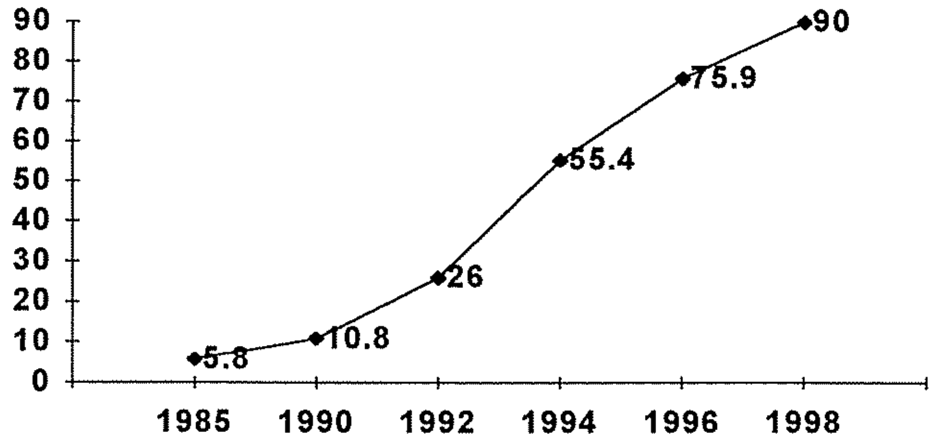
SCRAP TIRE MANAGEMENT COUNCIL

SCRAP TIRE USE/DISPOSAL STUDY
1996 UPDATE
APRIL 1997

Percentage of new scrap tires with markets



Scrap Tire Management Council

REDUCE, RE-USE, RECYCLE, RECOVER

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HIGHLIGHTS

The last full STMC market study reported on markets at the end of 1994. This section highlights some of the major gains since then.

Scrap Tire Use Reaches 75.9% of Annual Generation

Total markets for sound reuse of scrap tires stood at 202 million tires by the end of 1996, or 75.9 % of the 266 million new scrap tires that were generated during the year. This was a new high and a 36 % increase from the level reached just two years ago.

Fuel Markets Grow 51% from 1994

Tire fuel markets reached 152.5 million tires at the end of 1996, an increase of 50.9 % from the level reached in 1994. Cement kilns, electric utilities and pulp and paper mills all showed gains.

Tire Fuel Used in 107 Facilities

The number of facilities of all types using tires as fuel numbered 107 at the end of 1996. This included 35 cement kilns, 23 pulp and paper mills, 15 electric utilities and 34 other industrial and electrical generating facilities.

Three New Fuel Markets Come on Line

Since 1994, three new markets have started using tires: lime kilns, iron cupola foundry and copper smelters. While only in limited use in these facilities at the end of 1996, they show the continuing interest in tires as fuel.

Ground Rubber Markets Show Huge Growth

The markets for size reduced rubber from whole tire reduction showed a 177 % jump from the end of 1994 to the end of 1996. Total use was estimated at 12.5 million tires as of the end of 1996, up from just 4.5 million tires in 1994. New markets and expansion of some old markets accounted for the increase.

Civil Engineering Use Stays Steady

Civil Engineering uses were up only slightly from 1994, from 9 million to 10 million tires. However, in view of the set back caused by heating incidents in two roadbeds, this market segment showed remarkable strength. Landfill construction and septic field markets helped keep these markets numbers up.

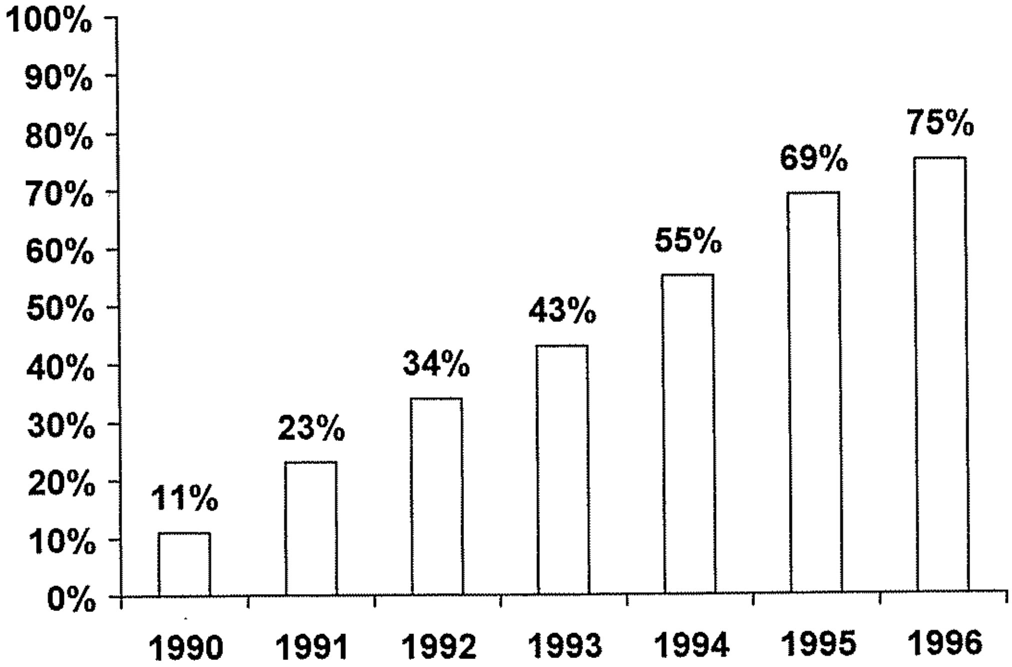
Reported and Estimated Market Demand for Scrap Tires by Market Segment

(Millions of tires, except totals)

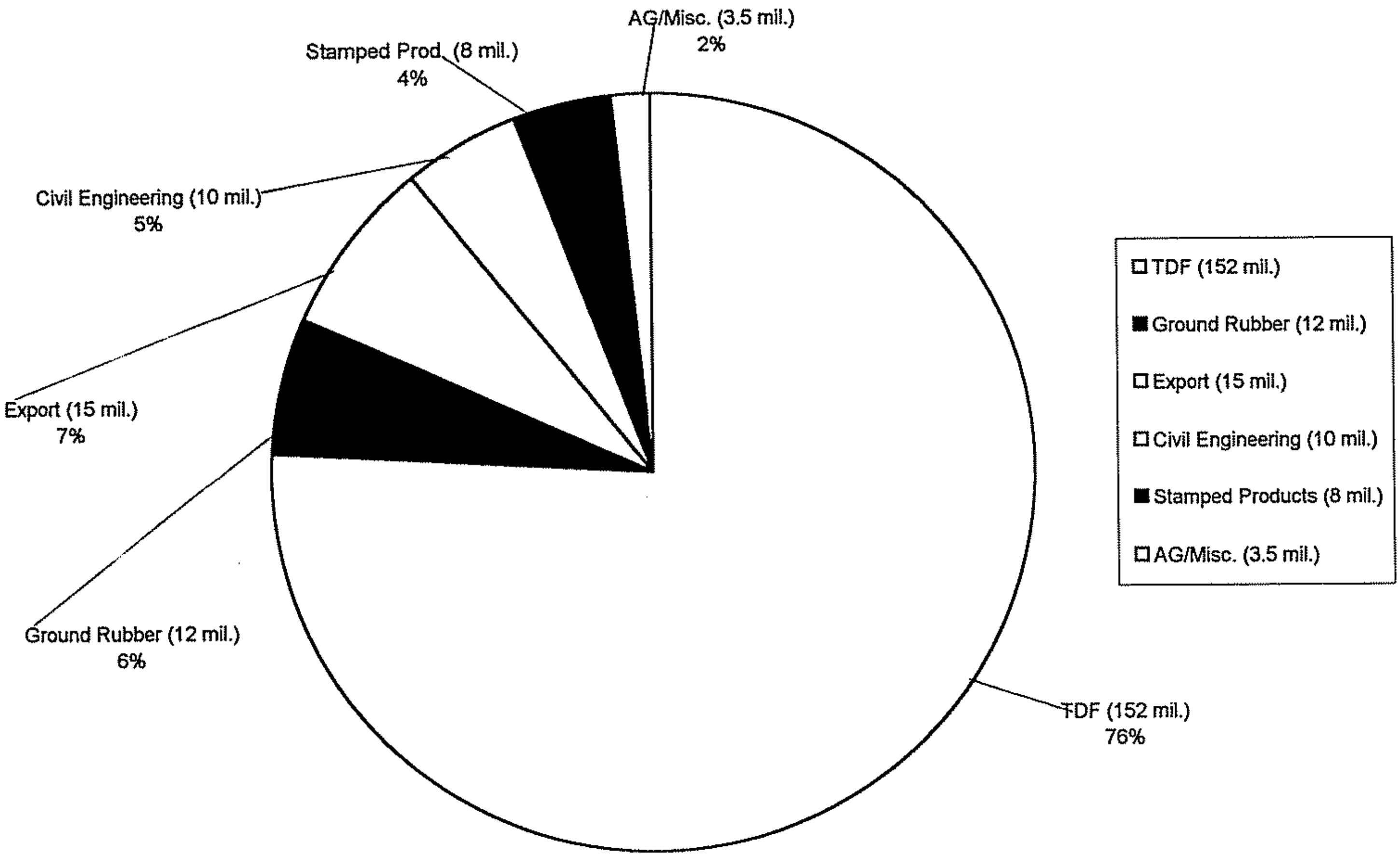
MARKET SEGMENT	1996	1997*	1998*
Tire-Derived Fuel			
Cement Kilns	45.5	53	58
Pulp & Paper Mills	35	37	39
Utility Boilers	29.5	32	36
Dedicated Tire To Energy	15	15	10
Industrial Boilers	20.5	23	25
Resource Recovery Facilities	6	8	10
Lime Kilns	1	2	3
Copper Smelters	0	1	1
Iron Cupola Foundries	0	1	4
Total Fuel	152.5	172	186
Products			
Size-Reduced Rubber	12.5	15	18
C/S/P Products	8	8	8
Civil Engineering	10	14	18
Pyrolysis	0	Unknown	Unknown
Agricultural	2.5	2.5	2.5
Export	15	15	15
Miscellaneous Uses	1.5	1.5	1.5
TOTALS	**202,000,000**	**228,000,000***	**249,000,000***
Annual Generation	266,008,000	270,000,000*	275,000,000*
Scrap Tire Markets as % of Total Generation	75.9 %	84%	90 %

