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Scrap Tire Consumption In New England And New Jersey

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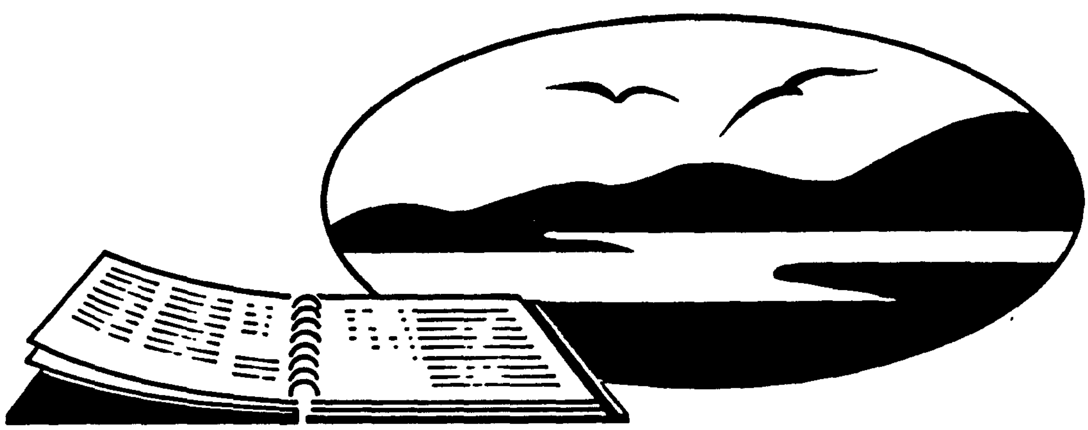

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SCRAP TIRE CONSUMPTION IN NEW ENGLAND AND NEW JERSEY

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Abstract

The disposal of scrap tires is one facet of the current solid waste dilemma that is currently receiving an increasing amount of attention in the northeast. Above-ground disposal in tire stockpiles has become a common phenomenon. One way to avoid continued stockpiling of scrap tires, and to reduce the number and size of existing piles, is to find ways to consume the tires. The economics of scrap tire consumption in the region has not yet been examined in great detail. The main goal of this paper is to describe the current pattern of scrap tire use and disposal in New England and New Jersey, and the changes expected in the near future. In the course of this description, various economic, regulatory and other factors emerge as significant forces shaping the consumption and disposal pattern. The concluding sections of the paper highlight some of these factors and identify policy options available to increase scrap tire consumption in the region.

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I. INTRODUCTION AND OVERVIEW

The disposal of scrap tires is one facet of the current solid waste dilemma that is currently receiving an increasing amount of attention in the northeast and nationwide. While tires represent only a small percentage of the municipal solid waste stream, some states have classified them as a "hard to dispose of" waste. Problems with the landfilling of whole tires have led to a reduction in the number of disposal sites, and increases in disposal costs at facilities that continue to accept tires.

Above-ground disposal in tire stockpiles has become a common phenomenon. Some stockpiles contain tens of millions of tires and carry the risk of serious health, safety and environmental hazards. Fires at tire stockpiles produce toxic runoff that can pollute soil and water, in addition to generating acrid smoke and reducing visibility. Tire fires are difficult to extinguish because the tires tend to trap pockets of oxygen that help to maintain combustion, and some fires have been known to smolder for months. In addition, piles of whole tires collect rainwater and thus provide breeding grounds for mosquitoes that can serve as vectors for infectious diseases. Among the diseases that have been linked to mosquitoes breeding in tire piles are dengue fever and La Crosse or St. Louis encephalitis.

One way to avoid continued stockpiling of scrap tires, and to reduce the number and size of existing piles, is to find ways to consume the tires. Promoters of recycling believe that the materials that go into the manufacture of tires retain at least some of their value even after the tire itself is no longer usable. Whether it is economically feasible to employ various tire recycling technologies is a subject of great interest to those trying to address the solid waste problem posed by the vast numbers of scrap tires generated every year. The fact that some tire recycling is already taking place provides evidence that private markets can sustain some level of some forms of this activity.

Government entities, from the Environmental Protection Agency at the federal and regional levels, to interstate cooperative groups, to state, county, and local agencies, recognize that the private sector can play an important role in solving the scrap tire problem. Many have expressed an interest in learning how market mechanisms are affecting the recycling of tires and tire-derived products, and if there is a role for the public sector to facilitate greater activity in this area. The present study was motivated by the interests of EPA's Region I and the seven states that comprise the New England Waste Management Officials Association (NEWMOA): Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont and New Jersey.

Before the role of the public sector can be discussed, however, a better understanding of the current status of tire recycling in the region is necessary; only after some initial investigation of the existing and newly developing markets for scrap tire products can informed policy questions be addressed. The main goal of this paper is thus to describe the current pattern of scrap tire use and disposal in New England and New Jersey, and the changes expected in the near future. In the course of this description, various economic, regulatory and other factors emerge as significant forces shaping the consumption and disposal pattern. The concluding sections of the paper highlight some of these factors and identify policy options available to increase scrap tire consumption in the region. A fuller policy analysis would also have to address the more general market for waste disposal services, to which scrap tire disposal and consumption is closely related.

Two caveats are worth noting at this stage. First, due to the numerous ways in which tires can be consumed, some of which are technologically complex, additional research is needed to describe the economics of many of the potential uses. Second, the markets for scrap tires in the northeast are in a state of flux, and the picture that emerges from this paper should be regarded as a snapshot of an evolving situation. Monitoring changes in the region's uses of scrap tires will be necessary to maintain a reasonably accurate picture of these markets.

II. SCRAP TIRE CONSUMPTION AND DISPOSAL IN THE NEWMOA STATES

It is useful to think of the scrap tire issue in terms of a stock of material to which new additions are being made every year, and from which consumable tires are flowing. The stock can be represented by the number of scrap tires currently stored in above-ground stockpiles or other storage facilities, and at many small dump sites. The annual scrap tire generation rate may be thought of as the flow into the stock, while the flow out of the stock is accounted for by landfilling, recycling, or export. When the rate of land disposal, recycling, and export exceeds the annual generation rate, the stock shrinks. Conversely, if the generation rate exceeds these outflows, the size of the stock grows. Earlier this century, scrap tire generation was roughly matched by the rate of tire recycling, and significant stockpiles did not exist. Several factors have served to change this picture, however.

Background

Scrap tires are generated in two ways. First, for every replacement tire purchased, an old tire is discarded. Second, for every car that is junked, four or five scrap tires are generated. Approximately 80% of the generation is due to replacement and 20% to vehicle disposal.[1]

Until World War II, and for some time thereafter, most scrap tires were recycled. Tire jockeys, people in the business of removing scrap tires from the premises of tire dealers and scrap yards, would typically pay for the privilege of collecting the tires. They would then resell the tires for reuse, retreading, or reclamation. These outlets accounted for approximately 10%, 20%, and 70% of the scrap tires, respectively.[2] Rubber reclamation plants sold most of their output to tire manufacturers, who could use the product in making new tires.

Over the past several decades, tire jockeys have seen dramatic changes in the outlets for their haul. After World War II, tire manufacturers began to use increasing amounts of synthetic rubber in their product. The result of reclaiming synthetic rubber is not as suitable for the manufacture of new tires as is the product derived from natural rubber. Presumably, the price for reclaimed rubber fell, and reclaimers competed for customers by lowering the price of their product. As some reclaimers went out of business, the remainder could lower the price they paid jockeys for scrap tires, and could eventually begin to charge the jockeys to take the tires off their hands. Eventually, the reduced demand for reclaimed rubber forced most of the reclaiming plants out of business, including ones in Naugatuck, CT, Butler, NJ and Buffalo, NY. The Naugatuck facility, which closed in 1975, was probably the largest in the region, processing 3 to 4 million tires per year.[3] Only two reclaimers are left in the country today.

In addition, the advent of the radial tire made retreading a more difficult operation. While retreading bias-ply tires was often a viable small business opportunity, the more expensive equipment required to retread radial tires significantly decreased the number of retreaders. Furthermore, the availability of relatively low-cost new tires has made it difficult for retreaded tires to compete in the replacement tire market. These factors have greatly reduced the numbers of passenger car tires being retreaded, and thus, the outlets for the tires collected by the jockeys.[4]

Consequently, tire jockeys began to realize less profit from the sale of the tires they collected. As their markets for scrap tires diminished, the jockeys reduced the amount they were willing to pay to collect tires, eventually charging for this service instead. Tires were increasingly disposed of in landfills or low-visibility dumps, which initially may have been available at little or no cost. Eventually, the jockeys' expenses and sources of revenues switched places: tire collection became the principal revenue-producing side of the business, and tire disposal a major cost.

Returning to the picture of a stock with tires flowing in and out, we see why New England and New Jersey did not always have a scrap tire problem: the rate of reuse and recycling kept pace with the scrap tire generation rate. As these activities declined, disposal increased. The cheapest and least visible disposal opportunities were exploited first. As these opportunities were exhausted, we have turned to the more visible disposal options remaining, i.e., larger tire piles, piles in less remote locations, and costly landfills.

The Size of the Problem

Given the undesirability of tire stockpiles, and the public interest in reducing the piles, it would be helpful to know the rate at which the stock of scrap tires is shrinking or growing. Knowledge about the magnitude of the problem will aid discussion on the means of reducing it.

Unfortunately, good estimates of the size of the stock and the rates of flow into and out of this stock are not readily available. Estimates of the size of the existing stock depend on inventories of tire piles in the region. While the locations and approximate sizes of the larger piles are usually known to state environmental agencies, smaller piles may go uncounted. Accurate estimation of the size of the total stock, including the many smaller piles in the region, may require much additional investigation.

Better estimates are available for the rate of flow of scrap tires into the stock, that is, the scrap tire generation rate. Each state in the study area was able to provide an estimate of the number of scrap tires generated per year. These estimates tend to be proportional to the states' populations.

The following figures on generation rates and stockpile sizes were supplied by each of the states in the region:[5]

Table 1

CURRENT GENERATION AND STOCK

	Annual Generation	Stockpiles
Connecticut	3,500,000	15,000,000
Maine[6]	1,200,000	50,000,000
Massachusetts[7]	6,000,000	30,000,000
New Hampshire	1,000,000	1,500,000
Rhode Island[8]	1,000,000	40,000,000
Vermont[9]	500,000	10,000,000
New Jersey[10]	9,700,000	8,000,000
Total	22,900,000	~155,000,000

A comparison of these estimates yields the observation that the size of a state's stockpiles does not seem to be proportional to its generation rate. One explanation for this is that tires cross state lines very easily, and disposal does not always take place in the state where a scrap tire is generated.

Finally, the flow of tires out of the stock depends on the degree of recycling, export, and alternate forms of disposal taking place. (The shifting of stockpiled tires to other forms of disposal occurs when, for example, tire pile cleanups result in the shredding of tires for subsequent landfilling. While this practice reduces the number of tires in above-ground stockpiles, it is not a consumptive use.) Information on tire consumption and disposal is the most difficult to obtain. While some national estimates of the level of recycling and export are available[11], no clearinghouse on tire information keeps statistics that are sufficiently detailed to enable a quick regional analysis of these activities. While the number of companies in this region currently involved in tire recycling or export may still be relatively small, these firms engage in significant trade among themselves and across state and regional boundaries, complicating attempts to obtain accurate figures for the region.

In the following section, an attempt is made to estimate the numbers of the NEWMOA states' tires that are going to each of the recycling, export, and other disposal alternatives currently available. The information for this section was gathered primarily through interviews with people involved in these activities. Following the description of the current pattern of scrap tire consumption and disposal, is a discussion of some of the major changes that appear likely to take place over the next few years.

The Current Pattern of Scrap Tire Consumption and Disposal

The majority of scrap tires in the region currently are going to landfills or stockpiles, where their numbers are almost impossible to document. Retreading and export account for the greatest number of tires going to non-disposal options. The total number of tires going to other recycling activities is relatively small. It should also be noted that many recycling options for scrap tires only use a portion of the tire, and that the byproducts from the recycling process may still account for a substantial volume of solid waste.

A summary of scrap tire consumption and disposal is presented as Table 2. (The following sections will briefly describe what is included in each of categories and how the figures on Table 2 were derived.) All non-disposal figures should be regarded as *upper bounds* on the numbers of tires consumed in those categories. The non-disposal estimates total 7.5 million tires per year. Annual disposal is then the number of scrap tires generated per year less the number consumed, or 15.4 million tires. The disposal figure is thus a *lower bound* estimate. Based on these figures, we conclude that at least two-thirds of the scrap tires generated in the NEWMOA states are being stockpiled, landfilled, or otherwise disposed of, and up to one-third are being put to other uses.

Table 2

CURRENT CONSUMPTION AND DISPOSAL

Destination	Tires per Year	Percent
Retread	3,000,000	13.1%
Export Abroad	2,400,000	10.5
Manufactured Products	1,800,000	7.9
Experimental Uses	300,000	1.3
Subtotal	7,500,000	32.8
Disposal	15,400,000	67.2
Annual Generation	22,900,000	

Readers should note that much of the information used to compile these figures was obtained by informal means and was usually impossible to verify independently.

Retreading

Deriving an accurate estimate of the number of tires retreaded in the NEWMOA states was surprisingly difficult. National sources of tire data[12] do not make state or regional breakdowns, and a detailed survey of all the retreaders in the region was beyond the scope of this study. Therefore, extrapolating from national rates was necessary.

One way to estimate the number of tires retreaded is to start with the region's annual generation rate, and reduce it by 20 percent to account for tires derived from vehicle disposal. The remaining 80 percent can then be multiplied by the national rate of retread sales as a percentage of total replacement tire sales, which is 8.5 percent.[13] If we assume that all of the tires being replaced are passenger car tires, we get a regional retread estimate of about 1.6 million tires per year. If we assume that the scrap tire generation rates reported by the states include medium and light truck tires, and use a weighted average percentage of replacement tire sales including these categories, or 16.3 percent, our estimate of the number of tires retreaded rises to about 3.0 million per year.[14] This is the figure listed on Table 2.[15]

A serious problem with this estimate is that it is not clear whether the scrap tire generation rates reported for each of the states include or exclude tires to be retreaded. If these rates exclude tires that are retreaded, the actual number of tires being retreaded is higher than that estimated above.[16] Since this number would not be part of the consumption of scrap tires, the disposal estimate would have to increase by 3 million tires per year; the number of tires recycled by other means or exported would then equal only 20 percent of the total annual generation of scrap tires.

Export

The next destinations accounting for relatively large numbers of tires are various export markets. Metropolitan Tire Converters of Newark, NJ, and their affiliate, Integrated Tire, ship tire chips to be used as fuel in foreign industrial facilities.[17] In the past year, the companies have made two shipments from the port of Newark of 25,000 metric tons each. This is the equivalent of about 5.7 million tires. However, Metropolitan Tire Convertors suggested that 2 to 3 million tires is a better annual estimate. About 80 percent of the tires delivered to the Newark company are believed to originate in New

Jersey, and the rest to come from New York City. Given the collection ranges of some tire haulers, however, it is difficult to determine the origin of the tires. It is likely that some are coming from New England. The figure listed on Table 2 represents 80 percent of 3 million tires.

The reliability of this rate of export in future years is unknown. Recent shipments have gone to Greece and Mexico, but additional customers are being sought in Canada and England.[18] This suggests room for expansion in the export market for tire chips as fuel.

Whole tires are also shipped abroad for reuse in countries where tread standards are not as high as in the United States. Shipments to several Caribbean may be made from ports in Massachusetts, Connecticut, New York, and New Jersey.[19] Little detailed information was available on how such shipments are arranged or the numbers of tires involved.

Manufactured Products

A New Bedford, MA company that makes equipment for the fishing and scalloping industries and other specialized products is the largest manufacturing consumer of scrap tires in the region. Their products consume about 1.4 million tires per year.[20] Two New Jersey counties are making artificial reefs from whole scrap tires. This accounts for about 95,000 tires per year.[21]

The NEWMOA states are also sending about 425,000 tires worth of material per year to a crumb rubber manufacturer in Pennsylvania.[22] At least some of this quantity (anywhere from one-fifth to three-quarters) represents leftover portions of the tires consumed by the New Bedford manufacturer,[23] which must be subtracted to avoid double-counting. About 100,000 of these tires come back to the region in the form of intermediate or finished products. Most of this volume is accounted for by an asphalt rubber contractor in Rhode Island. Other consumers of the crumb in this region include a brake manufacturer in Massachusetts, and a New Jersey manufacturer of molded rubber products.

Additional products made from recycled rubber are being used in the region, but most of the scrap tires consumed probably originated elsewhere. Examples of such products are woven rubber mats, custom-fitted rubber railroad grade crossings, and poured rubber flooring and roofing materials.

Experimental Uses

Some tires are being consumed as part of research projects or in experimental applications. For example, the state of

Vermont is to use about 130,000 tires worth of chips this year in an experimental road shoulder expansion project. Research on the use of rubber chips as backfill material for retaining walls is also underway at the University of Maine. Additional pavements using crumb rubber additives not accounted for by the Rhode Island firm may consume some tires. A Connecticut company developing rubber-plastic polymers may consume about 30,000 tires' worth of material per year. While it is difficult to identify all the experimental uses that may be occurring in the region, a rough estimate of the number tires consumed in these applications is 300,000 per year.

Disposal

The principal disposal options in the region include landfills (accepting either whole or shredded tires) and sites where shredded tires are stored above ground. Some tires may be burned in incinerators, but most incinerators try to exclude tires because they do not burn well in facilities designed for municipal solid waste. Ideally, the disposal figure on Table 2 would have been calculated from actual data on the numbers of tires accepted by the various disposal facilities in the region. Had this been possible, an estimate of the number of tires going to unregulated tire piles could have been made. The unavailability of detailed tire disposal data meant that all disposal -- permitted or unpermitted -- had to estimated together by subtracting estimated known consumption from estimated scrap tire generation.

A particularly noteworthy disposal facility in the region is known as the "Tire Pond". Owned by Tire Salvage, Inc., in Hamden, CT, this facility is a former clay quarry that has filled with water. Tires are have been dumped in the 42-acre pit since 1976. Since they are under water, they do not present the fire hazard that tires stockpiled above ground do. Because the Pond apparently has no natural outlets to other surface or groundwaters, water quality concerns are reduced. The State of Connecticut currently requires a discharge permit for the facility, but no solid waste permit.[24]

Total storage capacity of the Pond is estimated by Tire Salvage to be 35 million tires, of which there may be room left for 18 million. The operator is currently accepting tires at a rate of about 3 to 5 million tires annually. About 60% are brought by large tire hauling companies, and the remainder come from Tire Salvage's own collection service. Based on the company's estimate that it culls 20 percent of its intake for reuse, retread, or recycling,[25] an estimated 2.4 to 4 million tires will be added to the Pond this year.

Expected and Potential Near-Future Changes in Scrap Tire Consumption

Several developments likely to take place in the next few years may have important effects on scrap tire disposal and consumption in the NEWMOA states in the near future. This section describes these potentially major developments. The most probable events are discussed first. A summary of these uses is presented as Table 3. Further detail is provided in Chapter 3.

Exeter Energy, Sterling CT

The most significant change about to take place in the consumption of scrap tires in the Northeast will be the operation of a tires-to-energy plant in Sterling, CT. Exeter Energy, a subsidiary of the Oxford Energy Company of Santa Rosa, CA, has already begun construction of the plant and expects to begin burning tires in 1991. The plant will have a maximum capacity of about 25 megawatts of electricity, and is expected to operate at approximately 85 percent of capacity. Exeter's financial pro forma indicates expected tire usage to be about 80,000 tons (8 million whole tires) per year. The electricity will be sold to the Connecticut Light and Power Company under a 25 year contract.[26]

Once on line, the incinerator will consume tires collected by Oxford Tire Supply, another subsidiary of the same parent company, as well as those collected by other tire haulers. Oxford Tire Supply is currently collecting tires at the rate of 3.5 million per year. Of these, approximately 10% are culled for reuse or retreading. The company's strategy is to steadily increase the number of tires it collects so that by the time the incinerator is operational, an adequate supply network will be in place.[27] Oxford expects to be collecting tires within a 250 mile radius of Sterling, thus including parts of New York State (New York City, Long Island, and towns east of the Hudson up to Saratoga) and northern New Jersey, in addition to most of New England, except Vermont and the parts of Maine north of Portland. The proportion of tires that will come from New York was not available at this time.

Until recently, tires that were not usable for resale or retreading were shredded and stored at two facilities owned by Oxford Tire Supply, and affiliate of Exeter Energy. Over one million tires' worth of chips are in storage at a facility in Bloomfield, CT, and an undetermined amount are in Walpole, MA.[28] Now that these facilities are closed, Oxford is sending most of its haul to the Tire Pond.

