60 million tires, only 17 states report their largest stockpile contains at least 1 million tires, and only one other state, Texas, reports its largest stockpile exceeds 10 million tires. By far the largest number of stockpiles contain fewer than 100,000 tires each.

While better counting has reduced the estimated number of stockpiled tires, they continue to represent a major challenge to the ultimate goal of developing sound markets for all scrap tires.

Remediating scrap tire stockpiles

Efforts to remediate stockpiles must consider two special problems. The first is that stockpiled tires have limited uses because of the possibility for contamination from other materials dumped on the tire stockpile or just from environmental exposure. The second problem is that flows of tires from stockpile remediation can disrupt the markets for scrap tire flows from the annual generation stream. Both must be considered in dealing with stockpile clean up.

Some states have made substantial progress in abating scrap tire stockpiles, including Illinois, Wisconsin, Minnesota, Maryland, Florida and Virginia, among others. Some of these states, including Illinois, Maryland and Florida, have had success in feeding these stockpiled tires into the market flow without adversely affecting markets for current generation tires. Illinois, for example, has created market capacity for around 120% of annual generation. The development of market capacity is also the key to the success Maryland and Florida have had.

Should any state begin clean-up of stockpiles before substantial markets have been developed, one result is that tires from stockpiles could displace the current flow tires. In turn, those tires will be going to landfills (if allowed) or to stockpiles.

Principal markets for scrap tires: types and volumes

In the United States and in Canada there continue to be recognized three major markets for scrap tires: tire-derived fuel (TDF), products that contain recyclable rubber, and civil engineering applications. There are three lesser uses for scrap tires – export, agricultural and other miscellaneous uses – which do not fall into the preceding three market areas.

Markets for scrap tires, 1994–1998, in millions

	1998 (est.)	1996	1994
Energy	140	152.5	101
Civil engineering	18	10	9
Ground rubber	12	12.5	4.5
Fabricated products	8	8	8
Export	15	15	12.5
Agriculture, misc.	3.5	4.0	3.5
Retread	31.1	32.5	33.0

Tire-derived fuel

Since 1985, TDF has been the largest single market segment for scrap tires in the United States. Markets have grown from around 24.5 million units in 1990 to an estimated 140 million units in 1998. There has been some ebb and flow in this market as new users come into the market and others depart for a variety of reasons. There are nine specific components to the TDF market:

cement kilns,
pulp and paper mill boilers,
utility boilers,
industrial boilers,
dedicated scrap-tire-to-energy facilities,
municipal waste-to-energy facilities,
copper smelters,
iron cupola foundries, and
limekilns.

Each of these combustion technologies has its own set of engineering considerations and fuel requirements. The technical issues involved with each of these market sectors fall outside the scope of this report. However, information on this topic was reported in the 1990 and 1992 Market Surveys, which can be obtained from the Scrap Tire Management Council (STMC).

In general, two methods of using tires as fuel are employed in the United States: whole tires and processed tire-derived fuel. Whole tires are used in cement kilns and dedicated scrap-tire-to-energy facilities. Approximately 60 percent of the tires going to cement kilns are whole tires. There are two dedicated scrap-tire-to-energy facilities: one only accepts whole tires while the other can accept both whole or processed tires. All other fuel markets use processed (cut or shredded) tire-derived fuel, normally referred to as TDF. TDF sizes range from a 3"x3" chip to a one-inch minus chip, with 95+ percent of all steel removed.

The markets for all forms of TDF have generally increased in the period of 1985–1998. While there has been some recent slippage, the STMC is projecting a turn-around with continued increases in this market segment.

Environmental considerations

All facilities seeking to utilize tires or TDF as a supplemental fuel must first secure a revised permit from the appropriate state or provincial air-permitting authorities. This can be an arduous process, involving extensive emissions testing, public hearings, and other permitting requirements. Basically, the facility must demonstrate that the use of tires will not cause emissions of regulated pollutants in excess of its current permit levels. The fact that tire fuel-using facilities have been permitted in at least 34 states and several Canadian provinces illustrates that tires can meet these requirements. On occasion in Canada, provincial governments have decided, as a policy issue, that they will not allow tire fuel use. This occurred in Ontario for several years, although not currently, and presently in Nova Scotia and the other Maritime Provinces. No US state has by policy refused to grant permits for use of tire derived fuel.

Scrap tire fuel in cement kilns

Cement kiln use of scrap tires as a supplemental fuel is a dynamic market. Currently, 35 cement kilns are using TDF in the United States and Canada, with another 20 kilns in some phase of the planning and permitting process, and could be using TDF within the next two years. The outlook suggests that the use of TDF as a supplemental fuel will very likely continue to increase. Kilns currently using scrap tires have individual permitted volume capacities ranging from 250,000 to three million scrap tires per year. The driving forces behind the current and anticipated use of TDF are: improved emissions; increased production; and decreased fuel costs.

Scrap tire fuel in limekilns

The use of scrap tires as a supplemental fuel in limekilns is a new market niche for tire derived fuel. Lime kilns, like their cousins, cement kilns, are an energy intensive process. At the present time, one limekiln is using TDF on a production basis, and consumes around 10,000 tons of TDF annually, or around 1 million tires. Three other limekilns are currently testing TDF or are in the permitting process.

Scrap tire fuel in pulp and paper mill boilers

Tire-derived fuel can be used as supplemental fuel in pulp and paper mill boilers, usually stoker grate units using wood waste as their primary fuels. The technology is proven and has been in continuous use in the US since the early 1980's and was the earliest known use of TDF in the US. Consumption of TDF in the US pulp and paper mills has almost tripled since the mid-1980's to approximately 35 million tires per year. There are currently 19 mills known to be using TDF on a continuous basis. Mills use TDF to decrease total fuel costs, to improve emissions and improve combustion efficiency.

Scrap tire fuel in electricity generating facilities and industrial applications

Three types of facilities are covered by this category: large-scale utility boilers, industrial boilers, and resource recovery facilities. TDF is used as a supplemental fuel, usually not exceeding 10 percent of the total fuel mix.

Utility boilers: In the utility market, the use of TDF in wet bottom, cyclone, stoker, and fluidized bed boilers is proven. Currently at least 15 utility power plants use TDF. Three utilities are close to starting up on TDF and another three utilities are seriously considering TDF.

Industrial boilers: Ten industrial power plants are currently using TDF.

Municipal waste-to-energy facilities: Approximately 13 facilities, which combust municipal solid waste to generate electricity, are currently using TDF on a regular basis.

TDF use in these combined markets decreases fuel costs, improves emissions and improves combustion efficiencies. Currently these combined markets consume around 70 million scrap tire per year, a figure that could grow to 85 million scrap tires within three years.

Scrap tire fuel in other industrial applications

Three other types of combustion facilities have been approved to use TDF. They are iron cupola foundries, copper smelters, and rock wool plants. While these new TDF markets currently only involve a few facilities, they do represent a significant potential end-use market.

Scrap tire fuel in dedicated tire-to-energy facilities

Only two US facilities use tires as their only fuel to produce electricity, the Modesto Energy Limited Partnership (MELP) in California and the Exeter Energy Project (EEP) in Connecticut. A third facility, the Chewton Glen facility built in Ford Heights, IL (outside Chicago), is shut down and has filed for bankruptcy. The development of any other large-scale, dedicated scrap tire-to-energy facility appears to be unlikely due to the high cost of such facilities and the pending deregulation of the utility industry. Deregulation will result in downward pressure on rates utilities pay for electricity, and will be especially hard for facilities using alternative fuel sources that have traditionally enjoyed preferential rate treatment. Current tire usage at these two operating facilities is around 15 million tires annually. This could be reduced to 10 million per year if MELP is forced to close.

Scrap tires in civil engineering applications

The civil engineering market encompasses a wide range of uses for scrap tire-derived material where it is used to replace some other material currently used in construction (*eg*, dirt, clean fill, gravel, sand, *etc*). It is potentially a major market for scrap tires and one of the best fits for tires from pile clean-ups, as the presence of dirt on the tires is not usually a problem.

In order to be considered a beneficial use, the performance of the scrap tire-derived material should be equal or superior to the material it replaces, and/or should provide some additional advantage to the project, such as lower cost. In some cases, the advantage to the use of scrap tire-derived material might be only the avoidance of additional costs associated with other disposal options for scrap tires.

Each potential civil engineering use brings with it a particular set of technical, environmental and economic constraints that must be fully evaluated before the application is accepted. Civil engineering applications also encompass both small and large-scale projects, which makes their consideration particularly useful to persons seeking a wide range of uses. The potential usage of scrap tires in civil engineering applications is substantial, particularly if their use in federally aided highway construction is encouraged.

ASTM guidelines

A major difficulty in expanding this market is a general lack of published information about the physical characteristics of scrap tires as an engineering material. The American Society for Testing and Materials Committee D 34.15, at the urging of the STMC, has after three years work, published set of guidelines to fill this need. The *Guidelines for the Use of Scrap Tires in Civil Engineering Applications* are designated as *ASTM Document D 6270-98* and are now available for engineering professionals around the country and the world.

Tire-fill guidelines

The STMC was also instrumental in developing and promulgating a set of guidelines entitled *Design Guidelines to Minimize Internal Heating of Tire Shred Fills*. These guidelines are an outgrowth of three incidents where tires used in thick fills (greater than 6 meters in depth) experienced an exothermic heating reaction that destroyed the fills. The *Design Guidelines* limit tire-shred fills to 3 meters in depth and establish other design and construction criteria. These *Guidelines* have been issued by the US Federal Highway Administration for use in all states.

In 1998, with the thin-fill guidelines in place, scrap tire use in civil engineering applications should grow to around 18 million tires. Principal applications include landfill cover, leachate collection systems, road-bed fill, septic field leaching systems and road insulation material.

Reutilization for new product manufacture

Use of size-reduced rubber

The market for size-reduced rubber continues to grow, although not as rapidly as the ability to produce ground rubber. In recent years, new applications for ground rubber have been developed and other uses have expanded. In addition, the US auto industry, the largest market for new rubber products, has said it wants to see recycled rubber used as an ingredient in the new rubber parts it purchases. While it may be a few years before many parts containing a significant amount of recycled rubber are used in new cars, the rubber parts industry is developing and testing new compounds using ground rubber. This market has also seen an influx of new producers, greatly increasing the potential material supply. Unfortunately, the supply capacity continues to exceed the market demand, placing heavy pressure on prices. The overall market demand for size-reduced rubber was around 450 million pounds at the end of 1997. This compares with the 1992 market of 160 million pounds of size-reduced scrap tire rubber and the 1994 market volume of 240 million pounds.

Ground rubber comes from two principal sources: tire buffings and processed, whole, scrap tires or other rubber scrap. Of the total market volume of 450 million pounds generated, about 210 million pounds, or 47 percent is obtained from tire buffings. The balance of 240 million pounds, or 53 percent, was obtained primarily from whole scrap tires reduction. For the purposes of this report, we estimate that 12 million scrap tires are being reduced to ground rubber. No attempt is made to differentiate between buffing dust and scrap tire rubber in identifying markets, nor to differentiate between cryogenically produced or ambiently ground scrap-tire rubber. Scrap tire processing will be the source of most new ground rubber in the future as the supply of tire buffings, a by-product of the retread industry, will be limited by the slow overall growth of retreading.

There are six general categories of markets for ground rubber. The categories and the approximate volumes they consume are as follows:

Ground rubber market share, %

Bound rubber products:	10
New tire manufacturing:	20
Rubber modified asphalt (RMA):	42
Athletic and recreational applications:	17
Friction material:	2
Plastics/rubber composites	3
Molded & extruded parts:	6

Two new technologies may have an impact on the ground rubber industry: surface modification and devulcanization. Both attempt to deal with a basic problem encountered when trying to incorporate ground rubber into new rubber compounds: ground rubber is not a chemically active material.

While the longer-term outlook for the ground rubber segment suggests a more stable market, there does not appear to be any overwhelming market or technological breakthrough that will radically alter the market dynamics in the short-term. The industry forecast is for continue and sustained growth, perhaps 10–25 percent annually.

Canadian ground rubber production

Several Canadian provinces have a strong policy preference for production of ground rubber that can be recycled into new products. In Alberta and in the Maritime Provinces, ground rubber producers receive significant assistance both to produce and to market ground rubber produced from scrap tires, even if markets are relatively limited within the province.

Cut, stamped and punched rubber products

The process of cutting, punching or stamping products from scrap tire carcasses is one of the oldest methods of reuse of old tires. This market encompasses several dozen, if not hundreds, products, all of which take advantage of the toughness and durability of tire carcass material. The basic process uses the tire carcass as a raw material. Small parts are then die cut or stamped, or strips or other shapes are cut from the tires.

One limitation of this market is that it generally uses only bias-ply tires or fabric-bodied radial tires. As the number of bias-ply and fabric-bodied medium-truck tires being produced decline, it appears unlikely that this market segment will increase substantially. In the meantime, the value of scrap tires which can be used for cutting or stamping will likely increase slightly. Because of the demand in this market, virtually all of the scrap bias-ply, medium-truck tires that are collected by major truck casing dealers are finding their way to a cutting or stamping operation. This market is estimated to use eight million tires annually, or three-and-one-half percent of the market. This segment is expected to remain stagnant, since there is a limited number of bias ply tires.

Tire exports

Export of sound used tires and retreadable casings constitutes a major market for tires removed from initial service. Many tires initially removed from a vehicle are still sound and have adequate tread depth to be used as tires. In addition, many tires without proper tread are usable as candidate casings for retreading. Both categories of tires have ready markets both within the US and North America and in many other parts of the world and are regularly sold into these markets. Virtually all tire-producing countries also participate in this world trade in used tires. Used tires and casings exported from the United States are assumed not to return to the US for ultimate disposal. US exporters routinely ship more than one million units per month, or more than 18 million tires per year, based on the estimates of participants in those markets. This constitutes about five percent of the annual volume of discarded tires.

Tire retreading

The Council is a strong supporter of retreading. Retreading is most economical in North America in the medium truck segment. Data on the North American retread market is as follows:

1997 Retreading: North America

Total sales of retreaded tires:		30.9 million
Sales value:		More than $ 2 billion
Passenger tires		3.8 million
Light truck tires		7.8 million
Medium and heavy truck tires		18.7 million
Other		800 thousand
Aircraft, off-road, industrial/lift trucks, motorcycles, farm equipment		
Tread rubber used		More than 640 million pounds
Number of retread plants: North America		1,440

Source: Tire Retread Information Bureau

Having said that the Council is a strong supporter of retreading, it should also be explained that the Council does not consider retreading to be a market for waste or scrap tires. By definition, a waste or scrap tire is one that can no longer be used for its original intended purpose because of wear or damage. A retreadable tire on the other hand is capable of being used for its original intended purpose.

Instead of being viewed as a market for scrap tires, retreading is more properly the continued use of a tire. Manufacturers are under pressure from the trucking industry to provide ever-longer-lived tire casings. While it is possible to produce tire casings that have expected useful life spans approaching 500,000 miles, it is not possible to produce a 500,000-mile tread. Therefore, retreading such a casing is part of the intended pattern of use designed by the manufacturer. The retreadable casing is not a waste tire, but rather a middle-aged tire with much lifetime still to go. To suggest, as some observers have, that one of the 'solutions' to scrap tire problems is to retread more waste tires, is not really a solution at all. That casing will reach the end of its useful life and will then be a scrap tire. Until then, retreading is the process by which tire owners recover all of the economic value built into tires by manufacturers. There should be no need to subsidize what is already a positive economic process.

Scrap tire markets: conclusions

This section has presented information on the various markets for scrap tires. In general, there continue to be three major markets that form the basis of the demand for scrap tires. These markets are tire-derived fuel, products, and civil engineering applications. Also discussed were tire exports; additional markets not discussed include agricultural uses, thermal distillation (pyrolysis) and miscellaneous uses, which account for small volumes and limited growth potential.

Over the last several years there have been continuing growth in scrap tire markets. In 1990, 11 percent of the annually generated scrap tires had markets. In 1992, 38 percent of the annually generated scrap tires had markets. By the end of 1994, 55 percent of the annually generated scrap tires had markets, and by the end of 1995 some 69 percent of all the annually generated scrap tires had markets. By 1996 these markets had grown to around 75.9 percent, or 202 million of the 266 million scrap tires generated. While the markets have not enjoyed great growth in the past year or so, they have maintained this high level. The STMC is projecting renewed increases in all the major markets for scrap tires. While the factors which impact the markets suggest that the number of scrap tires with markets should continue to increase, it is unlikely that the market will sustain the same rate of increase it sustained over the last six years. With the presumption that there are no major disruptions to the market place, it is reasonable to conclude that by 2002, markets should consume all current flow scrap tires reasonable attainable.

The rationale for this assessment is that the majority of the readily available market, *ie*, potential fuel users, have already begun their use of TDF. While there are still a significant number of potential fuel users seriously considering or already in the permitting process, their numbers will not equal the new entrants to the TDF markets in the past two years. Furthermore, many of these potential fuel users are in states which have arduous permitting processes.

It is clear that TDF will continue to be the most significant market in the near and intermediate term. The use of TDF has proven to be both environmentally sound and cost effective. With the implementation of the Clean Air Act Amendment of 1991, and with utilities becoming more competitive, the indications are that TDF will be considered more positively than previously.

The use of scrap tires in civil engineering applications, with its major problems apparently behind us, should increase significantly. We are optimistic that this market niche will increase over time. The development of industry guidelines and construction practices should assist greatly to this end.

The use of size-reduced rubber from scrap tires remains on the verge of becoming a larger market segment. The reasoning is two-fold. First, there is a finite limit to the quantity of tire retread buffings that are available, a limit that is rapidly being approached. Second, if markets for the size-reduced rubber increase dramatically over the next two to five years, the only major source would be whole tire reduction.

Of the other markets for scrap tires, indications are that export, cut, stamped and punched products, agricultural and other uses will not increase to any great extent over the next several years. It also is likely that the thermal distillation (pyrolysis) of scrap tires will not be a technology which will have any impact on the market for scrap tires.

There are several other technologies which should be monitored over the next several years. It is possible that new applications will be found for rubber that has gone through a devulcanization process. At this point, there has not been a significant quantity of scrap tire rubber used in this manner.

The conclusions reached about various pyrolysis and gasification technologies, including microwave, is even less encouraging. All of these technologies have been in existence for many years, but to date, none are in, or close to, commercial operation. The outlook for these technologies becoming significant markets for scrap tires anytime within the next two to five years, given the current conditions, is highly unlikely. The limitations of these technologies, like the limitations for thermal distillation, is a combination of the manner in which tires are constructed and the nature of the by-products generated from each respective technology.

Finally, it is evident that the scrap tire industry is entering into a new era, one where the processed products generated from the scrap tire will have specifications. The level of processing efficiency has improved significantly, with improvement expected to boost productivity even further. While there are many positive indicators in the field, there are also some indications that there will continue to be continued consolidation and attrition in the scrap tire industry. It is hopeful that once this business correction subsides, that the industry will be more efficient, which should result in stronger market place.