*ESTIMATED

MARKET DEVELOPMENT
1990-1996



Market for Scrap Tires in 1996:



1.0 INTRODUCTION

This is the fourth in a series of biannual market studies on scrap tires. This report is not intended to repeat the basic information found in the previous market surveys. The 1990, 1992 and 1994 market surveys, which provide base information on the economics and technology assessments for the various market applications and disposal options for scrap tires are still available through the Scrap Tire Management Council (STMC). This document, like the 1994 market survey was completed by the STMC. Similar to the earlier studies, the 1996 update:

- Identifies and evaluates the level of progress made with the various market applications since the 1994 report.

- Identifies new markets and technologies which have emerged since the 1994 report.

- Identifies market, technical, institutional, and other barriers to the expanded use of these markets and technologies.

The 1996 market study also provides information not previously presented. In this survey, the STMC presents information on markets in a regionalized format. Furthermore, this report attempts to define the flow of scrap tires, from their location of origin to their final destination.

As with all the previous studies, the results of this study are once again intended to help evaluate the progress that has been made in the development of scrap tire uses or disposal methods which can significantly reducing the number of tires going to stock piles in the near future.

ABOUT THE SCRAP TIRE MANAGEMENT COUNCIL

The Scrap Tire Management Council is an independent advocacy organization, created by the North American tire industry. The Council's primary goal is the creation of sufficient market capacity to consume 110 percent of the annually generated scrap tires. The Council serves as the focal point of industry concerns regarding the disposal of scrap tires. The mission of the Council is to assist in developing and promoting the utilization of scrap tires as a valuable resource. To this end, the Council supports all technologies and uses for scrap tires that are both environmentally sound and cost efficient.

The Council does not represent nor have any vested interest in any product derived from scrap tires or used in the processing of scrap tires. The Scrap Tire Management Council promotes the concept that scrap tires can be a resource that can be used in a wide array of applications.

TIRE MAINTENANCE, RETREADING & REPAIR

Reduction is the first order of importance in any solid waste hierarchy. The Council encourages proper tire maintenance to prolong the tire's useful life, enabling tire owners to derive full value and benefit from their purchase. A simple maintenance program consists of rotating your tires every three to four thousand miles, balancing your tires, aligning the vehicles front end, and properly maintaining a tire's air inflation, will not only result in even and longer wear of the tire, but will increase gas mileage and reduce auto emissions. Proper driving techniques will contribute to safety and increase tire life. Finally, proper vehicle maintenance, especially alignment, will add to tire and vehicle life.

The Council is a strong supporter of retreading. In 1996, approximately 30 to 33 million tires were retreaded, enabling them to be returned to useful applications as tires and keeping them from entering the waste stream. Retreading processes have been in use almost as long as tires have existed. Retread and repair technologies continue to increase the useful life of tires, thereby ensuring fuller utilization of the resources built into the tire. For additional information on retreading and repairing of tires, we suggest you contact any of the organizations listed in Additional Sources (Section 5.0).

OVERVIEW OF FINDINGS

The results of our market survey indicate an overall increase in two of the three major markets for scrap tires; tire-derived fuel (TDF) and size-reduced (ground) rubber applications. The third major market, civil engineering applications, did experience a setback due to the uncertainty created by heating incidents within two road embankments in Washington state and an embankment in Colorado.

Each of these general market areas will be detailed in their respective sections of this report. In general, however, the use of tires as a fuel continues to be the most significant market for scrap tires. The other markets for scrap tires (i.e., export, stamped products, etc.) remained at approximately the same levels as was reported in 1994. One potential market, pyrolysis, although the subject of continuing interest, has not demonstrated an ability to consume many, if any, scrap tires. It would appear there are no commercially operating pyrolysis facilities in the United States, although there are a series of pilot projects, demonstration facilitates, prototypes, and announcements of proposed commercial scale facilities.

LAND DISPOSAL ISSUES

In addition to the markets which have been mentioned, several states allow scrap tires to be landfilled or monofilled. In general, landfilling of scrap tires is allowed when there are no viable markets for scrap tires within an economically accessible distance. Many factors, including transportation costs and limited scrap tire volumes, may make it virtually impossible to have substantial scrap tire markets in some locations. Where this is the case, it is understandable that landfilling may be the most reasonable and cost efficient management option. Nevertheless, land disposal of scrap tires should be considered a last resort solution.

Since 1994, the use of scrap tire monofills (a landfill, or portion of, that is dedicated to one type of material) has become more prominent in some locations as a means to manage scrap tires. In certain cases, monofills are being used because there are no other economically viable markets available and landfills are not accepting, or are not allowed to accept, tires. In other cases, monofills are being portrayed as a management system that will allow for the long-term storage of scrap tires without the problems associated with the above ground storage of scrap tires. In theory monofilled processed scrap tires can be harvested when markets for scrap tire material improve.

Placing scrap tires into monofills is preferable to above ground storage, especially if a pile is not well managed. Available data indicates that there are no negative environmental impacts from placing tires into monofills. While monofilling scrap tires is environmentally sound, the belief that these tires will be readily available for the market place at some time the future is questionable. One problem is that the dirt used to cover every lift of monofilled tires (a lift is equal to some measurement of height, i.e., 10 feet) will contaminate the processed tires, and render them inappropriate as feed stock for ground rubber production (Also see the discussion on stock piled scrap tires). It is also likely that economic factors would limit retrieval of monfilled tires for either civil engineering or fuel uses.

In addition, monofilled processed scrap tires will have to compete with both the annually generated scrap tires plus any tires that are made available to the market from tire pile abatement programs. Typically, abatement tires are subsidized by state scrap tire project funds, which gives abatement tires an economic advantage over monofilled tires, since monofills are usually operated as private ventures, and are not recipients of state funds.

Permitting of tire monofills must be carefully evaluated by state solid waste regulators. The presence of monofills, and landfills that still accept whole or processed scrap tires, tends to impact regional scrap tire flow. Typically, landfills and monofills should be the least cost, legal, disposal option available to the marketplace. Consequently, a significant quantity of scrap tires will be directed towards these facilities, and away from other market applications. The existence of monofills and landfills will restrict the development of other markets for scrap tires, and in the end, become the disposal option in that region.

Monofills, although they may be environmentally sound and economically viable, should not be considered as a market. No value is added to the processed tire, nor does the placement of tires into monofills have any engineering benefit.