Table 3

ADDTIONAL FUTURE ANNUAL TIRE CONSUMPTION

MOST PROMISING LARGE CONSUMERS		STARTING DATE
Exeter Energy	8,000,000	1991
Champion	3,000,000	Fall 1990
Another Paper Mill	3,000,000	1992
SUBTOTAL	14,000,000	
POTENTIAL LARGE CONSUMERS		
TireCycle	3,000,000	?
Dragon Cement	3,750,000	1994 (?)
State Road Projects		
based on the replacement of 10% of the clean fill or common borrow currently used		
Vermont	1,000,000	
Maine	1,000,000	
Rhode Island	1,200,000	
New Hampshire	1,200,000	
Connecticut	1,000,000	
Massachuestts	not available	
New Jersey	800,000	
Road Projects Subtotal	5,400,000	?
SUBTOTAL	12,150,000	
TOTAL	26,150,000	

Champion Paper Mill, Bucksport ME

Champion International began investigating the feasibility of burning tire-derived fuel (TDF) at the Bucksport facility about three years ago, in cooperation with the Maine Department of Environmental Protection (DEP). The idea was to replace a portion of the coal used in the multi-fuel boiler with tire chips. The first experiments used chips supplied by Sawyer Environmental Recovery of nearby Hampden, ME. These chips proved unsuitable because they contained too much wire. Champion then obtained chips manufactured in Georgia by Waste Recovery, Inc. that had a greater percentage of the wire removed. Test burns with form of TDF were eventually successful.

In the fall of 1989, the Maine DEP monitored emissions from the plant using different amounts of TDF, with environmentally acceptable results.[29] The DEP is currently in the process of amending Champion's air licenses to allow the use of TDF on a regular basis. Champion hopes to begin using the fuel during the fall of 1990. The plant will be capable of consuming 3 million tires' worth of chips per year.[30] The choice of a fuel supplier or suppliers has not yet been made public, but it is likely that TDF meeting Champion's specifications can be supplied from within the region.[31]

Additional Users of Tire-Derived Fuel

Negotiations between Sprague Energy, a New Hampshire-based energy marketer, and potential suppliers of tire-derived fuel may soon change the channels by which TDF would be supplied in northern New England. Sprague, which handles Champion International's energy needs at both the plant and corporate level, recently developed a relationship with Sawyer Environmental Recovery, a TDF manufacturer. Conversations with representatives of both Sprague and Champion suggest that centralized marketing of TDF by a company such as Sprague may facilitate greater consumption of TDF in the region.

Currently, potential large consumers of TDF, such as pulp and paper mills, would each demand far greater quantities than an individual TDF supplier is likely to produce. The industrial consumer would thus have to deal with several small suppliers in order to obtain a sufficient volume of material. This introduces potential complications for the consumer in terms of managing several supply contracts, assuring steady supply, and assuring uniform product quality.

The services of an intermediary who could offer a single contract to the consumer and assure that the fuel will meet quality specifications may help relatively small TDF producers overcome barriers to entry into the vast, established market for fossil fuels. Given the newcomer status of tire chips as a fuel, the participation of a major energy marketer in the supply of TDF lends a legitimacy to the material that may help encourage potential consumers to experiment with it. The energy marketer thus reduces some of the risk and uncertainty associated with TDF.

Those in the industry agree that there is a strong possibility that at least one more pulp or paper mill in Maine may begin to use TDF in the near future. Both favorable experiences on the part of Champion and more reliability in the supply of TDF may provide the evidence for which these firms are waiting. Of the four or five mills that employ the type of grate that can accommodate TDF, two or three may seriously consider using it to replace some of the coal they now consume.[32] Some of these other boilers have the potential to consume larger quantities of TDF than Champion.[33] Table 3 lists just one additional paper mill, of a size comparable to Champion.

Dragon Cement

The only cement kiln in New England is operated by Dragon Products in Thomaston, ME. The plant is not now capable of consuming either TDF or whole tires. However, the company may undertake capital modifications that would allow the burning of whole tires. If the plant is modified, it will be capable of consuming 3.75 million tires per year, which would represent 25 percent of its fuel requirements. The modification would cost about $4 million and would not occur before 1993.[34]

TireCycle of New England

The TireCycle chemical process takes tires as a raw material and produces an intermediate feedstock for plastic injection molding and other uses. The first company to use the process on a large scale was Rubber Research Elastomerics at a plant in Babbitt, MN. The venture was partially financed by the state of Minnesota, and its failure in 1989 was well publicized. However, TireCycle of New England believes that economic conditions in Rhode Island, where they would like to locate a plant, are substantially different. The company is currently seeking a site and financial backing. If their plans succeed, they will have the capacity to consume 3 million tires per year.[35]

Road Construction Projects

Table 3 also lists the tire-consuming potential of one aspect of state road construction projects that might become a significant consumer of scrap tires in the future. The use of tire chips as a substitute for ten percent of the clean fill currently used in these projects could total more than 5 million tires' worth of material per year. The use of crumb rubber additives to asphalt concrete is not included in this estimate, but is another potentially large consumer of scrap tires.

III. CHARACTERISTICS OF THE INDUSTRY TODAY

To better understand the current pattern of tire disposal and recycling in the NEWMOA states, we need to look at the factors that face each of the actors who make decisions about what to do with a used tire or its derivatives. Many types of actors are involved, representing all stages of the waste disposal path or recycling loop. These actors include individual car and truck owners, the managers of private or government vehicle fleets, tire dealers, tire retreaders, and those in the business of hauling scrap tires. They also include landfill and incinerator operators, manufacturers of recycled products, manufacturers of intermediate tire-derived products, manufacturers of goods that consume intermediate tire-derived products, and the ultimate consumers of these products. Engineers who design highway reconstruction projects and businesspeople who buy fuel for industrial boilers make decisions that can affect the fate of large numbers of scrap tires.

Economic factors play a significant role in influencing the decisions made by these people. In addition to more obviously quantitative factors, government regulations, the availability of information, professional reputations, and business ethics also affect the way people regard options for handling used tires and their derivatives. An attempt has been made to bring all these factors into the discussion, where appropriate.

The current scrap tire recycling industry is small but diverse. One dimension of this diversity is the degree of vertical integration exhibited by different firms. That is, some firms are involved only in one stage of the recycling loop, such as tire collection, production of crumb rubber, or consumption of tire-derived fuel. Other firms participate in two or more stages, using the output of one step as an input to the next. For example, a company may collect tires from dealers, sort out reusable casings, and make consumer-ready stamped products from the remaining casings. Alternatively, a company may collect tires and shred them for sale to another processor who will make rubber crumb. The crumb manufacturer may itself consume the crumb as a feedstock, or sell it to other manufacturers. Vertical integration is neither a "good" nor "bad" feature of an industry. However, when it is displayed by some firms and not by others, it makes the industry somewhat more difficult to describe.

The following sections will discuss the actors involved in the tire disposal path or recycling loop. Due to the overlapping functions of some of these actors, the lines between various steps are somewhat difficult to draw. In general, the first few sections will trace the route of a scrap tire toward disposal, indicating where the tire may branch off to one of the recycling options. The later sections will deal more explicitly with these options.

Options Facing Tire Consumers

The individual car owner who needs new tires typically goes to a tire dealer from whom she purchases the new tires and leaves the old ones for disposal. In the states of Maine and Rhode Island, the customer pays a tax of $1 and $.50, respectively, for each new tire purchased. Given the small amount of the tax relative to the price of a new tire, the customer is unlikely to bother going out-of-state for the purchase. As of this writing, however, a bill before the Rhode Island legislature proposes to establish a $10 deposit on new tires at the point of sale; a deposit this large might encourage consumers to cross state lines to buy their tires.

Customers usually have the gas station or dealer from whom they bought the new tires replace the tires on the vehicle. Gas stations and dealers sometimes take the old tires for free, but may charge the customer a nominal fee for this service.

If the tire dealer or gas station will not take the used tires back, or if the tire consumer is getting rid of tires without making a new purchase, the consumer must investigate other disposal options. Some communities that have curbside garbage pick-up will take one or two tires per household at a time, but others will not. Residents who take their garbage to the town landfill may have to pay a special fee to dispose of tires there. Landfills in New England typically charge $.50 to $2 per tire. Some may charge as much as $5 per tire. The fee on truck tires may be higher than that for passenger car tires.

If all the legal disposal options facing the consumer charge a fee or are otherwise inconvenient, the consumer may consider storing the tire or dumping it illegally.

Options Facing Tire Dealers

Tire dealers sometimes inspect returned tires and sell those in good condition as used tires. They may also sell them to used car dealers who need to replace tires on the cars they sell. The average retail price for a reusable passenger car tire is about $15.[36] Tire dealers do not typically get involved in culling for retreadable casings, unless they do some retreading on their own premises. Dealers store the remaining majority of the tires until disposal. Smaller gas stations that change tires for their customers often pay a tire dealership to handle the disposal of their scrap.

Regulations in some states limit the onsite storage of scrap tires. For example, Rhode Island prohibits the storage of more than 400 tires except by persons engaged in the tire recycling or recovery business and licensed by the Department of Environmental

Management.[37] Maine limits the area of tire storage to 2,500 square feet. To comply with these regulations, tire dealers must thus have regular pick-up of the returned tires they accumulate.

Tire collection services are provided by a few large companies that serve large parts of New England, as well as by many independent "tire jockeys". Tire collection companies will sometimes spot a trailer on the dealer's property and collect it when it is full. Alternatively, the dealer may be on a regular route established by the tire hauler, and receive periodic collection service. Other tire haulers will respond to calls from dealers when they have enough tires to warrant a pick-up. The costs of these services vary by region, number of tires collected at a time, distance, whether reusable tires have already been culled, and other factors. Collection service fees range from about $.50 to $1.35 per tire.

In some cases, tire dealers and municipalities may work out cooperative arrangements that take advantage of tire haulers' lower rates for large quantities. For example, the tire dealer may pay the municipality for use of a container kept at the landfill, or the municipality may provide free disposal for dealers who agree to keep trailers on their property and accept the town's tires.[38]

Tire dealers sometimes face the problem of finding that others have illegally dumped truckloads of tires on their property. They then have little choice but to pay for the disposal of these tires along with their own.

Options Facing Tire Haulers

Some tire haulers choose to serve only large tire dealers or chain stores, while others also do business with single-outlet dealers. In addition, some tire haulers serve municipalities, either collecting tires from transfer stations or landfills, or performing tire pile clean-ups.

Most tire haulers cull out reusable or retreadable casings and sell them, as this is the most valuable component of the material collected. Retreaders will pay from about $.80 to over $4.00 per casing, depending on size.[39] Some reusable tires that are not sold for use in this country are exported. The price obtained for these casings was unavailable for this report. The major tire collection companies say that they cull about 10 to 15 percent of their total haul for reuse or retreading.

After this step, tire haulers vary substantially in the ways they handle the remaining tires. A few tire collection operations represent the first stage of businesses that themselves recycle tires into other intermediate or final products. An example of this type of business is F&B Enterprises of New Bedford, MA, which manufactures equipment for the fishing and scalloping industry out of some of the tires it collects. Other collection services may be provided by businesses that also operate landfills, thus providing "in-house" disposal. Similarly, the Tire Pond in Hamden, CT provides both collection and disposal services.

Some businesses both collect and recycle the whole tire, such as Sawyer International of Hampden, ME, which makes tire-derived fuel. Others use only a portion of the tire or only some of the tires collected, and must still find disposal or purchasers for either whole tires or the scraps from their operation. Furthermore, many tire haulers do not use the tires at all, and must dispose of all they collect.

New England and New Jersey tire haulers sell some of their tires to other recycling businesses, both within and outside the region. However, most of the tires collected are not ultimately recycled. The tire haulers usually must pay a tipping fee for disposal at landfills, the Tire Pond, tire shredding operations, or at permitted or unpermitted tire stockpiles. Incinerators in the region generally will not accept truckloads of tires.

The costs of haulers' disposal options depend heavily on tipping fees, which range from zero for illegal sites, to $100 per ton (about $1/tire) at permitted facilities. At some landfills, the tipping fee is the same as for other refuse, and at others it is substantially more.[40] The tipping fees that the Exeter tires-to-energy facility is expecting to receive in its first few years of operation are in the $35 to $40 per ton range.[41]

Another factor affecting a hauler's choice of disposal site is the cost of transportation to the facility. A rough estimate of the cost of transporting tires in fully-loaded trucks is $20 per ton per 100 miles, or 20 cents per tire per 100 miles.[42] The cost of transportation is significant because it means that low-cost disposal sites are low-cost only within a certain radius.

Haulers can be expected to seek the least-cost alternative for their tire disposal needs. Whether haulers include illegal options in their decisions may depend on their business ethics and/or their estimate of the risk of being caught and held responsible, as well as the price differential when compared to legal options. Clearly, a tire hauler who collects tires for a given service fee will not stay in business long if the only disposal options cost nearly as much or more.

Options Facing Landfill and Stockpile Operators

If not constrained by law or ordinance, landfill operators can choose whether to accept tires from individuals and/or by the truckload, and the tipping fee for this service. An important consideration in whether to continue to accept whole tires for burial is whether new cells in the landfill will be opened in which the tires can be placed as the bottom layer. In this position, the tires are much less likely to rise and disrupt the cap. Since disruption of the cap is an expensive situation to remediate, tires are not buried near the top of a landfill.

Landfill operators are increasingly requiring that tires be cut or shredded before burial. This significantly reduces the volume of the tires and their potential for rising. If the landfill is shredding the tires onsite, this adds significantly to the cost of disposal. Estimates range upward from $.60 per tire.[43]

"Consumption" of Tire Shreds at Landfills

The potential for shredded tires to replace some of the daily cover consumed at landfills may offset some of the costs of shredding. Daily cover is the material placed over the waste each day to cover the day's operating area and control vectors, blowing litter, fire, and moisture. It typically consists of soil found at the landfill site, and is usually spread to a depth of at least 6 inches. Tire chips have been used as a component of daily cover in several states, including Florida and Wisconsin, and are reportedly successful at controlling blowing litter and vectors. They are not as useful in controlling moisture or fire,[44] but the soil with which they are mixed may serve these functions. Another disadvantage of tire chips is that protruding wire can puncture the pneumatic tires on landfill equipment. This is not a problem at landfills that use steel-wheeled vehicles, however, or where tires can be replaced with steel wheels.[45] Whether it is economic for a landfill to use tire chips will depend largely on the availability of conventional daily cover onsite, or the price and transportation costs associated with cover obtained offsite.

Tire chips may also be used at landfills as erosion control materials, as part of the drainage layer of a landfill's cap at final closure, or as onsite roadbed construction material. However, these consumptive uses of tires, including the daily cover application, are currently being practiced at very few, if any, landfills in the NEWMOA states.

Tire Storage at Landfills

Some landfills accept tires but do not serve as the final disposal site for them. For example, the Central Landfill in Johnston RI, which receives about one third of the scrap tires generated in Rhode Island, charges $75 per ton for dedicated loads ($.75 per tire) or $5 per individual tire mixed with other garbage. The tires are temporarily stored at a paved area on the site before a private hauler takes them away for $70 to $100 per ton ($.75 to $1 per tire).[46] In this case, the landfill is acting as a transfer station for tires.

Regulations and Guidelines Affecting Tire Disposal

As of this writing, state regulations directly affect the landfilling of tires only in Maine, although Vermont and Massachusetts are considering bans on the landfilling of whole tires. In Maine, the facility operator must submit a plan acceptable to the Department of Environmental Protection that details the handling of tires. This usually calls for tires to be shredded or for whole tires to be placed only at the bottom of a landfill cell.[47]

State regulations also affect the above-ground storage of tires at landfills and stockpiles. Many pre-existing stockpiles are being required to come into compliance with tire pile regulations in order to obtain permits for continued acceptance of tires. For example, Maine regulations limit tire pile dimensions, specify fire lane widths, and require buffer strips around the storage site. In addition, some storage facilities must take measures to protect surface and groundwater and limit access to the site. Some facilities must provide escrow accounts or other financial sureties to ensure the availability of adequate funds for cleanup operations or final closure.[48]

Similarly, Connecticut treats applications for permits to establish and operate tire storage facilities as applications to establish "bulky waste" disposal areas. To obtain a permit, the applicant must show that the facility will comply with bulky waste disposal area guidelines, as well as guidelines developed specifically for scrap tire storage. The latter specify the maximum dimensions of individual tire piles, minimum fire lane widths, and additional fire prevention and control measures. A bond sufficient to cover the cost of onsite burial of the tires must also be posted.[49]

In New Hampshire, state regulations affect tire disposal availability and tipping fees. Towns or solid waste districts are required to provide a disposal site for tires, although this does not necessarily have to be a landfill. New Hampshire towns that charge a special disposal fee at the time of vehicle registration, an option they have under state law, are prohibited from charging a tipping fee on tires.

In general, special measures that must be taken to dispose of tires at landfills, whether required by law or not, represent increased expenses to the landfill for accepting this waste. New regulations or more widespread adoption of precautionary means of dealing with tires can be expected to further increase this expense, resulting in higher tipping fees. Similarly, compliance with tire pile regulations represents an increase in operating costs to stockpile owners, which will likely be reflected in increased tipping fees by those who wish to maintain legal operations.

Like tipping fees for ordinary refuse, the tipping fees charged for waste tires may not represent the true social cost of disposal. While the true costs of landfill disposal, should be incorporated in a full cost-benefit evaluation of waste tire management, estimation of such costs is beyond the scope of this study. When merely identifying the incentives that face individuals and tire haulers when they consider their tire disposal options, however, tipping fees are an appropriate measure of cost. Factors that increase the fees are relevant to the choices that these people make.

Incineration for Energy

Exeter Energy's tire incineration plant under construction in Sterling, CT will begin operation in mid-1991. The design of the plant is based on technology used by Exeter's parent company at its tires-to-energy facility near Modesto, CA. That plant has been in operation since 1987.

The Sterling facility is designed to burn whole tires unloaded directly from trucks or from onsite tire storage cells.[50] A separate conveyor will be available to feed shredded tires, although these are expected to provide only a small percentage of the fuel burned. Two reciprocating grate combustion systems will burn the tires at temperatures over 2,500°F. The steam produced in the two boilers will be piped to a turbine to generate the electricity. Underground transmission lines will connect the facility to a Connecticut Light and Power line in Plainfield.

The plant's environmental controls will consist of a flue gas cleaning system that will be comprised of thermal deNOx, a baghouse, and a wet scrubber. Fly ash collected in the baghouse will be stored in a silo until shipped offsite. Trace metals, principally zinc, can be recovered from the ash with additional processing. The gypsum produced by the wet scrubber will be dewatered onsite. The bottom ash, the result of melting steel belts, will also have to be shipped offsite.

Exeter Energy has already arranged contracts for some of the process's byproducts. The gypsum will be sent to US Gypsum in New York, and the zinc will go to the Zinc Corporation of America in Pennsylvania. Negotiations are still underway with cement kilns that might accept the steel slag.[51] The company also emphasizes that the plant will not burn tires that would be suitable for reuse or retreading.

Terms of the Electricity Purchase Agreement

The Public Utility Regulatory Policies Act of 1978 requires electric utilities to purchase the electric output of qualifying cogenerators and small power producing facilities. Since the Sterling plant is considered a qualifying facility under the appropriate criteria, Connecticut Light and Power (CL&P) must buy its output.

The rate at which Exeter will sell its power to CL&P is based on the utility's avoided costs, i.e., what it would cost CL&P to generate the power itself or purchase it elsewhere. The contract between Exeter Energy and CL&P specifies that the utility will pay Exeter a fixed rate per kilowatt-hour that is initially expected to be greater than CL&P's avoided cost. In later years of the term of agreement, CL&P is expected to pay Exeter at a rate less than its then-current per-kilowatt-hour avoided costs. According to the contract,

> [t]he initial fixed rate, expected to be above Buyer's [CL&P's] avoided costs in the early years of the Term, is necessary to allow Seller [Exeter] to obtain financing and have assurance of adequate cash flow to go forward with construction of the Facility. The payment rate expected to be below Buyer's avoided costs in the later years of the Term is necessary to provide Buyer's ratepayers with a reasonable expectation of recovering payments above avoided costs made in the earlier years of the Term.[52]

Based on projections by Exeter and CL&P, the utility will start receiving the benefits of the lower rates in the year 2000.[53] The total savings to Connecticut ratepayers is estimated to be $228 million over the life of the contract (*not* discounted to the present).[54]

Anticipated Effects on the Scrap Tire Market

According to the projections accompanying the electricity purchase agreement between Exeter and the utility, the plant will consume 80,523 tons of tires per year during the first 10 years of operation, and 83,321 tires per year thereafter.[55] This is the equivalent of about 8 million tires annually. Some of these tires will originate in New York, so only a portion of the 8 million will represent consumption of tires from the seven states included in this study. A breakdown of tire origin by state was not available.

Not only is the volume of tires to be consumed significant, but so is the price at which tires will be supplied to the facility. About 56 percent of the tires consumed by the plant will be acquired through contracts with large volume tire haulers.[56] These contracts were established before 1989, when Exeter needed to show the Connecticut utility commission that oversees the contract with CL&P that the facility would have a reliable source of fuel. At the time the contracts were arranged, Exeter believed that it would be receiving 100 percent of CL&P's avoided costs of electricity generation, and that it would not need to collect substantial tipping fees on the tires. Thus, it offered the tire haulers very favorable terms. For most of the tires acquired under contract, Exeter will be paying only the cost of transporting the tires to the facility.[57]

Later in the negotiations with CL&P and the utility commission, it was decided that Exeter would not receive 100 percent of CL&P's avoided costs, but that the difference would be made up by the tipping fees Exeter could collect on the remaining number of tires that would have to be acquired on the spot market. The savings to the utility would then be passed on to its ratepayers.[58] To take further advantage of any increases in tipping fees that Exeter might obtain on the spot market, the contract with CL&P also contains provisions whereby Exeter will have to share a greater portion of the tipping fees in times of good cash flow.[59]

The significance of these terms is that haulers who were lucky enough to sign contracts with Exeter in the late 1980s will have a very low-cost means of disposal for a combined 4.4 million tires per year. If typical tire disposal costs remain high over the next 25 years, these haulers will earn comparatively high profits on the portion of their business accounted for by their pre-1989 Exeter contracts. These contracts alone will probably not affect tipping fees observed in the market, however; despite the large number of tires accounted for by the contracts, the total number of tires to be disposed of in the region is several times this.