Diversity of US and Canadian experience

The United States and Canada are both organized as federal systems. The principal governmental subdivisions, states in the United States and provinces in Canada, retain substantial responsibility for governing broad sectors of public life. In addition, in many instances where the national government does enact broad legislation, that legislation assigns substantial responsibility for implementation and administration to the states or provinces. The result can be a broad range of individual state and provincial approaches to problems that are found in every region of the country.

Lack of a national law or regulation specifically dealing with scrap tyres

In both the United States and in Canada, there are no national laws that specifically regulated scrap tire management. In the United States such laws have been introduced in Congress on several occasions, both as stand alone proposals, and as part of broader legislative proposals, such as amendments of the Resource Conservation and Recovery Act. With most of these legislative proposals, the emphasis would remain with assigning responsibility to the states to enact and administer scrap tire programs that would meet minimum standards established in the legislation. A bill was introduced in the current session of Congress that follows this broad pattern, but the likelihood of enactment is very small. It may, however, be reintroduced when Congress reconvenes in 1999.

Although there has not been specialized scrap tire legislation enacted by the US Congress, there are several federal statutes that affect scrap tire management and the markets that utilize scrap tires. These include the Resource Conservation and Recovery Act, which establishes standards for municipal solid waste activities; the Clean Air Act, which establishes minimum air emission standards for combustion facilities; and the Clean Water Act, which establishes standards involving effluent discharges. Scrap tires may also fall under the purview of CELCLA, also known as the Superfund Act, if they are involved in an open-air fire and the site becomes contaminated to the point that it falls under the requirements of Superfund. All of these laws are administered by the federal Environmental Protection Agency. The result is there is substantial federal interest through regulations promulgated under these various acts in the technical and policy issues raised by scrap tires. In addition, various departments within the EPA have conducted research and published other studies relating to scrap tires.

Congress has made one attempt to legislate scrap tire issues. In 1990, Congress included in federal highway legislation a mandate that all states would begin using rubber-modified asphalt paving materials on projects built with federal assistance. The intent of this legislation was to help create a demand for scrap tire-derived materials. After enactment, this mandate was met with very strong resistance from state highway departments and from the asphalt paving community. After nearly four years of this opposition, the mandate was repealed in 1995.

The state highway departments resisted this legislation for several reasons. It constituted a mandated engineering requirement, the first one ever enacted by the Congress in more than 35 years of federal aid highway programs, and the highway departments resisted such an engineering mandate. They believed that Congress had no place telling them how to build roads. In addition, there had not been a lot of experience nationwide with rubber-modified asphalt. While states did do many test and demonstration projects in the 1990–1994 time frame, many of these projects failed or performed poorly, largely as a result of improper techniques or poorly designed materials. A related problem was one of perception. While the original use of rubber in asphalt paving, beginning in the 1960s, was to improve the performance of asphalt concrete, the intent of the mandate was to help solve a solid waste problem. The perception then was that Congress was trying to convert roads into linear landfills, obviously not a desirable prospect for most highway departments. A final problem was that use of rubber-modified asphalt paving was generally more expensive than normal paving materials. The asphalt paving community was also opposed, for many of the same reasons, and they are a potent political force in virtually all states.

Historical development of specific scrap tyre legislation or regulation in virtually all of the separate country states (individual US States and Canadian Provinces)

With broad latitude to enact their own laws to deal with matters they believe warrant legislation, the states and provinces follow no particular timetable. However, often legislation on a particular topic can sweep fairly rapidly through both countries. Such was the case with scrap-tire legislation. The first efforts began in the late 1979 in

New Jersey. Without any specific examples of successful scrap-tire legislation, this jurisdiction looked to existing legislation and regulation that dealt with other scrap materials. This first proposal was for a deposit system, similar to the type implemented for soft-drink cans and bottles. In the tire industry's view, this would not have been a workable law. While a small deposit and refund might aid in collection of soft-drink cans, it did not appear to be needed for tires. The problem that leads to indiscriminate dumping of scrap tires is not the initial collection, which normally occurs at the retail tire vendor when replacement tires are purchased, but rather at the subsequent stage of collection and handling by a scrap-tire hauler or tire jockey. In addition, the structure of tire sales and distribution would have created substantial problems for marking of tires sold in New Jersey that would have been covered by the deposit system. In addition, this proposal would have done little to assist in market development or to clean up the existing stockpiles.

The New Jersey legislation was not enacted. The first state to actually past legislation was Minnesota in 1985, with Oregon following soon after. By the later 1980s, the movement to enact scrap tire legislation was in full swing across the country. By 1989, legislation had been enacted, or was on the verge of being enacted, in 40 states. At the present time, 48 of the 50 states have either specific legislation, or specific regulation under broad solid waste statutes, of scrap-tire management.

Canada's first foray into scrap tire legislation was a fee provision enacted in Ontario in 1989 that imposed a $5 per tire fee on the sale of new tires. While the intent was to utilize the funds for scrap tire projects, the collections went into the Provincial General Fund. While some money was distributed as grants, principally to companies in the ground rubber business, the largest share of the tire fees was not used for scrap-tire management purposes. Other provinces enacted scrap tire legislation in the early 90's, with legislation now in place in every province, except Ontario.

One issue driving the scrap tire legislation issue in the United States was concern about the regulation of landfills. Under the Resource Conservation and Recovery Act, the Environmental Protection Agency developed national performance standards for municipal solid waste landfills, to be implemented by each state. Landfills had been a common disposal site for scrap tires for years. With the greater regulation of landfills, which was generally perceived to greatly increase the cost of landfill air space, there was concern about continuing to accept scrap tires. It is important to note that the federal regulations **do not** prohibit the continued landfilling of tires. At the state level, however, there was concern that landfill space would become more valuable and that tires ought to be kept out. One feature of most scrap tire legislation is a prohibition on landfilling of whole tires. Several states also went the next step and eventually prohibited the landfilling of shredded or cut-up tires. In a few states, the landfill ban was the only specific scrap tire law enacted.

Multiple approaches to a common problem

One of the features of the US and Canadian federal systems is that there can be multiple approaches to common problems. In a country as geographically diverse as the United States, there are often widely differing attitudes towards common problems and there can be equally widely diverse solutions. The attitude toward landfilling of scrap tires can illustrate this split. In many states, as has been noted, bans are in place prohibiting the landfill disposal of whole and, in some cases, shredded tires. These states are often more densely populated states with limited landfill siting options, and a resulting desire to keep as much material out of landfills as possible. In addition, the populace may view themselves as being more environmentally conscious and be willing to accept the limitations such a policy might impose. By contrast, some more sparsely populated western states may be more tolerant of landfilling, with more space available, and would rather enjoy the lower costs of sending scrap tires to landfill. Additionally, as will be seen, some states further delegate responsibility to smaller units of government (counties or solid waste management districts), while other states retain more control and responsibility at the state level.

In addition, as we shall see, the states have taken substantially different approaches to both the generation of revenues needed to deal with scrap tire issues and the utilization of those funds.

Common regulatory and economic instruments in North American scrap tire management

While there is much diversity in the North American scrap tire regulatory experience, there are some common features that are usually found in comprehensive scrap tire regulation. While not all of these elements appear in all states, the consensus is that any effective program must include most of these elements. These features include:

a. Registration or licensing of haulers and processors; manifests; financial assurance requirements.
b. Ban on stockpiles; provision for remediation.
c. Limitations on landfilling of whole or processed tires.
d. Establishment of dedicated taxes for scrap tire related programs.
e. Assistance to create or expand scrap tyre markets.

Registration or licensing of haulers and processors; manifests; financial assurance requirements

The first of these common features is a provision for establishing regulatory control over the business entities that deal with scrap tires. The mechanism used is a registration or licensing requirement. Businesses desiring to engage in scrap tire hauling or processing are required to register with a state agency and provide such information as the agency requires. This requirement is in addition to any other more general business licenses and permits it may be required to secure. Continuation of the scrap tire registration or license is contingent on compliance with rules and regulations established for that type of operation. In a limited number of states, scrap tire generators, such as tire dealers or vehicle dismantling yards are also required to register, although such registration is usually intended only to assign them a generator number to be used to track scrap tire transactions.

A concurrent requirement is that scrap tire generators can only contract with licensed or permitted haulers to secure collection services. Licensed or permitted haulers, in turn, must only deliver tires to a licensed processor, storage site or end user. A limited exception to the permitting requirement may be provided to anyone carrying a minimum number of tires, typically 10 or fewer, or in a few instances for tire dealers hauling their own tires to processors or markets.

Many states have also established manifesting requirements to provide a paper trail from generator to ultimate use or disposal. Manifests are initiated at the generator when scrap tires are collected, travel with the scrap tires to the processor or end user, and provide both an audit trail for enforcement activities and a sentinel effect for all the parties involved.

Another common requirement is that processors, and less frequently haulers, may be required to post a financial assurance instrument in favour of the state to insure adequate funds to remediate their sites in the event they fail to do so. These may be bonds, letters of credit, insurance policies, or other instruments as allowed by state regulation. The amount of the financial assurance is normally calculated on the maximum number of whole or processed tires permitted at the processor's site, or on the number of vehicles the hauler is operating.

Ban on stockpiles; provision for remediation

Most state programs prohibit any new scrap tire stockpiles from being created and require owners or operators of existing stockpiles to cease taking any new scrap tires and to develop a plan to eliminate the existing stockpiles. Recognizing that scrap tire processors may require some scrap tire storage, state laws require that any such above ground storage be allowed only in accordance with the terms of a permit that will specify the maximum tires allowed to be stored. These processors would be required to post a financial assurance instrument as described above. Typical financial assurance amounts will be around $1 for each stored tires.

Most states also have adopted standards for the outdoor storage of scrap tires. These standards typically follow guidelines adopted by the National Fire Protection Association (NFPA), the principal fire safety standards development organization in the United States. These guidelines are contained in Appendix C to *NFPA Standard 231D*, and provide specific guidance on physical size limitations on stockpiles, and on minimum management requirements for stockpile operations. A related requirement is for treatment of the piles to reduce or eliminate disease vectors, such as mosquitoes and rodents.

Eliminating existing stockpiles is also a major legislative and regulatory concern. If a responsible party can be found, that party typically is required to comply with the storage regulations and to prepare and follow a plan to eliminate the stockpile. Often, however, there is no financially capable party present, or the stockpile is on public land. In these cases the public scrap tire authority is responsible for the stockpile remediation effort.

The specific mechanisms used to remediate stockpiles have varied among the states. Some states have provided funds to counties or other local government units to manage site clean-ups, while other states have taken on the task directly through a state agency. Another complication is access to the stockpile. In some states, the agency is provided direct legal powers to enter property to clean up a tire pile. In other states, a more involved legal process must be observed, usually adding extra time to the process.

State scrap tire funds are the usual source of funding for publicly supported clean ups, even on private property. If the site is on private property, the state will normally seek a lien on the property to recover the funds expended. At least one state, Maine, has used part of the proceeds of a public bond issue for environmental projects to be dedicated for scrap tire pile remediation.

When a state begins to undertake stockpile remediation efforts, it often results in substantial voluntary remediation efforts by private landowners at their own expense. While these tend to be smaller piles, usually under 50,000 tires, they tend to be the largest number of piles and to contain, in the aggregate, a substantial number of tires.

Limitations on landfilling of whole or processed tires

A substantial majority of states (35) have banned whole scrap tires from landfills, and at least nine states have banned all scrap tires from landfills. Some states have allowed the establishment of scrap tire monofills, which are landfills that can accept only scrap tires. Removing whole scrap tires from landfills eliminates several problems, including the high volume whole tires occupy, the fact they do not easily compact, and their tendency to move through the landfill and break the cap. Cut or shredded tires remove all these problems. As was noted above in the discussion of scrap tire markets, shredded tires are being used in several ways in landfill construction and operation.

Pressure to limit landfilling of shredded tires often comes from people who are seeking to build higher-value markets for tires. Landfill or monofill disposal, even of shredded tires, often is the lowest-cost option for handling scrap tires. Higher-value markets typically require higher tipping fees or other financial support. In order to help develop these higher-use markets, states should consider prohibiting landfilling of shredded tires.

One caution is in order. If landfill is the current destination for most scrap tires, imposition of an immediate ban will normally result in an increase in illegal dumping. Any land fill ban should be phased in to allow alternate markets to be established.

Establishment of dedicated taxes for scrap tire-related programs

A common feature of US and Canadian scrap tire programs is a dedicated fee or tax imposed by the government to support scrap tire programs. This is one very pointed mechanism intended to internalize some of the direct costs associated with scrap tire management. These fees vary in such basics as the point of imposition, the amounts, and the pattern of utilization.

The most common point of imposition is retail sales transactions involving tire purchases. In the US, most states limit the taxes to replacement tire sales. In a few states and in Canada, the taxes are also imposed on tires mounted on new vehicles at the retail sale level. In two states, Ohio and Maryland, the tax is imposed at the wholesale level and collected and remitted by the wholesaler. Retail or wholesale level taxes are usually a fixed amount per tire. In two states, the amount is calculated on a percentage basis, with a cap on the maximum amount that can be imposed.

Several states avoid the tire sales transaction entirely and increase other fees imposed on vehicle ownership. Four states impose additional fees on vehicle title transfers. One state imposes a separate environmental fee on new car sales, with a portion of this fee dedicated to scrap tires. The rationale for this approach is that it avoids the administrative burden of establishing a new tax. The existing collection system is in place, and it is a relatively simple matter to transfer funds to the appropriate state account.

The amount of tax or fee varies substantially and reflects the different approaches to internalizing management costs. Tax amounts imposed on passenger tires range from $0.25 per tire to $4.00 per tire. In the United States, the most common figure is $1 per tire. States with tax levels at $1 or below per unit do not intend that the money generated will cover the cost of initial collection from tire generators. Jurisdictions in both the US and Canada that impose higher taxes, ranging from $1.50 per tire to $4.00 per tire, have established programs where the taxes represent prefunded disposal or collection costs.

Fund utilization will be discussed in greater detail in other portions of this paper, but in general funds are utilized to support the staffing necessary to administer the program, for cleanup of scrap tire piles, to provide market development assistance designed to create self-sustaining end use markets, and to fund the tire collection system.

Assistance to create or expand scrap tyre markets

The key to success in any effort to divert recyclable and reusable materials from the solid waste stream is to develop end-use markets. Diversion of materials is not recycling, although many people who participate in such programs believe it to be so. Only when materials have markets is recycling or reuse taking place.

When states and provinces enact comprehensive scrap tire legislation, one of the most prominent features is assistance to create or expand scrap-tire markets. Assistance programs can take several forms and are detailed more completely below. The point to note here is that successful programs have strong market development features.

Principal US and Canadian models of scrap tyre cost internalization, regulation and market development

The stated subject of this paper is a discussion of the models of cost internalization of scrap tire management costs utilized in the United States and Canada. Effective scrap tire management programs include several distinct elements, including establishing sound collection practices, developing end use markets or disposal alternatives, providing effective enforcement, and remediating the negative impacts of earlier practices. The issue of cost internalization is fundamentally one of determining who should pay any costs associated with this end-of-life management program and how should the necessary funds be collected and disbursed. In general, a world consensus seems to be growing with respect to tires that costs associated with this end-of-life management should be reflected in the product itself, and methods should be developed to include these costs in the cost of its ownership.

Direct *versus* indirect costs and benefits

Earlier it was mentioned that there are two sets of costs associated with scrap tire management and utilization or disposal. The first set is the immediate and direct costs of collection, processing, reuse and disposal, and can be extended to include the cost of governmental oversight and management of a scrap tire industry and the cost of remediating the failures of past scrap tire management techniques, especially stockpiling.

The second set is higher order costs that can be a consequence of scrap tire use or reuse. These are more diffused social and environmental burdens and benefits that result from various scrap tire management options. At least one attempt has been made to quantify both the first set of direct costs and the second set of higher order costs. The report of this effort, *Tyre Recycling in Europe: open borders in the waste hierarchy, EPCEM Study Report No. 1998/2*, (IVM, Institute for Environmental Studies, Vrije Universiteit, Amsterdam, April, 1998), reflects an ambitious attempt to determine through cost-benefit analysis and life-cycle analysis the most beneficial method of tire reuse. As with any such analysis, this report relies heavily on various economic and technical assumptions that affect the ultimate outcomes. There are, no doubt, many individual assumptions that could be challenged. On balance, however, it appears to be an honest effort to calculate these higher level burdens and benefits of some scrap tire options.

At least one point of exception must be noted here. The report includes retreading in its analysis and concludes that retreading is the highest order method of dealing with waste tires. However, as outlined above in the discussion of tire retreading, it is not properly a method of dealing with scrap tires. Rather, it is part of the intended initial life of the tire.

The IVM study also evaluated some other markets for scrap tires, including fuel use, pyrolysis, and the material recovery market, both grinding and reclaiming. Because of the lack of any significant civil engineering applications in Europe, this market was not included. The report's analysis suggests that all of the options discussed have a positive social benefit, of approximately the same order if magnitude. Given that the social benefits of these options are approximately equal, one conclusion that can be drawn is that the market place ought to be the mechanism for determining the ultimate destination for scrap tires.

Internalization of direct costs

In the United States and Canada, various approaches to this cost internalization for direct scrap tire management costs have been developed. These include:

Free market activity:

taxes or fees imposed by governmental jurisdictions on new tire sales to fund some or all of these end of life activities; and

increases in other vehicle-related levies dedicated to scrap tire programs.

Some jurisdictions utilize more than one approach, depending on the different parts of the program. For example, initial collection cost may be set by free market forces, while a tire tax system supports enforcement and market development.

In addition to different cost internalization methods, the North American jurisdictions have developed different regulatory structures for scrap tire management. In this regard, the United States and Canada have basically diverged. The US models generally rely on the free market for funding of collection and processing. Canadian provinces are tending toward a stewardship model that establishes a public-private board administering tire tax generated funds to pay for most collection and processing.

The US system can be described as a shared product responsibility system. At each point in the ownership cycle of a tire, the person in possession of the tire bears the responsibility for its proper handling and disposition. A tire in its life moves through a cycle that includes its manufacture, distribution, initial sale, use, initial removal from service, evaluation for reuse or retreading, subsequent sale, final removal from service as a vehicle tire, processing for further markets, utilization in those markets, ultimate use or disposal. Each owner in turn bears the responsibility for seeing to the next step in its life. A major advantage of this shared product responsibility system is a level of efficiency that reduces the cost of handling the tire at each point to the lowest level needed to move to the next level. At each level and in each location, the market establishes the lowest cost options for handling the tires. Obviously, some regulation is needed to eliminate illegal dumping and other harmful practices. However, it does not impose a heavy administrative burden that a more centralized control system would impose.