1.1 GENERATION RATES FOR SCRAP TIRES

To remain consistent with the previous three market surveys, data concerning the weight of tires remains the same as described in the original report; that is, one "scrap tire" is equal to 20 pounds of tire-derived fuel, or 12 pounds of size-reduced rubber. This method of accounting for scrap tires also maintains consistency with the vast majority of other reports on scrap tires, in particular the market analysis done by the United States Environmental Protection Agency (USEPA).

As reported in earlier editions, this manner of tracking the number of scrap tires is limited in that it fails to indicate which of the various types of scrap tires generated -- passenger, light truck, heavy truck, off-road tires, etc. -- are being used. The rationale for maintaining this approach is three fold: first, it is consistent with all earlier studies; second, the use of a tire weight based reporting system (a.k.a. tire equivalents) would distort the size of the scrap tire situation; and finally, regardless of how anyone calculates the total number or weight of scrap tires, the main issue is the creation of markets for all the scrap tires generated. This report concludes that there were around 266 million scrap tires generated in 1996 in this country (refer to the section below for detail).

As it so happens, the majority of the scrap tires which have markets are the passenger, light truck and bias ply truck tires. The majority of the heavy truck tires, off-road tires and agricultural tires are only slowly coming into market applications. Consequently, while we are certainly pleased with the dramatic increases in scrap tire markets, we know there are still significant challenges that need to be addressed before the more difficult classes of scrap tires find their way into the marketplace.

In order to give an understanding of the differential between the percentage of the total number of scrap tires generated versus the weight of those tires, refer to the table below.

Table 1.1 Tire Generation/Weight Differential

Type of Tire	Percent of Units in the Market	Percentage of Total Weight
Passenger/Light Truck	84	65
Medium/Heavy Truck	15	20
All Other Tires	1	15

Scrap Tire Generation

One basic set of data needed to understand the scrap tire market is the measurement of the annual volume of scrap tires. How many tires are discarded annually, and how is that volume calculated? A basic assumption in making a scrap tire estimate is that there is one scrap tire discarded for each replacement tire sold. In addition, it is assumed that tires are also discarded when the vehicle on which they are mounted is discarded. Thus national estimates can be made based on the total volume of replacement tires sales, and the total volume of vehicles scrapped each year.

In practice, many worn tires that are removed from vehicles continue to be used as tires. There is an extensive market for used tires: tires that have been removed from a vehicle but are still sound and have adequate tread remaining to continue to provide service. In addition, many worn tire casings are retreaded each year and returned to service as tires. The retread market is especially strong in the medium truck market segment, tires that are used on over-the-road tractor trailers.

Some light truck retread markets are also expanding. With the used and retreaded tire markets, the assumption is that for each used or retreaded tire put into service, there is another tire which goes to the scrap pile. Ultimately, however, tires diverted to the used tire or retread market do end up in the scrap stream, and it is assumed there is a tire going to the scrap stream when the retreaded or reused tire is mounted. Thus, the replacement tire market figure remains the best estimate of the volume of discarded tires.

Table 1.2 Scrap Tire Generation :1996 (-in units)

Passenger replacement [1]	175,328,000
Light truck replacement [1]	27,605,000
Medium, wide base, heavy & large off-the-road [1]	11,139,000
Farm [1]	2,460,000
Tires from scrapped vehicles [2]	49,476,000
Total Scrapped Tires	266,008,000
U.S. Population	265,100,000
Rate of Scrappage	1.00 per person

[1] Figures from Tire Industry Facts 1996, Rubber Manufacturers Association (in preparation)

[2] Estimates based on four tires per scrapped vehicle. Vehicle estimates for 1994 from the Statistical Abstract of the United States, U.S. Department of Commerce.

1.2 Scrap Tire Stock Piles

All parties involved in scrap tire management understand that there are actually two separate but interrelated aspects to sound scrap tire management. The first aspect is dealing with the newly generated scrap tires, the 266 million or so new scrap tires created by the normal process of use of tires. The second problem is dealing with the legal and illegal stock piles of tires which are the residue of past (and some current) methods of handling scrap tires. One of the major issues in dealing with tire stock piles is the sheer size of the problem: how many scrap tires do we have stock piled across the country?

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

As reported in the 1994 market survey, there are considerably fewer stock piled scrap tires than were once reported. In 1994, it was estimated that the total national stock pile was 700 to 800 million scrap tires, based on counts provided by a substantial majority of states. That figure remains a good estimate, we believe. Many states are actively working to reduce tire stock piles and virtually all states have undertaken efforts to quantify the number of stock piled scrap tires. The table 1.4 represents the most recent information received from the states.

Table 1-3: State Estimates of Scrap Tire Stock Piles: 1996

State	Estimated, Reported Stock Piled Scrap Tires	Estimated Number of Stock Piles	Estimated Largest Stock Pile Size
Alabama	N/A	N/A	N/A
Alaska	N/A	N/A	N/A
Arizona	N/A	N/A	
Arkansas	3,000,000	50	200,000
California	42,000,000*	N/A	
Colorado	Unknown	Unknown	Unknown
Connecticut	6,000,000	N/A	Unknown
Delaware	2,000,000	16	1 million
Florida	5,000,000	50	4 million
Georgia	2,000,000	130	65,000
Hawaii	150,000*	N/A	Unknown
Idaho	250,000	3	100,000
Illinois	4,000,000	400	200,000
Indiana	15,000,000	80	6 - 8 million
Iowa	7,300,000	53	2.5 million
Kansas	2,513,000	N/A	Unknown
Kentucky	8,000,000	300	440,000
Louisiana	6,173,224	228	800,000
Maine	60,000,000	N/A	Unknown
Maryland	12,000,000	N/A	Unknown
Massachusetts	6,000,000	29	200,000
Michigan	25,000,000	200	6 million
Minnesota	100,000	N/A	Unknown
Mississippi	1,000,000	30	400,000
Missouri	4,700,000	200	1 million
Montana	500,000	2	300,000
Nebraska	1,600,000	23	1 million
Nevada	1,000,000	17	500,000
New Hampshire	1,125,000	Unknown	500,000
New Jersey	5,000,000	7	3 million
New Mexico	1,400,000	30	900,000
New York	30,000,000	130	6 million
North Carolina	1,000,000	93	20,000
North Dakota	635,000	Unknown	Unknown
Ohio	100,000,000	36	15-60 million

Oklahoma	1,900,000	63	1.5 million
Oregon	6,000,000	20	4 million
Pennsylvania	21,000,000	72	5 - 7 million
Rhode Island	33,000,000	10	7 million
South Carolina	5,700,000	108	300,000
South Dakota	2,000,000	12	1,000,000
Tennessee	Unknown	Unknown	Unknown
Texas	84,647,000	18	21 million
Utah	500,000	15	Unknown
Vermont	Unknown	Unknown	100,000
Virginia	14,000,000	700	4 million
Washington	18,000,000*	N/A	Unknown
West Virginia	6,800,000	100	40,000
Wisconsin	1,000,000	75	20,000
Wyoming	Unknown	Unknown	Unknown
TOTAL	*548,993,224*		

*** 1994 Data**

The results of 1996 STMC survey shows that for the 43 states that had inventory or estimates available, the total volume of stock pile tires is 548,993,224. If a tire-to-population ratio of these states is calculated, it computes to 2.75 tires per person. Applying this rate to the states without estimates, and adding this figure to the figure for states with estimates, the total number of stock pile tires would be 599,692,224.

To remain consistant with the 1994 report we will add a 25% factor to be conservative in the estimate. Consequently, the total estimated figures, as reported, would be 749,615,000 scrap tires in stock piles. The decrease from the estimated 1994 numbers are because of state abatement programs. Nevertheless we believe that for all intent and purposes, the estimate of 800,000,000 tires in stock piles remains valid. The one point of concern in reviewing these numbers is that some states have inordinately high stock pile numbers, reflecting a past (and present) history of being major disposal sites for multi-state areas.

There are two points that must not be lost when considering the number and fate of stock piled scrap tires: the viable market applications and the impact of stock pile abatement programs on the existing, or hoped for market infrastructure.

Market applications for stock piled scrap tires:

Tires in stock piles have the same characteristics as those scrap tires generated in the present year. One of the first mis-perceptions concerning these inventoried tires is what actually happens to them while in storage. There are concerns that the tires lose heating value, that they begin to decompose, that toxic elements are leached from the pile or that the tires emits potentially dangerous fumes. All of these allegations, theories or beliefs are unfounded. Tires are extremely stable products, and are not subject to any of these conditions.