Rhode Island Reaction

Sterling, CT is upwind of a major reservoir that supplies Rhode Island with drinking water. Some Rhode Island residents have expressed concern over the possible effects of plant emissions on the reservoir. While Rhode Island can not stop construction or operation of the facility, the State legislature passed a law that prohibits both the burning of used tires within the state at facilities where they would be the primary source of fuel, and the export of tires to facilities in other states that burn tires within 30 miles of any Rhode Island reservoir watershed.[60] The Exeter plant falls under this description.

On its face, the Rhode Island law may represent an unconstitutional restriction on interstate commerce. Assuming it is not challenged, however, the law is unlikely to have a serious effect on the ability of Exeter to obtain tires, or the price it will have to pay for them. It is more likely to affect tire haulers doing business in Rhode Island, who will be precluded from disposing of their haul at this nearby facility.

Retreading and Remolding

Retreading refers to the process of removing the remaining old tread from a tire and replacing it with new rubber tread. Top capping refers to replacement of the tread alone, while full capping includes replacement of part of the crown. Bead-to-bead retreading, or remolding, is a process used on radial tires that involves a heat curing process in which a veneer of new rubber is applied to the sidewalls, in addition to the tread and crown. It appears that remolding has some advantages over recapping in terms of tire wear. The only remolder in the northeast is in New Jersey.

Truck tires have long been retreaded for both technical and economic reasons: truck tire casings are often durable enough to outlast the tread several times and withstand several retreadings; and new replacement tires are sufficiently expensive to make retreading worth the cost. For example, the state of Maine has a contract for retreading services that enables them to have truck tires retreaded at an average cost of $63 each, while new replacement tires would cost about $217 each.[61]

Lighter truck tires and passenger car tires are not as widely retreaded, and it is these tires that represent the majority of the scrap tire problem. The retreading of passenger car tires has declined in the past several years as consumers have been faced with the choices of cheaper or longer-lasting new tires.[62] The growth in use of radial tires has helped to prolong the initial life of a tire, but has led to lessened retreading because radials are more difficult and expensive to retread than bias-ply tires. In addition, consumer concerns over the safety of retreaded tires is frequently cited as a reason for the low rate of passenger car tire retreading.

According to the National Tire Dealers and Retreaders Association[63], the number of tires retreaded in 1989, and the number of new replacement tires sold were as follows (figures are in millions of tires):

Type	Retreads	New Replacement	Retreads as % of Total
Passenger	14	150	8.5
Lt. Truck	7	22.5	23.7
Md. Truck	14.8	11.2	56.9
Total	35.8	183.7	16.3

While figures for New England or the northeast are unavailable, the NTDRA gave no reason to believe that the regional rate of retreading was different from the national rate. However, Recycling Research, Inc., publisher of *Scrap Tire News*, suggests that retreading in the industrial northeast is lower than the national average. Vermont was cited as a state with somewhat higher reuse and retreading.[64] Another exception might be New Jersey, although its higher rate is due principally to truck tire retreading.[65]

When guidelines for proper tire maintenance are followed, as is often the case with truck tires, 80% of the casings are suitable for retreading. Only about 30 to 40% of passenger car tires are suitable for retreading, however, because of improper care. This rate could be doubled if all tires are taken out of service when they still have the legal limit of 2/32" tread remaining.[66] Some cheaper tires are constructed with casings that would never be suitable for retreading. Casings that have been in stockpiles for too long are also unsuitable for retreading.

Retreaders of passenger car tires may pay anywhere from under $1 to over $4 for a retreadable casing.[67] Retreaded and remolded tires retail for about 20 to 35% less than new tires. In addition, the retreader may receive some income from the sale of buffings, or the powdered rubber that is a byproduct of removing the old tread from the casing. Buffings sell for about 10 cents per pound.[68] Depending on the condition of the casing, one or two pounds of buffings may be produced for every passenger car tire retreaded.[69]

Retreaders do not usually have trouble obtaining enough quality passenger car tire casings. The New Jersey remolding company cited the price of the casings as a greater concern, and the cost of advertising as a constraint on reaching the private consumer market.[70]

Individual Consumers of Replacement Tires

From the consumer's perspective, the first question that must usually be addressed is that of safety. According to the Federal Tire Program, retreaded passenger car tires do tend to experience tread wear sooner than new tires, but they do not fail outright (blow out or split apart) any more frequently than new tires.[71]

Assuming equivalent safety, the value of a retreaded tire as compared to that of a new tire is based on the cost per mile of service that the tire can be expected to provide, and the terms of the warranty. One Massachusetts tire dealer provided the following "typical" figures for a customer considering replacement tires for a full-size American car. A good quality new radial tire costs $60 and comes with a 40,000 mile warranty. A retreaded radial tire costs $40 and is expected to last 25,000 to 35,000 miles. The new tire would thus provide service for 0.15 cents per mile, while the retread would provide service for 0.13 to 0.16 cents per mile. While a purchaser of retreads would have to go through the trouble of replacing tires again sooner than a purchaser of new tires, the cost per mile of the two products is similar.

Important differences may appear in the terms of the warranties, however. Both kinds of tires are usually guaranteed against defective workmanship or poor materials, but new tires may carry better guarantees on tread wear or mileage. This may have a significant effect on the relative price per mile if a tire wears out sooner than expected.

Another factor that might affect the consumer's choice is a disposal fee charged only on purchases of new replacement tires but not retreads. In the example above, a $2 disposal fee would raise the cost per mile of the new 40,000-mile tire to 0.155 cents, and a $5 fee would raise it to 0.1625 cents. The fee would have the effect of making the retread more competitive with the new tire.

Of course, these numbers will vary by dealership, tire quality, and tire size. This example is simply meant to show how the tire customer may approach the decision and how important both service life and cost are. There may be circumstances in which the customer decides that the retreads are appropriate, but it is not obvious that retreads will always or never be the better purchase.

Large Scale Purchasers of Replacement Tires

Fleet managers also face decisions about whether to purchase new or retreaded tires, and their calculations may be similar to those of an individual. Managers of government fleets face some special conditions. First, they are usually required to purchase only from suppliers with which the government unit has a contract. To date, none of the New England states provide the choice of retreaded passenger car tires to their fleet managers.

One of the main reasons that state procurement officials do not seek contracts with suppliers of passenger car retreads is that they usually rely on the federal government's Qualified Products List (QPL), and no retreaded or remolded passenger car tires have made it on to the list. According to Ken Collings of the Federal Tire Program (FTP), which tests tires for inclusion on the QPL, this is because the testing procedures require retreads to perform as well as new tires. This standard is used even though most retreads are not designed to last as long as new tires.

In the typical FTP test, a vehicle with one new control tire and three test tires is driven 20,000 miles with an 85% load. This load is much heavier than what most vehicles usually carry, and it enables the test results to be extrapolated to estimate tire life under other conditions. To pass, the test tires must last within 5% as long as the control tires. While most of the retreaded casings tested do not fail outright (i.e., split apart), they wear out prematurely as compared to the control tire, and this disqualifies them from inclusion on the QPL.[72]

The state, county, and municipality procurement officials who rely on the QPL do so because it provides a measure of quality assurance. Collings suggests that tire purchasers could still obtain some degree of quality assurance for retreads through use of the FTP's test results by looking for brands of retreads that wore out without failing. These tires may be appropriate for vehicles that are driven fewer than 25,000 miles per year and not at pursuit speeds.

Given an independent estimate of the expected life of the retreads, procurement officials could better evaluate the cost of these safe but shorter-lived tires. If procurement guidelines require that contracts be awarded to the lowest bidder, there will at least be a basis for comparing the cost-per-mile of retreads with the cost-per-mile of new tires. If life-cycle costing or preferences for recycled materials allow an agency to spend more for retreads, this information will be essential.

Tire-Consuming Potential

While none of the New England states or New Jersey currently have contracts for suppliers of passenger car retreads, some may be interested in using them on state fleets in the future. New Jersey is now in the process of trying to put a retread purchase program in place, and will develop its own evaluation criteria if the QPL does not approve a supplier. Even if it succeeds in arranging a contract with a retreader, the New Jersey Division of Purchasing will have to convince fleet managers in each of the state agencies to make use of the contract and actually buy the tires.[73]

Before mandating the use of retreads on its vehicles, a state would probably want to establish the characteristics of its fleets by conducting an inventory of the types and numbers of vehicles used by each department. Some vehicles may be kept only a short time before trade-in, precluding the need for replacement tires. In some fleets, only a small percentage of tires may be suitable for replacement with retreads.[74]

Due to the decentralized nature of tire procurement in most of the NEWMOA states, it was not possible to determine the potential size of the region's market for retreads on state vehicles alone. Activity at the county or city level is unknown, but may add significantly to the potential demand. Further research is needed to determine the size of the market for tires in the public sector. If the market turns out to be relatively small, the success of a government program to buy retreaded or remolded tires would be measured by its ability to encourage individual consumers to do the same, rather than by its own contribution to scrap tire consumption.

Manufacturers Using Whole Tires

There are very few manufacturers making finished products out of whole tires in New England or New Jersey. The combined tire consumption in these applications is probably no more than 1.8 million tires per year.

New inventions designed to consume scrap tires are sometimes proposed. Before such inventions are successfully marketed, it is difficult to evaluate how practical they may ultimately be. The proposal described at the end of this section is presented as an example of a creative use for whole tires, but its viability is unknown.

Stamped Products

F&B Enterprises of New Bedford, MA is the largest whole tire consumer in the region.[75] The company manufactures specialized equipment used in the fishing and scalloping industries, supplying about 400 boats. Its products include such items as dock bumpers, rollers, and chafing gear. As a smaller part of its business, F&B also makes non-pneumatic rubber wheels for large highway lawnmowers and other vehicles used where the risk of tire puncture is high.

The principal manufacturing process involves stamping pieces of the desired shapes out of the whole tire. Bias-ply truck tires are the most desirable raw material, although bias-ply passenger car tires can also be used. The company cites some difficulty in obtaining the truck tires, and suggests this may be due in part to lack of knowledge among potential local suppliers that the company is seeking them.[76] Another reason may be that because of the high rate of retreading for truck tires, a relatively small number need to be scrapped. Due to the low volume of local supply, the manufacturer obtains some of its supply from as far away as New Jersey and Pennsylvania.

Steel-belted radials can not be used in the stamping process. The radial tires that this company accepts are shredded and disposed of in the New Bedford landfill. The scraps from the bias ply tires are chipped and sold to a crumb rubber manufacturer in Pennsylvania.

For some of the fishing industry applications, the products represent beneficial additions to standard equipment that either help the equipment perform better or last longer; the stamped rubber products are not in competition with similar products made of virgin materials. The nearest competitors using recycled tires are in New Jersey and Tennessee, and do not substantially affect the business. However, the majority of the company's output, the fishing and scalloping equipment, serves a specialized market that does not provide much opportunity for growth. Other markets would have to be developed in order for business to expand. The reliance on bias-ply tires may also limit expansion of the stamping operation.

Artificial Reefs

Another application for whole tires is offshore fishing reefs. Cape May County, NJ has been building reefs from about 80,000 tires per year for several years. The labor is supplied by inmates from state correctional facilities. Initially, there was some difficulty from the reefs being broken apart by the tide, but this problem was solved. Atlantic County is now applying for permission from the state to use tire reefs. The county would consume up to 15,000 tires per year.[77]

The growth potential for this application is probably small. New England waters tend to be rougher than those off New Jersey, and breakage of the reefs might be more of a problem further north. Furthermore, the cost of reef construction may be as high as $2.50 per tire disposed.[78] This expense may be hard for a state to justify on solid waste disposal grounds. The cost may be justified if the value of the fish habitat created, but this determination would require further research. Since fishing reefs are a public good, it is unlikely that the private sector would become engaged in constructing them, even if they represent a socially beneficial way of recycling scrap tires.

Mats and Liners

At Tire Salvage, Inc., a small mat manufacturing operation is conducted as a sideline to the tire disposal facility. Whole bias-ply tires are cut into strips and woven into mats that can be used as truck bed liners, carpet pads, door mats, or other applications. The operation is currently consuming about 6,000 bias-ply tires per year.[79] Even if this rate doubles, as the company plans, total output will remain small.

Despite the size of the tire disposal operation at Tire Salvage, the company claims that the number of bias-ply tires coming in is sometimes insufficient to keep the mat operation with a constant supply. In general, tire pile clean-ups tend to yield more bias-ply tires than do current discards because they contain a higher proportion of old tires. When the incoming supply of bias-ply tires is low, the company can retrieve some from the pond. In fact, such retrieval accounted for more than half the tires made into mats.[80] This would suggest that other businesses that would rely on bias-ply tires as their raw material might experience unreliable supply.

Tire Tubing for Road Culverts or Septic Systems (Proposed)

A Connecticut inventor has patented a means of connecting tires sidewall-to-sidewall to create tubing for a variety of purposes. One proposed use is as a replacement for concrete or plastic in road culverts and drains. The tubes could be supplied in five or ten foot lengths of various diameters. A mile of tubing would consume about 10,000 tires. The inventor claims that they would cost one-third to one-half less than the concrete or plastic currently used, and would last 75 years longer.[81]

Another proposed use for the tubes is in home or commercial septic systems to replace both the holding tanks and the leachfield galleys. Home septic leaching systems traditionally used hollow, precast concrete cylinders placed in trenches as the galley portion of the system. The sewage is released slowly through perforations in the cylinders into surrounding stones, and is then absorbed into the soil. More recently, polyethylene pipes are being installed, and no stones are required. The MATES system would replace the concrete cylinders with perforated tire cylinders in the trenches. Like the concrete, the tire cylinders would also be surrounded by stones on the bottom and sides. The holding tanks would be constructed of truck tires, while the galleys would be made of passenger car tires. The inventor claims the system would be easier to install and cost less than concrete, but did not make comparisons to polyethylene. He estimates that sales equal to 5.8% of the Connecticut market alone could consume about 680,000 tires per year.[82]

Septic system use would require approval by the agency in each state responsible for regulating underground septic systems. Construction and design standards would have to be developed before the system is approved, establishing how much pressure the tires can withstand and how much fill is needed to cover and protect the system. The galley system would also have to be rated as to the amount of effective area (stone/soil interface) per lineal foot of tubing. This enables calculation of the size of a system necessary to serve a residence of a given size.[83]

An important concern of the state agencies would be whether the tires would leach any harmful constituents that could contaminate groundwater. While there has been some research on the leaching characteristics of tires[84], none has been performed that used septic effluent as the reagent. A related health and environmental concern might be that the diameter of the tire tube would require burial at greater depths than is typically needed, bringing the septic effluent closer than usual to groundwater. Since septic leachfields are already associated with low levels of toxins, any act that would introduce greater risk of groundwater contamination may meet with resistance.[85]

The inventor is trying to license a manufacturer to produce and install the tire tubing systems. He estimates that capital expenses would total $550,000 for a business processing 700,000 tires per year.[86]

Intermediate Material Manufacturers

Some tire processors make a product that is useful primarily as an input to another product or process. For example, tire chips or shreds may be usable as a road construction material, as a replacement for stone in septic leaching systems, or as a soil conditioner. Large granules may be used in paving aggregate or playground surfaces, while smaller sized crumb may be used in asphalt binder, roofing, or as an input to plasticized molding material. This section will discuss the manufacturers of the intermediate material and some of the market considerations they face.

Tire Shredding

There are several companies that shred tires in the region. Some are in the business simply to perform tire pile cleanups or reduce the volume of tires destined for landfills. Others shred tires with the goal of selling the chips as a usable product.

Slices or shreds to be landfilled can be produced by equipment through which the tires make a single pass. For shreds that will be put to some use, a smaller and more uniform output is often required. The equipment to produce a 2"x2" chip typically includes a classifier, which screens out the desired product chip size and returns oversize pieces to the shredder for further reduction. In general, the smaller the shred or chip needed, the more expensive the equipment.[87] Additional factors that raise the capital costs of shredding operations are generators (needed where there are no utility hookups), or trailers to make the system mobile.

One New England business, Palmer Shredding of Ferrisberg, Vermont, had capital expenses of about $225,000 for equipment to process 2,000 tires per day using a stationary system.[88] Sawyer Environmental Recovery of Hampden, Maine spent about $500,000 to establish a stationary operation that shreds 800 tires per hour.[89]

When trying to raise the capital for their shredding operation, the Palmers at first found banks unwilling to lend to them because there were no other similar businesses they could research to evaluate the viability of the proposal. The Palmers then went through the federal Small Business Administration to secure backing that satisfied a local bank. This process took about nine months.[90]

Operating expenses for the systems are primarily labor and energy. Shredding systems typically require about three operators to load the tires and monitor the equipment. Energy requirements are in the range of 200 horsepower.[91] Careful and regular maintenance appears to be critical in avoiding breakdowns, which can be a major problem. Both Sawyer and Palmer have experienced breakdowns. Sawyer claimed a breakdown could cost the company as much as $60,000.[92] Good relations with the equipment manufacturer was cited as an important factor in running the system. Sawyer and its equipment supplier are working together on improving the design both of machinery components and the system as a whole.

Both Sawyer and Palmer are considering adding additional equipment that will further process their output to meet specifications required by more higher valued uses. Sawyer plans to add a secondary granulator that will take the first product and further reduce it to a "one-inch" chip that is no more than 2 inches in any dimension. This equipment will also remove 90 to 100% of the bead wire and 50% of the cord, as specified by the paper mill interested in using the chips for fuel. The cost of this equipment, including a building in which to house it, is estimated at $350,000.[93]

Palmer Shredding is considering the purchase of a granulator that would produce crumb small enough to use for playground surfaces or as an additive to asphalt (see discussions below). The $500,000 price tag on the equipment is seen as a major obstacle, however.[94]

Depending on the form of the tire slice, shred, or chip, shredding operations may produce some byproducts. Typically, shredders accept tires either on or off the rim, because the rims can be removed and sold as #2 steel. The price obtained for the scrap varies from $50 to $85 per ton, and is usually around $70.[95] Inner tubes can be sold as butyl rubber. Markets for the waste wire, which at Sawyer accounts for about 5% of the original weight of the tire, are not readily available. Sawyer is currently landfilling this material, but may try to sell it to Dragon, a Maine cement manufacturer.[96]

Currently, the largest consumer of tire chips produced in New England or New Jersey is the export market. Two companies that shred tires are taking advantage of this outlet: Metropolitan Tire of Newark, NJ operates a fixed shredding facility, and Integrated Tire of Buffalo, NY performs onsite shredding with mobile equipment (often used to accomplish tire pile cleanups, such as the one in Danville, NH.) Through the Newark exporter TDF, Inc., both are shipping chips to Greece for use as fuel in a cement kiln.[97] The exact price received for exported chips is not publicly available, but is probably in the neighborhood of $35 to $40 per ton[98], or $14 to $16 per cubic yard.

Other shredders are selling relatively small amounts of chips to potential long-term consumers who are using them on an experimental basis. The prices currently charged in these situations may be lower than what the shredder would expect as a long-term price. A shredding company may offer the low price to encourage experimentation, and thus help develop markets for the material. For example, Palmer Shredding is charging the Vermont Agency of Transportation only $.40 per cubic yard, plus transportation, for tire chips to be used in a shoulder-widening project.[99] This price was low enough to enable the state to try the material in this application.

From the perspective of the shredder, however, this may or may not be a sustainable price. Forty cents per cubic yard translates to only one cent per shredded tire.[100] Clearly, Palmer's tipping fee on the tires, about 55 cents each for bulk loads[101], would represent a much larger percentage of the business's revenue than the sale of the shreds.[102]

However, the sale price of chips may not need to cover the cost of shredding, for the business to be profitable overall. If by selling the chips the cost of disposal is avoided, a company might continue to earn enough from the tire collection side of the business. For example, suppose a company accepts tires for $1 apiece and would face disposal costs of $80 per ton at a landfill or other facility. This disposal expense is equivalent to about $.80 per tire, or 80 percent of the revenue generated by collection. If the tires could be shredded and sold at the cost of shredding, the company would avoid this expense completely. Even if the sale of chips did not cover the cost of shredding, the company may find that it is worth taking a "loss" on the shredding operation to enable it to continue the profitable tire collection service. An important observation is that over a rather wide range of prices potentially obtainable for tire chips, the tipping fee will probably remain the dominant source of revenue for a shredding operation. Thus, factors that affect the tipping fee will be more important to the business than factors that affect the price of chips.