Cost internalization models:

a. Pure market-based system.
b. Minimal regulation.
c. County or regional system.
d. Intermediate processor model.
e. Stewardship board model.

a. Pure market based system. In most US jurisdictions, the costs of scrap tire collection, processing and end use are set by the market place. Scrap tires are usually left with the tire vendor when replacement tires are purchased. The costs incurred by tire vendors for initial scrap tire management, including the tip fees charged by scrap tire haulers and any storage and handling costs, are a cost of doing business. The tire vendor must either include these costs in setting the product price of the tire, or as frequently occurs, explicitly charges his customer a fee for tire disposal. In either case, the total purchase price paid by the customer includes these costs.

The hauler will charge the tire vendor a tip fee that reflects recovery of the hauler's costs and his return on investment, and will reflect his ability to maximize the value of the tires collected. These fees will also reflect the availability of local low-cost disposal options. If the state law allows, there may be low-cost landfill or monofill options available to the hauler. If tire collection fees are too high for the local market, other haulers will undercut these fees and secure the tire dealer's business.

In free market states, where a retail level tax or fee is imposed to support the state scrap tire program, this state fee is in addition to the market-based fee described above used to actually pay for the collection of scrap tires.

The subsequent costs associated with scrap tire handling are also set by market forces. Whole tire fuel users, principally cement kilns, are currently charging tip fees for tires consumed as fuel. The cement kiln also receives an economic benefit from using tires because of avoided costs for the fuel being replaced with the tires. The market will support a tip fee for kilns as the alternative destinations for the tires, even landfills, will charge a tip fee. At some time in the future, as markets for tire develop, cement kilns may be forced to reduce or eliminate tip fees.

Processors also charge the hauler a tip fee based on local market conditions and competition. The processor will receive an income stream from its sale of final products, whether that is tire-derived fuel, civil engineering material, playground cover, or ground or crumb rubber. The market will set the value for the finished product.

A market-based system operates in the context of the regulatory system in place in the state. Haulers, processors and end-users may be required to be registered or permitted, and will have posted financial assurance. Tire vendors will use only permitted haulers. Various limits may be imposed on processors and end-users. All parties would be subject to enforcement activities to ensure state regulations are being followed.

b. Minimal regulation. A few jurisdictions rely on minimal regulation. Essentially free market systems as described above, these minimal regulation jurisdictions have not seen the need for major scrap-tire-specific legislation or regulation. Instead, tires are just another solid waste and are dealt with accordingly. Laws regulating dump-site locations may be invoked to prohibit stockpiles from being formed, or there may be little or no concern about stockpiles. Landfills may continue to take tires, or may utilize high tip fees to drive them away. Litter laws can be used to punish persons responsible for illegal dumping, if they can be found. Any markets are established based on sound economics. General tax revenues are likely to be used if governmental action is needed on scrap tire problems. Normally, this was the state of nature before the initiation of scrap tire legislation. However, usually some major problem led to the enactment of more intensive scrap tire regulation. In the few remaining jurisdictions that would fall under this minimal regulation model, there may not have been a major fire or outbreak of mosquito borne disease that was the frequent precipitating event to more intense regulation elsewhere. These locations also tend to be in more sparsely populated areas where major scrap tire problems have not developed.

c. County or regional system. Three states have established a county or regional district model for responsibility for scrap tire control. In North Carolina and Arizona, each county is responsible for establishing a scrap tire management system. In Arkansas, similar responsibility is given to regional solid waste management (SWM) districts, which may include more than one county. In this model, the state-imposed scrap tire fee imposed on retail tire sales is in fact a prepaid collection fee. The state scrap tire program provides funding to each county or SWM district. The county or district in turn establishes at least one site in each jurisdiction to which scrap tire generators may bring tires without additional charge. Tire dealers may transport their own scrap tires with their own employees, or may pay third parties to do the actual hauling to the site. In practice, each county or district usually contracts with a private party to provide the tire collection site and services. The contractor must establish at least one drop-off site, but may also establish route services to pick up tires at individual dealer establishments. In some counties in North Carolina, the county may elect to service its own scrap tires, typically at a county-operated landfill at which it then disposes of the tires. If the county can operate its site for less money than it receives from the state, it can utilize the excess for other purposes.

The major problem with the county responsibility model is the generally low level of expertise about scrap tire management and markets at the county level. In addition, the state agency may have little control over county decisions, even if they are poor.

Arizona presents an example of such a problem. In 1993, Maricopa County, which includes Phoenix, the largest city in the state, and several other counties contracted with a third party to collect their scrap tires. The contractor was going to erect a pyrolysis plant. The state agency could not intervene, even though the choice of a pyrolysis plant looked to be a poor option. After several years of collecting and storing tires, the permitted storage sites were closed by the state fire marshal. The contractor had not built the pyrolysis plant and went bankrupt. The next major event was an arson cause fire at a storage site containing several hundred thousand tires. Clean up of this fire site and another storage site has become mired in charges and counter charges among several parties about who should bear the cost. The US Environmental Protection Agency entered the dispute to force the parties to clean up the site.

A related problem is the equitable distribution of funding. Normally funds are distributed among the counties based either on population or on the basis of registered vehicles. For several reasons, this may not reflect the volumes of tires actually managed in the district. In Arkansas, one of the SWM districts is the home of several major national trucking lines, and they all have major maintenance facilities in the district. As a result, the district has a disproportionately large volume of scrap truck tires to deal with, far in excess of what would normally be expected for either the population model or the registered vehicle model.

d. Intermediate processor model. Another exception to the market-based model has been adopted in three states. Again, this model uses the state-imposed tax on new tires as a prepaid collection fee. However, rather than distributing the funds through local counties, the program pays scrap tire processors for collecting tires from scrap tire generators and processing them to a specified size, or using them in an allowed use. The processors and collectors receive their payments directly from the state agency. Originally enacted in Oklahoma, this model has been adopted in Texas and Louisiana; Texas allowed the program to expire at the end of 1997 and Texas now has a free market program. State scrap tire taxes are $1.00 in Oklahoma and $2.00 in Louisiana. Texas had also collected $2.00 on each new replacement tire sale.

The Oklahoma program illustrates most of the features of this program. In Oklahoma, tire dealers can have their scrap tires collected at no additional cost. The tires are collected and processed to a minimum size. Only then does the collector/processor receive compensation, at the rate of $0.85 for each 18.6lbs. of processed tire material with payment coming directly from the state agency. In Oklahoma, because the legislature wanted to insure that all sections of the state would receive collection service, the law provides that any company participating in the program had to provide collection service in all counties in the state. This establishes a *de facto* monopoly, as the state does not generate enough scrap tires to involve two companies collecting tires throughout the state. With only one company active in scrap tire collection and processing, the state has a problem enforcing the regulations. If the one active company does not continue service there is no competitor to take over. In addition, while this model contemplated that the processor would undertake activities to develop end use markets, in practice there has been limited effort made to create or promote markets.

This model in Oklahoma and Texas required that a specified percentage of tires shredded each month were to come from existing tire stockpiles. This provision was intended to abate all tire stockpiles. While the Texas program saw many stockpiles at least shredded up, few were shredded in Oklahoma.

The Texas program was similar in concept, but had a major difference. Because Texas is a very large state, both in area and in population, no one processor could handle the entire state. Accordingly, the state allowed anyone who could get a permit to participate in the program. Initially, forty processors received permits and began collecting and processing tires. The Texas program encountered many problems and was constantly being amended by the state legislature. Initially, the program did very little to promote end use markets. Later, after some new legislation, the markets improved.

However, as the reimbursement level was set by statute, the processor community was continually before the legislature seeking higher reimbursement levels or other modifications. One legacy of the early failure to develop markets is the nearly 70 million shredded scrap tires currently stored around the state, with little hope of being used. When new legislation was introduced in 1997 to convert the market development program to an end user reimbursement system, there were several competing factions, and no industry consensus. The legislature became disillusioned about the program and allowed it to expire at the end of 1997. Since early 1998, Texas has been in transition to a pure market based system, and has been having some difficulty. In the meantime, the processor community, which has dwindled to around a half dozen companies, is organizing to seek a new processor reimbursement system next year.

e. Stewardship Board model. Canada has developed its own basic system of internalizing scrap tire management costs. While adopted on a province by province basis, its key features are quite similar. A key difference between the US and Canada is the substantially higher scrap tire management taxes imposed by Canadian provinces. Ontario set the pattern when it imposed a $5-per-tire fee. While it did not use much of the money generated for scrap tire management purposes, and it has since been repealed, it did set a model for other Canadian jurisdictions. Presently most Canadian provinces have a $3.00 per tire tax, while Alberta checks in with a $4.00 per tire levy.

This tax or levy is used as a prefunded collection fee. While the model varies in slight ways, the usual procedure is to establish a stewardship board or corporation, with responsibility to administer the program. The stewardship board is typically composed of various stakeholders from government, industry, the environmental community and the general public. In turn, it may contract with private parties to carry out its activities.

The funds are used typically to provide a per tire subsidy to the processor who is producing and selling an end use product. Through the processor, scrap tires are to be collected at no additional charge from scrap tire generators. In some cases, collectors are contracted by the board to provide services to scrap tire generators. Tires from stockpiles are also eligible for a subsidy payment to help get them remediated. The key to the program is the fairly high per tire subsidies that are provided, some of which vary depending on the end use product. While the markets for scrap tires are basically the same as they are in the US, the stewardship boards seem to be interested in tire fuel use only as a last resort if at all. Instead, they seem to focus on producing crumb rubber for recycling applications, even though the end use markets for that material are slow growing. Alberta is undertaking an investigation of civil engineering uses that may see the spread of this market elsewhere in Canada.

Market development models

Market development was earlier identified as an important feature of scrap tire management program. Here again the US experience has developed several different models to help create and develop markets for scrap tires. The intent of each of these models is to help promote markets that can eventually be self-sustaining. The ultimate goal is to have end use markets capable of consuming all or virtually all of the newly generated scrap tires. Among the market development models are:

End user subsidies.
Grants or loans.
Intermediate stage subsidies.
Tax credits.
Buy Recycled requirements.

End user subsidies. This was the first market development model implemented, being used in Oregon starting in 1985. In this model, the state program pays a specific amount to the ultimate end user of a scrap tires or scrap tire-derived material. The state develops a tracking system to allow certification that the tires used were collected from tire establishments or other generators in the state. Payments are usually made monthly or quarterly, with an allocation system if the state fund does not have adequate money to meet all claims. Only five states – Oregon, Idaho, Utah, Wisconsin and Virginia – have ever implemented this system and three (Oregon, Idaho and Wisconsin) have allowed the programs to sunset. In Canada, it could be argued that the product stewardship model is basically an end user subsidy, although the payment typically includes the collection costs as well.

Oregon, Idaho and Wisconsin all provided end users a subsidy of $20 per ton, while Utah continues to provide a $65 per ton subsidy, and Virginia provides a $20 per ton subsidy for annual flow tires and a $50 per ton subsidy for tires from stockpiles.

The intent of the subsidy system is to provide the end-user a means of recouping any capital investment needed to use tires, or tire derived materials. The actual acquisition of tires is a market-based activity. Thus, tire dealers continue to pay collectors for tire collection services, and processors sell TDF or other tire derived material to end users.

The experience with the completed programs has been mixed. The Oregon experience provided enough new users to consume most of the tire stockpiles, but when the subsidy was removed, most of the new users stopped taking tires. In Idaho, which had a relatively small stockpile problem, the subsidy also served to eliminate the stockpiles. In Wisconsin, it appears that the subsidy was in fact used by the end-users to recover capital costs. Many of the end-users who came into the system when the subsidy was in place have continued after the subsidy was removed.

In Virginia, it appears the end use subsidy has caused some Virginia tires to displace tires from other states. The state has a good system of tracking Virginia tires to the end users. Currently, many Virginia tires are going to other states, to markets that existed before the Virginia program began, where they may be displacing tires form those states. Utah has the highest level of end-user subsidy. While some tires are consumed in the state, the subsidy also helps pay the transportation cost to end-users in other states, most notably California, where some cement kilns use a high percentage of Utah and other out of state tires.

Grants or loans. Several states provide low-cost loans or outright grants to scrap tire projects that have the prospect of becoming self-sustaining or of expanding the use of scrap tires. Some states have provided demonstration or developmental grants, where the prospect of immediate market success is remote. One state provides grants to local government entities to allow them to purchase scrap tire-derived materials for use in local government projects. Each state having a grant or loan program provides its own rationale and procedures.

California has provided grants for various scrap-tire-related demonstration or developmental projects. In addition, the state has provided grant funding for a technology transfer center for asphalt rubber technology

Illinois has used a grant program to investigate various markets and to assist end-users retrofit facilities to use scrap tires. Grants can be provided for initial feasibility studies and tests, and for production equipment. Florida provided funds to each county to purchase tire derived materials for county use. The intent was to help local processor develop markets. Other states have developed similar grant programs.

Of all the market development models, the grant and loan model appears, so far, to have had the best success. In the few states where it has been most robust, and has been effectively implemented, it appears to have help build the most sustainable markets. It is much akin to helping build a better, longer pipeline to end users who will take the material from the pipeline at its economic value, rather than paying parties a bribe to take the material that comes through a poor pipeline.

Intermediate stage subsidies. As previously discussed, three states – Oklahoma, Texas and Louisiana – have adopted a model that provides payments from the state agency to processors who both collect tires from scrap tire generators and process them to a specified size. The payment covers both collection and processing, so the tax imposed by these states represents prepayment of scrap tire collection. This model also intended that the payment to the processor would assist in developing end use markets. A feature of these programs was that eventually the processor would not receive any payment until the tire material had been delivered to an end use market. However, the deadlines for these requirements were continually extended. To the extent that the original intent of this model was to provide financial support to the tire processor to assist in developing ultimate end use markets, it has not been successful. Few if any markets have been developed through this financial support alone. There was some success in Texas when the program was modified to allow some end users to receive the same financial support given to processors.

Tax credits. A fairly common feature of recycling development programs is to allow tax credits for investment in recycling equipment. This covers investment in tire recycling equipment as well as equipment for recycling other materials. In addition, at least one state, Pennsylvania, has established a program of limited tax credits available to fuel users who began utilization of tires after the legislation was enacted, or who expand their utilization of tires. The tax credits are based on the number of tires consumed and are limited to a total of $1 million annually. Aside from the difficulties of administering such a program, it also tends to discriminate against facilities that had made the investment to use tires before the tax credit program began.

Buy recycled mandates/recycled content mandates. Many governments are subject to 'buy recycled' mandates. A typical mandate will require a governmental agency to buy a product with minimum recycled content if one is available and equal in performance. Often times there will be a price premium allowed for the recycled product. While these programs started with materials like paper, increasingly they are extending to other products, including retreaded tires and mats and other products with recycled rubber content.

The US federal government has such a requirement for all federal agencies and for any state and local government program receiving federal funds. Periodically, the EPA publishes an updated list of products that are covered by the mandate. A number of products containing recycled rubber are on the list. No study has yet been done to determine whether the federal government mandate has had any impact on the market for products containing recycled rubber.

Stockpile remediation models

Stockpile remediation is one of the major goals of every major state scrap-tire program. Often times, the motivating force behind adoption of a scrap tire program was a fire in a scrap tire stockpile that generated adverse publicity and a high level a public awareness that something had to be done to clean up scrap tire stockpiles. Even here, there is not a single model for stockpile remediation programs. Stockpile remediation models include:

Encouragement of private action.
County assistance.
Intermediate stage subsidies; end user subsidies.
Trust Funds.

Direct state action.

Encouragement of private action

Virtually all scrap tire programs began with an encouragement for private parties owning scrap tire stockpiles to bring the piles into compliance with storage regulations and to develop a plan to remediate the stockpile in a stated period of time. When programs are first being implemented, there appears to be considerable response from private parties to remediate their stockpiles. While the piles that are cleaned up by private action are often smaller in size, collectively they can constitute considerable volume. In Pennsylvania, nearly one third of all stockpiled tires were clean up by private parties in the first year of a newly adopted state program.

County assistance

Some jurisdictions impose responsibility to cleanup of tire stockpile on county governments. Oftentimes the major tire Stockpile is at a county owned landfill. In these instances, counties typically can apply for state grants to assist in remediation, although the state funds may be limited to only a portion of the total; cost, although that may be as high as 90%.

Intermediate stage subsidies; end user subsidies

As was discussed above, one of the features of state programs in Texas and Oklahoma that featured payments to processors for collection and initial processing was that a percentage of all tires shredded for payment were to come from stockpiles. In this manner, the programs were to eventually eliminate stockpiles of whole tires and remove at least the disease vector threat these piles presented. In Texas the program worked too well as some of the initial processors determined it was easier to locate at a large pile and shred it all up than it was to run around the country collecting tires at tire dealers. As a result, Texas saw virtually all of its 50 million stockpiled whole tires reduced to shreds. Unfortunately, most of they still remain stockpiled in their new form.

Virginia has used its end user subsidy program to remediate a substantial portion of its tire stockpiles. By providing a higher reimbursement rate for tires from ($50 *versus* $20 per ton), the state sought to encourage processors to handle stockpiles. While they have succeeded in getting the easiest sites remediated, several more difficult sites remain and will have to be dealt with in other ways.

Trust Funds

The use of a trust fund, with proceeds from a state bond sale, is limited to a single state, Maine. The bond issue was intended for many environmental projects, including scrap tires.

Direct state action

By far the most common model for stockpile remediation is direct state action. Typically a state will inventory all its stockpiles, then identify the most dangerous sites. Factors to be considered may be access difficulty, exposure of watersheds, proximity of schools, hospitals or other sensitive populations, and size of the stockpile. Once a priority has been established, the state will usually have to undertake efforts to identify the landowner, notify them of the need to remediate the location, and then take legal action to secure access. Some states allow easier access to sites determined to be potentially dangerous.

Once the site has been identified for action, the state typically advertises for remediation services and seeks to identify qualified contractors. Contractors will usually be required to have an identified end use for the material taken from the site. After evaluation of all bids, the contract will be awarded and the remediation undertaken. Typical costs will vary substantially depending on the difficulty of the site. At the low end, remediation may be as low as $70 per ton, while at difficult sites it may reach $200 per ton.

Analysis and recommendations

A framework for analysis

As public and private decision-makers face the issues of scrap tires, they must begin with an understanding of the specific facts and circumstances that surround scrap tires. Developing this understanding will result in establishing a preliminary set of priorities for action. However, as fuller information is developed, as analysis is made of the implications of these action priorities, and as other parties review and analyze the priorities, they will likely change or be rearranged. Even as initial decisions are implemented, they must be subject to continuing evaluation to determine if they are achieving the required results. If they are not, then they should be revised to meet the actual conditions encountered.