What does occur in these piles is that water, dirt, and non-tire wastes collect in and on the pile. These "contaminants" do not change the chemical composition of the tire. What they do cause is a limit to the market applications for these tires. To the best of our knowledge, no scrap tires removed from long-standing, outdoor stock piles have ever been used as a feed source for ground rubber. The reason, as indicated, is that these tires can be quite dirty. This dirt has two negative impacts: it increases the wear on processing equipment and will "contaminate" any ground rubber generated. A ground rubber high in non-rubber material is typically not a valuable commodity. Washing the tires is impractical, since it would add to the cost of processing and create a secondary waste disposal problem; the dirty waste water.

The impact of stock pile abatement programs on the existing market infrastructure.

From the inception of the STMC, it has been our belief that the most effective manner to address the scrap tire issue is first to develop markets for the annual flow of scrap tires. Once there is sufficient market demand for these tires, then attention should be placed on stock pile abatement programs.

The rationale for this recommended approach is simple. If scrap tires are removed from stock piles and sent into the existing market, they will supplant the newly generated scrap tire. Consequently there is a zero net gain in the total of scrap tires going to markets. Furthermore, the new scrap tires will end up going to a non-market disposal option; in certain cases, that would be to a stock pile.

We recognize that this approach of favoring markets for new generation scrap tires will not always be acceptable, especially where there has been a history of fires in a stock pile, or where there is the threat of a fire in a stock pile located in an environmentally sensitive area.

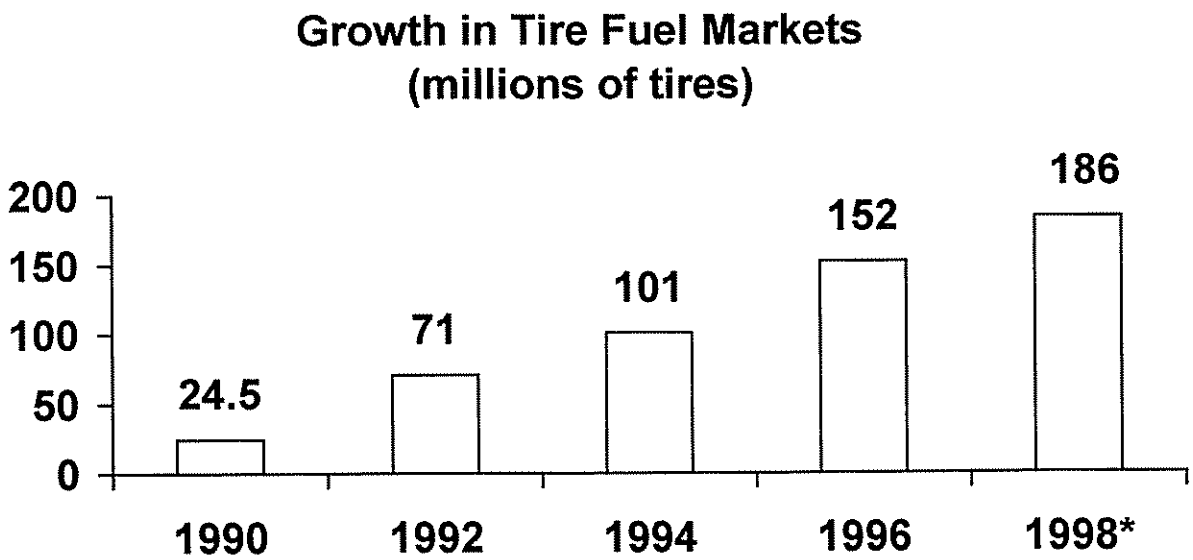
Some states have made substantial progress in abating scrap tire stock piles, including Illinois, Wisconsin, Minnesota, Maryland, Florida and Virginia, and Oregon among others. Some of these states, including Illinois, Maryland and Florida, have had success in feeding these stock piled tires into the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

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

2.0 MARKETS FOR SCRAP TIRES

This section provides a status report on the various market applications for scrap tires. Overall, the information obtained during our market survey suggests that there continues to be three major markets for scrap tires -- tire-derived fuel (TDF), products that contain recyclable rubber, and civil engineering applications. There are three lesser uses for scrap tires, export, agricultural and other miscellaneous uses which do not fall into the preceding five market areas. Finally, this report offers an analysis of pyrolysis, which does not appear to be making a contribution to the markets for scrap tires.

2.1 TIRE DERIVED FUEL



***estimated**

Since 1985, TDF has been the largest single market segment for scrap tires in the United States. From 1994 to 1996 TDF continued its upward trend, increasing from 101 million units annually to 152.5 million units annually, a 51 percent increase. There are nine specific components to the TDF market; cement kilns, pulp and paper mill boilers, utility boilers, industrial boilers, dedicated scrap tire to energy facilities, resource recovery facilities, copper smelters, iron cupola foundries, and lime kilns. Each one of these combustion technologies has its own set of engineering considerations and fuel requirements. This report will not review the technical issues for each of the combustion technologies. Information on this topic was reported in the 1990 and 1992 Market surveys, which can be obtained from the STMC.

In general, there are two methods of using tires as fuel; whole tires and processed tire-derived fuel. Whole tires are used in two combustion technologies; cement kilns and dedicated scrap tire to energy facilities. Approximately 60 percent of the tires going to cement kilns are whole tires. This occurs for three reasons: first, the configuration of the combustion technology can accept whole tires; second, whole tires are easier to handle than processed TDF; and third, the facility which accepts whole tires also receives a tip fee. There are two dedicated scrap tire to energy facilities, one only accepts whole tires, the other can accept both whole or processed tires. The rationale for accepting whole tires in these facilities is virtually the same as for kilns. Another combustion technology that can accept whole tires is wet bottom boilers; however, none are currently using TDF

The trend in processed tire derived fuel [normally referred to as TDF; however, for the balance of this report TDF will mean all tire fuel use] is towards a more refined fuel chip. With advances in processing technology, a one and one half inch minus chip, with 95+ percent of all steel removed is becoming the industry standard. While no official standards exist yet, this size fuel chip appears to be at the edge of the cost-revenue spectrum. This is to suggest that while the production of this size fuel chip is relatively more expensive than larger fuel chips, the return on investment is greater for the smaller sized fuel chip than the larger chip. Moreover, certain types of combustion technologies are only capable of using the one and one half inch chip (i.e., cyclone boilers).

Increasing TDF use can be traced to three factors. The first is that TDF has been used successfully in a wide array of end use markets that are both environmentally sound and cost efficient. This means that the use of TDF has not caused a facility to exceed its permitted air or other emissions limits. Furthermore, the use of TDF has been demonstrated to be economically competitive, offering a clear incentive to the end user.

The second factor, based in part on the first, is the development of an efficient private sector supporting the scrap tire industry. More well established firms are operating in this industry, and advances in processing technology are taking place. These technical improvements are employed to produce a more refined fuel chip, allowing for easier handling and more complete combustion.

While the private sector has grown, it is not risk free. Quite the contrary. There is considerable turmoil in the industry. There is still a significant failure rate among start-up companies, and even established companies have experienced serious financial difficulties. Anyone interested in entering into this market place should proceed with the utmost care and research prior to making any type of financial investment.

The third factor that has contributed to the growth of the TDF markets has been the efforts of certain state scrap tire program managers. There are some states that have been actively developing markets (Texas, Maryland, Virginia, Illinois, to mention a few of the more successful). The efforts of dedicated state employees can have a significant impact on the number of facilities using tire-derived materials.

The markets for all forms of TDF have continually increased in the period of 1985-1996, and the STMC is projecting continued increases in this market segment. While the TDF market has clearly demonstrated the ability to operate in an environmentally sound and cost efficient manner, there are several issues could adversely impact this market.

Regulatory Issues

Before discussing the specifics of the various TDF markets, a review of the state and Federal regulation on the use of TDF is in order. Many states have established permitting requirements specifically for facilities using tires or TDF. In addition, any facility using tires as fuel must operate within established air emission standards. All combustion facilities using TDF have gone through this process. Moreover, no facility using TDF has exceeded its air emissions limits due to the use of TDF.

Currently, TDF is considered a fuel by the US EPA [see Section 129 of the Clean Air Act]. As part of its continuing implementation of the Clean Air Act Amendments (CAAA) of 1991, the US EPA will be promulgating at least two new standards that may impact the use of TDF.