Crumb Rubber

"Crumb" or "granulated" rubber is a form of recycled rubber that contains no fiber or metal. It can range in size from half-inch granules down to 10, 20, or 30 mesh and smaller. A passenger car tire yields about 12 pounds of crumb.[103] The maker of crumb rubber closest to New England and New Jersey is the Chambersburg, PA plant of Baker Rubber. The combined output of this company's plants is about 60 million pounds of crumb per year, which represents 40 to 50% of the granulated rubber consumed in the United States.[104] A total of about 5 million tires per year are processed by the company, of which they estimate 425,000 per year originate in New England or New Jersey. An additional 280,000 come from New York.[105]

The capital costs for a whole-tire-to-crumb rubber system that processes 8,000 tires per day (about 2 million per year) are on the order of $3 million. Smaller systems cost proportionately somewhat more.[106]

Rubber-Plastic Polymers

Details on the technical and economic aspects of reprocessed tire rubber used as a feedstock in molded products is difficult to obtain due to the proprietary nature of the information. the two patented processes discussed here represent the first stages in the process of converting scrap tires into molded rubber-plastic products.

TireCycle (Proposed)

TireCycle is a patented system for completely recycling scrap tires into materials that serve as inputs to other processes. The tires are first shredded and ground to various sizes, and all metal and fiber are removed. The rubber particles are then treated with a series of patented liquid polymers that aid in the blending of the rubber with plastics or virgin rubber. The finished TireCycle product can be supplied in powder, pellet, or compound form. The fiber component will be sold to Teledyne-Monarch, and the metal will be sold to scrap dealers.[107]

In 1989, a TireCycle facility that was subsidized by the state of Minnesota closed due to financial and other difficulties. Nevertheless, a New England entrepreneur, has purchased a license from the patent holder, Rubber Research Elastomerics of Minnesota, and is trying to set up a plant in Rhode Island that would use the same technology. At full capacity, the plant would consume 3 to 4 million tires per year, producing 72 million pounds of rubber product, and 14 million pounds each of fiber and metal. TireCycle of New England believes that the problems faced in Minnesota, including the need to retool the plant twice, and the plant's location hundreds of miles from the nearest source of tires, would not be factors in Rhode Island.[108]

TireCycle of New England will not be involved in the tire collection business. It will rely on the existing trucking system to supply the material. At first, the company expects to be able to collect a tipping fee on the tires, but believes the operation will be sufficiently profitable that it would eventually be able to pay for tires, if that becomes necessary.

According to the company, the current demand for the principal TireCycle product is on the order of 130 million pounds per year.[109] No independent verification of this figure is available. Among its potential customers, the company cited two tire manufacturers and a major producer of molded rubber household products. Demonstration quantities of the product have already been provided to these firms.[110]

One potential problem the company forecasts in developing some markets is that a manufacturer might demand more of the product than one plant could produce.[111] This is the problem of minimum efficient scale: it may not be worthwhile for a manufacturer to develop a consumptive use of the feedstock below a certain volume. While two or more plants the size of the one planned for Rhode Island might produce enough for such a customer, investors are usually unwilling to finance such a large project without some demonstrated success on a smaller scale. Furthermore, a customer may be hesitant to develop a production line that depends on a single supplier for an important input; if the one supplier goes out of business, the investment in that production line will have been wasted.

Currently, the principal constraint on TireCycle of New England is raising the $10 million in capital necessary to purchase property and begin construction. Once the company raises $2 million from private sources and finds a site for the facility, it will be able to apply to the Rhode Island Industrial Facilities Corporation for state-issued taxable industrial revenue bonds. The terms of such bonds are generally more favorable than what can be obtained in the private capital market.[112]

The Rhode Island Department of Economic Development is helping TireCycle locate a site for its facility. The company's advocate at the DED has been advised by staff of the Department of Environmental Management's Office of Environmental Coordination that the TireCycle process is a good one. Given the state's opposition to the Exeter Energy tire incineration facility in Sterling, CT, it is perhaps not surprising that the DEM is supportive of the TireCycle proposal. However, there is no formal means by which the Departments of Environmental Management or Economic Development can influence the decisions of the quasi-public corporation that approves applications for industrial revenue bonds.[113]

Typlax

R.W. Technology of Cheshire, CT has also developed a patented process for recycling tires that combines granulated rubber with plastics to make a polymer suitable for injection molding. The capital costs of setting up a plant can range from $5 million to $30 million, depending on capacity.[114] So far, R.W. Technology has one licensee, American Typlax Systems of Washington, PA, which is still in the process of setting up its plant. At full capacity, expected to be reached in 1992, American Typlax will collect six million tires and produce 150 million pounds of product per year.[115]

According to American Typlax, the firm's products will participate in the 30 billion pound per year "non-visible" share of the nation's 57 billion pound total plastics market.[116] This refers to products such as piping or industrial goods for which appearance is not important. Demonstration quantities of the product have also been provided to manufacturers of automotive carpet backing and compartmentalized containers.

R.W. Technology and American Typlax have considered licensing additional companies to use the technology. Currently, the midwest seems a more likely site for a second plant than the northeast. The high costs of land, labor and electricity in the New England were cited as obstacles to locating there. Electricity is a major operating expense in the Typlax process; according to American Typlax, the cost of electricity in Pennsylvania is less than half that in New England.[117]

Pyrolysis

Pyrolysis is the thermal decomposition of a substance in the absence of air or oxygen. The pyrolysis of tires yields such products as oil, gas, and carbon black. Research and experimentation with tire pyrolysis is ongoing, but little commercial activity is taking place because the process has not yet proven to be economically viable. Recent process improvements may change this, however. A company that plans to build a commercial-scale plant in Detroit, MI estimates the capital costs of a tire pyrolysis plant at $4 to $5 million.[118] No proposals for building tire pyrolysis facilities in New England or New Jersey were discovered as of this writing.

Consumers of Intermediate Products: Tire-Derived Fuel

The rubber in tires is a synthetic made of petroleum products. When burned, the heat content of tires is comparable to that of other fossil fuels. "Tire-derived fuel", or TDF, is a term that is used loosely to describe any whole or reduced form of tires that can be burned. Depending on the degree of processing, it may be referred to as tire chip fuel, which has a high percentage of the tire wire remaining, or rubber derived fuel, with most or all non-rubber materials removed. Since the metal in tire chips does not burn, the heat value of TDF increases with the percentage of wire removed.

Table 4 lists the average heat content for several types of fuels, including TDF. Measured in terms of BTUs per pound, TDF (with some of the wire removed) contains about 21% more heat potential than bituminous coal; tire chip fuel contains about 11% more.[119] The differential is greater for other grades of coal. Understanding that it is primarily the heat content of a fuel the industrial consumer is buying is important to understanding how

Table 4

HEAT CONTENT OF COMMON FUELS

Fuel	Grade	Average Heat Content
Gas	Natural	1,000 BTU/cu ft
Oil	No. 6 "Bunker C"	151,000 BTU/gal
RuDF	Rubber Derived Fuel	16,000 BTU/lb
TDF	Tire-Derived Fuel	15,500 BTU/lb
TCF	Tire Chip Fuel	14,200 BTU/lb
Coke	Petroleum	13,700 BTU/lb
Coal	Lignite	7,300 BTU/lb
Coal	Subbituminous	10,500 BTU/lb
Coal	Bituminous	12,750 BTU/lb
Wood	Wet Wood ("Hog Fuel")	4,375 BTU/lb

Source: Rouse Rubber Industries, Inc., as presented in testimony given by Mike Rouse before the House Committee on Small Business, Subcommittee on Environment and Labor and Subcommittee on Regulation, Business Opportunity and Energy; Hearing on Scrap Tire Management and Recycling Opportunities, 10 April 1990.

TDF competes with more conventional fuels.

The costs of different fuels are typically compared as price per million BTU. Thus, tire chips selling for $45-55 per ton cost from $1.29 to $1.77 per million BTU.[120] Bituminous coal selling for $55 to $65 per ton costs the equivalent of $2.11 to $2.50 per million BTU. Even on the basis of equivalent heat content, some fuels command a higher price than others. Oil is typically more expensive than coal, which in turn in more expensive than wood, for the same heating value.

Since TDF competes most closely with coal as an industrial fuel, the lowest price for coal may be viewed as the ceiling on the selling price for TDF, when both are expressed in terms of heating value. To compare this price with prices obtainable for tire chips in other applications, it is more useful to express the price in cost per ton, per cubic yard, or per tire. If chips could be sold for $2.40 per million BTUs (an average price for coal delivered to industrial users is Maine[121]), that would be equivalent to $74.40 per ton (= $2.40/million BTU x 31 million BTU/ton). This ceiling price is also equivalent to $26.57 per cubic yard or 60 cents per tire.[122] At a hypothetical selling price of $55 per ton[123], TDF would earn $19.64 per cubic yard or 45 cents per tire. Thus, it appears that TDF manufacturers willing to sell their product at $55 per ton would be competitive with coal on the basis of heating value.

Some industrial facilities, particularly those designed to handle mixed fuels, are capable of replacing a portion of their conventional fuel supply with TDF. Among the characteristics of a facility that may potentially burn TDF are the ability to withstand very high temperatures and the ability to hold solid fuel long enough for complete combustion. Furnaces that burn coal on a grate are often mentioned as candidates for burning tire-derived fuel. Facilities that already have significant pollution control equipment in place are also better positioned for considering TDF.

The two types of plants most frequently discussed as consumers of TDF are cement kilns and pulp and paper mills. Currently, two cement kilns in this country are burning TDF, as are several pulp and paper mills. None of these facilities are located in New England or New Jersey. As indicated earlier, however, there is a high probability that at least one paper mill in Maine will soon begin using TDF, and an additional four or five mills in that state have the type of boiler that can accommodate TDF. A cement kiln, also in Maine, may be capable of burning whole tires at some point in the future. The following sections discuss the use of TDF by paper mills and cement kilns in greater detail.

Pulp and Paper Mills: Champion International

Multi-fuel paper mills typically burn a combination of oil, coal, and biomass. The oil and coal are used to boost the total BTU content of the fuel and control the burning of wood and sludge wastes. TDF has been successfully shown to replace some of the coal in multi-fuel boilers.

The Champion mill in Bucksport, ME started experimenting with TDF three years ago. It expects to receive amendments to its licenses from the Maine Department of Environmental Protection (DEP) during the fall of this year that will allow it to burn TDF on a regular basis. Champion's experience provides an instructive case study on some of the important issues facing a paper mill considering the use of TDF.

Champion's first trial burns used locally supplied tire chips that had most of the wire remaining in them. These chips caused mechanical problems in the fuel conveyor system. Champion then tried chips from which 75% to 80% of the wire had been removed. These chips, supplied by a shredder in Georgia, proved more satisfactory.[124] Champion paid only the cost of transportation for the TDF from Georgia.[125]

Champion conducted test burns using up to 3.5 tons of TDF per hour. This accounted for roughly 5% of the total BTU content of its fuel.[126] Initially, the plant engineer encountered some technical difficulties with the new fuel. For example, the rate of ventilation had to be adjusted to account for differences in the TDF's burning characteristics as compared to the low-sulfur coal it was partially replacing. Eventually, however, the higher temperatures at which the boiler operated with the TDF enabled more complete combustion of the sludge.[127] A shutdown inspection of the boiler in May 1990 confirmed that no damage had occurred as a result of tests with the new fuel.[128]

Both the Bureaus of Air and Solid Waste Management of the Maine DEP have been involved in the monitoring of Champion's TDF experiments, and in amending the plant's licenses. One area of concern to the Solid Waste regulators is the storage of chipped tires. They are investigating precautions to avoid arson or accidental fire. They are also concerned about a backlog of TDF accumulating if the boiler needs to be shut down and the fuel continues to be delivered.[129]

According to the Bureau of Solid Waste Management, the composition of the mill's ash does not change much when TDF is burned; while the concentration of zinc increases, cadmium and lead levels are lower.[130] The ash does not qualify as a hazardous waste[131] and will continue to be disposed of at the mill's own landfill, along with sludge and general mill wastes.

According to the Air Bureau, stack tests were conducted with TDF burned at the rates of 1.5, 2.5 and 3.5 tons per hour, and were compared to baseline emissions per unit of heat produced. The only significant difference in emissions was for zinc, which went up almost ten-fold when TDF was burned at 3.5 tons per hour. Other results were a slight increase in cadmium, decreases in beryllium and chromium, and no significant change for lead, hydrocarbons, SO_2 or NO_x.[132] The facility's current license does not specify a limit on zinc, but the new license will include limits for several heavy metals, including zinc.[133]

Maine regulations normally require that any change in fuel other than that specified in the license constitutes a "modification" of the facility and requires a new license. To get a new license, the facility must submit to Best Available Control Technology (BACT) analysis for environmental controls. This type of analysis includes consideration of technical, environmental, and economic factors. However, Champion International presented a bill to the legislature earlier this year to obtain an exemption from the BACT analysis requirement for industrial boilers that switch to TDF. The bill passed and became effective 15 July 1990.[134] A BACT analysis of the facility might have taken three or four months; it is not clear whether the results of the analysis would have suggested any changes in environmental controls.[135]

A spokesperson for Champion estimated that the emissions monitoring conducted during the trial burns and the testing of the ash cost the company about $50,000.[136] In addition, the company expended considerable human resources on the TDF project in terms of the time and effort of environmental engineers, public relations specialists, attorneys, and headquarters executives. In exchange, Champion expects to save about $500,000 per year on fuel costs and is "excited to part of the solution to a problem" by consuming up to 3 million tires per year.[137]

Cement Kilns: Dragon Products

Cement kilns are frequently mentioned as ideal consumers of tires as fuel. Among the advantages of burning tires at these facilities are that the exceptionally high temperatures allow thorough combustion, the plants usually have sufficient environmental controls already in place, and they have the capacity to incorporate some or all of the steel slag into their finished product, thus reducing the volume of byproducts. Cement manufacturers in the U.S., Germany, Greece, and Japan, have kilns that burn whole tires.[138]

The only cement kiln in New England is operated by Dragon Products in Thomaston, ME. This is a "wet process" kiln and is currently incapable of burning tires unless ground very fine. Dragon is frequently approached by tire chippers who wish to sell TDF, but the chips are too large to be used in this type of kiln.[139]

However, the company is considering converting the kiln to the "dry process". This major capital modification would not be undertaken specifically to enable the burning of whole tires, but the capacity to use tires as fuel would be one of its benefits. The cost of the conversion is estimated at $4 million for design and construction. Additional conveyor equipment would be necessary for handling tires, but its cost would be insignificant in comparison to the primary plant modification. The earliest that the conversion would take place is 1993 or 1994. Once converted, the kiln could consume 3.75 million tires per year, which would represent about 25% of its fuel needs.[140]

According to Garrett Morrison of Dragon Products, one concern about using tires would be the ability to secure a sufficient supply on a regular, long-term basis.[141] Given the avoided cost of coal consumption, however, Dragon may be able to provide a very competitive means of tire disposal that would ensure it of adequate supplies. Unlike companies that charge a tipping fee to dispose of tires, Dragon may be able to offer to pay for whole tires. The amount they would be willing to pay would depend on how much is saved through lowered expenditures on coal.

To estimate a lower bound on the annual savings to Dragon from burning whole tires, we can estimate the fuel value of whole tires and figure how much coal the tires would be replacing. If the heat content of whole tires is 12 to 14,000 BTU per pound, 3.75 million tires at 20 lbs each would be the equivalent of at least 900,000 million BTU. The bituminous coal that the plant currently burns has a BTU value of 12,500 BTU per pound and costs about $45 per ton.[142] Thus, 36,000 tons of coal could be replaced, saving the company about $1.62 million per year. On a per-tire basis, the lower bound estimate of Dragon's savings is $.43 for every tire burned (= $1.62 million / 3.75 million tires).

This suggests that Dragon should be willing to pay up to $.43 per tire. Given that most other New England disposal options will probably be charging tipping fees for whole tires, however, it seems unlikely that Dragon would actually have to pay anything for its tires. More likely, it will be able to collect a tipping fee, further increasing the profitability of burning tires.

Consumers of Intermediate Products: Roadway Maintenance and Construction

The feasibility of using crumb rubber as an additive to paving materials has been a subject of research and experimentation since the late 1960s. Engineers have developed several different ways of incorporating crumb rubber into paving and pavement repair materials, and all the northeast states have had at least some experience with one or more of these methods. More recently, some states have begun looking into the potential for using tire chips in various road construction and maintenance projects. These applications include slope stabilization, embankment fill, and subgrade road beds. This section will cover the status of research in these areas, and the economic and other factors that would affect the use of tire-derived materials in roadway projects.

Crumb Rubber Additives to Asphalt Cement

There are two principal means of incorporating crumb rubber into asphalt. The more common method calls for the addition of tire buffings (a byproduct of retreading) or fine mesh crumb rubber to the asphalt binder. During the heating and blending process, which requires specialized equipment, the rubber has an opportunity to react with the asphalt, forming a thick, elastic material. This process is referred to as the "wet" or "Arizona" process, and the product is appropriately called "asphalt-rubber binder" or "pre-reacted asphalt rubber". It can be used as a crack/joint sealant for maintenance purposes, or as a surface treatment. For the latter, the asphalt-rubber binder is sprayed on the road at a thickness of about 0.6 gallons per square yard,[143] and is then covered with aggregate and rolled. This may serve as the driving surface, or it may be covered with additional pavement.[144] The surface treatments are patented processes.

Crumb rubber accounts for at least 15% by weight of the asphalt-rubber binder,[145] and as much as 30%.[146] In New England, the typical range is 18 to 25%.[147] Once the aggregate is included, the rubber accounts for only 1 to 2% of the total weight of the material.[148]

The other means of incorporating rubber into asphalt is known as the "dry" process, or "hot mix" application. It involves the replacement of some of the mineral aggregate with rubber particles of various sizes. "PlusRide" is the patented trademark for the replacement of specific sizes of aggregate in specified ratios. The rubber accounts for 3% of the PlusRide mix. Generic (unpatented) versions of this process are also used, in which various sizes of aggregate are replaced with corresponding sizes of crumb. The results are sometimes referred to as "rubber-filled" pavements or "rubber-modified asphalt concrete" (RUMAC).

Many advantages are claimed for both asphalt-rubber binder systems and rubber-filled pavements. They include better longevity with less cracking, better traction or less skidding, reduced glare, reduced noise, and faster melting of ice, as compared to conventional asphalts. Despite the numerous experiments by cities and state departments of transportation, however, it is difficult to characterize the use of asphalt rubber or rubber modified asphalts as either successful or unsuccessful. In some cases, asphalt-rubber or rubber-filled pavements have outlasted their conventional counterparts; in others, they have deteriorated more rapidly.

Generalizing about the success of the pavements is complicated by variables characterizing both the application method and the site. Among the application variables are the percentage rubber incorporated, the size of the particles, the mixing and laydown temperatures, and the thickness of material applied. Then, an application technique that appears to work in one setting may not work in another due to site-specific conditions. These variables may include climate, slope, traffic load, or whether the new pavement is laid over cracked, old pavement or a new base. Technical reports have been prepared for many of the individual road, bridge and airport runway projects in the region. A comprehensive evaluation of the results is clearly needed, however.

Tire-Consuming Potential

A useful way to think about the tire-consuming potential of asphalts containing crumb rubber additives is to express the number in terms of tires consumed per mile paved. Caution must be taken in interpreting this ratio since it is sensitive to such variables as the thickness of the pavement and the proportion of rubber in the material.

The following estimates for a two-lane road (36 feet wide) with 2-inch thick pavement are based on industry estimates, adjusted for local practices:

	Tires Consumed Per Mile	Miles Needed to Consume One Million Tires
Asphalt-Rubber Binder System[149]	5,469	183
RUMAC (patented or generic)[150]	11,080	90

More research is needed to adjust these estimates for different paving practises in specific locations. More research is also needed to determine the miles of roadway in the NEWMOA states for which these applications might be practical.

Costs and Cost-Effectiveness

The initial costs for either of the rubber-added pavements are higher than for conventional asphalt concrete. Rubber-asphalt binder may cost as much as $350 per ton, as compared to $120 per ton for conventional binder.[151] Specially designed equipment is needed to spray the rubber asphalt binder on the road. Some experts say the total costs of a rubber-asphalt pavement, including aggregate and construction, may be 50 to 100% higher than for a conventional asphalt concrete pavement.[152]

For the PlusRide or generic rubber-modified asphalt concretes, the extra expense is encountered for the aggregate mix containing the rubber. The crumb rubber itself costs about $.12 per pound, or $7.20 per ton of PlusRide mix. According to one New Jersey contractor, adding the rubber to the mix takes more labor, requires more fuel to achieve higher mixing temperatures, and results in a slower production rate than the manufacture of conventional mixes. In addition, the plant can not make conventional asphalt mix on the same day, but must be dedicated to making the special mix for a given period of time.[153] This suggests there would be economies of scale if a plant could specialize in mixes containing rubber.

Two more factors lead to a higher cost for RUMACs. First, both the PlusRide and generic versions require a greater amount of binder, the more expensive component, as a percentage of total material. Whereas conventional asphalt concrete is 6% binder, generic RUMAC is 7% binder and PlusRide is 7.5% binder.[154] Second, contractors using the PlusRide formula must also pay a royalty of $2.50 to $4.50 per ton, depending on project size, to the holder of the U.S. and Canadian marketing rights.[155]

Other factors may offset the higher price per ton for the PlusRide or generic rubber-filled mix. For example, the lower density of the rubber-filled mix allows one ton to cover a greater area. The increase in yield per ton of PlusRide is approximately 6%.[156] More significantly, the ability to obtain the same level of performance from a thinner layer of pavement would offset the higher cost per ton. The City of Newark calculated that by laying the PlusRide mixture at a thickness of only 1.5", as compared to 2" for conventional mix, the final cost of the aggregate was virtually equivalent.[157]

Costs per Tire Consumed

One way of looking at the economics of using tire rubber in asphalt mixes is to compare the cost per tire consumed. This can be estimated by assuming that pavements containing rubber additives are identical in performance to conventional asphalt, and then spreading the increase in cost for the rubber-consuming pavements over the number of tires consumed by each.