A second concern for policy makers, at least when dealing with the utilization of scrap tires, is to make decisions based on sound science. Too often when policy makers start considering markets for scrap tires, they encounter individuals or groups opposed to some uses of tires, usually based on a misguided view of the risks that might be involved in that use. This often occurs with proposals to utilize tires as a fuel. These groups usually employ scare tactics to imply that the public will be placed at great risk, when the facts are quite the opposite. They will employ junk science, bad science, or no science at all, in an attempt to stir up public opposition to the project. Policy makers must stand firm when the sound science is in their favour. A substantial body of scientific data on the uses of tires has been built up world wide to respond to all legitimate public concerns.

Before each jurisdiction makes its decisions as to the type of program that it would seek to implement, it should conduct an analysis of the issues surrounding scrap tires as they are found in the jurisdiction. That analysis will include questions such as:

What problems are we having with scrap tires?
How are scrap tires now being handled?
What realistic options exist for scrap tires?
What goals do we want to set for our program?
How quickly do we want to reach those goals?
What are the economic and social implications of our various options?

How can we encourage the options?
Are any scrap tire costs now being borne as public costs?
Depending on options for scrap tires, will there be additional costs?
Do we want to convert current public costs to private costs?
Do we want these additional costs to be public or private?
If so, what structures can we use to make them private costs?
What parties are or ought to be involved in scrap tire management?
What role should government have? tire consumers? the tire industry? other private sector parties?
What measures can we use to judge success?

Each of these basic questions will generate a range of additional questions, but this should give a feeling for the range of issues that ought to be considered. This analysis can be relatively simple, or it can be quite complex. And the policy response can be equally simple or complex.

To expand this outline a bit, consider the issue of problems being encountered:
Do the problems include the presence of stockpiles?
of substantial illegal dumping or littering?
the lack of landfill space?
scrap tire fires?
mosquito-carried disease traced to tire piles?
the absence of any market for tires?
the presence of poor collection practices?

Or evaluate current collection practices:
are tires landfilled and stockpiled, or are there markets that are taking some tires?
do we have financially sound and responsible tire collection services available, or just a few good old boys with bad pick up trucks?

With respect to options available, do we have fuel users who could easily utilize tires?
are there civil engineering uses we could implement?
do we have any potential users for ground rubber?
could any be reasonable induced to enter our market?

This will be an extended exercise, with many parties involved. Ultimately however, some basic decision will be made.

For example, a jurisdiction may take a fairly simple route. They may conclude, for example, that an appropriate program is one that seeks the least costly disposal options for tires, that does, however, seek to control and eliminate illegal dumping and remediate existing scrap tire stockpiles, and that has little concern for seeking to divert scrap tires to higher values uses unless the markets can be competitive with low cost disposal. Such a set of decisions might result in a program that requires registration of haulers and processors, but continues to permit the landfilling of processed tires or the establishment of properly permitted tire monofills. Costs associated with the handling of current generation tires will be set by the marketplace, with haulers free to set tip fees for collection. A small tax would be imposed on new replacement tire sales to fund remediation of current stockpiles over a five- or ten-year period. Funds would also be available for enforcement and for some other cleanup activity, such as tire amnesty days. Some limited grant or loan funding might also be available for private or public parties to help develop alternative markets, but this would not be a high priority. Efforts might be made to encourage markets, such as fuel use by existing cement kilns where the possibility of being competitive with landfill exists.

Success for such a program would be relatively simple. Are scrap tires being handled as the program allows? Have stockpiles been eliminated? Has tire littering been reduced? If so, the program is likely to be considered successful by its architects. In some US states, especially where populations are sparse and land space is plentiful, this is the type of program being implemented.

Normally, however, in the contemporary world, policy makers seek more sophisticated analysis. They may view scrap tires as being more than a simple solid waste problem, but also an asset with value that should be recovered in some form. Then the analysis will go beyond the simple solid-waste management issues and seek to identify likely markets for the tires, and further evaluate whether and how to encourage those markets.

These states may signal their intention to promote higher value uses by establishing a future date for prohibition of landfilling of processed tires. There are also states that have spelled out allowable uses for scrap tires in their scrap tire legislation. These typically include material recovery, energy recovery, civil engineering applications, and listing of specific applications such as rubber-modified asphalt or use in septic drainage fields. In addition, or instead, they may establish a process of beneficial use determination with the state regulatory agency given the task of determining whether any proposed use for tires is a beneficial use.

Recommendations

Based on the United States experience, a few observations and recommendations can be made.

- In order to reduce the direct costs associated with scrap tire management, collection and management responsibilities should be lodged as close to the point of generation as possible.
- Effective control over scrap tire collection and transportation usually requires some form of registration of haulers and a requirement that only registered haulers are authorized to collect and transport tires.
- Markets, likewise, should be developed close to points of generation to reduce transportation costs.
- Market development efforts should focus on building sound infrastructure that will be capable of self-sustaining, market-based operations. Overt subsidy of scrap rubber use will likely not contribute to such markets over the long term, and in the absence of the subsidy.
- Ultimately, for every use for scrap tire and rubber, the market place will determine success or failure. If a use for recycled rubber makes economic sense and is technologically effective, it will succeed. If a market is only sustained by continued public sector imposed subsidies, it will fail when those are removed.

- In the US experience, the scrap tire management industry has developed independent of the tire manufacturing industry. This is similar to the experience in the auto recycling industry. While the scrap tire industry is not yet as fully mature as the auto recycling industry, it is making great strides and should be allowed to develop as a stand-alone industry.
- Technological developments are still possible that will increase the efficiency of all current and potential uses for scrap tires. Publicly and privately funded technology development programs, including those funded by scrap tire management programs, can provide targeted assistance in these effort, but should not be allowed to become open ended 'research' programs.

Further efforts

The United States is a fully developed economy, although to look at some experiences involving scrap tires one might think otherwise. Nevertheless, the US experience may be of some assistance to developing economies just evaluating the possibility of establishing a scrap tire management program.

There may also be room for significant additional assistance, either through direct consultation, or through international agencies. What kinds of additional information and assistance would be helpful? Would greater accessibility of technical information about the various reuse and recovery technologies be useful? Is there additional conceptual analysis that would be helpful to the evaluation of management and market alternatives? We seek your input and pledge continuing support to help establish sound management and supportable markets for scrap tires throughout the globe.

Internalization of Scrap Tire Management Costs: Malaysian experience

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Introduction

Rubber products after reaching the limit of their application have to be discarded and are normally thrown away as waste. Everywhere in the world today, there has been problem of rubber wastes accrued *eg* tyres which are not readily biodegradable. Ways and means are tried to reduce tyre wastes. Some tyres are retreaded to prolong their life, but ultimately they, too, will be discarded as waste material. In the retreading process, powder waste is generated in the buffing process of tyre retreading. The worn-out treads are buffed before recapping, and this leads to accumulation of tyre buffing waste.

Tyre buffings, especially the finest ones, are commonly reincorporated to a certain extent into new formulations for tyre retreading. The bigger crumbs are used with polyurethane binder to produce playground mats. Despite the diversity of applications of tyre/powder waste, there are still plentiful amounts of rejects/wastes to be disposed. In Malaysia it is estimated that four millions units of tyres are disposed annually.

The Department of Environment has put a stop to the open burning and burying of tyres/wastes as it causes air pollution and land instability, respectively. Wastes could be delivered to specific incinerating areas but at a cost to the rubber manufacturers.

Scrap tyres have also been used as artificial reefs for the breeding of fish and as dock fenders. Garden furniture has also been produced in a limited quantity. Waste tyres are also recovered and processed into reclaimed rubber for use in subsequent rubber product manufacture.

Reclamation is an old technology utilising the digester, reclamator and steam and pan process to degrade the rubber. The reclaimed rubber is added in the proportion of 10–20% to a new formulation as a higher level has a detrimental effect on the final vulcanizate properties.

In all technology of recycling, the tyres have to be buffed to produce tyre crumbs/buffings before the process of reclamation is pursued. There has been continuous a search to produce reclaimed rubber economically as the old technology is time consuming. New technologies have emerged in the last five years *eg* the *DELINK* process. This process is claimed merely to delink the S-S bond in the vulcanizates. After much a worldwide publicity, the technology has gone into obscurity. The Malaysian Rubber Board has developed its own ‘novel’ technology to recycle tyre buffings waste to help the Malaysian rubber industry. This is described in this paper.

Regulations

Under the present environmental law, used tyres are not allowed to be buried, burnt or dumped into the sea. In one municipality in the north of peninsular Malaysia, used tyres are required to be deposited to a site for recycling into tyre crumbs. Despite the prohibition under the Department of Environment law, used tyres are still disposed of indiscriminately.

Tyre-derived fuel (TDF)

Used tyres are not used as fuel substitute in Malaysia because of the hefty black smoke due incomplete combustion by burning of tyres. No incinerator is designed to accommodate waste tyres as fuel material yet.

Cement kilns

To accommodate tyres as supplementary fuel for the furnaces in this industry, the furnaces need redesigning. The industry is not in a position to shift because of the cost involved.

Binders in road construction

The stipulated law requiring the incorporation of rubber in road construction in Malaysia allows the market expansion for tyre rubber powder.

Recycling

Although the problem of tyre disposal is admittedly an increasing problem for the future, the current position in Malaysia is to adhere to recycling technology for used tyres. The technology that is most efficient, economic and cost effective is well sought after. There are currently four big tyre-recycling companies in Malaysia producing crumbs and recycled rubber using various technological approaches.

Economics

The thrust in Malaysia is help the product manufacturers to reuse recycled rubber in product manufacture economically to stay competitive in the market place.

Technology

Fine tyre buffings are passed through a two-roll mill and a masterbatch of a chemical (RRIMREA) developed by the Rubber Research Institute of Malaysia is added to 100 parts per hundred parts of rubber (parts phr) of crumbs at a mill temperature above 90°C. Due to the thermal, chemical and mechanical action, sulphur-sulphur bonds and to a certain extent the rubber chains (R-R) are severed (Figure 1). To form sheets, a small amount of virgin rubber is necessary. The revulcanization of the recycled material without curatives produces a tensile strength value of 4MPa, but upon addition of activators and curatives, a tensile strength above 7MPa is achieved (Figure 2), and this is comparable to that obtained by the *DELINK*, *SURCRUM* and *SIMAR D* processes (Figure 3).

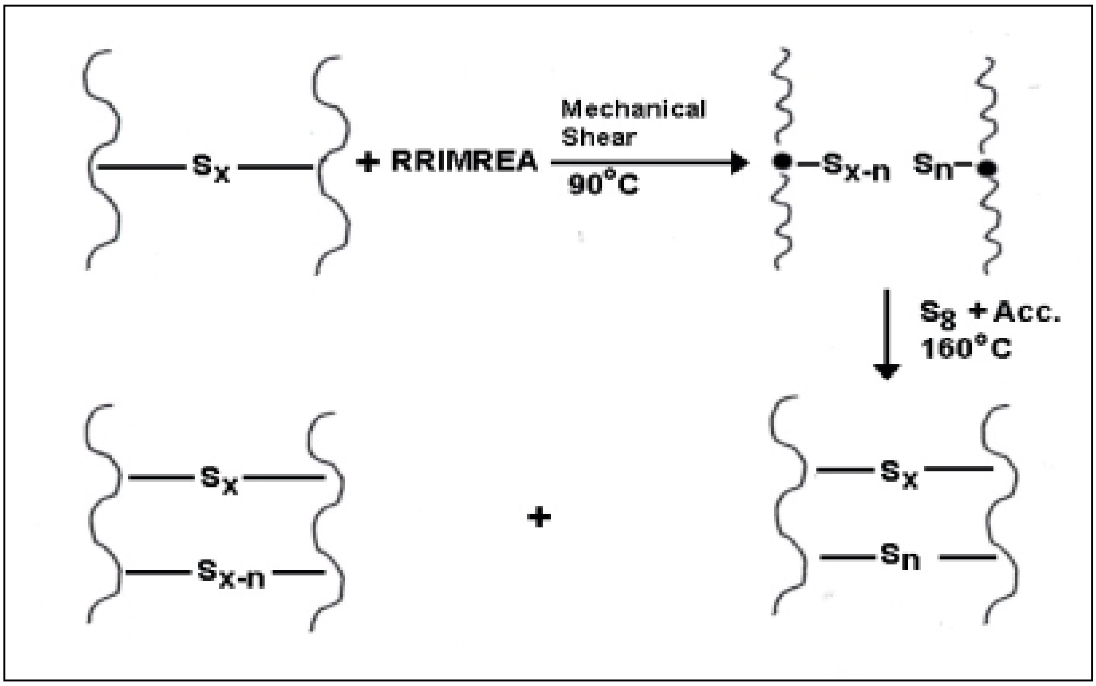

Figure 1. Theory of crosslinking mechanism in RRIMREC process.

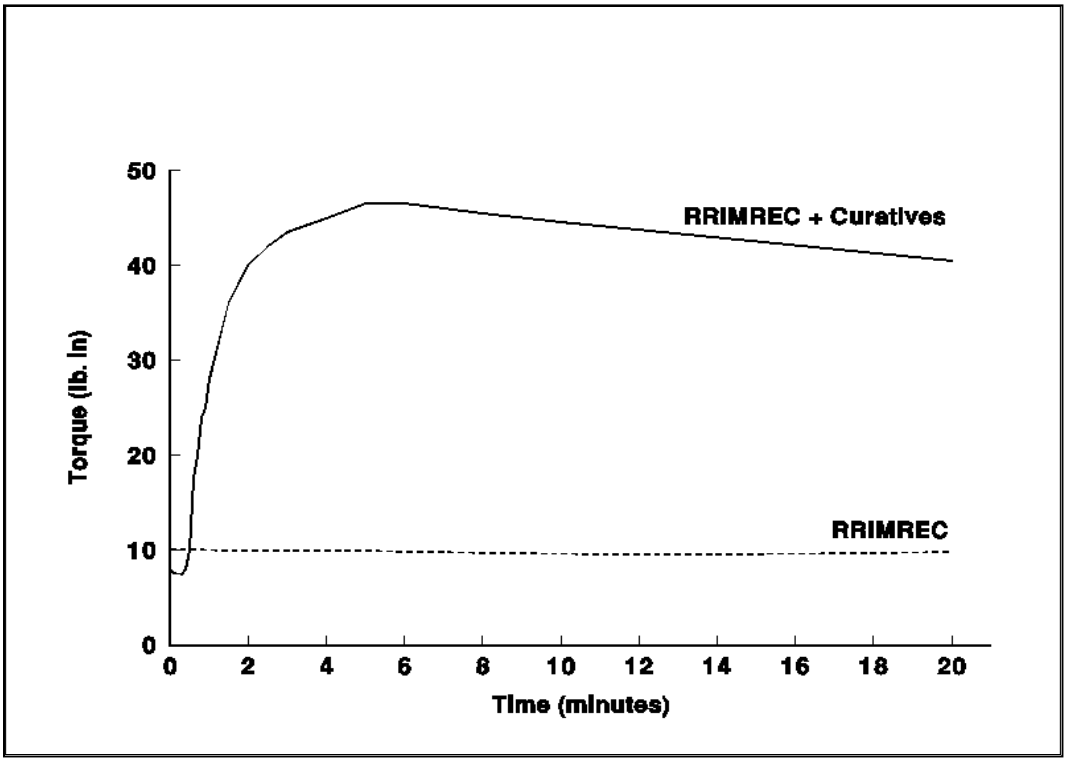

Figure 2. Rheometric traces of RRIMREC.

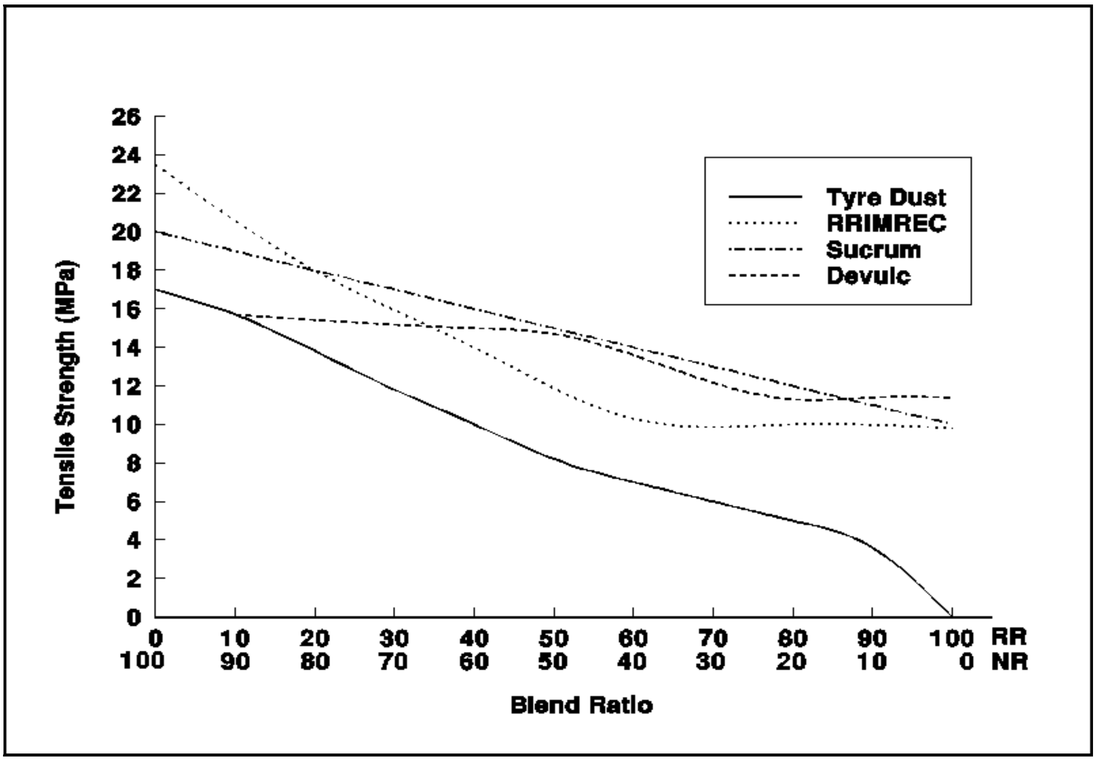

Figure 3. Tensile strengths of different grades of recycled rubber.

Evaluation Studies

The recycled rubber (RR) obtained by the process described earlier was evaluated using a black NR tyre tread formulation containing 50 parts phr HAF black (Table 1). In the experiment the recycled rubber is used a polymer substitute and as a filler.

Table 1: Tyre tread formulation.

Ingredients	Parts by weight.
NR	varied
Recycled rubber	varied
HAF black	50
Stearic acid	2
ZnO	5
Oil	5
IPPD	1
Flectol H	1
Sulphur	2.5
CBS	0.6
TMTD	0.1

Recycled rubber as a 100% polymer material

In the rubber industry it is common to use recycled rubber or tyre buffings as a polymer substitute in a tyre tread formulation. Thus in the experiment various proportions were used as illustrated in Table 2.