The first of these standards is a new program to develop emissions limits for the combustion of solid waste, a category that includes scrap tires. The US EPA must promulgate these new standards by September 2000. The US EPA has established a coordination committee and various working groups to develop a wide range of industrial combustion standards, including the solid waste standards. Committee members representing diverse industry, environmental and public viewpoints will assist the US EPA develop the standards. Apparently the growing use of tires as fuel will be of particular interest in this process. It is understood that scrap tires have been identified, along with creosote treated wood, as one of the two priority issues for this process. All parties with an interest in TDF will want to keep informed and participate in this rule making process.

It is understood that US EPA will be surveying a wide range of combustion facilities to develop information for this process. It is to be hoped that the agency will also make use of the substantial body of data has been developed in many states as a result of the growing use of TDF.

The second issue that could potentially impact the use TDF could be the proposed US EPA emission standards on particulate material emission limits, known as PM 2.5. These proposed standards are not specifically designed for TDF users, but for all combustion processes. As of the time this report is being prepared, there is a significant level of concern and opposition by the industrial sector about these proposed emission limits. Currently, the time table for promulgating these standards has not been determined, and the testing protocol for testing has not been established. Consequently, we can only raise the concerns and ask the questions about the potential impacts of these issues. The one point that must be recognized is that either or both of these proposals could have definite and long-term impacts on the use of TDF.

2.1.1 Scrap Tire Fuel in Cement Kilns

The use of scrap tires as a supplemental fuel in cement kilns continues to be a dynamic market. At the time of this printing, 35 cement kilns are using TDF, an increase of nine kilns from 1994. There are another 20 kilns that are in some phase of the permitting process, and could be using

TDF within the next 2 years. The outlook, once again, suggests that the use of TDF as a supplemental fuel will very likely continue to increase

Kilns currently using scrap tires have individual permitted volume capacities ranging from 250,000 to three million scrap tires per year. The driving forces behind the current and anticipated use of TDF have remained constant. These factors are:

- Improved emissions;
- Increased production; and
- Decreased fuel costs.

The principal impediments to the further use of tires as a supplemental fuel in U.S. cement kilns have also remained constant. These factors are:

- Delays due to difficulty in obtaining a permit or modified permit from the state regulatory agency;
- Kilns operating at full capacity;
- Reliability of tire/TDF supply in isolated areas;
- Local opposition to tire combustion; and
- The use of competing supplemental fuels such as solvents and hazardous waste.

There is one new factor that has had an impact on the TDF market. In certain cases, the demand for scrap tires exceeds the supply. Consequently, two conditions arise. First, the tip fee for scrap tires is reduced; second, some facilitates have not been able to secure an adequate supply, and have had to delay their implementation programs. Although these conditions are the exception and not the rule, they also are the end results of a well developed market, and should be considered as the ultimate goal of any scrap tire program.

Volume Characteristics

The following is an estimate of the potential usage of scrap tires by the U.S. cement industry:

- Current Usage: 45.5 million scrap tires per year
- Current Permitted Capacity: 47 million scrap tires per year
- Within Two Years: 58 million scrap tires per year
- Within Five Years: 70 million scrap tires per year

Table 2.1 Cement Kilns Using TDF

Company	Location	Kiln Type
Allentown Cement	Blanton, PA	Long wet
Ashgrove Cement	Durkee, OR	Preheater
Ashgrove Cement	Inkom, ID	Long dry
Ashgrove Cement	Leamington, UT	Preheater
Ashgrove Cement	Seattle, WA	Preheater
Blue Circle Cement	Harleyville, SC	Preheater
Calaveras Cement	Redding, CA	Preheater
California Portland Cement	Tucson, AZ	Preheater
Capitol Aggregates	San Antonio, TX	Long wet
Essroc Cement	Frederick, MD	Long wet
Florida Crushed Stone	Brooksville, FL	Preheater
Holnam Cement	Clarksville, MO	Long straight
Holnam Cement	Devil's Slide, UT	Long wet
Holnam Cement	Mason City, IA	Long wet
Holnam Box Crow Cement	Midlothian, TX	Ph/precalciner
Holnam Cement	Portland, CO	Long wet
Holnam Cement	Seattle, WA	Long wet
Holnam Cement	Theodore, AL	Ph/precalciner
Illinois Cement	LaSalle, IL	Ph/precalciner
Independent Cement	Hagerstown, MD	Long wet
LaFarge Cement	Davenport, IA	Ph/precalciner
LaFarge Cement	Whitehall, PA	Preheater
Lehigh Portland Cement	Leeds, AL	Preheater
Lehigh Portland Cement	Union Bridge, MD	Long straight
Lone Star Cement	Cape Girardeau, MO	Ph/precalciner
Lone Star Cement	Oglesby, IL	Long wet
Lone Star Cement	Pryor, OK	Long wet
Medusa Cement	Clinchfield, GA	Ph/precalciner
Mitsubishi Cement	Lucerne, CA	Ph/precalciner
Monarch Cement	Humboldt, KA	Preheater
North Texas Cement	Midlothian, TX	Long wet
Signal Mountain Cement	Chattanooga, TN	mid-kiln
Riverside Cement	Diamond Bar, CA	Heat exchange
Texas Industries	Hunter, TX	Preheater
Texas Lehigh	Buda, TX	Preheater

Table 2.2 Cement Kilns That Could Use TDF

Company	Location	Kiln Type
Alamo Cement	San Antonio, TX	Ph & Long wet
Ashgrove Cement	Forman, AR	Long dry
Ashgrove Cement	Leamington, UT	Ph/precalciner
Ashgrove Cement	Louisville, NE	Ph & Long wet
Blue Circle Cement	Atlanta, GA	Long wet
Blue Circle Cement	Ravena, NY	Long wet
Blue Circle Cement	Tulsa, OK	Long wet
California Portland	Colton, CA	Long wet
California Portland	Mojave, CA	Preheater
Capitol Cement	Martinsburg, WV	Long dry
Cementos Mexicanos	New Braunfels, TX	Ph/Precalciner
Dacotah Cement	Rapid City, SD	Preheater
Dragon Products Company	ME	Long wet
Essroc Cement	Bessemer, PA	Long wet
Essroc Cement	Speed, IN	Ph & long wet
Glens Falls Cement	Glens Falls, NY	Preheater
Hawaiian Cement	Honolulu, HI	Preheater
Holnam Cement	Ada, OK	Long dry
Holnam Cement	Dundee, MI	Long wet
Holnam Cement	Santee, SC	Long wet
Holnam Cement	Midlothian, TX	Ph/precalciner
Holnam Cement	Artesia, MS	Long wet
Hercules Cement	Stockerton, PA	Ph & Long wet
Independent Cement	Catskill, NY	Long wet
Kaiser Cement	Permanente, CA	Preheater
LaFarge Cement	Davenport, IA	Ph/precalciner
LaFarge Cement	Alpena, MI	Long dry
LaFarge Cement	Grand Chain, IL	Long wet
Lehigh Portland Cement	Mason City, IA	Preheater
Lehigh Portland Cement	Mitchell, IN	long wet
Lone Star Industries	Marylea, TX	Long wet
Lone Star Cement	Pryor, OK	Long wet
Medusa Cement	Charlevoix, MI	Preheater
Medusa Cement	Demopolis, AL	Preheater
Medusa Cement	Wampum, PA	Long wet
Mountain Cement	Laramine, WY	Long wet
National Cement	Ragland, AL	Preheater
Nevada Cement	Fernly, NV	Long wet
Rinker Cement	Miami, FL	Long wet

Rio Grande Cement	Tijeras, NM	Long dry
River Cement	Festus, MO	Long wet
Southdown Inc.	Brooksville, FL	Preheater
Southdown Inc.	Louisville, KY	Preheater
Southdown Inc.	Lyons, CO	Preheater
Southdown Inc.	Fairborn, OH	Preheater
Southdown Inc.	Neville Island, PA	Long wet
Southdown Inc.	Odessa, TX	Ph & Long wet
Southdown Inc.	Victorville, CA	Ph & Long wet

NOTE: MANY OF THESE KILNS HAVE USED TIRES IN THE PAST, OR ARE PRESENTLY IN THE TESTING OR PERMITTING PROCESS.