To maintain consistency with the above estimates for tire-consuming potential, we again consider a 36-foot wide two-lane road, one mile long. The cost of asphalt mix for a conventional pavement, two inches thick, is $76,032. [158] The cost for mix that uses asphalt-rubber binder is $110,168. [159] Subtracting the cost of mix for the conventional pavement, and dividing by the 5,469 tires consumed, the cost per tire is approximately $6.24.

The cost of the generic RUMAC process mix for the one-mile road is $90,911. [160] This translates to a cost of $1.34 per tire consumed.

Since one of the advantages claimed for the crumb-rubber additives is that they allow for the use of thinner pavements, we can also compare the cost of a 1.5-inch rubber-added pavement to the cost of the 2-inch conventional pavement. These calculations yield a per-tire cost of $1.61 for the asphalt-rubber binder system, and a *savings* of $0.95 per tire for the generic RUMAC mix. Of course, thinner pavements will consume fewer tires than thicker pavements.

The above cost estimates for a one-mile long two-land road are summarized as follows:

	2" Conv Asphalt	2" A-R Binder	2" RUMAC	1.5" A-R Binder	1.5" RUMAC
Installation Cost	$76,032	$110,168	$90,911	$82,626	$68,142
Tires Consumed	--	5,469	11,080	4,102	1,662
Savings (Cost) per Tire	--	($6.24)	($1.34)	($1.61)	$0.95

To compare the overall cost-effectiveness of any RUMAC or asphalt-rubber pavement to conventional pavements, additional information is needed. After initial costs are considered, the degree of maintenance and the time until the section will require repaving (the pavement's "design life") are also relevant. Some of the current research on asphalt-rubber pavements focuses specifically on estimating the design lives of various thicknesses under various conditions, or determining what thickness needs to be used to achieve a desired design life.[161] Once maintenance and rehabilitation factors are added, better estimates of the discounted "lifecycle" costs of the pavements can be made and compared. These may differ substantially from those presented above.

Planning and Budgeting Considerations

Understanding the design life of a pavement and being able to calculate its lifecycle cost are important for planning highway maintenance schedules. The timing and predictability of pavement maintenance requirements are important to planners who want to know how many projects can be accomplished with a given budget, and how long they can expect them to last.

Even if pavements containing crumb rubber additives prove to be cost-effective from the point of view of those responsible for highway construction and maintenance, procedures for allocating maintenance and construction funds may pose an obstacle to their use. The Federal Highway Administration requires that states have a pavement management system that ranks pavements in the state according to the degree and timing of the reconstruction or rehabilitation they are expected to need. Mathematical equations considering many variables are usually involved. Once the pavements are ranked, the state must follow a strategy for addressing the problems in each class. In essence, this strategy is an optimizing model that attempts to fix the most lane-miles for the least amount of money.[162]

A principal constraint in this system is the amount of money available at a given time. It may be that the most efficient long-term solution for a particular pavement section would be to use a treatment that has high initial costs, but would be expected to last a relatively long time. If, many pavements are in need of immediate attention, however, and currently available funds can cover only low-cost, short-term repairs, the more efficient long-term solutions may not be possible. Transportation officials may be constrained from choosing a more durable, high cost treatment for one section if it will mean other sections will have to go untreated. Short-term budget constraints will tend to work to the disadvantage of pavements characterized by high initial costs but greater longevity, such as those using crumb rubber additives.

Factors Affecting Costs in the Future

The patent on PlusRide will expire in 1992 and the patents on the asphalt-rubber binder systems will expire later in the decade. In addition, economies of scale might be available if there were a greater demand for crumb rubber additives. One example, cited above, might be the savings realized at a hot mix plant that makes the hot mix by not having to switch back and forth between producing mixes with and without rubber. Another factor that could bring down the cost of the crumb rubber itself would be a locally available supply. Currently, the crumb rubber used in northeast paving projects comes from Pennsylvania and Ohio. Finally, an increase in the number of contractors who use crumb rubber additives might increase the competition in this field and lead to lower bids on projects.

Recyclability Issue

A final issue that must be resolved is whether pavements containing crumb rubber additives are recyclable. Currently, old pavements can be recycled into new paving material, eliminating the need to dispose of great quantities of waste. If pavements made with crumb rubber additives are not recyclable, the technology may eventually exacerbate the solid waste problem, rather than help solve it. Proponents of crumb rubber additives claim the new pavements are recyclable, but other have expressed concern on this question.[163]

Tire Chips in Transportation Construction Projects

Several uses for whole, sliced or chipped tires in construction projects have been proposed. In most of these applications, tire chips would serve to replace or augment regular or lightweight fill material, as in embankments, for subgrade road beds, for slope stabilization, or as backfill behind retaining walls and bridge abutments. Tire chips have also been proposed as a replacement for stone in roadway subdrains.[164] Additional proposed uses of waste tires include mats of tires tied together to strengthen soft subgrades, tire retaining walls, and sound barriers consisting of mounds of tire rubber that are covered with soil and then landscaped.[165]

Physical Properties

Important characteristics of tire chips as a construction material are that they are light in weight and very porous. These properties are attractive for uses in swampy areas and where good drainage is needed. Since tire chips are not subject to rotting, they present an advantage over wood chips and sawdust under conditions where biodegradation might be of concern.[166] On steep terrain, tire chips can be used to help hold ordinary fill in place and prevent slope failures.

Transportation engineers have expressed a need for more research and experimentation to better understand the properties of tire chips in construction applications. Specifically, they need more information on the material's compressibility, resiliency, and weight-bearing capacity, by itself and in combination with other materials. Currently, researchers at the University of Maine are conducting a study funded by the New England Transportation Consortium that will address compressibility, weight-bearing capacity, and the use of tire chips behind retaining walls.[167] Compaction and compressibility of tire chips are also being investigated by researchers at the University of Wisconsin, where a test embankment has been constructed as part of a landfill access road. The embankment has sections in which tire chips are used alone, mixed with onsite soil, or layered with soil.[168]

Environmental Concerns

Another question that must be resolved before tire chips are used in some construction applications is whether they will leach harmful substances. This was the focus of a recent study for the Minnesota Pollution Control Agency,[169] and is a component of the University of Wisconsin study, cited above. The Minnesota study indicated potential problems with barium, cadmium, chromium, lead, selenium, and zinc under sufficiently acidic laboratory conditions, and with polyaromatic hydrocarbons under basic conditions. The study recommended that "the use of waste tires be limited to the unsaturated zone in a roadway designed to limit infiltration of water through the waste tire subgrade."[170] The Wisconsin study concluded that shredded tires pose little or no likelihood of affecting groundwater.[171] Both reports cited the need for additional field studies.

Recent Projects

A limited number of projects using tire chips in roadway projects are being tried in New England. In Georgia, Vermont, the town is experimenting with the use of tire chips to provide better drainage on a dirt road that becomes impassably muddy in the spring.[172] For this project, the top two feet of a 400 foot length of road were excavated. Two hundred cubic yards of chips were then placed in the roadway at a depth of one foot. The dirt and gravel were then replaced, and the chips compressed to a depth of about three inches. The outcome of this experiment will not be known until the spring. Another project in Vermont is using tire chips to flatten and widen a roadside slope, creating a shoulder and eliminating the need for a guardrail.[173] The chips represent 60% by volume of the total fill material needed for the job.

Tire-Consuming Potential

Most of the proposed applications for tire chips in road construction projects would involve using the chips in place of or to extend other fill material. State transportation agencies typically classify fill in several different grades, and these classifications may vary by state. To obtain a rough estimate of the volume of tire chips that might be used as fill replacement, state transportation officials provided estimates of the amount of low-grade fill or common borrow currently used in a year. These estimates are as follows:

State	Volume of Fill
Connecticut[174]	250,000 cubic yards (CY)
Maine[175]	250,000 to 300,000 CY
Massachusetts	no estimate available
New Hampshire[176]	300,000 CY
New Jersey[177]	220,000 CY
Rhode Island[178]	300,000 to 375,000 CY
Vermont[179]	250,000 CY

These figures are easily converted to numbers of tires using the rule of thumb of 40 whole passenger car tires to one cubic yard of tire chips. The following table converts the above figures to whole tires, and calculates the number of tires that could be used if 10% of the fill volume is replaced with tire chips:

State	Whole Tire Equivalents (millions)	Potential Annual Consumption at 10% Replacement
Connecticut	10	1,000,000
Maine	10 to 12	1,000,000 to 1,200,000
Massachusetts	?	?
New Hampshire	12	1,200,000
New Jersey	8.8	880,000
Rhode Island	12 to 15	1,200,000 to 1,500,000
Vermont	10	1,000,000

Tire chips are not the only material being considered as a replacement for fill. State transportation agencies are also investigating opportunities for construction projects to consume demolition debris, glass, plastics, synthetic aggregates made from sewage sludge, and vitrified toxics. Both the physical properties and the costs of using these materials will be instrumental in determining which, if any, will be used.

In New Jersey, the Department of Transportation's Recycled Materials Task Force is actively seeking materials that could replace some percentage of the borrow currently purchased. They have set an informal first goal at 10%, which may be increased. Glass, because it is so similar to the sand already used, is the material the NJ DOT is likely to approve first.[180]

Cost Factors

The materials with which tire chips typically will be competing for roadway applications are common borrow, sand, and gravel. The prices paid for these materials vary substantially across the region. In Rhode Island, for example, the common borrow used in roadway reconstructions ranges from $2 to $10 per cubic yard, and averages about $8 per cubic yard.[181] In Maine, the price of common borrow is in the range of $2 to $3 per cubic yard.[182] Lightweight borrow may cost several times this.[183] The New Jersey DOT is currently paying about $13 per cubic yard for borrow/fill.[184] Some of this variability may be due to the proximity of construction sites to the source of the material, and the cost of transportation.

The prices of other competing materials also vary. In Vermont, crushed stone is only about $3 per cubic yard,[185] but may cost considerably more in southern New England. In New Jersey, the crushed glass that is used to replace aggregate in bituminous concrete applications costs about $4.80 per cubic yard.[186] Glass to be used as fill will not need to be crushed as finely, and may therefore be cheaper.

In general, where tire chips can be used to replace conventional construction materials, the prices of the conventional materials will serve as a ceiling for the price of the tire chips.

Consumers of Intermediate Products: Play Surfaces

Tire rubber's resiliency and low compactibility properties have led to uses in athletic and play surfaces. Crumb rubber can be used as a soil amendment for grass turf or as a "soft bulk" surface for playgrounds, jogging trails, and horse arenas. As a soil conditioner for athletic fields, the material offers the opportunity to reduce watering and aeration; the technique is promoted primarily as a means of softening the turf and saving on maintenance costs, and its expense would have to be justified on those grounds. As a soft bulk surface, crumb rubber competes with a variety of other materials that vary with respect to physical advantages and disadvantages, as well as cost.

Soil Conditioning

A Colorado company is currently promoting the idea of rehabilitating football fields by adding crumb rubber to the top layer of the soil to produce a less dense turf.[187] This patent-pending process involves the removal of the top six inches of soil and combining it with metal-free 1/4" crumb rubber. Yard wastes and sewage sludge can also be incorporated in the procedure. The rubber typically accounts for about 15% of the total volume of the soil mixture. The soil is then replaced on the field, with new sod or seeding on top. As of 1987, the Environmental Protection Agency, Region VIII did not oppose the use of crumb rubber as a soil amendment based on its chemical characteristics.[188]

The advantages claimed for the process are better survival of the grass, fewer bald spots, less water needed (30-80%), lower maintenance costs, less compaction of the turf, and fewer or less severe injuries due to the softer surface. The most beneficial applications are likely to be where the turf is most heavily trafficked. The rubber additive seems to help worn turf recuperate itself, without the need to reseed. Savings on maintenance may include the costs of aerating the soil, fertilizing, reseeding, and special care during the germination of the grass seedlings.

In 1988, Colorado State University used this system to rehabilitate a football practice field. The project consumed 120,000 pounds of crumb rubber, the equivalent of 10-12,000 tires at 10-15 pounds of crumb per tire. The cost of the crumb, not including transportation, was $.10 per pound, or $12,000. This represents one-sixth of the total installation cost of about $72,000. The CSU installation is expected to last at least 25 years.[189] Artificial turf, by comparison, costs about $1 million to replace every 8 years, and the best natural turf may cost up to $80,000 per year to maintain.[190]

A study is currently underway at Michigan State University to evaluate the effectiveness of crumb rubber as a soil amendment. The preliminary findings of controlled experiments on a football practice field and on heavily trafficked plots of a golf course indicate better survivability of the grass and a softer surface.[191] Data are also being collected on the severity of football injuries on the experimental versus control turf, but are too preliminary to evaluate yet.

Data are not available on maintenance cost savings resulting from either the Colorado or Michigan projects. However, some simple present value calculations can be performed to show that if the soil treatment results in maintenance savings of 20% per year for 25 years, the project will result in positive discounted net benefits.[192] Any savings due to reduced water consumption are likely to be more substantial in the western (drier) parts of the country than in the northeast.

One factor that may increase the attractiveness of using crumb rubber as a soil amendment would be the development of standards by the American Society for Testing and Materials for athletic field construction and measuring field hardness. The ASTM is currently working on developing such standards, but they probably will not be completed before 1994.[193] While organizations responsible for athletic fields, such as universities or public school systems, would not be required to follow ASTM guidelines, the existence of such guidelines may affect the outcomes of injury lawsuits, and thus the requirements of companies that insure such organizations. Given the lack of alternatives for creating softer turf, the use of crumb rubber may become the best means of meeting the standards.

Tire Consuming Potential

In order to consume 1 million scrap tires per year, 100 fields consuming 10,000 tires each (or other projects of the same size) would have to be rehabilitated with the crumb rubber soil amendment per year. Note that once treated, we assume that a field would not be in the position to consume tire rubber again for at least 25 years. Thus, the idea would be somewhat of a victim of its own success.

According to estimates in a market study for the Colorado company promoting the technique, professional and semi-professional teams and NCAA and NAIA schools manage about 2,800 football fields nationwide. An additional 2,800 soccer fields are managed by NCAA or NAIA schools. These numbers increase about 24-fold if parks, high schools, and junior colleges are included.[194] Further study would be required to determine a reasonable number of fields in the NEWMOA states for which the investment would be feasible. The company has indicated that the opportunity to perform a demonstration project in the New England area would be an important step in convincing regional groundskeepers and athletic directors to try the system.[195]

Playground Surfaces

In 1981, the Consumer Products Safety Commission developed guidelines for impact attenuation for public playground playing surfaces. These guidelines recommend that the residual (unabsorbed) impact of a child falling from playground equipment be no more than 200 g's.[196] While not regulations, the guidelines have been used in a New Jersey court as the standard for playground safety.[197]

Several types of material, including rubber mats and a variety of soft bulk surfaces, can be used to provide a cushioned surface beneath playground equipment. Rubber matting is relatively expensive, at approximately $12 to $14 per square foot, and it does not meet the guideline for impact attenuation for falls from heights above about 5 or 7 feet. Soft bulk surfaces, when laid at a depth of 6 to 12 inches, can often meet the guideline for falls from a height of 10 feet.[198]

The most commonly used soft bulk surfaces materials are pea gravel, sand, wood chips, and wood fibers. Granulated rubber made from scrap tires can also serve as a soft bulk surface. One company that sells 1/2" granules for this purpose receives about $.10 per pound for the product. This is the equivalent of about $1.40 per square foot, 6 inches deep.[199] This is more expensive than pea gravel and sand, but less than wood fibers.[200]

Among the advantages of rubber granules as compared to some of the other materials are that they provide good impact attenuation, they retain this property in wet and freezing weather, they are subject to less frequent need of replacement, they are too light to cause harm if thrown, and they do not attract animals to the play area. Among their disadvantages are that the surface tends to be dirty, hot, and smell of rubber. In addition, there is concern that the granules are highly flammable. They have been banned from playground use in Australia for this reason.[201]

Tire-Consuming Potential

Given the need for 14 pounds of 1/2" granules for each square foot of playground surface, a 50' x 50' play area would require 35,000 pounds of crumb rubber. At 10 to 15 pounds of crumb per tire, this is the equivalent of about 2,300 to 3,500 tires. Assuming that the rubber granules would need to be replaced every 3 years, about 1,000 play areas of this size would need to use rubber granules as a soft bulk surface in order to consume 1 million tires per year. More research would be needed to determine a reasonable number of play equipment areas that might use crumb rubber as a ground cushion.

IV. FACTORS AFFECTING SCRAP TIRE CONSUMPTION

To say that the consumption of scrap tires in the NEWMOA states will increase over the coming years appears to be a reasonable statement. In addition to the large projects discussed earlier, it seems plausible that some new uses for tire chips and crumb rubber will develop and expand, although it is difficult to predict precisely what these will be. From the solid waste perspective, the relevant questions are how fast scrap tire consumption will increase, whether consumption will eventually be sufficient to accommodate all the scrap tires being generated (as well as eliminate those in stockpiles), and how soon this might all occur.

Given that there are already several ways in which scrap tires can be consumed, it is important to discover what factors are limiting the expansion of these activities. Also of interest are the factors that may be inhibiting new uses of scrap tires. This section will summarize the findings on these points, including the following:

- low-cost alternatives for scrap tire disposal;
- competition with existing products;
- attitudes toward new products and methods;
- minimum efficient scale of production or consumption;
- capital outlays;
- transportation costs;
- lack of standards and specifications;
- lack of coordination in research;
- environmental concerns; and
- limited size of some markets.

Low-Cost Alternatives for Scrap Tire Disposal

Tipping fees can represent a significant source of revenue for some tire-consuming businesses. Low-cost alternatives for scrap tire disposal exert downward pressure on tipping fees and will thus tend to hurt these businesses. Whether these alternatives are landfills that charge low tipping fees or unregulated tire stockpiles, the effect will be the same on the tire processor who must offer a competitive tipping fee. If tipping fees at disposal sites rise, recyclers can also raise their tipping fees and increase their revenues.

This analysis probably represents the majority opinion, but not everyone knowledgeable about tire recycling opportunities would agree that increasing tipping fees is the answer to increasing tire recycling. Some would argue that a business should not rely heavily on tipping fees because the fees represent an unreliable source of revenue that can be undercut at any time. This argument raises two interesting points. If any undercutting that takes place is the result of inexpensive disposal opportunities, the importance of low-cost disposal as a deterrent to recycling is highlighted. To the extent that the undercutting is due to another business finding a more profitable use for the tires, and thus offering lower tipping fees to a tire hauler, the undercutting represents evolution in the consumption of scrap tires to more highly valued uses. Uncertainty about future tipping fees illustrates the current state of flux in the market for scrap tires.

Competition with Existing Products

Most of the ways in which scrap tires can be consumed do not represent provision of completely new goods or services. Whether tires are burned for energy, incorporated into paving materials, used as a feedstock to produce molded products, or turned into septic leach fields, they are doing something that other materials already do. Therefore, they must compete with the more familiar means accomplishing the same basic ends.

This competition can take several forms. One of the most obvious is price. If the tire-derived product performs the same function as another material, it must do so more cheaply in order to be adopted. Good examples of this are retreaded tires or tire-derived fuel. If the performance of the tire-derived product differs somewhat from the performance of the conventional material, the consumer must decide whether any improvement in performance is worth the additional price, whether any decrease in performance is worth the savings, or how a different mix of attributes of the tire-derived product compares to the bundle of attributes of the conventional material. Potential consumers of retreaded tires, rubberized asphalt, or crumb rubber playground surfaces face these questions.

Existing markets may also present barriers to entry to new businesses trying to establish tire-derived products. In the industrial fuels market, for example, companies that have the kinds of boilers that could burn TDF will typically have well-established relationships with the suppliers of more traditional fuels. TDF suppliers may find potential customers unwilling to deal with them directly, for several reasons. These customers may have long-term contracts with other suppliers, they may fear potential unreliability of supply, or they may find that the transaction costs of dealing with a new supplier or suppliers outweigh the benefits of purchasing the product. As discussed above, the possibility of regional energy marketers including TDF in their offerings may be a critical step in overcoming these types of barriers.

Attitudes Toward New Products and Methods

Another factor affecting a new product trying to compete with existing products is the uncertainty associated with the new item's characteristics. A major reason for the slow pace of adoption of crumb rubber additives to asphalt appears to be the uncertainty on the part of transportation engineers as to how the pavements will behave under various conditions. This uncertainty can translate into risk for the person authorizing use of the new material. Even if the benefits of a new product or process look substantial, people are reluctant to choose something that might work better when they can continue to use something they know works well. Standard operating procedures in both private industry and the public sector may slow the adoption of tire-derived materials in new uses.

Minimum Efficient Scale

For many products, the cost of production will depend on the quantity produced, and efficiencies of scale may be realized only at relatively high levels of output. Thus, the need for a plant producing aggregate mix for road pavements to switch processes when producing mixes with or without rubber adds to the cost of the product; a plant dedicated to producing only the rubber-containing mixes might be able to do so more cheaply. When production costs are high for small quantities, it is also difficult for a firm to "ease into" a new activity gradually. Sometimes a plant must be built at the minimum efficient scale, or not at all. As the minimum required size of a facility increases, the amount of capital needed also increases. For example, TireCycle of New England is trying to establish a plant that will consume 3 million tires per year; one of the challenges facing the company is raising the $10 million needed to get a business of this size started.