Table 2. Tread formulation with variable proportions of recycled rubber

Ingredients	Parts by weight					
SMR 10	100	80	60	40	20	0
Recycled rubber	-	20	40	60	80	100
ZnO	5	5	5	5	5	5
Stearic acid	2	2	2	2	2	2
IPPD	1	1	1	1	1	1
TQ	1	1	1	1	1	1
N330	50	50	50	50	50	50
Dutrex R	5	5	5	5	5	5
CBS	0.6	0.6	0.6	0.6	0.6	0.6
TMTD	0.1	0.1	0.1	0.1	0.1	0.1
Sulphur	2.5	2.5	2.5	2.5	2.5	2.5

Processability Studies

One obvious phenomenon here is that the compound viscosity increases with the increase content of recycled rubber (Table 3).

Table 3. Compound viscosity with increasing recycled rubber content

Proportion - NR : RR	**Mooney Viscosity**
100 : 0	61
80 : 20	61
60 : 40	96
40 : 60	211
20 : 80	211
0 : 100	84

This phenomenon is further demonstrated by the Rheometer traces of the compounds (Figure 4).

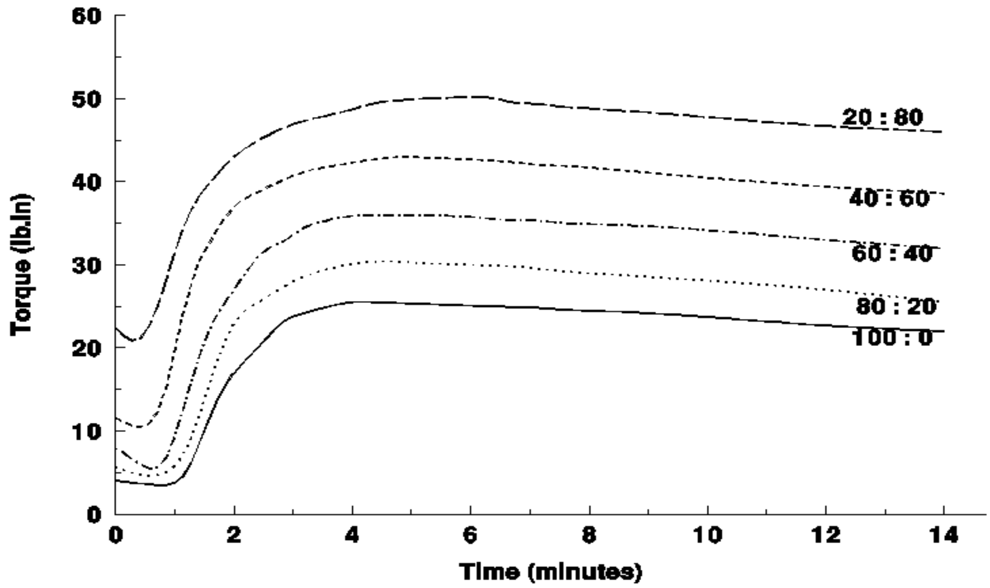

Figure 4. Rheometer traces of RRIMREC/NR.

Physical Properties

The tensile strength and elongation at break of the vulcanizates decreased as the proportion of recycled rubber increased (Figures 5 and 6*)*. The abrasion is also affected as indicated in Table 4.

Table 4. Abrasion Retention Index (ARI) of the vulcanizates.

Proportion::NR:RR	Abrasion Retention Index, **%**
100:0	94
80:20	90
60:40	82
40: 60	64
20: 0	44
0:100	63

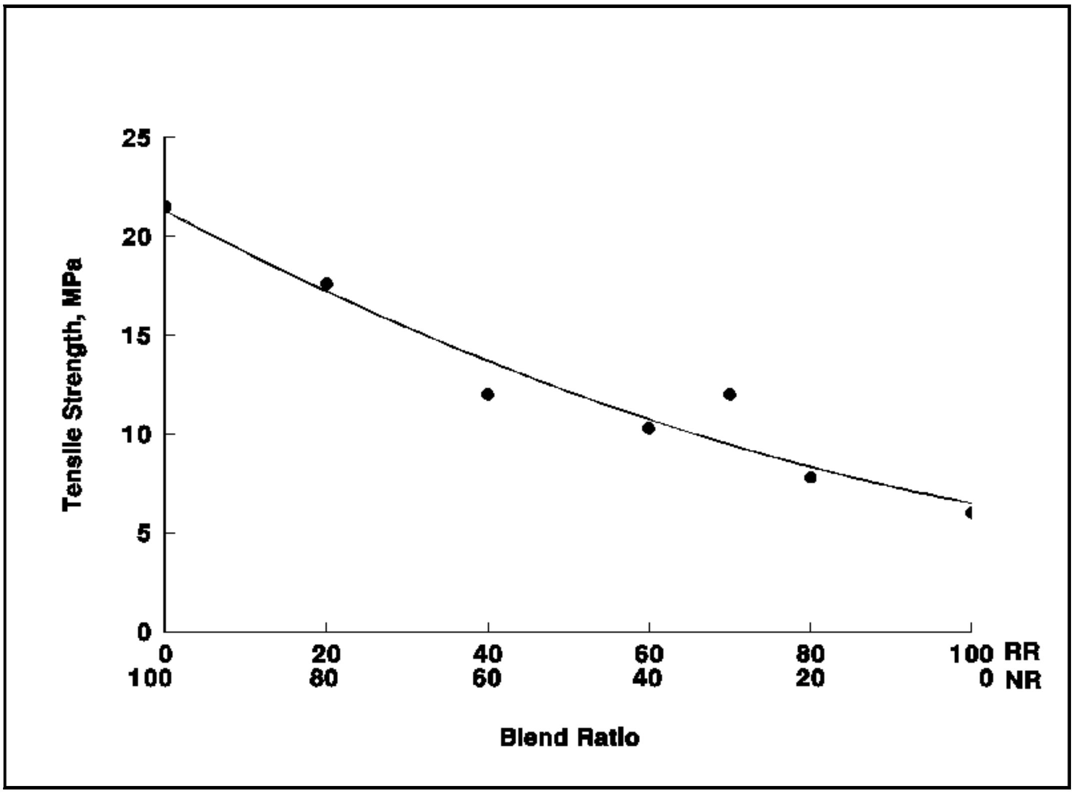

Figure 5. Effect of NR:RRIMREC on tensile strength.

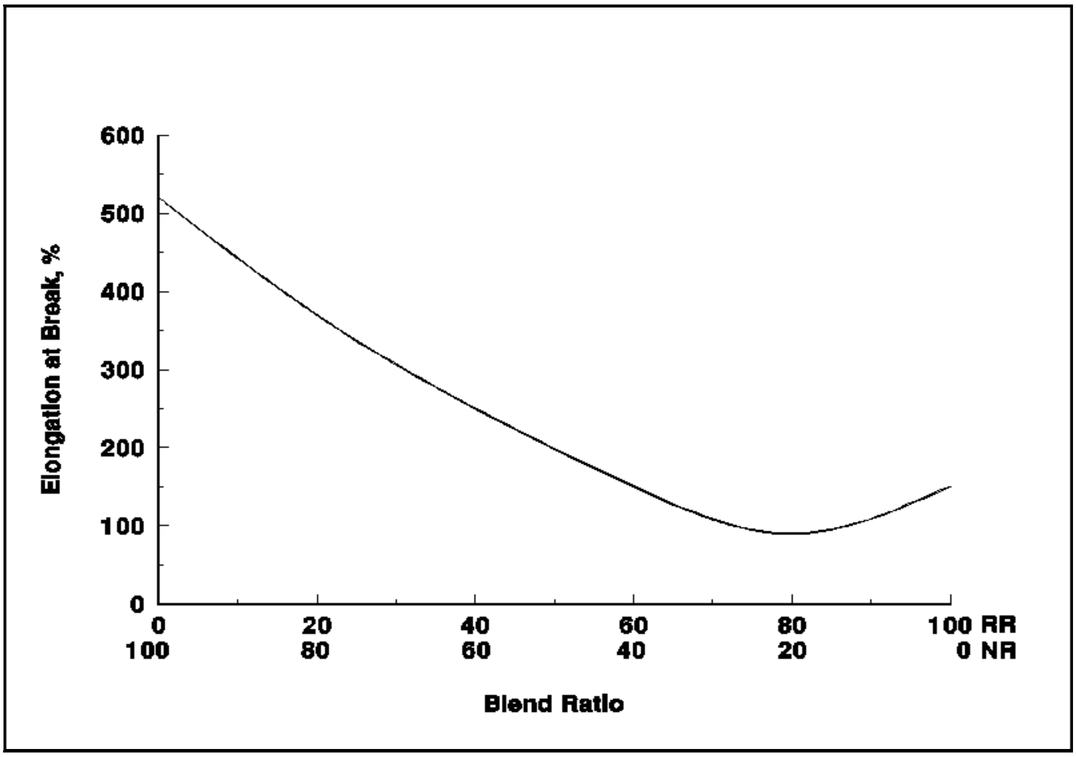

Figure 6. Effect of NR:RRIMREC on elongation at break.

Recycled rubber as filler

Manufacturers of rubber products have been using reclaimed rubber to replace some of the virgin rubber in a tyre tread formulation but have not utilised it as a filler to reduce the cost of compound. Hence the evaluation was pursued. Various levels of recycled rubber were incorporated in a NR tread formulation (Table 5).

Table 5.: Recycled rubber as filler.

Ingredients	Parts by weight						
SMR 10	100	100	100	100	100	100	100
Recycled rubber	-	20	30	40	50	70	100
ZnO	5	5	5	5	5	5	5
Stearic acid.	2	2	2	2	2	2	2
IPPD	1	1	1	1	1	1	1
TQ	1	1	1	1	1	1	1
N330	50	50	50	50	50	50	50
Dutrex R	5	5	5	5	5	5	5
CBS	0.6	0.6	0.6	0.6	0.6	0.6	0.6
TMTD	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sulphur	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Processability studies

The Mooney viscosity of the compound increases with up to 20 parts phr of recycled rubber present in the compound but upon increasing its content further to 50 parts phr the viscosity drops to that of the virgin rubber. Further input of the recycled rubber increases the viscosity again (Figure 7).

Mooney scorch t_5 at 120°C

The compound is most scorchy at 20 parts phr recycled rubber but tends to increase as the proportion recycle rubber increases (Figure 8). This is further elucidated in the Rheometric studies (Figure 9).

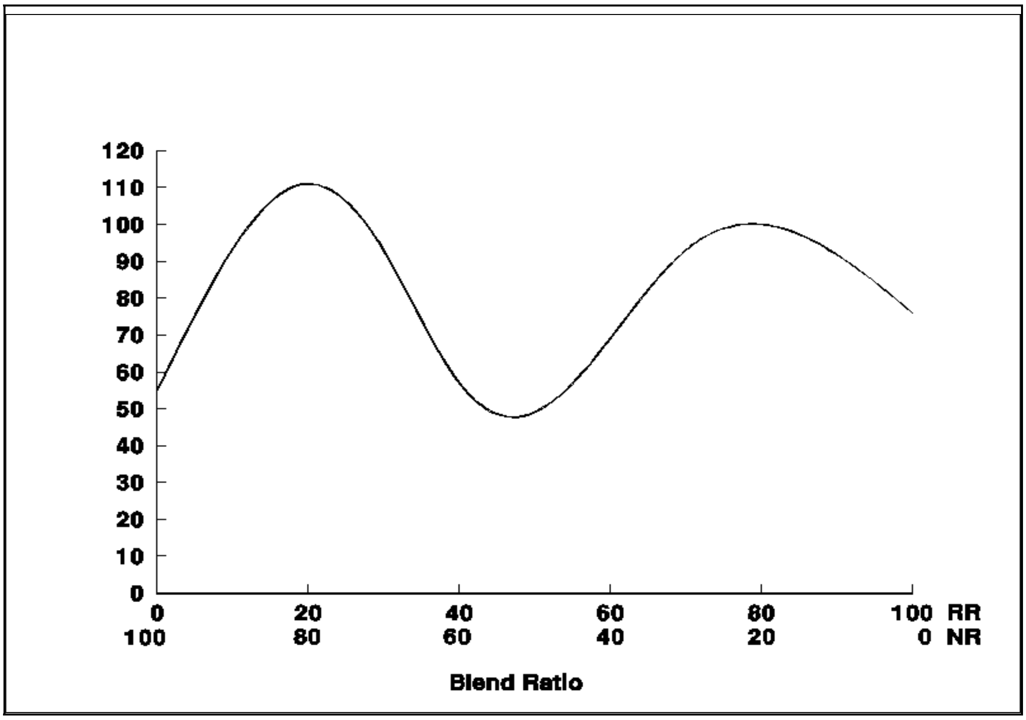

Figure 7. Effect of RRIMREC as filler on Mooney viscosity.

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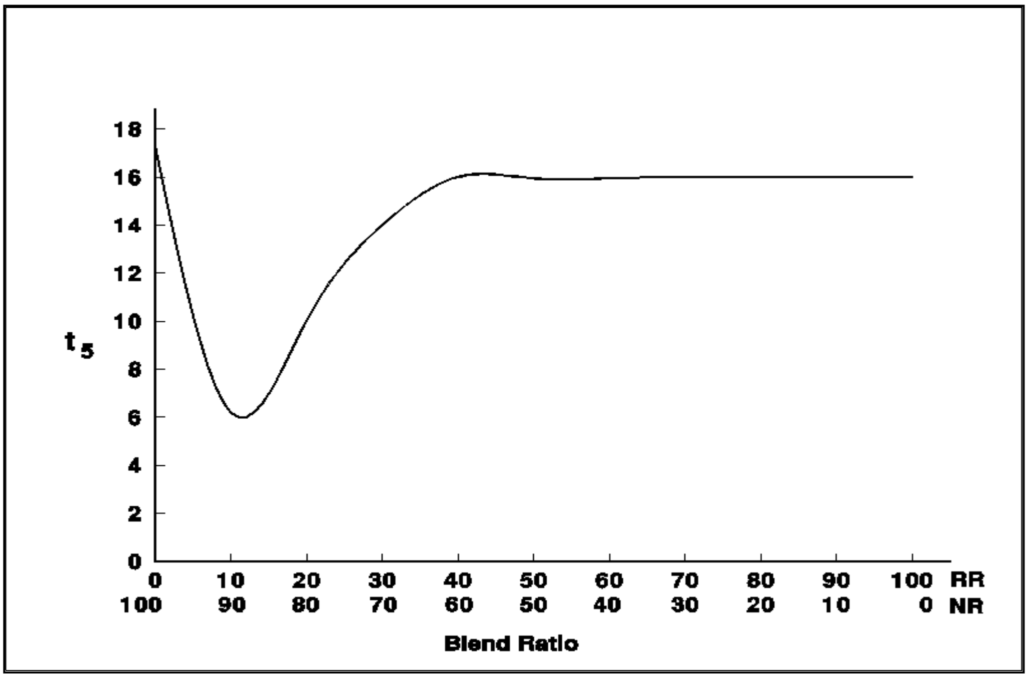

Figure 8. Effect of RRIMREC as filler on t_5.

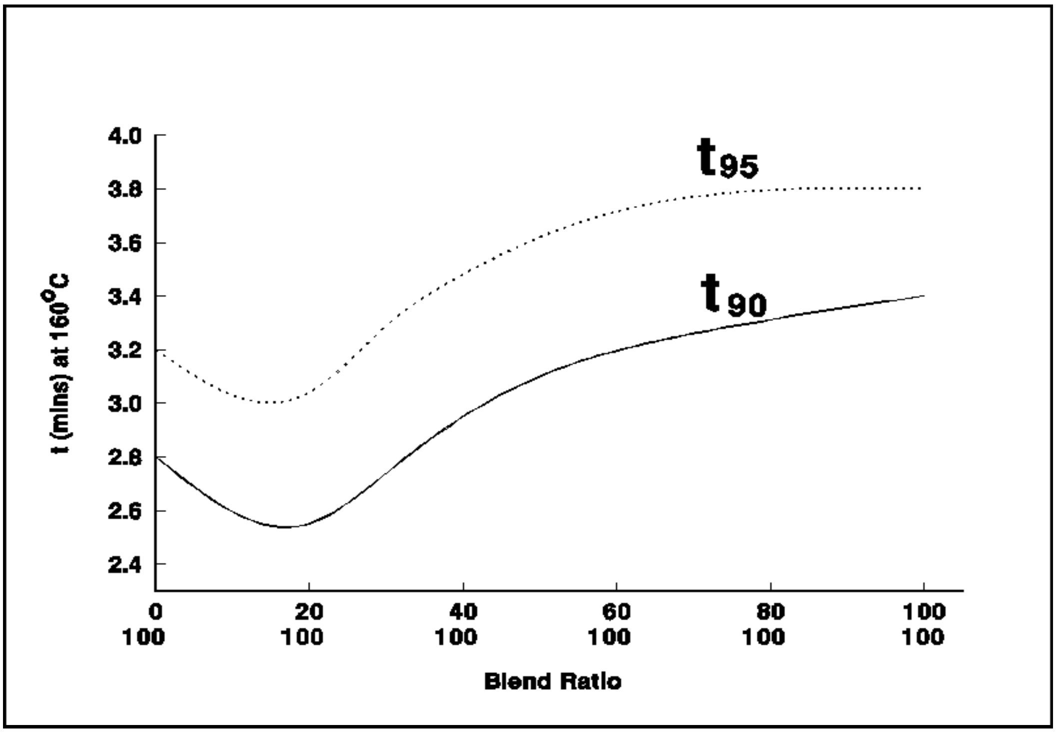

Figure 9. Effect of RRIMREC as fillers on t_{90} and t_{95}.

Physical Properties

At 20 parts phr recycled rubber, it shows reinforcement effect as the hardness increases. However as the proportion of recycled rubber increases the hardness tends to drop to that of virgin rubber compound displaying some dilution effect (Table 6).

Table 6. Effect of recycled rubber on hardness.

Proportion::NR:RR	IRHD
100:0	62
100:20	86
100:30	81
100:40	70
100:50	64
100:70	64
100:100	62

Tensile strength

Due to the phase stiffness effect, the tensile strength drops at 20 parts phr level of recycled rubber (Figure 10). Increasing the level of recycled rubber causes an increase in tensile strength up to 20MPa.