2.1.2 SCRAP TIRE FUEL IN LIME KILNS

The use of scrap tires as a supplemental fuel in lime kilns is a new market niche for TDF. In 1994, no lime kilns were using TDF. Lime kilns, like their cousins, cement kilns, are an energy intensive process. The high level of heating value in TDF is clearly of interest to this industry. The differences between lime kilns and cement kilns is that the lime kiln is shorter in length and often produces a different color end product. Some commercial lime must be white, while cement is usually gray. The use of TDF in lime kilns, under certain circumstances, can darken the product. If the color of the lime is a critical element for its sale, the use of TDF will be not be possible

At the present time, one lime kiln is using TDF on a production basis, and consumes around 10,000 tons of TDF annually, or around 1 million tires. Three other lime kilns are currently testing TDF or are in the permitting process.

TABLE 2.3: LIME KILN TDF ACTIVITY

Kiln using TDF	
Chemical Lime Company	**Grantsville UT**
Kilns in permitting or Testing	
Dravo	**Mays, KY**
Redland Ohio Inc.	**Woodville, OH**
Redland Ohio Inc.	**Millersville, OH**

2.1.3 SCRAP TIRE FUEL IN PULP AND PAPER MILL BOILERS

Tire-derived fuel can be used as supplemental fuel in pulp and paper mill boilers. The technology is proven and has been in continuous use in the U.S. since the early 1980's. Consumption of TDF in the U.S. pulp and paper mills has almost tripled since the mid-1980's to approximately 35 million tires per year. There are currently 23 mills known to be using TDF on a continuous basis.

Thirty two additional mills, with a combined potential capacity to consume approximately 40 million tires per year, could begin using TDF on a continuous basis within the next two years.

Environmental constraints associated with the use of TDF vary widely depending on facility characteristics (e.g., type, age, pollution control equipment, etc.) and the local regulatory climate. In general, intervieWI with mill managers and environmental professionals indicate that permitting processes have become less complicated as access to air emissions data has increased, however, the permitting process remains an impediment.

The main reasons given for the use of TDF in pulp and paper mill boilers continue to be:

- Decreasing the cost of fuel;
- Improving emissions; and
- Improved combustion efficiency.

The principal impediments to the further use of TDF in the U.S. pulp and paper industry continue to be:

- Marginal cost advantage of TDF over typical mill fuels (coal, purchased hog fuel);
- Environmental permit modification requirements; inconsistent regulatory guidance;
- Remote location of many mills (higher transportation costs);
- Reluctance of state officials to accept out of state emission and TDF characterization data;
- Reliability of TDF supply in remote locations;
- Variable quality in some fuel chips; and;
- Facilities with wet scrubbers must contend with elevated zinc levels in their effluent;

The following is an estimate of the potential usage of scrap tires by the U.S. pulp and paper industry:

- Current Usage: 35 million scrap tires per year
- Within Two Years: 39 million scrap tires per year
- Within Five Years: 42 million scrap tires per year

Table 2.3 Pulp and Paper Mills Using TDF

Boise Cascade	Calhoun, TN
Boise Cascade	Rumsford, ME
Bowater	Catawba, SC
Champion International	Bucksport, ME
Champion International	Hamilton, OH
Champion International	Shelton, TX
Ft. Howard	Bowater, GA
Ft. Howard	Green Bay, WI
Ft. Howard	Ricon, GA
Georgia Pacific	Brunswick, GA
Georgia Pacific	Crosett, AR
Georgia Pacific	Cedar Springs. GA
Georgia Pacific	Cedar Springs, VA
Georgia Pacific	Big Island, VA
Inland Container	Rome, GA
International Paper	Kaukauna, WI
Jefferson Smurfit	Newbury, OR
MacMillan Blodel	Montgomery, AL
Mead Paper	Escanaba, MI
Packaging Corporation of America	Tomahawk, WI
Simpson Timber	Shelton, WA
Southeast Paper	Dublin, GA
Union Camp	Prattville, AL

Table 2.4 Pulp & Paper Mills That Could Use TDF

Bear Island	Ashland, VA
Boise Cascade	DeRidder, LA
Boise Cascade	Wallula, WA
Bowater	East Millenocket, ME
Champion International	Sartell, MN
Chesapeake	West Point, WV
Georgia Pacific	Ashdown, AR
Georgia Pacific	Montecello, MS
Georgia Pacific	New Augusta, MS
Georgia Pacific	Port Edwards, WI
Georgia Pacific	Billingham, WA
Georgia Pacific	Toledo, OR

Grace Harbor Paper	Aberdeen, WA
James River	Clatskanie, OR
James River	Camus, WA
Jefferson Smurfit	Newbery, OR
Inland	Orange, TX
International Paper	Lockhaven, PA
Louisiana Pacific	Somoa, CA
Overland Corporation	Ashville, VA
Packaging Corporation of America	Counce, TN
P.H. Glatfelter	Spring Grove, PA
Potlatch	Lewiston, ID
S.D. Warren	Skowhegan, ME
S.D. Warren	Westbrook, ME
Scott Paper	Everett, WA
Stone Container	Hopewell, VA
Union Camp	Franklyn, VA
Westvaco	Covington, VA
Weyerhaeuser	Plymouth, NC
Willemette	Albany, OR
Willemette	Camped, LA

2.1.4 Scrap Tire Fuel in Electricity Generating Facilities

This section will discuss the use of TDB in various types of electrical generating facilities and industrial boilers, except dedicated scrap tire to energy facilities. Overall, there are three types of facilities covered: large-scale utility boilers, industrial boilers, and resource recovery facilities. Overall, the use of TDB in the combined market segment typically is as a supplemental fuel, not exceeding 10 percent of the total fuel mix.

***Utility Boilers*:** In the utility market, the use of TDB in wet bottom, cyclone, stoker, and fluidized bed boilers is proven. Our survey indicates that 15 utility power plants use TDF. Three utilities are close to starting up on TDF and another three utilities are seriously considering TDF.

Industrial Boilers: Thirty industrial power plants are currently using TDF. While TDF has not demonstrated any adverse affects on these facilities, we are aware of only four companies with industrial boilers seriously considering the use of TDF.

Resource Recovery Facilities: In 1996, the STMC completed a survey of the municipal resource recovery facilities, (RRFs). The results indicated that there are 13 RRFs currently using TDF on a continuous basis. The facilities listed below are the larger-scale end users of TDF. Many facilities indicated that they did use TDF, although the rate of usage was in the 1 - 2 percent range. Most of these facilities also requested that their names not be divulged.

The increase in the use of TDF in RRFs can be attributed to two factors: the demise of flow control and increased participation in recycling programs. Although the use of TDF in RRFs is still limited to a range of two to five percent of their fuel mix, more RRFs are allowing scrap tires to be fed into their systems. Considering that there are more than 110 RRFs in the US, even the use of TDF in limited amounts can result in a significant market niche.

The benefits derived from the use of TDF in these combined markets continues to be:

- Decreased fuel costs;
- Mass balance & energy source;
- Improved emissions; and
- Improved combustion efficiencies.

The principle barriers to the further use of scrap tire material in electricity generating facilities are:

- Marginal cost advantage of scrap tire material over competing fuels;
- Environmental permit modification requirements; inconsistent regulatory guidance in some states;
- Conservative/risk adverse nature of a particular industry;
- Inability for blending fuel (TDF becomes uneconomical viable when pulverized coal is the main fuel source);
- Limits of ash handling systems; and
- Variable quality of some TDF.