Related to the scale of production, is the scale of consumption. A new producer of an intermediate product, such as TireCycle or crumb rubber, must be assured of sufficient demand for the output of a large facility. For a crumb rubber plant to locate in the northeast, it might want to see significant local use of crumb rubber additives to asphalt concrete, for example. It is possible that such uses have been low because of local unavailability of the material or the high cost of transporting it from distant producers. If so, it may be difficult for the producer to estimate the demand for the product at the price that could be offered when the product is locally supplied.

Conversely, some potential consumers, such as manufacturers of plastics or molded rubber products, may find it worthwhile to buy the feedstock only if it can be assured of large quantities on a reliable basis. As mentioned in the earlier discussion of TireCycle of New England, the quantities demanded by some potential consumers might exceed the output of a single plant. A similar situation might exist for TDF, in which it would take two or more suppliers to produce enough fuel to interest a paper mill or other industrial consumer.

Capital Outlays

Many uses for tires require new capital stock. Whether the investment is a $100 million incineration facility, a relatively minor alteration to a fuel feed system, or new equipment to spray asphalt-rubber binder, businesses need to raise capital to undertake the project. If the cash is unavailable internally, it will have to be borrowed. In general, raising capital for innovative investments is more difficult than for proven enterprises. This is because new companies and new technology are associated with greater risk. The viability of new business proposals may be difficult to evaluate when there are few similar businesses upon which to base comparisons. When lenders and investors are willing to supply the needed capital, they must be compensated for the higher risks of default by higher interest rates on loans and bonds.

Transportation Costs

The cost of transportation is an important consideration in trying to determine the appropriate geographic scale from which to view the size of potential markets for tire-derived products. Transportation costs can figure significantly in at least two stages: getting scrap tires to the processor, and delivering the finished product to the end user. If intermediate processing stages are involved, additional transportation costs may be incurred. Since transportation costs increase with distance, total costs of tire-consuming activities will depend on the proximity of the processors both to their sources of tires and to their customers.

The use of tire chips as fill in a Vermont road rehabilitation project provides a good example of the effect of transportation costs can have on the economics of a tire-consuming activity.[202] The State paid about $1.50 per cubic yard of tire shreds, of which only about 45 to 50 cents was received by the company that did the shredding; the remainder was spent on transporting the shreds to the construction site. The parties considered setting up a portable shredder onsite instead of shipping the finished product, but a lack of scrap tires near the site meant that whole tires would also have to be brought in, more than offsetting any savings this approach would have provided. (Ultimately, however, the tire shreds cost less than the crushed stone the project would otherwise have used.)

If transportation costs are significant, they may tend to offset the economies of scale achieved by very large tire processing facilities. The larger the facility, the wider the geographic area necessary for it to obtain a steady supply of tires. However, the greater the distance the tires have to be transported, the more expensive they will be. Those in the tire hauling and recycling businesses in the region often say that it is not profitable to ship tires more than 150 to 200 miles. Of course, this will depend on how important transportation costs are to total costs, and how close to the margin these firms are operating; the more profitable the overall business, the less important tire transportation costs will be. The evidence that some chipped tires from eastern Massachusetts are finding their way to Pennsylvania to be processed into crumb, or from northern New England to exporters in Newark, suggests that transportation over 200 miles may be worthwhile in some circumstances. One regional estimate for whole tire transportation costs is approximately 0.45 cents per tire per 100 miles.[203] Chipped tires are substantially less expensive to truck because they are less bulky.

Lack of Standards and Specifications

The use of tire-derived products is sometimes hampered by a lack of product standards. In some cases, the existence of standards can be a prerequisite for using the product. An example of this would be the need to rate the "effective area" of tire galleys for septic fields, so that contractors could install the systems in compliance with health regulations. In other cases, standards are not required, but might highlight the advantages of a tire-derived product. For example, the development of standards for athletic field hardness may greatly encourage the use of crumb rubber as a soil amendment.

In general, the lack of product standards contributes to uncertainty about product characteristics and variability. Lack of standards and specifications can hamper communication between suppliers and consumers, and make it difficult to measure product quality. Insufficient knowledge about the engineering properties of tire-derived products means that individual consumers must conduct their own tests. Testing can be expensive or beyond the technical capability of some potential users. If an organization such as the American Society of Testing and Materials were to publish standards or specifications for TDF and tire chips or crumb rubber of various sizes, more companies or state agencies may be encouraged to discover ways they can use these products.

In the public sector, where procurement can be highly institutionalized, potential users sometimes need authorization to use certain materials. In addition to understanding the engineering properties of materials such as tire chips, for example, those in charge of roadway maintenance may need to have the material listed along with other approved materials from which to choose. They may also need established contracts with suppliers of the material.

While specifications for car and truck tires exist, the inability of retreaded tires to meet federal specifications for passenger car tires appears to be a serious obstacle to state procurement. Managers of state automobile fleets are usually constrained by purchase contracts that determine from whom they may buy replacement tires or retreading services. Lack of contracts with suppliers can limit their procurement options.

The lack of standards may also pose liability questions that discourage the use of tire-derived products. One paving contractor interviewed said that if a pavement using a crumb rubber additive failed, the contractor would be protected from liability if it could say it had followed the federal or state department of transportation's specifications for materials and procedures. When no such specifications exist, contractors are hesitant to bid for risky projects that might expose them to financial liability.[204]

When no appropriate national standards exist for a particular product, states may develop their own. Thus, New Jersey is planning to develop its own standards for procurement of retreaded passenger car tires if the federal government, due to its strict standards for long wear, does not approve any. For some products, such as construction materials and home septic systems, states are accustomed to devising their own specifications. In addition to some duplication of effort on the part of the states, individual state standards can sometimes make it difficult for manufacturers to provide a uniform product that meets everyone's specifications. Opportunities may exist for cooperative state efforts in devising standards for some tire-derived products.

Lack of Coordination in Research

Highway construction and maintenance activities represent some of the most promising scrap tire applications, in terms of volume of tires consumed. They also represent areas where additional research is needed before those responsible for roads can be expected to make more widespread use of tire-derived products. While substantial research into crumb rubber additives has already taken place, much of the information gathered is not easily accessible. The Federal Highway Administration (U.S. DOT) serves as a clearinghouse for information on research projects that received federal funds, but it has limited data on projects that did not use federal funds, since state, county, or municipal projects are not required to submit results of their tests to the FHWA.[205] Furthermore, those responsible for these projects may not have documented their experiments in a way that would be useful to others. Given the complexity of this research, and the specificity of the results to various climatic and topographic variables, there would appear to be an advantage to coordinating any further research at the regional level.

Environmental Concerns

The full effects of some tire-consuming activities on the environment have not been clearly established. One area of concern is the composition of leachate resulting from tires in underground applications, such as subgrade road beds. Based on the very few studies on this subject, it appears that tires should not be used in highly acidic or highly basic environments where the leachate could enter groundwater. However, there is no consensus yet as to appropriate precautions that might be necessary for less extreme conditions.

Concerns have also been expressed about fumes given off by asphalt concrete containing crumb rubber additives. Worker safety would be of primary interest here. No studies on this subject were uncovered in the course of this research.

Burning tires as fuel can have environmental impacts in the form of air emissions and the disposal of ash. When TDF is used to replace coal at existing industrial facilities, the net environmental impacts could be assessed by comparing operation with the TDF to operation of the same facility with its traditional mix of fuels. In the case of newly built tires-to-energy plants, the plant's emissions may represent a net increase in pollutants in the vicinity or downwind of the site. However, to the extent that the increase in generating capacity represents a decrease in energy generated elsewhere, overall emissions within a larger geographic area may or may not be affected. Thus, it is the distributional concerns associated with siting a tires-to-energy facility that are more likely to present a problem.

While the environmental impacts of tires-to-energy facilities are important to establish in weighing the desirability of such plants, a full analysis was beyond the scope of this paper. It is assumed here that the state permitting process will adequately protect the health and welfare of residents downwind of a plant. If this is not the case, incineration for energy may represent an intermedia transfer of the scrap tire problem, rather than a solution to it.

Finally, it should be noted that not all consumptive uses of scrap tires represent an equal reduction in the volume of tire waste. For example, the manufacture of crumb rubber yields only about 10 to 12 pounds of usable product from a 20 pound tire. While some of the byproducts, such as the rims and beadwire, may also be recoverable, much of the tire may still need to be disposed of in a landfill. If applications can be found for tire chips from which the wire and fabric need not be removed, such as construction fill, a much smaller percentage of the original tire will be left as byproduct.

Limited Size of Some Markets

While scrap tires *do* make good backyard swings, those charged with finding alternatives to scrap tire disposal quickly recognize that the market is limited. Unfortunately, several other scrap tire uses are similarly limited. For example, the manufacture of fishing reefs from whole tires is not likely to consume a significant number of tires on a sustainable basis. Nor will specialized gear for scalloping vessels, crumb rubber tracks for horse-training arenas, or rubber railroad grade crossings find large markets. This is not to say these uses are unprofitable or unwelcome, but simply that they are not likely to have a significant impact on scrap tire consumption, even if the potential markets are fully exploited.

V. POLICY OPTIONS FOR DECREASING SCRAP TIRE DISPOSAL

The focus of this section will be to explore the implications of various policy options designed to decrease the rate of scrap tire disposal. Given our initial framework of a stock of scrap tires to which new additions are made every year and from which a certain number of tires are consumed, it is clear that the rate of scrap tire disposal could be reduced in two ways: a lowered rate of scrap tire generation, or an increase in scrap tire consumption. The first policy option discussed below is to do nothing. Most of the remaining proposals address the factors identified in the previous section that tend to work against increased consumption, and would thus affect scrap tire disposal by increasing consumption. They include:

- regulating tire disposal and hauling;
- promoting coordinated research;
- developing standards and specifications;
- public sector consumption;
- demonstration projects;
- subsidizing tire consumption;
- assisting companies with capital costs; and
- raising revenue to fund these activities.

The proposals considered here are those that could be implemented at the state or regional level. Additional options may be available at the national level. One such option was proposed in Congress this year by Representative Esteban Torres of California. The Torres bill will also be described.

This discussion is not intended to be a full policy analysis. A more complete analysis would include more background on the history of tire recycling, the dynamics of unregulated dumping, and the market for waste disposal services in general. In addition, the full social costs of tire disposal would have to be addressed.

The No-Further-Action Alternative

Each of the NEWMOA states has already addressed its scrap tire problem through some combination of regulations, guidelines, procurement, or economic development activity. Recent events in the private sector have suggested that the consumption of scrap tires will increase over the next several years even if the states take no further actions. As discussed in the section "Expected and Potential Near Future Changes in Scrap Tire Consumption," above, some of the anticipated uses are very significant in terms of the number of scrap tires to be consumed as a percentage of the annual generation rate.

Tables 1, 2 and 3 are reproduced on the next page to allow comparison of potential tire consumption to current scrap tire

Table 1

CURRENT GENERATION AND STOCK

	Annual Generation	Stockpiles
Connecticut	3,500,000	15,000,000
Maine	1,200,000	50,000,000
Massachusetts	6,000,000	30,000,000
New Hampshire	1,000,000	1,500,000
Rhode Island	1,000,000	40,000,000
Vermont	500,000	10,000,000
New Jersey	9,700,000	8,000,000
TOTAL	22,900,000	~ 155,000,000

Table 2

CURRENT CONSUMPTION AND DISPOSAL

Destination	Tires per Year
Retread	3,000,000
Export	2,400,000
Manufactured Products	1,800,000
Experimental Uses	300,000
Subtotal	7,500,000
Disposal	15,400,000
Annual Generation	22,900,000

Table 3

ADDITIONAL FUTURE ANNUAL TIRE CONSUMPTION

MOST PROMISING LARGE CONSUMERS		STARTING DATE
Exeter Energy	8,000,000	1991
Champion	3,000,000	Fall 1990
Another Paper Mill	3,000,000	1992
SUBTOTAL	14,000,000	
POTENTIAL LARGE CONSUMERS		
TireCycle	3,000,000	?
Dragon Cement	3,750,000	1994 (?)
State Road Projects (use of chips as substitute for 10% of clean fill)	5,400,000	?
SUBTOTAL	12,150,000	
TOTAL	26,150,000	

generation. The figures on the top half of Table 3 suggest that the most promising large consumers could together consume over half the current annual generation rate, or 14 million out of 23 million (from Table 1), and close to the number of tires currently being disposed of in the seven NEWMOA states (15.4 million, from Table 2). The only state actions required to achieve this annual rate of consumption are permitting and monitoring of the industrial facilities.

At this point, it should be noted that the scrap tire generation rate may also rise. Factors that would contribute to this rise are increases in population and in the number of miles driven. The following table shows how many scrap tires would be generated per year at selected dates in the future if the current generation rate were to grow by 2 percent or 4 percent per year. (These growth rates were selected primarily for illustrative purposes and are with not based on specific projections of the growth in scrap tire generation; however, they are consistent with national estimates of scrap tire generation for 1984 through 1987.[206])

Table 5

SCRAP TIRE GENERATION RATES (Millions/Yr)
WITH EXPONENTIAL GROWTH

Year	2% Growth/Yr	4% Growth/Yr
1989	22.9	22.9
1994	25.3	27.9
2000	28.5	35.3
2010	34.7	52.2

These figures are important, because any increases in scrap tire consumption will not happen instantaneously, but over a period of time. Even if consumptive uses grow enough to account for the *current* annual generation, by the time that rate of consumption is achieved, the annual generation rate will probably be higher.

If in addition to the 7.5 million tires currently consumed, all the consumption listed on Table 3 except the road construction projects were realized, a total of about 28 million tires per year would be consumed by the private sector.[207] This would not happen until several years from now at the earliest, but even with the scrap tire generation rate growing in the interim, this level of consumption might be close to the annual generation rate in the mid-1990s. It is emphasized, however, that considerable uncertainty is associated with all but the first one or two projects listed on Table 3.

In order for progress to be made in reducing the existing stockpiles listed on Table 1, scrap tire consumption must proceed at a higher rate than scrap tire generation. Thus, additional consumptive uses would have to be found. In order to eliminate the estimated 155 million tires stockpiled in the region over a period of 10 years, the annual consumption rate would have to exceed the annual generation rate by 15 to 16 million tires per year. To eliminate the tire piles in 20 years, the excess rate of consumption would have to be about 8 million tires per year.

It is difficult to predict whether the economics of tire consumption will be sufficiently attractive to achieve these rates through normal operations of the market. Entrepreneurs can be expected to invest in the most profitable activities first, which currently appear to be those associated with the use of tires as fuel. The conversion of scrap tires into feedstocks for other manufacturing processes, such as rubber-plastic polymers, may represent other highly-valued uses. Additional technological advances may improve the outlook for some processes, such as pyrolysis, or create new investment opportunities of which we are as yet unaware. Small-volume specialty applications may also prove to be profitable forms of tire consumption. As these opportunities are exhausted, however, only less profitable investments will remain, and these may not be sufficiently attractive to lead to the consumption of the remaining number of scrap tires generated.

The public sector's opportunities for increasing scrap tire consumption include direct use of tire-derived materials or taking actions that make investments in tire-consuming activities more attractive to the private sector. While both these approaches will be discussed in greater detail in the policy options that follow, one of the potentially large forms of public consumption is included on Table 3 for comparison purposes. The use of tire chips as a substitute for 10 percent of the clean fill used in state road construction projects could consume over 5 million tires per year. When added to the private sector uses that might develop over the next few years, public sector consumption could play a significant role in ensuring that the annual generation of scrap tires is consumed, or in starting to reduce existing tire stockpiles.

Regulating Tire Disposal and Hauling

Regulating the disposal of scrap tires to safeguard public health and safety could include such means as requiring that fire prevention and vector control measures be taken, limiting the dimensions of tire piles, requiring financial sureties from stockpile operators, or prescribing how tires are to be landfilled (e.g., only sliced or shredded). Compliance with the regulations will usually have the effect of increasing the costs of landfilling and stockpiling. If these costs are passed on in the form of higher tipping fees to those using the facilities, tire haulers will have an increased incentive to find lower-cost means of disposal. Non-disposal consumers of scrap tires would thus be able to charge a higher fee for taking the tires from the haulers. This can increase the profitability of existing tire consumers, and might encourage them to expand. Higher tipping fees may encourage the development of new businesses that consume scrap tires. Public consumption of tires would also look more attractive, as the effective cost of using scrap tires in public works would decline.

Since higher tipping fees increase the incentive to find lower-cost disposal, they will also increase the incentive for illegal disposal. To the extent that the higher tipping fees are passed along to tire dealers and car owners, these individuals will also face increased incentives for illegal disposal. Enforcement against illegal dumpers would have to tighten in order for the positive effect of the higher disposal fees to reach the scrap tire consumers.

Enforcement: Tracking Systems, Licensing and Deposits

One way to make illegal disposal more difficult would be to develop a tracking system that records the movement of all tires from the point of first discard, such as at a tire dealer, to the point of final consumption or disposal, such as a manufacturing operation or landfill. An important component of any tracking system would be to license all tire haulers and require that they keep records of the volume of material they handle. The licensing of tire processors may also be necessary

Some individuals in the tire business interviewed for this study felt that a tracking system would be very cumbersome and unworkable. One potential problem is that scrap tires often move across state boundaries, and that neighboring states would have to have compatible reporting requirements. But others in the industry welcomed the idea, saying that it would benefit legitimate businesses. Since many businesses already keep records like this, a tracking system would not necessarily represent a great deal of additional paperwork. Development of a tracking system would probably best be accomplished with input from tire dealers, tire haulers, and others in the tire disposal and recycling industry.

If a state has reason to believe that illegal dumping by individual consumers is an important contribution to the scrap tire problem, it may want to provide car owners with incentives to return their used tires to appropriate locations, such as tire dealers. One way to do this would be to impose a deposit scheme on the sale of new replacement tires, much like that on beverage containers. Since deposit schemes rely on voluntary compliance, the deposit would have to be set high enough to provide consumers with sufficient incentive to return the tire to an appropriate facility. However, a deposit at that level, perhaps $5 or $10 per tire, might be high enough to discourage the purchase of replacement tires in the state. Residents of one state may find it worthwhile to buy their replacement tires across the state line to avoid the deposit. Thus, regional coordination may be necessary for such a scheme to work.

Promoting Coordinated Research

Despite over 20 years of experimentation with crumb rubber additives to asphalt concrete, little consensus has emerged as to the applicability of the technologies in northern climates. It may be that sufficient data have been collected to develop guidelines for use of the materials under various conditions; if so, there is a need for some synthesis and evaluation of the data currently available. Economic analyses could then be performed that take into account not only the initial costs of the pavements, but also their durability, performance, and maintenance requirements. If the data are still insufficient to do this, additional field research would be necessary. The NEWMOA states could try to coordinate any further research such that the results would be useful in addressing concerns common to the region.

Research on the use of tire chips in construction projects is just beginning. The interest of the New England Transportation Consortium in this area was instrumental in funding the research project currently underway at the University of Maine. The Consortium was formed in 1984 by member states Maine, New Hampshire, Vermont, Rhode Island and Massachusetts. Based at the Center for Transportation Studies at the Massachusetts Institute of Technology, the Consortium selects and funds transportation-related research projects to be carried out by state universities in conjunction with the state departments of transportation. Given the large potential for roadway construction projects to consume tire-derived products in various ways, additional research in this area appears desirable. The NEWMOA states could explore the potential for pooling resources and coordinating further work through the NETC on additional transportation-related projects.

Developing Standards and Specifications

A number of uses for tire-derived products would be aided by the development of product standards or specifications. Some of these standards may be most appropriately developed at the national level, through such organizations as the American Society for Testing and Materials or branches of the federal government. Where these standards are inadequate or slow in forthcoming, states may want to consider developing their own. New Jersey's consideration of developing its own standards for retreaded passenger car tires is one example. For other products, such as home septic systems or some construction materials, specifications are traditionally written at the state level. In these cases, states may help each other speed the development of specifications by sharing information they have gained about new tire-derived products.

Public Sector Consumption (Procurement)

Some of the largest potential tire-consuming activities that may prove to be economically feasible are activities that are typically financed by the public sector. Foremost among these are road construction and maintenance projects. The Departments of Transportation in some of the NEWMOA states have already begun to explore the feasibility of using tire-derived materials, as well as other forms of solid waste, in these projects. While public officials responsible for solid waste will naturally want to encourage further research and experimentation, they should understand the technical and financial constraints facing transportation officials that may hamper progress in this area. Mandating the use of tire-derived materials before the engineering or budgeting implications are sufficiently understood may only serve to antagonize the people whose cooperation is most necessary.

The purchase of retreaded tires for publicly owned vehicles is another area where the public sector can directly affect scrap tire consumption. While the use of retreading services for truck tires is a common practice, the purchase of retreaded passenger car tires is not. If specifications for these tires can be developed, and supply contracts established, increased retread purchases may help expand the market for retreaded tires. More research is needed to determine the number of tires potentially involved and whether this number is significant in light of the magnitude of the scrap tire problem. More research may also help determine whether the public sector's example of using retreads would encourage more private consumers to buy them.