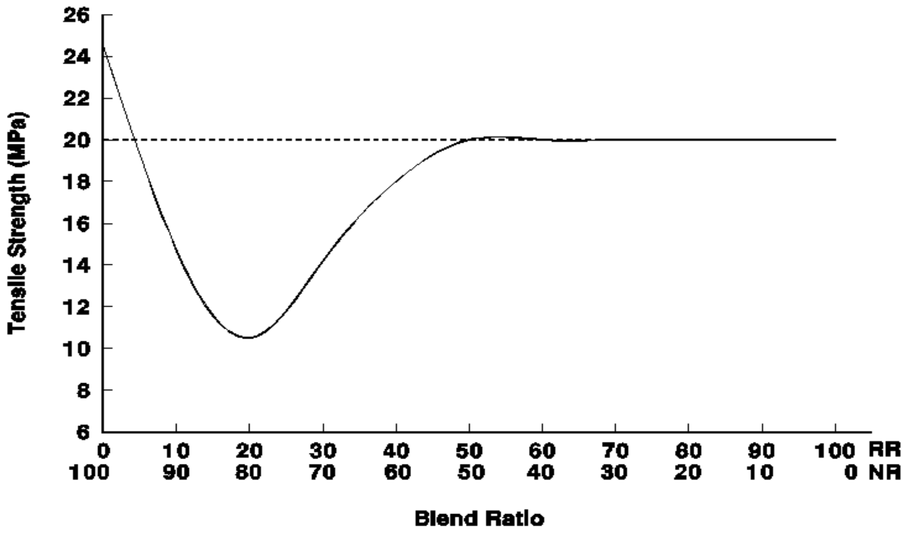

Figure 10. Tensile strength at hardness of IRHD 65 ±5.

Elongation at break

The stiffness effect at 20 parts phr of recycled rubber in the formulation is further illustrated by elongation at break results (Figure 11).

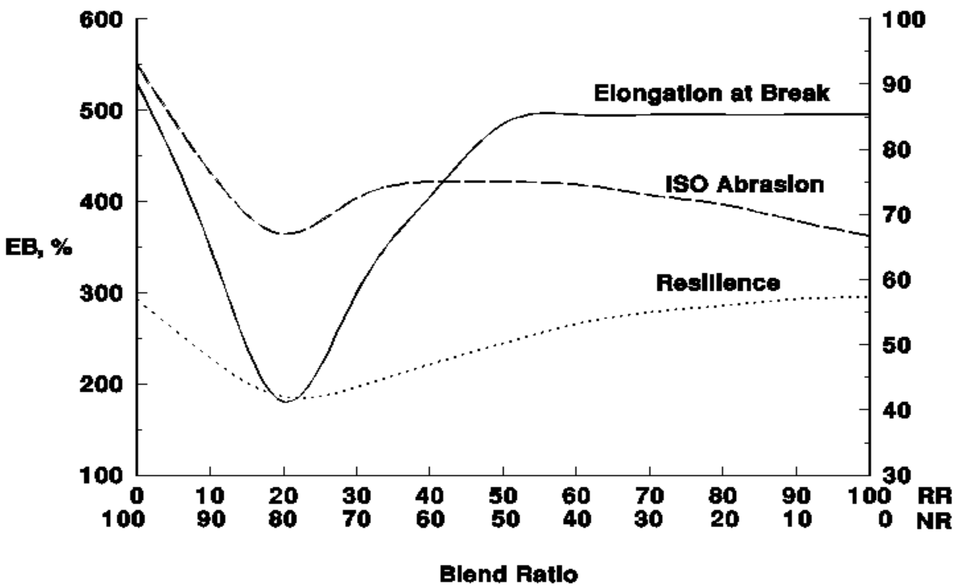

Figure 11. Effect on elongation at break.

Target 65 ± 5 hardness value

With the exception of hardness increases at 20 and 30 parts phr of recycled rubber, the rest of the vulcanizates have hardness in the range of 65±5. Hence extra oil levels were added in the formulation as shown in Table 7 to achieve a hardness range of ±5.

Table 7. Addition of oil to maintain hardness 65±5.

Ingredients	Parts by weight		
SMR 10	100	100	100
Recycled rubber	0	20	30
ZnO	5	5	5
Stearic acid	2	2	2
IPPD	1	1	1
TQ	1	1	1
N330 black	50	50	50
Dutrex R	5	15	13
CBS	0.6	0.6	0.6
TMTD	0.1	0.1	0.1
Sulphur	2.5	0.3	0.3

The tensile strength improved from 12MPa to 20MPa (Figure 12). This indicates that recycled rubber behaves as a filler at low levels. Hence extra processing oil is necessary to soften it and render it processible. The elongation at break also increases (Figure 13).

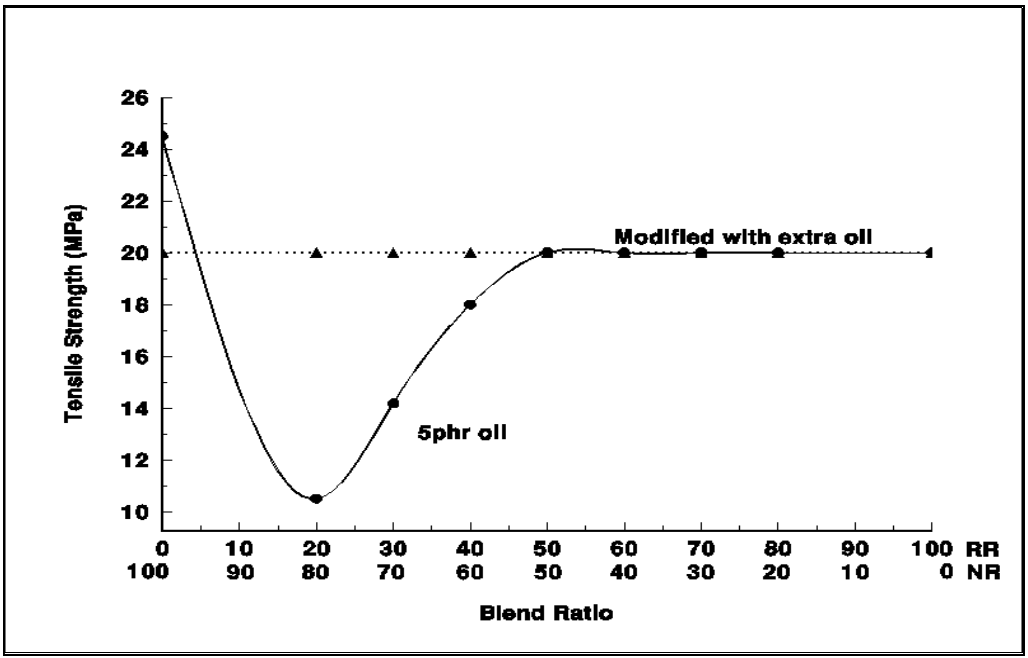

Figure 12. Effect on tensile strength.

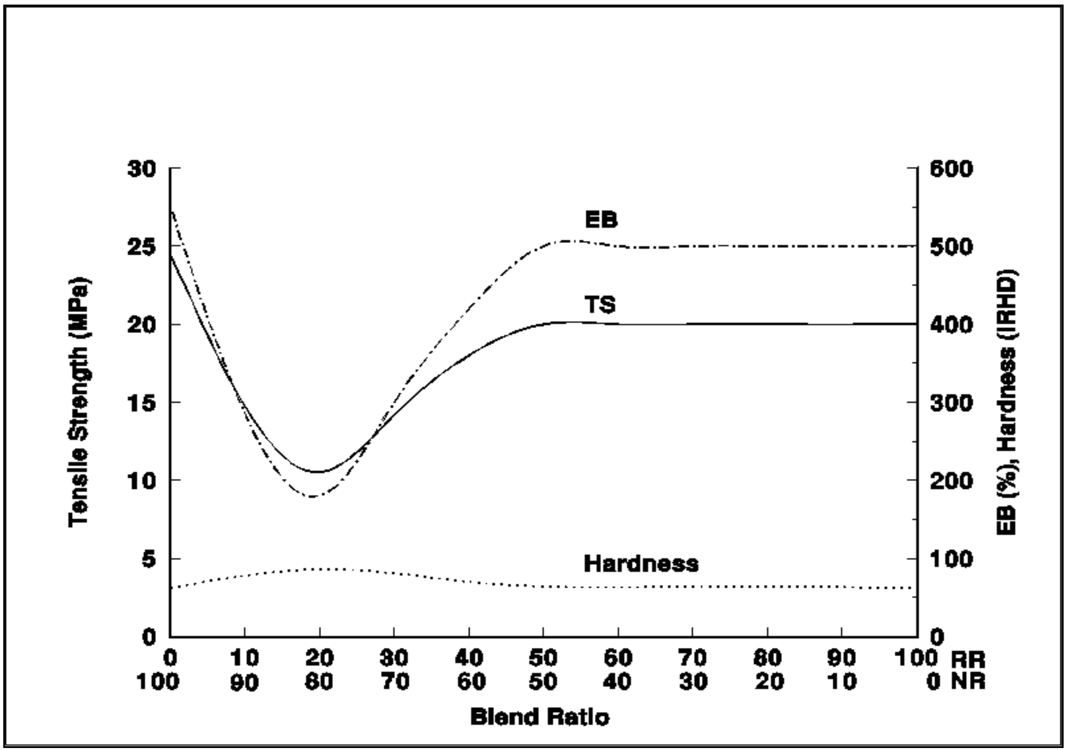

Figure 13. Effect on elongation at break.

Tyre buffings as filler

Various levels of buffings were incorporated into a black compound (Table 8).

Table 8. Tread formulation with tyre buffings.

Ingredients	**Weight (part phr)**			
SMR 20	100	100	100	100
Tyre buffings	0	10	20	30
Zn0	5	5	5	5
Stearic acid	2	2	2	2
IPPD	1	1	1	1
TQ	1	1	1	1
N330 black	50	50	50	50
Dutrex R	5	5	5	5
CBS	0.6	0.6	0.6	0.6
TMTD	0.1	0.1	0.1	0.1
Sulphur	2.5	2.5	2.5	2.5

The viscosity of the compound increases as the proportion of tyre buffings increases (Table 9).

Table 9. Effect of tyre buffings on compound viscosity.

Tyre buffings	Compound viscosity
0	38
10	47
20	58
30	67

The physical properties of the vulcanizates are illustrated in Table 10.

Table 10. Physical properties of vulcanizates with tyre buffings as fillers.

Properties	NR/Buffing			
	100/0	100/10	100/20	100/30
TS, MPa	24	23	22	23
EB, %	500	500	500	500
M100, MPa	2.4	2.2	1.9	1.9
M300, MPa	11.4	10.3	9.6	10.2
Aged, 7d @ 70°C				
TS, MPa	22	21	21	20
EB, %	400	420	430	430
M100, MPa	3.5	3.1	3.2	3.0
M300, MPa	11.7	13.8	13.7	13.5
ARI, %	88	84	82	71
R. Resilience, %	63	62	63	61

Further increase in the proportion of tyre buffings creates processing difficulty.

Natural rubber:butadiene rubber (Buna): recycled rubber blends

In truck tyre sector, NR:Buna blends are commonly used to provide synergistic properties on the tread portion depending on the severity of use. It is usual to find a tread recipe comprising 60NR:40BR and in the evaluation pursued, recycled rubber is added as a filler to reduce material cost. The following formulation (Table 11) was used.

Table 11. Typical tyre tread formulation.

Ingredients	Parts by weight		
	(1)	(2)	(3)
SMR 10	100	60	60
BUNA CB11	-	40	40
Recycle rubber	100	-	100
ZnO	5	5	5
Stearic acid	2	2	2
IPPD	1	1	1
TQ	1	1	1
N330	50	50	50
Dutrex R	5	5	5
CBS	0.6	0.6	0.6
TMTD	0.1	0.1	0.1
Sulphur	2.5	2.5	2.5

The results are shown in Table 12.

Table 12. Physical properties of NR:BR:RR tyre tread formulations.

Properties	1	2	3
TS, MPa	18	14.6	16.2
EB, %	480	320	450
M100, MPa	1.9	3.4	2.0
M300, MPa	9.1	12.7	8.4
ISO abrasion, ARI%	70	140	120
Compression set 22h/70°C	55	40	55
Hardness, IRHD	62	71	63
Dunlop Resilience % @ 23°C	53	68	56
DeMattia Flex to grade C	20	140	47
Trouser tear, N/mm	15	10	15
HBU (24lb/0.175"/100°C) Time to 25^{o} temperature rise, min	40	19	34
Aged 7d/70°C			
TS, MPa	19	13	15.5
EB, %	430	280	370
M100, MPa	2.5	4.2	2.7
M300, MPa	11.9	-	11.9
Hardness, IRHD	70	76	71

An important feature to note here is that even at 100 parts phr level of recycled rubber incorporated into NR60:BR40 blends, the drop in ARI is only 10% compared with pure 60NR:40BR blend. Not only is the compound cheaper, it maintains the ARI characteristics. The hardness is lower in the case of NR:BR:RR blends but the tensile strength is better. Like in any compound containing RR, the flexing characteristics are inferior compared with compounds without recycled rubber.

Conclusion

In the present context where environmental issues are an important aspect of life, it is imminent that used, discarded vulcanized rubber has to be considered as a reusable polymer. This is also in line with the manufacturing industry's requirement to reduce production cost and reap better profit. The use of recycled rubber is one way to reduce material cost. The process described can be used in an individual factory to reutilize its waste. Hence it reduces or eliminates its disposal cost to transport the waste material to the dump site.

Discussion

Dr U Hoffmann. Thank you Dr Yusof. I suggest that we now have the open discussion on these two papers. Before giving you the opportunity to raise questions, I would like to say a few words on the objective of our dialogue this afternoon. The idea of this Workshop is to go a bit further than a coffee-shop discussion. Wherever considered justifiable and required – and required means required for example by a Member Government or an industry association or a group of companies – UNCTAD would be interested in helping to conducting pilot activities on the subjects discussed this afternoon. So therefore where we discuss the two issues, I would attach particular importance to any suggestions you may have along these lines. Whenever you feel there could be some useful activities – Mr Serumgard has mentioned a number of areas on the empirical front but also general concepts – we would certainly be willing to discuss pragmatic ways of turning concepts into action. The floor is open for questions.

Dr L M K Tillekeratne. In order to start the ball rolling, I would like to ask Mr Serumgard what precautions are being taken in landfilling with old tyres to prevent mosquito breeding. After what length of time are such areas suitable for cultivation or for building?

Mr J Serumgard: The first question asks what precautions are being taken in landfilling old tires to prevent mosquito breeding. The first issue is a function of our desire to eliminate stockpiling as a method of handling – or postponing handling – scrap tire problems. We oppose tire stockpiling. Where it may be allowed, even temporarily, we urge that an appropriate anti-mosquito treatment be required. Where tires are landfilled, the most common requirement is that they be cut or shredded so as to not hold water. This eliminates mosquito breeding. In addition, most landfills require a daily cover with inert material. Normally this is dirt but can include shredded tire themselves. This further reduces the possibility of mosquito breeding, even if the landfill allows whole tires to be tipped. With respect to further use of landfill areas, that is not affected by the presence of tires once the landfill has been properly closed. Whatever can be done with the landfill is not altered by the presence of tires. In situations where tire monofilling is allowed (a tire monofill is a landfill that only contains tires), I know of no limitations on further use of the land once it has been closed and an appropriate covering layer of dirt has been placed. Some settling may occur, but if the shredded tires in the monofill have been compacted, this settling should conclude within a one-year time frame. This settling should not affect cultivation. It may affect construction, such as roads.

Mr K Jones. Mr Serumgard suggested that in Europe, civil engineering applications were not developing. I get the impression that this is not quite true. There are certainly one or two very interesting projects that appear to be taking place, in particular in using rubber crumb as a material for drainage channels on highways. Just before leaving to come here I read a very bullish paper suggesting that the use of tyres as fuel was a transient phase and that really Europe was moving towards higher-grade outlets for scrap tyres.

Mr J Serumgard. I am encouraged that there may be civil engineering applications extant in Europe. With respect to fuel applications, it may be a transient phase. However, I would submit that there are some very serious technical problems with respect to the performance of rubber compounds that have a recycled component that we are only slowly overcoming. While it is to be – and is being – encouraged in the US, Europe and elsewhere, it will be a significant period of time before it fully displaces fuel applications. Fuel applications are certainly not the highest and best use. However, they are a broad, large-volume use that will consume substantial qualities of tyres in most jurisdictions for the foreseeable future.

Mr M E Cain. I think a very important point has been raised and I think this is an area where decisions can and should be taken. The tyre is an identifiable waste source that should not go into landfill for several reasons. One of them is that it is an energy source and energy should not just be thrown away. Any diversion of tyre material into other uses loses the identity of that material as a waste stream in almost every case. Thus all that you are doing is delaying the appearance of that particular tyre-derived material in a landfill, and if you do that you are still wasting the energy resource. Isn't it time that someone really made a decision as to what is the most environmentally sound way of disposing of tyres? Personally, because of these considerations, I cannot see any route that has more value than energy recovery through use as fuel.

Dr U Hoffmann. Perhaps I should make an observation on that comment. I have collaborated very closely with a team of students and graduates at the Free University in Amsterdam. At the end of 1997 and early in 1998, the team attempted – and that word I would like to underline twice – to come up with a framework on the basis of which one can evaluate the private and social benefits and costs of the various recycling and disposal routes just described. It was certainly a very courageous effort, whatever one might say about the limits and limitations of the assumptions that underlay the variables used in the model. However, one thing that was surprising was that, as Mr Serumgard has already flagged, the social benefits or the social costs incurred by all disposal routes – excluding retreading – are not very different. There is, however, still a variation in the order of some 30–40%. If that is the case, Mr Cain's point is well taken, in that one should very carefully think about what guidelines a government may want to provide to the industry in encouraging or discouraging a number of these options. It is clear from the empirical picture that all the intervention activities of governments at central or local level to foreshadow some of the disposal costs of a scrap tyre have not been very successful. In fact, most such schemes have hardly covered their administrative costs. The transaction costs should not be underestimated. Furthermore, the lesson learned from Mr Serumgard's paper is that so far the only thing that has really worked, looking at the growth figures in a very sober-minded way, is tyre-derived fuel. This is not only providing the lion's share of the market but also has growth dynamics that by far outpace the other disposal markets. There are good reasons for this. It needs to be clearly understood, as Mr Cain says, that a tyre is a substitute fuel. Anyone who uses a scrap tyre as a fuel substitute will replace costs incurred for other fuels, so there is already an inherent saving which is very different from that of other disposal avenues where there is no natural substitute. The user of a scrap tyre as a fuel saves costs on account of this substitute function and in addition he gets a payment in the form of a tipping fee. The tipping fee is not an invention by governments, but a common rule in the market. It allows the final disposer or the user of the scrap tyre as fuel to make up any additional costs for shredding the scrap tyre, for removing non-rubber components if required and also for transport costs, *etc*, if necessary. From an economic point of view, this works out in a profitable way. It also works out from the point of view of social costs, which include emissions created by transport and processing and also reflect the material and emission savings for the alternate that the scrap material replaces. If you read that into the equation, then you conclude that the various processing avenues have social costs that are not much different. There are no orders of magnitude between them. This explains why tyre-derived fuel has been a success story in the United States and, according to the figures Mr Serumgard has given, the trend seems to be continuing. In Europe in particular, tyre-derived fuel is a hot iron that only some like to touch, yet there is not much empirical evidence to support this reluctance. However there is a strong political sentiment that makes this option very, very difficult for a number of European governments. Is there a need for this discussion to be conducted in a different light as we get more empirical evidence and one can think of using more abatement technology to meet even the highest emission standards?