Volume Characteristics

The following is an estimate of the potential usage of scrap tires in the combined market is:

- Current Usage: 46 million scrap tires scrap tires per year
- Within Two Years: 71 million scrap tires per year
- Within Five Years: 85 million scrap tires per year

TABLE 2.5 UTILITY BOILERS USING TDF

Atlantic Electric	Cape May, NJ
Illinois Power	Baldwin, IL
Maine Energy Recovery	Biddeford, ME
Montana- Dakota Utilities	Mandan, ND
New York State Electric & Gas	Bainbridge, NY
Northern States Power	Ashland, WI
Otter Tail Utilities	Big Stone, SD
Penobscot Energy Recovery	Orrington, ME
Sheboygan Edgewater	Sheboygan, WI
Tampa Electric	Tampa, FL
Tennessee Valley Authority	Memphis, TN
Union Electric	Portage Des Sioux, MO
Wheelabrator Ridge Energy	Polk County, FL
Wisconsin Power & Light	Beloit, WI
Wisconsin Power & Light	Cassville, WI

TABLE 2.7 UTILITY BOILERS THAT COULD USE TDF

Chillocothe Municipal Utility	Chillocothe, MO
Commonwealth Edison	Springfield, IL
Iowa Power	Cedar Rapids, IA
Manitowac Public Utility	Manitowac, WI
Missouri Public Service	Kansas City, MO
Nebraska Power	Shelton, NE
New York State Electric & Gas	East Corning, NY
NIPSO	Hammond, IN
Northern States Power	Stillwater, MN
Ohio Edison	Niles, OH
Ohio Edison	Shadeyville, OH
Texas-New Mexico Power	Bremond, TX
Traverse City Light & Power	Traverse City, MI
Wisconsin Power & Light	Green Bay, WI

TABLE 2.6 INDUSTRIAL BOILERS USING TDF

A.E.S.	Barbers Point, HI	Industrial Boiler
Archer Daniels Midland	Decatur, IL	Industrial Boiler
Camden Resource Center	Camden, NJ	Resource Recovery Facility

Caterpiller	Decatur, IL	Industrial Boiler
DuPont	Parkersville, WV	Industrial Boiler
Elemendorf USA Base	Anchorage, AK	Industrial Boiler
Fairfax County Resource Recovery Facility	Lorton, VA	Resource Recovery Facility
Firestone Tire	Decatur, IL	Industrial Boiler
Grain Processors Corp.	Muscatine, IA	Industrial Boiler
Harrisburg Resource Recovery Facility	Harrisburg, PA	Resource Recovery Facility
Hartford County Resource Recovery	Aberdeen, MD	Resource Recovery Facility
Iowa State University	Ames, IA	Industrial Boiler
John Deere	East Moline, IL	Industrial Boiler
Lee County Waste-to-Energy Facility	Fort Myers, FL	Resource Recovery Facility
LFC Power Systems	Hilman, MI	Wood Fired Industrial Boiler
Maine Energy Recovery	Biddeford, ME	Resource Recovery Facility
Mead Johnson	Hindsdale, IL	Industrial Boiler
Monsanto	Sauget, IL	Industrial Boiler
Montenay Power Corporation	Miami, FL	Industrial Boiler
Norfolk Waste-to-Energy Plant	Norfolk, VA	Resource Recovery Facility
Okeelanta Power	Okeelanta, FL	Industrial Boiler
Osceola Power	Osceola, FL	Industrial Boiler
Palm Beach County	West Palm Beach, FL	Resource Recovery Facility
Penobscot Energy Recovery	Orrington, ME	Resource Recovery Facility
Regional Waste Systems	Portland, ME	Resource Recovery Facility
Savannah Energy Systems	Savannah, GA	Resource Recovery Facility
Semass Resource Recovery	Rocester, MA	Resource Recovery System
South Eastern Public Service Authority	Norfolk, VA	Resource Recovery Facility
Waste Energy Partners	Joppa, MD	Industrial Boiler
York Waste-to Energy Plant	York, PA	Resource Recovery Facility

TABLE 2.8 INDUSTRIAL BOILERS THAT CAN USE TDF

Air Products, Inc	Edenburg, PA	Industrial Boiler
Alcoa	Rockdale, TX	Industrial Boiler
Cargill	Eddyville, IA	Industrial Boiler
Chrysler Corporation	Fenton, MO	Industrial Boiler
CMS Hydro Company	Imperial, CA	Industrial Boiler
Dow Corning	Midland, MI	Industrial Boiler

Eastman Chemical	Kingsport, TN	Industrial Boiler
Eastman Kodak	Rochester, NY	Industrial Boiler
John Deere	Waterloo, IA	Industrial Boiler
Panther Creek Partners	Nesquehoing, PA	Industrial Boiler
UDG/SEI	Niagara Falls, NY	Industrial Boiler
University of Iowa	Iowa City, IA	Industrial Boiler
University of Missouri	Columbia, MO	Industrial Boiler
Utilities Management Corporation	Evansville, IN	Industrial Boiler

2.1.5 Scrap Tire Fuel in Other Industrial Applications

Since the 1994 report, in addition to the lime kiln market discussed earlier, there are two other new types of combustion facilities that have begun, or will soon begin, using TDF: iron cupola foundries and copper smelters. While these new TDF markets currently only involve a few facilities, they do represent a significant potential end-use market.

***Iron Cupola Foundries*:** Presently, there is only one cupola foundry using TDF and one other investigating TDF as a replacement for petroleum coke. On average, TDF can replace up to 20 percent of a cupola's petroleum coke. Considering that there are some 157 cupola foundries in the U.S., there is a tremendous potential market for this segment. While potential abounds, it must be kept in mind that the use of TDF in additional facilities will be a function of the experience of the one cupola using TDF.

***Copper Smelters*:** This is another new TDF market niche. Copper smelters, like iron foundries, use large-amounts of energy in their manufacturing process. Once again, the characteristics of TDF are attractive to this combustion technology. Given the specialized nature of this technology, it is uncertain how significant a market segment this combustion technology can be.

Table 2.9 Other Industrial Facilities

Using TDF		
ASRACO	El Paso, TX	Copper Smelt
Lufkin Industries	Lufkin, TX	Cupola
Testing TDF		
Dalton Foundry	HAMMOND,IN	Cupola

2.1.6 Scrap Tire Fuel in Dedicated Tire-To-Energy Facilities

There has been one change in this market sector since the 1994 market survey. The Chewton Glen facility built in Ford Heights, IL (outside Chicago) has filed for bankruptcy and is shut down. This project did not fail because of the failure of the combustion technology, the availability of scrap tires nor the failure to comply with emission standards. Rather, the facility was closed due to a change in the Illinois Retail Rate law that provided subsidized power rates for certain facilities, including Chewton Glen, using solid waste as fuel to generate electricity. In April 1996, the Governor of Illinois signed a bill eliminating the retail rate provision. This made the operation the Chewton Glen facility not economically viable. The result was the Chapter 11 filing.

The operators has sued the state, but the Illinois courts so far have upheld the state's elimination of the subsidized rates. Chewton Glen was not the only facility affected by the repeal, but as yet no financial settlement for any losses sustained by the repeal has been offered. At this point it appears the Chewton Glen facility will not be able to open, nor is it likely to be converted into any other type of tire combustion facility.

The development of any other large-scale, dedicated scrap tire-to-energy facility appears to be unlikely due to the pending deregulation of the utility industry. Deregulation will result in downward pressure on rates utilities pay for electricity, and will be especially hard for facilities using alternative fuel sources that have traditionally enjoyed preferential rate treatment.

Deregulation also affects the Modesto Energy Limited Partnership, located in Westley, California, which currently receives above market rates for its electricity. Its preferential contract runs out at the end of 1997, and it is an open question whether it will remain in operation. For future projections, we anticipate that the Modesto facility will be adversely affected by the loss of its preferential power rate. It is also apparent that there will not be any other dedicated scrap tire to energy projects started within the foreseeable future.

Volume Characteristics

The following is an estimate of the potential usage of scrap tires by U.S. dedicated tire-to-energy facilities:

- Current Usage: 15 million scrap tires per year
- Within Two Years: 10 million scrap tires per year
- Within Five Years: 10 million scrap tires per year

Table 2.9 Dedicated Scrap Tire-to-Energy Facilities

Facility	Location	Status
Exeter Energy Limited Partnership	Sterling, Connecticut	Consumes 10 million scrap tires annually
Modesto Energy LP	Westley, CA	Consumes 5 million whole tires annually

2.2 USE OF SIZE-REDUCED RUBBER

The market for size reduced rubber continues to grow, although the last two years have seen both positive and negative developments in the last two years. On the negative side, the Federal mandate to use rubber modified asphalt in federal aided highway construction was repealed, significantly reducing a major potential ground rubber market. On the positive side, a number of new applications for ground rubber have been developed and several other uses have been expanded. In addition, the automotive industry, one of the largest markets for new rubber products, has expressed its desire to see recycled rubber used as an ingredient in the new rubber parts it purchases. While it may be a few years before many parts containing a significant amount of recycled rubber are actually installed in new cars, the rubber parts industry is currently developing and testing new products using ground rubber. This market has also seen an influx of new producers, greatly increasing the potential material supply. Unfortunately, the supply capacity continues to exceed the market demand, placing some pressure on prices.

The overall market demand for size-reduced rubber was around 400 million pounds at the end of 1996. This compares with the 1992 market of 160 million pounds of size-reduced scrap tire rubber and the 1994 market volume of 240 million pounds. While the increase is substantial, this market segment is not without its impediments.