One way of encouraging the use of tire-derived products in the public sector would be to allow price preferences for them. Some states already have price preferences for products made from recycled materials, which could be extended to include tire-derived products. In Massachusetts, for example, products made with recovered materials may be given a price preference of up to 10%. The Massachusetts Department of Environmental Protection is currently working with the Department of Public Works to determine whether to recommend that the Massachusetts Purchasing Agent consider asphalt-rubber a recovered material.[208]

If price competition is the major reason for low levels of use of tire-derived products, a price preference may result in greater use of the tire products. If the reason for not using tires is related not to price but to some other factor, such as uncertainty about engineering properties, the price preference is less likely to affect consumption of the tire-derived product.

Demonstration Projects

As a means of exchanging information about new technologies or products, demonstration projects can help educate potential consumers and lessen the uncertainty associated with new products. Some of the past paving projects using crumb rubber additives may be regarded as demonstration projects. Demonstration projects for other applications may be helpful, such as the use of crumb rubber as a soil conditioner on heavily trafficked public lawns or athletic fields. If these projects are successful, they may encourage use of the product in either public or private settings.

Subsidizing Tire Consumption

One way to increase the attractiveness of tire-consuming activities would be to offer a rebate for every tire, or portion thereof, consumed. The rebate could be offered either to the processors or end-users of tire-derived products. If the consumer is the party that receives the rebate, the effect of the policy is to lower the cost of using the product. Tire processors may be able to capture some of this savings by raising the price of their products. If the processor receives the rebate, the effect on the business will be much the same as a rise in the tipping fee; the subsidy will represent income from the acceptance of tires rather than from the sale of the finished product. Since processors may pass some of the benefit of the subsidy along to consumers in the form of lower prices, the net effect on price and quantity of material exchanged is likely to be about the same whether the rebate is paid to the processor or the consumer.

While a subsidy would have a similar effect on tire-consuming businesses as an equivalent increase in tipping fees, such as might come about through tightened regulation of tire disposal, two differences might be important. First, unlike tipping fees that may fluctuate with changes in market conditions, subsidies offer the potential of a more stable source of revenue. If the subsidy is perceived as reliable in the business community, it may reduce the risk associated with a new tire-consuming enterprise, and enhance an entrepreneur's chances of securing financing from lending institutions. Second, to the extent that unregulated dumping is encouraged by high tipping fees, a subsidy may promote recycling without this undesirable side-effect.

Two states that currently have subsidy programs are Oregon and Oklahoma. Oregon's program, begun in November 1988, offers a one-cent per pound ($20 per ton or about $.20 per tire) reimbursement to users of products derived from Oregon's waste tires. The program is funded by a $1 per tire tax levied on the sale of new replacement tires.[209] While there was little activity during the first year of the program, by March 1990, the state paid out $273,000 in reimbursements[210], which accounts for over 1.3 million tires.

According to the Oregon Department of Environmental Quality, about 97 percent of the subsidies were paid to businesses using the tires for energy recovery, and 3 percent for non-energy uses. This pattern is explained by the fact that the subsidy can represent as much as a 50 percent savings in fuel applications, but is far less valuable in other applications where factors other than the cost of materials determine the overall cost of the tire-consuming activity.[211] In reaction to this pattern, and in recognition of EPA's stated "solid waste hierarchy" that deems recycling to be preferable to incineration, a rule change in January 1990 allowed a higher rate of reimbursement for non-energy demonstration projects.[212] Whether this change has had an appreciable impact on the distribution of the subsidy by type of tire consumption was not available as of this writing.

Since businesses both within and outside Oregon are eligible for the rebate, the Oregon program has affected scrap tire usage in neighboring states. A Washington pulp mill uses TDF from Oregon because of the subsidy,[213] and a California cement kiln has reduced its consumption of California tires in favor of those from Oregon.[214] While these results are evidence that a subsidy the size of Oregon's can indeed affect the decisions of some industrial consumers, they also suggest that states be aware of the potential for interstate consequences of various tire policies, and that regional coordination be considered.

Oklahoma's subsidy program is newer and has thus generated less data. It nevertheless offers some interesting ideas. Like Oregon's program, Oklahoma's subsidy is financed by a $1 fee on new replacement tires. Unlike Oregon, the subsidy is paid to the first-stage processors of tire-derived products, and not to the end-users. The state offers permitted scrap tire processors up to $.50 per tire processed. In order to qualify for reimbursement, at least 25 percent of the tires processed by the facility must be collected from tire dumps identified on a priority list developed by the State Department of Health.[215]

One hazard the Oklahoma program faced in its early stages was that the fund created by the fee on new tire purchases accumulated about $1 million over nine months before the first request for reimbursement by a private sector processor. The delay was due in part to the time it took to promulgate regulations, institute the permitting process, and identify priority clean-up sites. Meanwhile, the accumulation of the fund gave the impression that the program was not active, and prompted some members of the state legislature to try to repeal the act that created it. The repeal attempt failed, but some have suggested that criticism of the program could have been avoided if the timing of the implementation of the fee had been delayed until later in the program process.[216]

As with other policies whose effect would be to increase per-unit revenue to a tire processor, a subsidy will be most effective when it is the cost of the tire-derived product that is the principal constraint on increased consumption. To be effective, the subsidy must be large enough to bridge the gap between what producers are willing to accept for a particular product and what consumers are willing to pay. It will be interesting to see if the higher value of the Oklahoma subsidy, at $.50 per tire, results in more varied enterprises consuming scrap tires than the Oregon subsidy, at $.20 per tire, which has thus far supported primarily TDF. If the principal barriers to consumption of tires in a particular application are lack of product specifications, environmental concerns, or other non-price factors, a subsidy program will have little effect on increasing tire consumption in that application.

Some of the issues that have to be addressed in creating a subsidy program are the administrative costs of the program, whether public activities, such as road construction, would be eligible for the subsidy, and how to make the subsidy appear reliable in the view of those who would be making investment decisions that rely on it. In addition, some legal issues may affect the design of a subsidy program, for example, whether the constitutions of any of the NEWMOA states prohibit the direct subsidization of private industry.

Capital Cost Assistance

To address the capital barriers facing potential new tire recyclers (or existing firms that wish to expand), it has been suggested that states make subsidized capital available directly to entrepreneurs. This could be accomplished through industrial revenue bonds, low interest loans, or loan guarantees. State-issued industrial revenue bonds typically carry interests rates that are a little lower than those charged by other lenders or investors. The Exeter Energy facility is being constructed with the assistance of bonds backed by the state of Connecticut, and TireCycle of New England is trying to qualify for Rhode Island industrial revenue bonds. The ability of a company to obtain state backing for a portion of its capital needs may help convince private lending institutions of the legitimacy of the business proposal and make it easier for the company to gain additional private financing.[217] For smaller businesses, backing by the federal Small Business Administration may be an option.

There are at least two important reasons to view this approach with caution, however. First, the announcement of special low interest loans for tire recycling may elicit many applications from private entrepreneurs. The state would need the ability to evaluate all these proposals and determine which, if any, present good risks for the state. The state may or may not have the expertise available to make such evaluations. Personnel with expertise on solid waste issues may not be trained in finance, and those in the state's department of economic development, if it has one, may have financial expertise but be unfamiliar with solid waste concerns. Developing cooperative relationships between these types of people may be a prerequisite to evaluating the business proposals.

Secondly, some in private industry believe that there is still a shortage of good ideas about how to use scrap tires, but that there is no shortage of investors actively seeking tire recycling opportunities and willing to put money into promising ventures.[218] To the extent that this is true, we would expect that the proposals most likely to result in viable business ventures that will need no further support are already fully capitalized. For a state to identify a successful proposal that others overlooked, it would have to have better information than private capital markets about the likelihood of success of tire-consuming enterprises. Given the scarcity of state funds for such activities, and the difficulty in evaluating proposals, state assistance for capital needs may represent a particularly risky expenditure of public funds.

The failure of the state-subsidized TireCycle plant in Minnesota is sometimes given as an example of the dangers of public investment in private recycling industries. Among the problems that the enterprise faced were political factors that led to the siting of the plant at an economically unfavorable location.[219] The political pressures potentially associated with choosing recipients of large sums of money should be considered in the development of a program designed to lower capital barriers.

New York State's Department of Economic Development currently offers "secondary materials technology adoption loans" for businesses engaged in the recycling of a variety of materials. A limited number of loans have been made for tire-related activities thus far. As this program develops, it may offer important lessons to other northeast states considering this approach to addressing capital cost barriers to increased tire recycling.

Raising Revenue

Most of the policy options discussed above require expenditure of public funds. The source of these funds could be either general revenue, allocations from existing agency budgets, or new taxes or fees earmarked for a scrap tire program. How much money the selected program will require may influence a decision about which type of funding to pursue, and how high to set the fee.

New taxes or fees could be imposed at one of several points. One option is to charge a fee at the point of tire disposal. This has the advantage of raising public consciousness about any social costs of tire disposal that may not be reflected in the normal cost of disposal. It has the disadvantage of reducing the incentive to bring tires to appropriate disposal sites, and it may result in an increase in illegal dumping.

Alternatively, a disposal tax could be imposed at the point of new replacement tire purchase. This, too, would raise consumers' awareness of the costs associated with the product. The tax could be imposed on new replacement tires only, giving retreaded tires a slight advantage. Unlike a fee at the point of disposal, this tax would not affect disposal behavior. The logistics of collecting the tax from tire sellers would have to be considered, and tire dealers may have to be compensated for their participation by allowing them to keep a small percentage of the tax.

Administratively, imposing an additional fee at the time of vehicle registration may be the easiest course. It would also avoid the problem of consumers crossing state lines to avoid taxes on new tires. A disadvantage of this approach is that people who drive very little, and thus generate the fewest scrap tires, would pay just as much as those who drive a lot and consume more tires. Similarly, a tire disposal fee imposed at the time of vehicle title transfer might be easy to collect, but would affect those who buy or sell used cars frequently more than other drivers. Either of these approaches raises a question about fairness.

National Legislation

Early in 1990, Representative Esteban Torres of California proposed comprehensive scrap tire legislation designed to create economic incentives for scrap tire recycling.[220] The "Tire Recycling Incentives Act" would place the responsibility for tire recovery on tire manufacturers and importers. These businesses would have to guarantee, through their own activities or through the purchase of recycling "credits", that a certain percentage of their tires had been recycled. Credits would be generated by licensed recyclers who consume tires in an EPA-approved manner. The amount of recycling credit created for each scrap tire processed would depend on the type of processing. A market for recycling credits would develop as tire manufacturers and importers are required to obtain an increasing number of credits for every tire they sell.

Another important provision of the proposed legislation is a ban on land disposal, except for the monofilling of shredded tires. Other aspects of the legislation include requirements that each state inventory its tire collection and storage facilities and develop an abatement plan. States are also charged with licensing scrap tire haulers, and licensing all scrap tire collection, storage, and recycling facilities. Inspection, enforcement, and monitoring the tracking system are likewise state responsibilities. The legislation does not provide the states with any funds to carry out these activities, although it does not prohibit them from levying any of their own fees or taxes on tires to pay for the required programs.

National legislation would do much to avoid the interstate side-effects possible when each state develops its own program for addressing scrap tires. This coordination would come at the cost of an additional layer of bureaucracy, however. It is also unclear how states with existing programs would be affected by the new regulations. The Tire Recycling Incentives Act did not pass this year, but due to the serious implications the legislation could have for the market for scrap tires, state solid waste officials will want to be aware of any further developments in this area.

VI. CONCLUSIONS

The markets for scrap tires and tire-derived products currently reflect considerable uncertainty about future conditions in the NEWMOA states. Despite the few large consumers about to come on the scene, namely Exeter Energy, Champion International, and perhaps another paper mill, plenty of scrap tires will still be available for additional large-scale consumers who can find profitable uses for them. Some entrepreneurs must be optimistic about the potential for recycled rubber to break into the market for rubber-plastic polymers, or companies such as TireCycle and R.W. Technology would not exist. However, these firms also appear to be having some difficulty attracting investors (although this is hard to tell without more information than the companies are willing to divulge). One reason may be that their products will be only marginally profitable. Alternatively, the products may be quite profitable, but the risk factor may be keeping investors away.

Without more detailed information about the internal finances of potential tire-consuming companies, it is difficult to determine whether increased tipping fees would be of much help to them. Tipping fees may have the greatest impact on companies that do relatively little processing and produce a relatively simple product, such as tire chips for fill or fuel, where the cost (or negative cost) of the input has a large effect on overall profitability. For more intensely processed, higher valued products, the initial cost of the material input may be less important, and the impact of tipping fees on overall profitability may thus be less significant. This latter description may apply to rubber-plastic polymers or pavements using crumb rubber. For these uses of scrap tires, the capital costs of establishing a plant or increases in labor may pose more of a barrier than the cost of the tire inputs. Thus, measures that increase tipping fees may not have much of an impact on them.

From the perspective of solid waste management, we do not particularly care about the value of the final product, be it a simple dock bumper or high-tech polymer, as long as the processes that make it are sustainable and self-sufficient in the marketplace. If these conditions can be met by raising the tipping fee, then policies that result in higher tipping fees are worth exploring. Moreover, the risks involved in capital cost assistance to potential recyclers suggest that other avenues be tried first.

One logical place to begin working on tipping fees is to require that appropriate safety measures be taken at landfills and tire storage facilities. Since there may be social costs associated with tire stockpiling that are not properly considered by stockpile operators, in the form of fire hazards, risk of disease, and aesthetics, this action is defensible even on theoretical grounds. As the costs of these operations rise, disposal site operators would have to raise their tipping fees. As discussed earlier, a permitting and tracking system for both facilities and tire haulers may be necessary to achieve higher tipping fees without additional unregulated disposal sites appearing.

Another way to increase front-end revenue to tire consumers would be to offer a per-unit subsidy on consumption. This would not be incompatible with measures to increase tipping fees through regulation of disposal and hauling. One question deserving further research would be a comparison of the administrative costs of providing a subsidy to the administrative and enforcement costs of achieving an equivalent increase in tipping fees by regulatory means.

If states pursue either or both of these means of making tire consumption more attractive, and if these measures would have the most impact on relatively simple forms of recycling, then additional policy initiatives to stimulate demand should complement the increased attractiveness in tire shredding or chipping. This suggests that research on the use of tire chips to replace sand and gravel in construction applications would be more fruitful than state-assisted polymer research, for example. It should be noted that such research may aid not only public consumption of the material, but private construction activities, as well. If the additional front-end revenues from higher tipping fees and/or subsidies help the more complicated processing methods become profitable, efforts to increase the use of shreds and chips can always be abandoned.

Before any measures are taken, beyond the regulation of tire disposal for health and safety reasons, solid waste officials should seriously consider waiting to see what happens in the private market over the next few years. In addition to the consumption opportunities identified within the seven states discussed here, it is possible that the export of tire products will increase, or that new tire-consuming capacity in New York, Pennsylvania, or Canada will appear. The risk in waiting, of course, is that nothing will develop and that the severity of the tire disposal problem will grow.

NOTES

[1] Robert Snyder, Consultant, Tire Technology, Inc. Personal communication, 2 October 1990.
[2] Robert Snyder.
[3] Robert Snyder.
[4] The story is considerably different for heavy truck tires, which are still consistently retreaded because of the substantial cost savings as compared to the purchase of new tires. While these casings, too, must eventually be discarded, they represent a relatively small component of the scrap tire problem.
[5] Paul Bedrosian, U.S. Environmental Protection Agency, Region I, 3 October 1989, unless otherwise noted.
[6] Maine Department of Transportation, Technical Services Division, "Preliminary Report on the Use of Tire Rubber in Pavements," March 1990, p. 1.
[7] Massachusetts Executive Office of Environmental Affairs, Department of Environmental Protection, "Toward a System of Integrated Solid Waste Management: The Commonwealth Master Plan," June 1990. Generation rate listed is 5.5 to 6 million tires per year.
[8] Ron Gagnon, Rhode Island Department of Environmental Management. Personal communication, 27 November 1990.
[9] Al Morrison, Vermont Agency of Environmental Conservation, Department of Solid Waste. Personal communication, 6 August 1990. The stockpile estimate should be considered very rough.
[10] New Jersey Department of Environmental Protection, "Emergency Solid Waste Task Force Preliminary Report," 6 July 1990. The generation rate estimate does not seem to include the 20-30% of tires estimated to be culled by jockeys for resale or retread. Furthermore, the rate is apparently based on a recycling market development study by Arthur D. Little, Inc., that offered this figure as the 1986 generation rate. It represents 8.4 million passenger car tires and 1.28 million truck tires, or a total "passenger car equivalent" of 13.5 million tires. The ADL report projected the scrap tire supply to grow to 17.6 million passenger car equivalents per year by 1993. Thus, a 1990 estimate may be closer to 15 or 16 million tires generated per year.
[11] See "Markets for Scrap Tires," research presented by Hope Pillsbury, U.S. Environmental Protection Agency, and Jacob Beachey, Franklin Associates, at the First U.S. Conference on Municipal Solid Waste Management, 13-16 June 1990.
[12] For example, the National Tire Dealers and Retreaders Association and Recycling Research, Inc. (publisher of *Scrap Tire News*).
[13] John Bittner, National Tire Dealers and Retreaders Association. Personal communication, 24 July 1990.
[14] Assumptions: 22.9 million tires generated annually in the NEWMOA states; 80 percent of scrap tires resulting from tire replacement; 8.5 percent of passenger car tires retreaded nationally; 16.3 percent of car, light truck, and medium truck tires retreaded annually.

[15] The rate at which tire haulers say they cull for reusable or retreadable casings provides a rough check on this figure. Haulers say they pull about 10 to 15% of the tires they collect for these uses, but that the tire dealers have sometimes picked out the best tires already. Thus, 16.3% seems to be a reasonable figure for the rate of retreading.

[16] If we assume that the generation rates reported do *not* include tires to be retreaded, we obtain an estimate of 4.5 million tires retreaded per year in the NEWMOA states. Calculation: .163 = x/(22.9 + x), where x is the number of tires retreaded.

[17] Warren Schambeau, Metropolitan Tire Convertors. Personal communications, 24 July and 10 August 1990.

[18] Kevin Parks, Integrated Tire. Personal communication, 18 June 1990.

[19] Chris Chisseri, Oxford Tire Supply. Personal communication, 30 July 1990.

[20] Tom Ferreira, F&B Enterprises. Personal communication, 27 June 1990. Based on 4,000 passenger car tires and 1,000 truck tires per day, 5.5 days per week. The tires are not completely used; 20 tons of leftover material is disposed of at the New Bedford landfill per day.

[21] Joe Carpenter, New Jersey Office of Recycling. Personal communication, 6 August 1990.

[22] Tim Baker, Baker Rubber. Personal communication, 9 August 1990.

[23] The two companies involved in this exchange provided widely varying estimates of the amount of material involved.

[24] John England, Connecticut Department of Environmental Protection. Per communication with Carole Ansheles, NEWMOA, 25 July 1990.

[25] Bruce Eber, Tire Salvage, Inc. Personal communications with Amy Barad and Paul Bedrosian, EPA Region I, 27 June and 8 August 1990.

[26] Electricity Purchase Agreement between Exeter Energy Limited Partnership and the Connecticut Light and Power Company for the Exeter Energy Sterling Project, 1 December 1989, p. 6..

[27] Chris Chisseri, Oxford Tire Recycling of Connecticut. Personal communication, 12 July 1990.

[28] Kevin O'Reilly, Oxford Energy Company. Personal communication, 29 June 1990.

[29] Eric Kennedy, Maine Department of Environmental Protection, Air Bureau. Personal communication, 22 June 1990.

[30] Andrea Maker, Champion International. Personal communication, 18 June 1990.

[31] Bill Murdoch, Sawyer Environmental Recovery, 26 July 1990 and Tom Flaherty, Sprague Energy, 26 July 1990.

[32] Andrea Maker, Champion International; Tom Flaherty, Sprague Energy; and Mark Hope, Waste Recovery, Inc.

[33] Mark Hope.

[34] Garrett Morrison, Dragon Products. Personal communication, 18 August 1990.

[35] Steven Roberts, TireCycle of New England. Personal communication, 22 June 1990.