The second point is that Dr Yusof and Mr Serumgard mentioned that there is a whole range of options and one might establish guidelines according to the preference of a specific country. In the light of the economics, this might imply that at the beginning you have to anticipate a rather hefty financial intervention to cope with disposal charges or disposal costs to make up for the non-existent replacement or substitute function which is available in the case of tyre-derived fuel. On the other hand, to cover the additional costs for the development of technology or alternative markets, one would have to conceive of a fairly hefty fee to make them financially interesting. This is a question on which opinions differ very much from country to country even within Europe.

Mr M E Cain. I think you have just taken a long time to say ‘yes’.

Mr J Serumgard. I would just like to make one comment. When I mentioned good science we have to understand that there is good science that proves that a utilization is safe. There is also good science that proves that there are problems with some applications. I have seen countless sets of slides like those of Dr Yusof that demonstrate what happens when you attempt to modify some rubber compounds by adding 20, 30 or 40% recyclate. We in the rubber industry have to make those outside our industry aware that, unlike a tin can or newspaper, there is no easy method of recycling rubber back into new rubber. When we bake a tyre, we are baking bread and it is impossible to recover new flour from old bread. That is a technological problem that I am afraid some in the environmental world either don’t care to or don’t want to understand. Frankly, they don’t understand. We have to look at what the realistic options are, and we have to promote those realistic options to the policy-makers. We have to make them understand that rubber is not like a tin can and cannot be melted down and returned to new tin stock and go back into the next beer can. Rubber is a different kind of material and hence we need to focus on those utilization methods that are, in fact, practicable, including fuel.

Mr M E Cain. There is good science, and there is good science pointing in the wrong direction. Research scientists – and I was one – will love spending their time looking at possibilities, sometimes whether they have any commercial reality or not. People are going to waste a lot of time, and I am saying that the time is approaching for governments to say ‘this is good’. We don’t always expect governments to make right decisions but we want them to make a decision. I think that at some time in the near future governments have got to say ‘this is good and this is what you should do’. I think that would help everybody and would stop a lot of good science being pointed in the wrong direction.

Dr U Hoffmann. I could not agree more. May I pose one question to Dr Yusof? You mentioned that tyre derived fuel does not play a significant role in your country as a disposal route. What is the reason for this and do you foresee some change through the opportunity to install anti-pollution devices that would meet very strict emission standards. Second, what is the proportion of scrap tyres for which markets do currently exist and what goes into the tyre heaps.

Dr Yusof. If there is pollution control equipment that can be installed in the burners it is possible that tyres will be used as tyre-derived fuel. Currently in Malaysia the design of the incinerators is such that they cannot accept waste tyres as fuel substitute because of the smoke emitted during burning. As regards scrap tyre disposal, roughly 20% – a quite substantial level for a small country like Malaysia – is recycled. We hope that the government will introduce some legislative policy that scrap tyres will be disposed off at certain sites where disposal can be controlled and reprocessed or used as tyre-derived fuel in the near future when we have good anti-pollution control systems installed in the factories concerned.

Dr Tillekeratne. Dr Yusof, can you use waste tyres freely as a fuel? It has been observed that because of the degradation products like sulphur dioxide and the acidity of the fumes there are environmental problems. Can you use tyres freely even in an incinerator without special precautions to neutralize and control the quality of the smoke or would there be environmental problems?

Dr Yusof. As far as I know, in Penang they have incinerated tyres. The design of the incinerator will probably be different to absorb the gases emitted in the combustion of rubber materials.

Opportunities and constraints for international payments for carbon sequestration services to natural rubber producers

Chairman's introduction

Ladies and gentlemen, the pendulum of interest has now swung from the internalization of environmental costs to the internationalization of an environmental benefit. In other words, the payment for an environmental service that has previously been unrewarded. The issue we are considering is referred to in the international environmental community as 'carbon offset financing'. This is nothing more than being paid for the carbon sequestration or carbon-sink function of the rubber tree by an emitter of greenhouse gases, particularly carbon dioxide. The Kyoto Protocol provides a global emission cap, and greenhouse gases know no frontiers. The Protocol is binding only for the industrialized countries and the transition economies in Eastern Europe. A greenhouse gas emitter, such as a power generating plant, in a developed country wishing to expand will get permission from its government only if water-tight evidence is provided that emissions will not increase either at all or directly in proportion to the expansion. If emissions increase, the emitter must pay for a sequestration service, thus critically affecting the profitability – but not the productivity – of natural rubber growing. This is the background to the subject to be addressed by Dr Wan Rahaman.

Studies of carbon sequestration in rubber

Dr Wan Rahaman and Dr Sivakumaran

Malaysian Rubber Board, Kuala Lumpur

Introduction

Global awareness on the effects of climate change has resulted in a great deal of interest in the management of greenhouse gases. The First World Climate Conference in 1979 highlighted the seriousness of the problems and attempted to identify the impact of the climate change on humanity. The Second World Climate Conference in 1990 called for a framework treaty on climate change and, in the same year, the UN General Assembly provided the green light for the start of the treaty negotiation. The 1992 Rio Earth Summit saw the signing of the United Nations Framework Convention on Climate Change (UNFCCC) and other related agreements such as the Rio Declaration, Agenda 21, and the Convention on Biological Diversity. Following these, various commitments were being made by both developed, developing and underdeveloped countries related to the environmental issues. An important pledge outlined in the Kyoto Protocol adopted in December 1997 is the legally binding commitment of the industrialized countries to reduce greenhouses gas emission by at least 5%, (relative to the 1990 levels) by 2008–2012. All these are geared toward addressing the climate change issues.

This paper attempts to highlight the role that can be played by rubber trees and its contribution to the environment in our effort to manage greenhouse gases. Pertinent to this is the management of CO_2 through the efficient photosynthetic processes and sustainable plantation and agricultural practices. It will attempt to project, from the technical point of view, the potential of the global rubber ecosystem in the carbon source/sink relationship. The paper will also highlight various issues that must be addressed if the rubber ecosystem is to be part of the greenhouse gases solution. This paper, however, will not address issues related to the forestry and land use change or other policy related matters pertaining to the Kyoto Protocol that are currently being discussed elsewhere.

The Kyoto protocol and carbon offset activities

On 11th December 1997, delegates from 160 countries agreed upon a historic treaty, which will form the basis for the ever-important climate change agenda. Known as the Kyoto Protocol, the treaty will supplement the United Nations Framework Convention on Climate Change that was agreed upon during the 1992 Earth Summit in Rio de Janeiro. The important element in this treaty is the binding commitment of industrialized countries to the agreed target in the reduction of green house gas emissions.

In essence, the Kyoto Protocol calls for the following:

- carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride were identified as the gases to be limited;

- the emissions of the greenhouse gasses by 38 industrialized countries to be reduced by 5% from the 1990 levels during the period of 2008–2012. The individual country's reduction will however be dependent on the country's economic profiles. For instance, the USA would reduce the emissions of greenhouse gases by 7%, Japan by 6% and the European Union by 8%;
- provisions for 'emissions trading' between a country that cannot meet the agreed emissions targets with another country that have not exceeded their emissions limit;
- the establishment of the 'Clean Development Mechanism' – a mechanism that would permit corporations or companies based in wealthy countries to initiate specific investment in emissions-reduction projects in developing or underdeveloped countries.
-

The Kyoto Protocol therefore allows for international co-operation in the transfer of emission reductions between countries through the *carbon-offset market*. Industrialized countries as defined in Annex 1 of the Protocol can obtain their obligatory emission reductions credit by financing the greenhouse gas reduction activities in countries with economies in transition or other developing countries. However, in the case of emission reduction transfer between industrialized countries and developing countries, the activities can be carried out only through the Clean Development Mechanism.

The Carbon Offset Team of the World Bank[1] has identified the following requirements for enabling the carbon offset market:

- commitment among the industrialized countries to binding emissions reductions, compelling the obligated countries to search for the least-cost emission reduction opportunities;
- the existence of relatively high marginal cost of abatement of carbon in industrialized countries and low marginal cost of abatement in other countries;
- the framework for the industrialized countries to purchase carbon offsets from countries with economies in transition and/or developing countries and then to receive 'credit' for these offsets achieved outside their borders towards their own reduction obligations; and
- verification of offsets by an established authority in order for them to be valid and marketable.

Forest plantation and carbon sequestration

Forest plantations as defined by Parks *et al*[2] include contiguous areas greater than one hectare of planted trees for any of the following purposes: reforestation; roundwood plantation; bioenergy; and non-wood purposes materials production.

Forest and plantations have been considered as the natural ‘sponges’ for absorbing carbon dioxide from the atmosphere. Carbon sequestration is achieved *via* the uptake of CO_2 from the atmosphere and its conversion into cellulose and plant organic compounds. The amount of carbon sequestered depends on the type of forest or plantation ecosystem and the type of organic compounds assimilated as the result of photosynthesis. The stability of the resulting sequestered carbon to remain in the sink very much depends on the nature of organic products produced and the external ‘disturbances’ these products are exposed to. Carbon in wood, some soil organic compounds, coal and petroleum are stable until the carbon is released again through respiration, combustion or in the case of coal and petroleum until extraction or occurrence of major changes.[3]

There remain however, a number of important and critical issues that need to be resolved before plant carbon sequestration projects could be accepted or implemented. While basic scientific data points to the fact that photosynthetic processes convert CO_2 into plant carbon sink, there is uncertainty as to the actual quantum of carbon being sequestered by specific ecosystem in question. Available data being used are extrapolated from basic laboratory experiments and deduced from the assumption that organic matter is 50% carbon.

Other pressing issues include the tagging of the economic value to the impact of carbon sequestration. Van Kootan *et al* (as cited by Sampson and Sedjo[4]) suggested that the value of each tonne of CO_2 sequestered from the atmosphere could be obtained if data on the value of the damage created by each additional tonne of CO_2 released to the atmosphere can be developed.

Sufficient scientific and commercial data are available for well-established plantation crops such as rubber and oil palm, which could support these ecosystems as having sequestered or having the potential for sequestering the carbon from the atmosphere. To date, these data have not been made use of for specific carbon sequestration projects. This is not for lack of interest or effort, but due to the overall uncertainties on a number of conceptual issues relating to the overall carbon sequestration.

Carbon sequestration by *Hevea*

Biomass produced per rubber tree over a 30-year cycle

Data given in Table 1 shows that the total biomass produced by a single rubber tree over a 30-year cycle is 0.52 tonnes. The bulk of this biomass is made up of that contained in the branches and roots, amounting to 0.30 tonnes.

Table 1. Oven dry weights of various components of rubber trees.

Weight, kg/tree								
Site	Leaves	Tertiary branches & twigs	Secondary branches	Main branches	Crotch	Trunk	Roots	Total
1[a]	10.5	90.6	110.7	175.5	14.7	59.1	141.6	602.7
2[b]	10.9	76.3	54.1	133.4	6.0	21.7	136.7	439.1
Mean	10.7	83.5	82.4	154.5	10.4	40.4	139.2	520.9

a. Weights given are means of five polyclonal trees aged thirty years.
b. Weights given are mean of three polyclonal trees aged twenty-nine years.
Source: Reference 5.

Carbon sequestered in one hectare of 30-year-old rubber

The total biomass of one hectare of 30-year-old rubber is 140,643kg or 140.64 tonnes (Table 2). The total amount of carbon sequestered in this biomass is 92,836kg or 92.8 tonnes and forms 66% of the total biomass. The amount of carbon removed in logs harvested for timber is 36.2 tonnes, while the carbon in the residual timber left unharvested on the ground is 56.6 tonnes. This amount of carbon will be returned to the soil if zero burning practices are adopted at the time of replanting.

Table 2. Carbon sequestered in one hectare of 30-year-old mature stand of rubber.

Item	kg/ha
Total biomass	140,643
Total carbon sequestered	92,836 (66%)
Carbon sequestered in logs removed for timber production	36,206
Carbon sequestered in timber not removed*	56,630

* Released into soil if zero burning is practised.

Amount of carbon released to soil from decaying rubber timber

It is estimated that 71% of the total biomass consisting of branches, rootstock and roots, which are not removed at the time of felling, have about 56.63 tonnes of sequestered carbon per hectare. The carbon sequestered in these materials is released by a slow process of decaying to the soil provided zero burning methods are used for land clearing and preparation. The rate of release of carbon from this biomass to the soil over a two-year period is given in Table 3. The total amount released to the soil at the end of 25 months is 48.57 tonnes or 86% of the amount sequestered in the residual timber left after removal of logs following felling.

Table 3. Amount of carbon released to soil from decaying rubber timber not removed.

Time after felling, months	Amount of carbon released to soil, kg/ha
3	11,892
8	17,555
12	23,785
18	37,942
25*	48,570

Stand per ha: 270 trees of mixed clones.
Age of rubber: 29 to 30 years.
*By 25th month after felling, 48570 kg/ha of carbon or 86% is already released to the soil.

Potential amount of carbon sequestered in existing planted world hectarage of rubber

The amount of carbon sequestered in one hectare of 30-year-old rubber is 92.8 tonnes (Table 4). Statistics on the breakdown of the world planted hectarage of rubber in terms of age of material are not available for precise calculation of carbon sequestered according to age. Nevertheless, it can be assumed that all these 8 million planted hectares will, at the age of 30 years, have 742.4 million tonnes of carbon sequestered in the total biomass on the basis of extrapolation from the figures available for one hectare (Table 4).

Table 4. Potential amount of carbon sequestered in existing planted world hectarage of rubber at 30 years of age.

Item	Tonnes/ha at 30 years
Total carbon sequestered in 1 ha of 30-year-old rubber	92.8
Total carbon sequestered in 8 million hectares of rubber at 30 years of age	742,400,000

Potential total amount of carbon sequestered in rubber produced per hectare

The annual average production of rubber per tree over a 25-year economic lifecycle is 0.16 tonnes, of which 0.14 tonnes is carbon (Table 5). The total amount of rubber produced per hectare over a 25-year economic lifecycle is 48 tonnes, of which 42.2 tonnes is carbon. The total carbon in rubber produced from 8 million hectares of rubber over a twenty-five year cycle is 337,920,000 million tonnes. The total carbon sequestered in the wood biomass and rubber produced from one hectare of 30-year-old rubber is 135 tonnes (Tables 4 and 5).

Table 5. Amount of carbon sequestered in rubber (*cis*-polyisoprene) over 25-year economic life cycle of a rubber tree.

Item	Tonnes/ha/25 years	
	Total rubber produced	Amount of carbon**
1 Rubber tree	0.16	0.14
1 Hectare of rubber (300 trees)	48.00	42.20
8 million hectares* (world planted area)	384,000,000	337,920,000

* Based on an annual production of 1920kg/ha/yr.

**Based on the assumption that carbon is 88% of basic isoprene unit (mw 68).

Total carbon sequestered globally in 8 million hectares of rubber

The potential carbon sequestered in wood biomass and rubber produced globally from 8 million hectares of rubber is a little over one billion tonnes (Table 6). This is made up of 742.4 million tonnes of carbon in wood biomass and 337.9 million tonnes in rubber produced over 25 years from the eight million hectares.

Table 6. Total carbon sequestered globally in wood biomass and rubber produced from 8 million hectares.

Item	Tonnes/ha (millions)
Biomass at 30 years	742.4
Rubber produced over 25 years	337.9
Total	1080.32

Relevant carbon offset reforestation and forest rehabilitation projects: technical similarities with rubber

This section reports a joint project on large-scale enrichment planting with dipterocarps as an alternative for carbon offset.[6] The technical similarities and potential for carbon sequestration is compared with that of rubber. The project chosen is the Innoprise - Face Foundation Rainforest Rehabilitation Project (INFAPRO), which is being carried out as a co-operative venture between Innoprise Corporation Sdn Bhd (Malaysia) and Forest Absorbing Carbon-dioxide Emissions (FACE), in Ulu Segama Forest Reserve, in Sabah, Malaysia. FACE is the organization set up by the Dutch Electricity Generating Board aimed at promoting the planting of trees to absorb carbon dioxide to offset the emissions of the gas by their power stations.

The ultimate objective of INFAPRO is to carry out enrichment planting with dipterocarps and forest fruit trees on 25,000ha of degraded forestland. Dipterocarps are local tree species that have high timber value. Just like rubber, these are also tropical species. It is targeted that the project will have the potential of sequestering 195 tonnes of carbon/hectare under a rotation period of 60 years. The project is sited at 5^{o}N, 117^{o}E in an area receiving 2800mm of rainfall and having an annual mean temperature of 26.7^{o}C. The site, rainfall and mean annual temperature are equally suitable for rubber. The main species planted are *Shorea leprosula* and *Drypbalanops lanceolata*. Planting materials are produced from seeds collected in the forest. Normal silviculture nursery practices are adopted in the preparation of the planting materials. The planting system adopted is the enrichment planting line of 2-m wide with a 3-m intra-row planting distance. The fertiliser application follows the normal silviculture for the region and four rounds of weeding were carried out the first three years.

The planting system adopted for the above project is comparable to the agronomic practices being adopted in the rubber plantation. The first two years of growth reported for the project gave an average of 1.2m height increment per year and an annual diameter increment of 0.95cm per year. This points to the fact that the forest enrichment program calls for proper adoption of cultural practices, contrary to the belief that forest plantation can be established just by planting and leaving the field unattended. Given this requirement, the use of rubber species for carbon sequestration is equally suitable.

The estimated carbon sequestration of 195 tonnes per ha per 60 years cycle for the project is also comparable to that of rubber. As indicated earlier, the total carbon sequestration for rubber is 135 tonnes per ha per 30-years cycle. However, it should be noted here that the carbon sequestration figure for rubber is calculated on the basis of a real rubber plantation situation using planting materials that are widely planted. There is therefore less uncertainty in the case rubber with respect to the impact on carbon sink. This is because the materials used are bred and selected for both rubber and wood biomass productivity. In addition, the cultural practices such as nursery practices, field husbandry and disease controls are well established. In the case of the majority of tropical forest species, the silviculture and the experience of managing the forest on a plantation basis is still at its infancy. Rubber, on the other hand, has been cultivated for over 100 years as a plantation crop. The overall carbon sequestration issues in the majority of the forest ecosystem would require more research input to collect specific scientific, economic and social data.

Innoprise is also actively co-operating with the New England Electric Services (NEES) of Massachusetts, USA on reduced impact logging project that is aimed at reducing the damage to residual trees and soil during logging. This reduction in damage would minimize the wood debris and hence reduce the decomposition rate that would result in the release of radiatively active gases. More carbon would therefore be retained on site. The NEES interest in this project is to contribute to the enhancement of the carbon-sink process and therefore claim the increased carbon sink as a carbon offset.