[36] Chris Chisseri, Oxford Tire Recycling. Personal communication, 30 July 1990.
[37] Rhode Island General Laws, 63-23-2.
[38] Bruce Eber, Tire Salvage, Inc. Personal communication, 27 June 1990.
[39] Frank Mann, Pol-X International. Personal communication, 23 July 1990.
[40] Paul Bedrosian, Environmental Protection Agency, Region I.
[41] Electricity Purchase Agreement between Exeter Energy and Connecticut Light & Power, Exhibit J-1, Exeter Financial Pro Forma, 1989.
[42] Ray Gile, International Soil Systems. Personal communication, 28 September 1990.
[43] Mike Kennedy, Waste Management, Inc. Personal communication.
[44] Kay Beaton, R.W. Beck and Associates, in letter to William Evans, New Hampshire Department of Environmental Services, 9 February 1990.
[45] Mike Kennedy, Tire and Fuel Reduction Group, Waste Management, Inc. Personal communication, 10 July 1990.
[46] Adam Marks, Rhode Island Solid Waste Management Corporation. Personal communication, August 1990.
[47] CMR 406.3.
[48] CMR 406.3-5.
[49] Connecticut Department of Environmental Protection, Solid Waste Management, "Guidelines for Rubber Tire Storage Areas."
[50] The description here is based on the Electricity Purchase Agreement between Exeter Energy Limited Partnership and the Connecticut Light and Power Company, 1 December 1989.
[51] Kevin O'Reilly, Oxford Energy Company. Personal communication, 29 June 1990.
[52] Electricity Purchase Agreement, p. 7.
[53] Electricity Purchase Agreement, Exhibit J-1, Exeter Financial Pro Forma.
[54] Philip Rettger, Vice President, Oxford Energy Company. Personal communication, 9 October 1990.
[55] Electricity Purchase Agreement.
[56] *Ibid.*
[57] Philip Rettger.
[58] Philip Rettger.
[59] Exeter will have to share tipping fees only when it meets certain conditions of positive cash flow that exceed expectations. Electricity Purchase Agreement, Appendix J, Description of Method of Sharing of Excess Tip Fee Revenues.
[60] Rhode Island P.L. 1989, 23-63-2.
[61] Eugene Bishop, Maine Department of Transportation. Inter-Departmental Memorandum, 8 August 1990.
[62] John Bittner, National Tire Dealers and Retreaders Association. Personal communication, 24 July 1990.
[63] John Bitter. These figures exclude heavy truck tires, which are often retreaded two or more times each.
[64] Mary Sikora, Recycling Research. Personal communication, 16 October 1990.
[65] According to a Preliminary Report of the New Jersey Emergency Solid Waste Assessment Task Force, Appendix D, 6 July 1990, 20

percent of the state's scrap tires are retreaded. However, relatively few of these are passenger car tires and many are heavy truck tires. Insufficient data are included to separate the rate of retread for each category.

[66] *Ibid.*

[67] Frank Mann, Pol-X International. Personal communication, 23 July 1990. Chris Chisseri, Oxford Tire Recycling of Connecticut, cited a figure of $1.50 and up. Personal communication, 12 July 1990.

[68] Frank Mann.

[69] Lola Cline, Cline Retreading Co. Personal communication via Paul Bedros ian, 7 August 1990.

[70] Frank Mann, Pol-X International.

[71] Ken Collings, Federal Tire Program. Personal communication, 30 July 1990.

[72] Ken Collings.

[73] Joe Sullivan, New Jersey Division of Purchasing. Personal communication, 23 July 1990.

[74] Allen S. Caldwell, U.S. EPA, Region VII. Personal communication, 12 July 1990.

[75] Tom Ferreira, F&B Enterprises. Personal communication, 27 June 1990.

[76] Tom Ferreira.

[77] Joe Carpenter, New Jersey Office of Recycling. Personal communication, 6 August 1990.

[78] Franklin Associates, Ltd. "Market Development Study for Tires," prepared for Hope Pillsbury, Office of Solid Waste, U.S. Environmental Protection Agency, Draft of 30 August 1989.

[79] Bruce Eber, Tire Salvage, Inc. Personal communication, 27 June 1990.

[80] Bruce Eber.

[81] Mickey Tracy, MATES Tire Systems. Personal communication, 5 July 1990.

[82] MATES Tire Systems Business Plan, 15 May 1990.

[83] Dr. Frank Schaub, Connecticut Department of Health. Personal communication, 19 July 1990.

[84] See "A Report on the RMA TCLP Assessment Project," prepared by the Radian Corporation for the Rubber Manufacturers Association, 25 September 1989; and "Waste Tires in Sub-grade Road Beds: A Report on the Environmental Study of the Use of Shredded Waste Tires for Roadway Sub-grade Support," prepared by the Twin City Testing Corporation for the Minnesota Pollution Control Agency, 19 February 1990. The former found no values exceeding proposed regulatory values for any of the organics or metals tested. The latter reported the concentrations of some metals leached under acid conditions (ph 3.5 or 5) to exceed Minnesota Department of Health Recommended Allowable Limits for drinking water under worst-case conditions.

[85] Don Robisky, Vermont Department of Public Health. Personal communication, 8 August 1990.

[86] Mickey Tracy.

[87] Matt Mayo, Triple S Dynamics. Personal communication, 10 August 1990.

[88] Jane Palmer, Palmer Shredding. Personal communication, 2 July 1990.
[89] Bill Murdoch, Sawyer Environmental Recovery. Personal communication, 26 July 1990.
[90] Jane Palmer.
[91] Matt Mayo.
[92] Bill Murdoch.
[93] Bill Murdoch.
[94] Jane Palmer.
[95] Jane Palmer.
[96] Bill Murdoch.
[97] Warren Schambeau, Metropolitan Tire Converters, Inc. Personal communication, 10 August 1990.
[98] Kevin Parks, Integrated Tire. Personal communication, 18 June 1990.
[99] Ron Frascoia, Vermont Agency of Transportation, Materials and Research Division, per Carole Ansheles, NEWMOA, 8 August 1990.
[100] Assumes a cubic yard of chips is the equivalent of 40 whole tires.
[101] Jane Palmer.
[102] Note: The term "revenue is used here rather than "income", because neither the tipping fee not the price of the chips used is net of expenses, i.e., costs of collection (transportation, labor), or processing (energy, labor, depreciation on equipment).
[103] Bill Stoler, Baker Rubber. Personal communication, 10 July 1990.
[104] Tim Baker, Baker Rubber. Personal communication, 20 July 1990.
[105] Tim Baker.
[106] Robert Snyder, Tire Technology, Inc. Personal communication, 28 October 1990.
[107] Steven Roberts, TireCycle of New England. Personal communication, 14 August 1990.
[108] Steven Roberts. Personal communication, 22 June 1990.
[109] Steven Roberts.
[110] Steven Roberts. Demonstration quantities are supplied by Rubber Research Elastomerics in Minnesota and Eagleton & Goldsmith in Ohio, each of which performs half the process. Together, they generate 40,000 to 50,000 pounds per week of the rubber product.
[111] Steven Roberts.
[112] John Riendeau, Rhode Island Department of Economic Development. Personal communication, 26 June 1990.
[113] John Riendeau.
[114] John Minicucci, R.W. Technology. Personal communication, 1 August 1990.
[115] Mike Deep, American Typlax Systems, Inc. Personal communication, 1 August 1990.
[116] Mike Deep.
[117] Mike Deep.
[118] John H. Fader, "Scrap Tires: A Potential Alternative Energy Source to Replace 40,000 Barrels of Oil per Day," *Environmental Manager*, October 1990, p. 30-34.

[119] Based on information provided by Rouse Rubber Industries, in testimony given by Mike Rouse before Representative Esteban Torres, 10 April 1990.
[120] To express price per ton as price per million BTUs, first divide the price per ton by 2000 to get price per pound, then divide by the number of BTUs per pound and multiply by 1 million.
[121] Tom Flaherty, Sprague Energy. Personal communication, 29 October 1990.
[122] The conversion from price per ton to price per cubic yard is based on the following assumptions: tires lose 20% of their weight in the conversion to TDF (most of the wire removed) and 10% of their volume. Thus, while 40 whole chipped tires (with no wire removed) fill a cubic yard and weigh 800 pounds, 44.4 tires are needed to make a cubic yard of TDF, which will weigh only 704 pounds. At these ratios, a ton of TDF takes up about 2.8 cubic yards.
[123] Suggested by Tom Flaherty as a plausible selling price.
[124] Andrea Maker, Champion International. Personal communication, 18 June 1990.
[125] Mark Hope, Waste Recovery, Inc. Personal communication, 18 June 1990.
[126] Michael Barden, Maine Department of Environmental Protection, Bureau of Solid Waste Management. Personal communication, 25 June 1990.
[127] Andrea Maker.
[128] Irving D. Hodgkin, Chamption International, in letter to Michael Barden, Maine Department of Environmental Protection, Bureau of Solid Waste Management, 8 June 1990.
[129] Michael Barden.
[130] Michael Barden.
[131] Michael Barden. Based on total metals and EP Toxicity tests. Other states may use other tests, with important implications for the use of TDF. For example, in Washington, bioassays are used on ash to be landfilled. When TDF is burned in wood processing facilities, the concentration of zinc has been high enough to cause the ash to fail the test. One Washington pulp mill that has been using TDF as a fuel supplement for ten years has a variance for its ash due to grandfathering, but no other paper, pulp, or wood processors in the state can use TDF because the ash would have to go to the state's only hazardous waste landfill. Source: Dale Clark, Washington Department of Ecology, Waste Reduction, Recycling and Litter Control Program. Personal communication, 12 June 1990.
[132] Eric Kennedy, Maine Department of Environmental Protection, Air Bureau. Personal communication, 22 June 1990.
[133] Eric Kennedy.
[134] Eric Kennedy.
[135] Eric Kennedy.
[136] Andrea Maker, 21 June 1990.
[137] Andrea Maker, 18 June 1990.

Note: We can use Champion's estimates of tire consumption and cost savings to calculate Champion's implicit savings per million BTU:

3 million tires = 30,000 tons x .8 x 31 million BTU/ton
= 744,000 BTU

$.5 million / .744 million BTU = $0.672 savings per million BTU.

This estimate suggests that the earlier computations comparing the cost of TDF to the cost of coal were reasonable.

[138] Garrett Morrison, Dragon Products, Inc. Personal communication, 26 July 1990. See also, SCS Engineers, et al., *Feasibility Study to Site and Operate a Tire Recycling Facility in Washington State*, for the Washington State Department of Trade and Economic Development, Business Assistance Center and the Washington State Department of Ecology, January 1989, p. 2-7.

[139] Garrett Morrison, 25 June 1990.

[140] Garrett Morrison, 18 August 1990.

[141] Garrett Morrison.

[142] Garrett Morrison.

[143] Asphalt Rubber Producers Group, *Uses of Asphalt Rubber*.

[144] When the asphalt-rubber with aggregate is the final driving surface, it is called a chip seal. When the chip seal is applied to a stressed surface, it is called a "SAM", or stress absorbing membrane. When it is covered by a layer of asphalt concrete, it is called a "SAMI", or stress absorbing membrane interlayer.

[145] H.B. Takallou, "Benefits of Recycling Used Tires in Rubber Asphalt Paving," in testimony before the House Committee on Small Business, Subcommittee on Environment and Labor, and Subcommittee on Regulation, Business Opportunities and Energy, 18 April 1990.

[146] Douglas Bernard, Chief, Demonstration Projects Division, Federal Highway Administration, U.S. Department of Transportation, in testimony before the House Committee on Small Business, Subcommittee on Environment and Labor, and Subcommittee on Regulation, Business Opportunities and Energy, 18 April 1990.

[147] Joe Wedge, Asphalt Rubber Systems. Personal communication, 9 July 1990.

[148] H.B. Takallou.

[149] Based on 3,416 tons of asphalt mix required for a 3-inch thick pavement (H.B. Takallou, BAS Engineering Consultants, in testimony before the House Small Business Subcommittees on Environment and Labor, and on Regulation, Business Opportunity and Energy, 18 April 1990). Tonnage for 3-inch pavement was reduced by 2/3 for 2-inch thickness. Conversion to number of tires assumes the binder accounts for 7% of the asphalt mix, the binder is 20% crumb rubber, and 12 pounds of crumb can be obtained per tire.

[150] Takallou, *op. cit.* No revisions to estimate made.

[151] Tim Baker, Baker Rubber. Personal communication, 20 July 1990.

[152] Douglas Bernard, *op. cit.*

[153] Al Conforti and Michael Snure, R.A. Hamilton Corp. Personal communication, 10 July 1990.

[154] H.B. Takallou, in testimony presented by Michael D. Harrington, PaveTech Corporation before the House Committee on Small Business, Subcommittee on Environment and Labor, and Subcommittee on Regulation, Business Opportunities and Energy, 18 April 1990.
[155] PlusRide Asphalt, Inc. Promotional materials.
[156] According to the PlusRide marketer, the density of the mix is 140 pounds per cubic foot, as compared to 150 pounds per cubic foot of conventional asphalt concrete mix. H.B. Takallou, PaveTech Corporation.

However, the density can vary with the type of aggregate used. The City of Newark, NJ quotes a density for their conventional mix at 155 pounds per square foot. Frank J. Sudol, Newark Department of Engineering. Materials accompanying press release of 21 November 1988.

Furthermore, the contractor that supplied the mix used in Newark found that his aggregate resulted in a higher density for the mix, thus requiring more tons of mix than applications in other parts of the country. Michael Snure, R.A. Hamilton Corp. Personal communication, 10 July 1990. Presumably, however, the rubber content of this mix still reduced its overall density as compared to a mix composed entirely of New Jersey's conventional aggregate.
[157] Frank J. Sudol. Materials accompanying press release.
[158] Takallou, *op. cit.* Estimate of $114,048 for 3-inch pavement is based on 3,564 tons at $32 per ton. Using 2/3 the tonnage would cost $76,032.
[159] Takallou, *op. cit.* Cost of asphalt-rubber binder is estimated at $47 per ton; quantity based on 2/3 of 3,516 tons.
[160] Takallou, *op. cit.* Cost of RUMAC mix is estimated at $41 per ton; quantity based on 2/3 of 3,326 tons.
[161] Jack Van Kirk, California Department of Transportation. Personal communication, 2 July 1990.
[162] Michael Heitzman, Federal Highway Administration, U.S. Department of Transportation. Personal communication, 3 July 1990.
[163] Douglas Bernard.
[164] Donald Kavenaugh, Massachusetts Department of Public Works, personal communication, 19 July 1990; and Mike Bennett, Rhode Island Department of Transportation, Design Division, personal communication, 24 July 1990.
[165] Maine Department of Transportation, Technical Services Division, *The Use of Tire Rubber in Pavements* (Preliminary Report), March 1990, p. 11.
[166] Twin City Testing Corporation, *Waste Tires in Sub-grade Road Beds: A report on the Environmental Study of the Use of Shredded Waste Tires for Roadway Sub-grade Support*, prepared for the Minnesota Pollution Control Agency, 19 February 1990, p. 1.
[167] Dana Humphrey, University of Maine. Personal communication, 11 July 1990.
[168] Peter Bosscher, University of Wisconsin (Madison), Department of Civil and Environmental Engineering. Personal communication, 18 July 1990. See also, Tuncer B. Edil, Peter J. Bosscher, and Neil N. Eldin, *Development of Engineering Criteria for Shredded*

or Whole Tires in Highway Applications, Interim Report to the Wisconsin Department of Transportation, June 1990.
[169] Twin City Testing Corporation, *op. cit.*
[170] *Ibid.*, p. 34.
[171] Edil, et al., *op. cit.*, p. 16.
[172] Herb Webster, Town of Georgia, Vermont. Personal communication, August 1990.
[173] Raymond Cyr, Vermont Agency of Transportation. Personal communication, 5 July 1990.
[174] Dr. Charles Dougan, Connecticut Department of Transportation, Director of Research and Materials, *Report to the General Assembly on the Feasibility of Expanding the Use of Materials in Projects Undertaken by the Department of Transportation*, December 1988, p. 15. The state generates an average excess of 630,000 cubic yards of clean fill material per year, suggesting little opportunity for using tire chips in highway embankments. However, the annual demand for subbase material averages 249,700 cubic yards per year. Specifications for this material are that it consist of "a clean soil-aggregate mixture of bank and crushed gravel, crusher-run stone, or a combination thereof." (p. 15) The volume demanded of this material is listed on the table as a potential consumer of tire chips.
[175] Warren Foster, Maine Department of Transportation, Technical Services Division. Personal communications, 12 and 18 July 1990. In 1989, the Maine used 200,000 cubic yards of common borrow. However, the legislature recently passed a bill providing $30 million per year for the next several years for rebuilding the state's primary highway system. Some of the projects related to this reconstruction will involve embankments and retaining walls. The annual consumption of fill during these years is expected to be about 250,000 to 300,000 cubic yards.
[176] Rick Antonia, New Hampshire Department of Transportation. Personal communication, 20 July 1990.
[177] Cathy Diringer, New Jersey Department of Transportation, Recycled Materials Task Force. Personal communication, 8 August 1990. This figure represents the amount of "zone 3 borrow/fill" purchased in 1989.
[178] Mike Bennett, Rhode Island Department of Transportation, Design Division. Personal communication, 24 July 1990. Rhode Island is currently involved in some large highway construction projects that require large volumes of fill. One such project may use 200,000 cubic yards, and another may use an additional 200,000 to 300,000 cubic yards. These projects are not typical, however. The estimate presented here is based instead on an ongoing program to reconstruct old roads with narrow lanes and no shoulders. A typical reconstruction project consumes about 15,000 cubic yards of common borrow, and 20 to 25 such projects are completed each year.
[179] Milon Lawson, Vermont Agency of Transportation, Materials and Research Division. Personal communication, 24 July 1990.
[180] Cathy Diringer.
[181] Mike Bennett.
[182] Warren Foster.

[183] Maine Department of Transportation, Technical Services Division, *Preliminary Report on the Use of Tire Rubber in Pavements*, March 1990, p. 13.
[184] Cathy Diringer.
[185] Bill McGrath, Vermont Department of Economic Development. Personal communication, 2 July 1990.
[186] Based on a price of $3 per ton, and a density of 120 pounds per cubic yard. Cathy Diringer.
[187] Ray Gile, International Soil Systems. Personal communication, 11 July 1990.
[188] Diana Shannon, Chief, RCRA Compliance Monitoring Section, US E.P.A., Region VIII, in a letter to Bill Lawsen, Colorado Department of Agriculture, 9 January 1987: "Based on the chemical data that [the president of a company promoting the use of crumb rubber] submitted for the proposed soil amendment...the concentrations are an order of magnitude less than those standards for the characteristic of EP toxicity (40 CFR 261.24)."
[3] Ray Gile.
[190] John N. Rogers, Department of Crop and Soil Sciences, Michigan State University. Personal communication, 27 September 1990.
[191] John Rogers.
[192] Based on an installation cost of $72,000, conventional annual maintenance costs of $50,000 per year, and a discount (interest) rate of 10%. Higher conventional maintenance costs, a higher savings rate, a longer time horizon, or a lower interest rate will increase the attractiveness of such a project; the opposites will decrease the value of the project.
[193] John Rogers.
[194] International Soil Systems, Inc. April 1990 Business Plan.
[195] Ray Gile. Personal communication, 28 September 1990.
[196] U.S. Consumer Product Safety Commission, *A Handbook for Public Playground Safety, Volume II: Technical Guidelines for Equipment and Surfacing*, p. 22.
[197] Dr. Francis Wallach, Total Recreation Management Services. Personal communication, 20 July 1990.
[198] Francis Wallach.
[199] Ken Richardson, Tire Turf Systems. Personal communication, 11 July 1990. Cost based on 14 pounds needed to cover a square foot 6 inches deep. For purposes of comparison, a cubic yard of 1/2" granules weighs 756 pounds, and thus costs about $75.
[200] Wallach. Pea gravel and sand are about $1 per square foot, while wood fiber is about $2.80. However, wood fiber surfaces need to be replaced more frequently than rubber granules.
[201] Francis Wallach.
[202] Bill McGrath, Vermont Department of Economic Development. Personal communication, 2 July 1990.
[203] Maine Department of Environmental Protection, Bureau of Solid Waste Management, *Report to the Legislature on Tires, White Goods, & Demolition Debris*, May 1989, p. 25. Figure based on estimate of 68 cents per ton per 150 miles, cited from a 1988 interim report for the State of New Hampshire by R.W. Beck, and 100 tires per ton.

[204] Robert Vail, Vice President, R.A. Hamilton Corp. Personal communication, 10 July 1990.
[205] Michael Heitzman, U.S. Department of Transportation, Federal Highway Administration, Pavement Division. Personal communication, 3 July 1990.
[206] Franklin Associates, Ltd. *Market Development Study for Tires*, Draft Report, prepared for Hope Pillsbury, U.S. Environmental Protection Agency, 30 August 1990, Table 2.
[207] To be precise, some of this consumption depends on public expenditures because it includes a small number of retreaded truck tires purchased by the public sector, and crumb rubber additives to paving materials that are typically paid for by states or cities. However, the volume of material accounted for by these uses is probably only a small percentage of the 7.5 million tires currently consumed.
[208] Massachusetts Executive Office of Environmental Affairs, Department of Environmental Protection, "Toward a System of Integrated Solid Waste Management: The Commonwealth Master Plan," June 1990, p. 53.
[209] The fee is also used to cover the costs of other aspects of Oregon's waste tire program, including the permitting of tire storage sites, the licensing of tire haulers, and the cleanup of some tire piles. Additional tire pile cleanups have been privately financed.
[210] Deanna Mueller-Crispin, Oregon Department of Environmental Quality. Personal communication, 15 June 1990.
[211] Deanna Mueller-Crispin.
[212] Deanna Mueller-Crispin.
[213] Dale Clark, Washington State Department of Ecology. Personal communication, 12 June 1990.
[214] Deanna Mueller-Crispin.
[215] Thomas E. James, Science and Public Policy Program, University of Oklahoma, and Richard Brooks, Solid Waste Division, Oklahoma State Department of Health, "State Incentives for Private Sector Scrap Tire Recycling: The Oklahoma Program," presented at the First U.S. Conference on Municipal Solid Waste Management, 13-16 June 1990.
[216] *Ibid.*
[217] John Riendeau, Rhode Island Department of Economic Development. Personal communication, 26 June 1990.
[218] Mike Kennedy, Waste Management, Inc., Tire and Fuel Reduction Group. Personal communication, 10 July 1990.
[219] Steven Roberts.
[220] H.R. 4147.