Carbon offset and rubber-producing countries

The cost of production of rubber in most rubber producing countries is on an upward spiral due to constantly rising wages and inflationary pressures. This increase in costs in the absence of any marked upward climb of prices for the raw commodity in the international markets has meant that the incomes of small growers or farmers and profitability per hectare for plantations has steadily been on the decline. This has also resulted in the fact that most of the rubber smallholders or growers have generally remained in the poverty bracket or merely at the subsistence level in most of the rubber producing countries. This has had tremendous national impact on the social/economic scene in most of these countries if it is considered that the bulk of the producers (80% or more) in all the rubber producing countries are smallholders or small growers. The negative fall-out effects of the depressed economic status of rubber producers on a population basis will be huge if the total number of people who depend on rubber for their livelihood is taken into consideration. The above has resulted in an increasing trend in most rubber producing countries to move away from rubber to cultivation of other lucrative crops or other economic activities which are more rewarding, in order as to uplift the economic well being and status of a broad section of the population. This has been further aggravated by the lack of adequate funds for small growers or smallholders to replant their rubber, because of difficulty in sourcing funding for cultivation of rubber from relevant authorities or the banking sector within a country.

It is apparent that, given the potential carbon sequestration of 1 billion tons in the 8 million hectares of rubber worldwide, the impact of this shift away from rubber cultivation on the global carbon balance will be very significant. In view of this, carbon offset financing could play a key role in ensuring that rubber continues to be cultivated at current prevailing levels. This mode of financing could also be along lines currently being studied for logged-over forests. The mechanism or *modus operandi* for this carbon offset financing could be through established international rubber bodies so that the operations are well co-ordinated and mutually beneficial to all parties.

Constrains in carbon sequestration and carbon offset financing

Differences of opinion still exist regarding the application of carbon sequestration as part of Clean Development Project or Actions Implemented Jointly Programme under the Kyoto Protocol. For instance, the details of the plan for trading of emission credits have not been resolved as yet. In addition, carbon sink accounting for the purpose of allocating carbon credit for natural forest remains uncertain. While theoretical understanding is that carbon credits could be given for activities that resulted in the net increase of the carbon stocks, confusion may arise if, for instance, 'reforestation' projects are given credits without deducting the emission as a result of harvesting the forest.

It has also been indicated that many developing countries are reluctant to accept forest carbon sequestration projects under the Clean Development Mechanism because of scientific uncertainties. Scientific issues such as the quantum of carbon sequestered under a specific forest ecosystem, be it natural or plantation forest, are also not resolved. Unavailability of data on natural forest decay and the classification of forest carbon sink as temporary sink further complicates the matter, particularly when addressing the carbon credit or debit issues.

The above reservations raised by developing countries are indeed understandable and valid – as there is insufficient information to fully understand what, when, how and how much carbon is sequestered under natural forest. It is only recently that mathematical and economic models are being put forward and natural and plantation forests are being set up to test these models.

As discussed earlier rubber plantations, unlike natural forest, have accumulated almost 73 years of scientific data on every aspect of cultural practices and basic as well as applied sciences of the crop. It is therefore proposed that the data and experiences obtained from over 100 years of rubber cultivation be studied and analysed from the perspective of carbon sequestration leading to the formulation of a mechanism of carbon offset financing. The analysis of the genetic, physiology, agronomic and economic data could facilitate the following studies:

1. Optimal funding for carbon offset in *Hevea* plantations.
2. Economic and environmental impact of using rubber for carbon sequestration.
3. The benefit/cost ratio of carbon sequestration in rubber.
4. Enhancing biodiversity in rubber for improved carbon sequestration.

The output of the above studies would strengthen the case for rubber as one of the candidates for sequestering carbon from the atmosphere under the Clean Development Mechanism.

On carbon offset financing, the constraint is the unavailability of an acceptable mechanism being put forward as yet. The World Bank prototype carbon fund (PCF) is now being proposed and the Bank is formulating the various mechanisms for the implementation of this prototype. The mission of the PCF is to promote a global market in greenhouse gas (GHG) emission reduction that serves client countries development needs. The objectives of the PCF are to supply high quality offsets at a competitive price in an emerging market and to seek to provide buyers and suppliers of offsets with a fair deal from their own perspective and a share of the value added.

A possible approach specific to rubber could be towards an international fund for carbon offsets in rubber established either under the auspices of an existing rubber organization or under any of the international bodies. It has already been proposed that a carbon tax be imposed globally. In the event that this materialises, then the source of funds for the carbon offset in rubber can also come from such carbon tax. It is also incumbent upon certain industries to develop technologies to minimize carbon dioxide emission into the atmosphere as a result of their manufacturing processes. However, in parallel to this it would be prudent and beneficial if these industries could also purchase carbon credits by financing carbon offsets in natural rubber producing countries.

Conclusion

On the basis of available data, rubber can be an equally, if not more efficient, carbon sequester compared to the extrapolated data for natural forest. The available data need to be analysed in line with the guidelines for the Clean Development Mechanism projects. Attempts to cost and charge the services of the rubber plantation in providing the service of reducing the carbon dioxide from the atmosphere will no doubt influence the producers in their decision to remain in rubber or to go for a more lucrative activities. Should there be a special fund for rubber offset financing, the money from the fund can than be made available to the respective rubber producing countries for purposes of replanting and/or sustaining their current hectarage of rubber. Each rubber producing country’s entitlement will be governed by the amount of carbon sequestered in the rubber hectarage available in the respective country. The socio-economic implications of this funding for these countries will be tremendous. The countries purchasing carbon credits by way of carbon offset financing can take comfort in the fact that they have contributed to the sustenance of an environmentally friendly, ecologically sustainable crop with dual economic potentials of both rubber (latex) and timber production for world consumption, while simultaneously contributing to maintenance of the global carbon balance in the atmosphere.

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Discussion

Mr K Jones. I think that following the last speaker and showing what can be achieved, it is worth re-examining the use of rubber as a feedstock for chemicals. In fact if you could produce enough rubber, then – provided you did not have vast energy input – the production of derivatives would be worthwhile in ecological terms. This is returning to Professor Calvin, who pushed very hard during the energy crisis that one should be looking to bio-materials as feedstocks for what are normally regarded as petrochemicals.

Dr Wan Rahaman. Are you referring to the conversion to bio-fuels, as was suggested by Calvin in 1975?

Mr K Jones. In part one could look towards that. Already in Europe there are plans to grow ash, I think it is, in Scandinavia as a source of fuel. They are setting up plantations as fuel sources. Now, if you can do that you have gin the case of *Hevea*, an output of a very high value material. If you can modify that output, namely the rubber, and turn this into what one would normally consider petrochemical products then this, in environmental terms, would be extremely significant. I am not talking about use of *Hevea,* other than by-products from it, as fuel. I am talking about rubber as a chemical feedstock.

Dr Wan Rahaman. Mr Chairman, this seems to be the trend today, and if you could recall that as reported in the *Far Eastern Economic Review* on the 17th of October for example, the Asian Innovation Award on the Environment goes to the Toyota Green Model. It is not a 4-wheel drive Toyota, it is a Toyota with leaves, stems and roots. So they have come up with these manipulations of the plants that are more efficient in the fixation of carbon dioxide and also for specific targeting as certain usage of the biochemicals from the plant. In fact, in the context of the global environment the success is basically on improvement of the plants that can increase the efficiency of carbon dioxide uptake. This is again one case of the interest from an industrial sector of getting into plants and they are working, if am not mistaken as reported during this award, with Australia on planting with checks on the efficiency of carbon dioxide uptake. Obviously it should not stop there, they are also working on the production of biochemicals from the plants. In the case of rubber, for instance, work is going on and for the Malaysian Rubber Board, we have obtained a patent for genetically engineering the specific proteins in the rubber plant. The process is there, so now we are trying to put in specific proteins which would obviously fetch a higher value. We got the patent in February 1997. Obviously, it is one idea that is indeed a long-term aspect, not short-term. The use of sequestration is immediately obvious to us, if it is agreeable to the associates we need, within six months we should as I have suggested in my presentation be able to get all the data to push for rubber as a sequestor and acceptance as a sequestor for carbon dioxide.

Dr U Hoffmann. In your proposal, Dr Rahaman, you refer to optional subsidies for carbon offsets. Could you just clarify what you mean by that?

Dr Wan Rahaman. I do realise that the word subsidy is not a good word to be using at this time because it gives a different connotation. What we are talking about here is basically trying to determine the quantum to put a value to sequestration of the carbon dioxide. There are papers that have come up with models. Sedu for instance has come up with models for plantation crops suggesting that at a certain level, at today's level, where the investment on the fixation of carbon oxide is free, we are getting this amount of carbon dioxide being fixed. What then would be the optimum level for input of investment that could be added into the rubber cultivation such that we can further increase the sequestration processes? I think there is a model too that involves the fixing of certain parameters within the model and we should be able to determine that. If we add in this additional quantum of investment we should be able to get this further increase in sequestration. So what is free today may still remain free if it is economical for us to get that increase by a certain amount of additional investment. We are trying to get that optimum level of investments. I used the word subsidy mainly because of the nature that it may be construed as subsidy, maybe in inverted comas, because it will go into probably the cost of production rather than putting it onto the price as we discussed during the Workshop in Liverpool last year. I think there is a difference, so the investment from the carbon credit can come into the cost of production.

Mr M Cain. I think this is a very interesting discussion and I know that there are reasons being advanced as to why this sort of 'subsidy' should not be applied in this sort of case. I think it is interesting to remember at the moment that in Europe, the farmers are paid for two reasons. First, they are paid to produce food and that everybody accepts. They are also paid for not producing food but for protecting the environment. As I see it, the suggestion that the person owning the rubber tree should be paid both for the rubber that he produces normally and commercially and also be paid because he has a rubber tree and not some other crop which sequestrates less carbon dioxide is not essentially different in principle from what is happening in Europe already. I know that at the last meeting this is idea was really picked up on and I am glad to hear what Dr Rahaman said they were doing. I wonder if Dr Hoffman has any real view of what the chances are of this sort of policy being adopted, because it is apparent that the rubber market is not going to pay a lot of rubber producers enough to stay in the business. If the users of rubber are not prepared to contribute at a level that makes future supplies sustainable, then some other methods must be found of doing so, and this seems to me that this is a not unreasonable approach.

Dr U Hoffmann. Your question seems to fall into two parts. The first part is something I have quickly tried to calculate. That is what might be the financial benefit or the remuneration for the sequestration service rendered per hectare under the very conservative assumptions used these days by some who negotiated the Kyoto Protocol. The rough calculation is based on a yield per hectare of about 1,200–1,300 tonnes, which is certainly almost an optimistic assumption, and you know what this is worth under prevailing natural rubber prices. So let us say we end up with 8–900 US dollars, then according to Dr Rahaman we can reckon with a sequestration potential of about 3–4 tonnes of carbon per annum per hectare. If we now take as a reference value some 30 US dollars (the State Department reckons with 50 but I think that is excessively optimistic, so let us calculate with 30) you end up roughly or at least with 100 US dollars. On the basis of $8–900 from your yield, whatever profit rate you had it would definitely greatly embellish your rate of profitability. Even 100 US dollars on the basis of 8–900 US dollars of total sales as a rate of profits is not too bad, and that comes on top of your usual rate of profitability. That is just to put the entire method into context. I am afraid no one at the moment will be in a position to come to a closer calculation than this one, as these are all very hypothetical assumptions but I think they are sufficiently close to what is necessary for at least making the case.

Turning to the second aspect of your question, what are the chances from a political point of view of lifting carbon offset financing as a financial mechanism off the ground? A major step in this direction will be certainly taken next week in Buenos Aires at the Conference of the Parties to the Climate Change Convention and the Kyoto Protocol, where carbon sequestration will definitely figure as one of the key issues. It is, however, not very likely that a formal decision will be taken. Besides the reasons mentioned by Dr Rahaman on the scientific uncertainties, for example, the big uncertainty is what happens in the case of forest fires, so if what has been sequestered once again dissipates into the atmosphere. According to Dr Rahaman, this risk is only confined to a third of the quantity sequestered, if I understood his presentation well, but then the question arises to whom incinerated rubber plantations would be accounted. This is one kind of uncertainty. Second, a good number, particularly of developing countries, object to the risk. They say that as this is the easiest and most profitable area of sink investment, it might distract from harder or from more investment-intensive projects, for example in energy generation and in transport. These sectors are regarded as more valuable by a good number of developing countries because investment in such sectors is associated with more technology and skill transfer. They are saying, not only is this the way of least resistance – carbon sequestration – but it is only a financial investment which does not come in tandem with technology and skill transfer. Then there is, of course, the third group of concerns articulated by a good number of countries, that sequestration is not only a property of rubber trees but of a rain forest or of any crop. However, these crops have very different environmental benefits or problems and in some cases, for example a natural rain forest, the exact species composition is either unknown or very difficult to establish and therefore the sequestration volume is very difficult to establish as a base line. These are the sort of concerns which are brought forward.

There is then another big problem, which I see from a conceptual point of view as probably the biggest hurdle to surmount, and which has not been mentioned in our discussion. According to the Kyoto Protocol only those investments will be considered eligible which are or which will be made in addition to the normal trend, which means investment which would not have come under normal circumstances. In terms of rubber, this would mean that, for example, a country such as Malaysia or any big producer of rubber with established plantations would fall by the wayside under this principle. Only the newcomers, for example Papua New Guinea or Vietnam, greatly expanding their acreage, could make the point that this was not planned and, after looking at the sequestration potential, they realised the benefit which might be produced, and therefore want to register that as an eligible project. This so-called additionality principle is something which is very difficult to accept, because one can equally conceive a situation where Malaysia temporarily took out of service one-third of its acreage under rubber now and, after a few years lapse and diversification away from rubber, could relaunch the planting of rubber and then register. The fact of the matter is, a major producer would be penalised under current circumstances and there is little reason from both the logical view and from a pragmatic point of view of accepting that as the result remains the same. You produce or you generate a service, and this service from a qualitative, quantitative and accounting point of view remains unchanged. This is something which needs to be addressed by the policymakers. The final word from a political point of view is that so far there is strong support all over America with very few exceptions in South America but the majority of North and Central and Southern American countries are in favour of sequestration projects. In Asia, the picture is very mixed. The three major rubber producers at least as far as their official positions are concerned, have put on record that they are not in favour. Most of the ASEAN member countries have articulated concern. In Europe, the EU as a group made an official recommendation against, while several individual countries have associated themselves with a statement made by the US and some Central American countries in favour. That illustrates that the subject is a very moot one, and it is open to discussion. No one can predict at the moment the outcome. As far as the Kyoto Protocol is concerned, sequestration is not referred to in Article 11 which refers to the Clean Development Mechanism. It is mentioned, but only in passing, in Article 3 which refers to co-operation between Annex 1, or developed, countries so that would allow sequestration projects among Annex I countries. As far as the developing world is concerned, or the non-Annex I countries, for the time being there is no written reference to it and from a political point of view this makes it very difficult to predict what the outcome might be. I know that this is far from satisfactory, but that is just a description of what the situation looks like at the moment. It is very confusing, but what we can do, or have been doing – and Dr Rahaman made a tremendous step in the right direction – is providing more empirical information including socio-economic information and information on the general agrochemical and agricultural merits of the crop as being little damaging to the environment. This sort of information is needed to illustrate the case as well as the carbon sequestration potential.

Unidentified speaker. On the issue of additivity that was mentioned by Dr Rahman just now, in certain countries it is already written on the wall that the trend [of the rubber industry] is downward. So if sequestration were to be attractive enough, then if it takes place [the industry] is not moving in the normal downward trend, but it may push it upward. This is then going to be additivity, but according to what Dr Hoffmann just said you can stop first, just to qualify, and get moving again. On the issue of technology, for instance, judging from what is written in the various negotiations, a certain timeframe is given. The pilot activity is to be carried out from the year 2000, and then the 5% achievement in the reduction in the greenhouse gases is to be achieved between 2008 and 2012. Now, certain countries are talking about the development of technologies – transfer of technology if it is existing technology – and maybe it is possible to transfer and use that as a pilot project for Middle Eastern countries. If they are talking about initiating research using this fund to reduce the GHGs by the new technology that is supposed to be initiated and transferred, I wonder if the time frame that is being discussed can materialise. So the issue now is as agreed in the Kyoto Protocol, something has got to be done. We are going to get the global warming achieved in 10,000 years to happen in just about 100 years by 2100. The temperature will rise by 2–3ºC and that normally happens in 10,000 years. So what do we do? Something has to be done and that is what the Kyoto Protocol is trying to push. I would say that what is available today is sequestration; this is the immediate thing that can go in and falls into the lower risk technology. We are not saying that it should be the only one, it should complement all the other technologies being developed.

Chairman's concluding remarks

Dr U Hoffmann

I would now turn to our last point for this Workshop, and try to summarize the discussion we have had this afternoon. Starting with the second subject, I think it is well worth looking very carefully at the suggestions Dr Rahaman made that some further analytical work is required along the four lines he described. First, he highlighted what he called optional subsidies for carbon offset. It is more the addition of a specific value to the sequestration service or the sink function on the basis of the estimates already available, on agriculture or the re-use or the transformation of land use. The second suggestion he made was more work on the economic and environmental impact of using rubber for carbon sequestration. The third was the cost/benefit ratio of carbon sequestration and rubber, which might be a good idea when it comes to pilot projects. The fourth issue he brought to our attention was enhancing bio-diversity in rubber for improved carbon sequestration. These are the four areas, I think, merit some more work. The IRSG Secretariat and UNCTAD would look into that and see to what extent we can initiate some activities in the next twelve months and probably get back to you on that with some preliminary results. We would also try to influence such activities and the political discussion. I am personally involved in the negotiations of two multilateral environmental agreements, the Basel Convention on Hazardous Waste and the so-called PIC Convention, which is the Prior Informed Consent Convention on Export of Hazardous or Problematic Chemicals such as fertilisers. It so happens that the negotiators in these conventions are also the key negotiators in the climate change context, so in particular from Asia, I know many negotiators. What I can do is bring to their attention the work which will be carried out in this respect and then liase with them to what extent that can be used for official negotiations. These negotiations have, of course, nothing to do with our Forum here but it can at least have a spillover effect and have some sort of bearing when it comes to useful empirical information.

Wrapping up our discussion on scrap tyre management, UNCTAD discussed shortly before our Workshop that it might probably be a good idea to extend a helping hand to one or two developing countries if so desired. We will probably check with the Government of Malaysia and one other government to see if they might be interested in more empirical analytical activities in this regard. Profiting from the accumulated information, we might then launch a pilot activity. This could consist first in studying the situation in detail in the respective country, and second in organising a seminar or workshop to discuss the findings of the empirical work and then sharing with them some of the management options which remain: to what extent one can use economic instruments to make full use of the market or to drive the market into a desirable direction. That would be in tune with our objective to become gradually involved in specific activities and turn concept gradually into action to the benefit of one or the other member country.

I thank you very much for your active participation and your attention and wish all of you on behalf of UNCTAD and the IRSG a safe journey home.

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