There are two sources for tire derived size-reduced rubber: tire buffings and processed, whole scrap tires. Of the total market volume of 400 million pounds generated, about 210 million pounds, or 52 percent is obtained from tire buffings. The balance of 190 million pounds, or 48 percent, was obtained from whole scrap tires. As was earlier predicted, the major increase in market supply has come from whole scrap tire reduction. For the purposes of this report, we estimate that 12.5 million scrap tires are being reduced to ground rubber. No attempt is made to differentiate between buffing dust and scrap tire rubber in identifying markets, nor to differentiate between cryogenically produced or ambiently ground scrap tire rubber. Table 2.5 addresses total markets for all ground rubber, while the table of scrap tire markets (page 1) only includes scrap tires reduced to ground rubber.

The need to rely on scrap tires as the main source of increased capacity in this market is due to the finite supply of tire buffings. Buffings are a by-product from the retreading industry, and are created when a used tire is being prepared to accept new tread. The existing tread, and sometimes the shoulder and sidewall of a tire, are removed by a high speed buffer. The buffings, relatively long, tubular shaped particles, are collected, packed and sold to the producers of size-reduced rubber.

The estimated quantity of buffings available in the U.S. is 250 million pounds. It appears that this quantity will not increase since the number of tires retreaded annually has leveled off at approximately 30 to 33 million units. According to industry experts, the only likely growth potential for retreaded tires is in the utility and recreational tire market. Of the total 250 million pounds of tire buffings, 210 million pounds are currently sold into the size-reduced rubber market.

Standards

One of the most important recent developments for this market segment was the publication in late 1996 of two revised standards for ground rubber. Both standards were developed by Committee D11.26 of the American Society for Testing and Materials. The first standard, **D5603-96, Standard Classification for Rubber Compounding Materials - Recycled Vulcanizate Particulate Rubber**, provides a set of size standards for all types of particulate ground rubber. The second standard, **D5644-96, Standard Test Method for Rubber Compounding Materials - Determination of Particle Size Distribution of Recycled Vulcanizate Particulate Rubber**, provides a standard method for measuring particle size. The combined effect of these two standards, developed jointly by ground rubber producers and users, should be to greatly enhance the possibility that ground rubber can became a commodity material and be freely bought and sold in the marketplace. [The standards are available from ASTM, 100 Bar Harbor Dr., West Conshohocken, PA 19428]

Chicago Board of Trade

Another development that should enhance the ground rubber market is the inclusion of ground rubber and other tire derived materials on Recyclables Market Exchange that the Chicago Board of Trade operates on the World Wide Web. The Web address is http://www.cbot.recycle.com. The Exchange lists various recyclable materials, including paper, plastic, and glass, in addition to rubber, and allows buyers and sellers to meet electronically and conduct trades. Sellers can list they materials they have to offer, while buyers can either scan the list of materials being offered, or can post their own offers to purchase specific materials. At present, rubber materials are listed merely as a "bulletin board" in that materials are posted without specific standards for them and buyers and sellers make their own agreements. The CBOT hopes to develop standards and a related arbitration system, supported by competent testing laboratories, in order to provide a more regular trading system and a means to resolve trading disputes. It is hoped that the ASTM standards just published will be the basis for the CBOT standards and procedures.

Definitions:

One term often used to describe finely processed scrap tires is "crumb rubber". In the rubber industry, this is a specific term used to describe a particular form of virgin rubber, usually, but not always, natural rubber. The preferred terms for processed vulcanized rubber are those terms which have been accepted by the ASTM committee D11.26 (Terminology) and published in standard D 1566. The terms are as follows:

Particulate rubber: raw, uncured, compounded or vulcanized rubber that has been transformed by means of a mechanical size reduction process into a collection of particles, with or without a coating of a partitioning agent to prevent agglomeration during production, transportation, or storage.

Buffing rubber: particulate rubber produced as a by-product of the buffing operation in the carcass preparation stage of tire retreading; characterized by a wide range of particle sizes which are predominately elongated or aciculate in shape.

Granulated rubber: particulate rubber composed of mainly non-spherical particles that span a broad range of maximum particle dimension, from below 40 mesh (0.635 mm) to 0.47 inches (11.75 mm); the key feature of this type of particulate rubber is that the fraction of the material is greater than 0.08 inches (2 mm) up to 0.47 inches (11.75 mm) maximum particle dimension.

Ground rubber: particulate rubber composed of mainly non-spherical particles that span a range of maximum particle dimension, from below 40 mesh (0.635 mm) to 0.08 (2 mm) inches as a maximum "particle dimension".

Powdered rubber: particulate rubber composed of mainly non-spherical particles that have a maximum "particle dimension" equal to or below 40 mesh (0.635 mm).

Recycled vulcanizate particulate rubber: recycled vulcanizate rubber that has been processed to give particulates or other forms of different shapes, sizes, and size distributions (From D 5603 - 96).

2.2.1 Market Applications for Ground Scrap Tire Rubber

There are six general categories of markets for ground rubber. Market availability is a function of cost, product availability, product characteristics and substitute material availability. While all these factors deserve explanation, this survey will only give a general description of the markets.

Bound Rubber Products: Ground scrap tire rubber is formed into a set shape, usually held together by an adhesive material (typically urethane or epoxy). The rubber can also be mixed with another polymer before the adhesive is added. Bound rubber products include, but are not limited to carpet underlay; flooring material; dock bumpers; patio floor material; railroad crossing blocks, and roof walkway pads.

This market segment currently consumes an estimated 134 million pounds of recycled rubber, and is likely to increase by 10 percent in 1997. The major limiting factors in this market segment are: (1) competition from other recycled or virgin materials; and (2) the fact that tire rubber is vulcanized (bonding of the carbon atoms from rubber with sulfur). Since this bond can not be broken, no other polymer can chemically bond with the rubber.

New Tire Manufacturing: Powdered scrap tire rubber can be used as a low volume filler material in two components of a tire: the tread and sidewall. In addition, powdered rubber produced from inner tubes is used in the inner liner. In general, scrap tire rubber is limited to a maximum of one and one half percent of the tire (by weight). Powered rubber can be used in off-road tires, intermodal tires, bias ply truck tires and solid tires.

Currently, this market segment consumes 48 million pounds of recycled rubber annually. While there is no expected dramatic increase in the use of recycled scrap tire rubber in new tire manufacturing in the next few years, there is the possibility of a significant increase by 1999 or later.

One tire manufacturer, Michelin North America, has reported that it is developing a tire that will incorporate up to 10 percent recycled scrap tire rubber. Depending on the outcome of developmental testing to insure that the tire meets performance and durability requirements, this time might be available, according to the company, for installation on model year 2000 vehicles.

The problems that must be overcome in reusing scrap tire rubber in new tire construction, and what any tire manufacturer seeking to increase recycled content must deal with, are relatively well know. In the past, the use of recyclable ground scrap tire rubber in new tire construction resulted in higher hysteresis loss, heat build up and increased rolling resistance. High hysteresis loss returns less energy during stretching, flexing and compression. The unreturned energy is converted primarily into heat, which has a negative impact on the rolling resistance of a tire. Increased rolling resistance, in turn, causes increased friction between the tire and the driving surface, which increases traction and decreases fuel economy. With today's emphasis on longer lasting, more fuel efficient tires, adding recycled scrap tire rubber would normally be counter productive. Abrasion resistance has also been a reported problem, with resulting loss of tread ware.

Rubber Modified Asphalt (RMA): Ground rubber can be blended with asphalt to modify the properties of the asphalt in highway construction. Size-reduced scrap tire rubber can be used either as part of the asphalt rubber binder, seal coat, cape seal spray or joint and crack sealant (generally referred to as asphalt-rubber), or as an aggregate substitution (rubber modified asphalt concrete, or RUMAC).

Repeal of ISTEA Mandate

One of the major hopes for the development of a major ground rubber market was the enactment of Section 1038(d) of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). This provision would have required all states to begin using rubber modified asphalt for a specified portion of their asphalt paving beginning in 1994, with the requirement increasing each year until 1997, when 20 percent of all federally aided asphalt paving would have had to contain a specified volume of rubber. When originally enacted, it was calculated that by 1997, this requirement would have utilized the equivalent of 80 million tires in paving applications, or nearly 1 billion pounds of ground rubber. However, the provision generated major opposition from the asphalt paving community and from state highway administrators. In 1994 and 1995 riders to federal transportation appropriations legislation prevented funds from being spent to enforce the Section 1038(d) mandate. Ultimately the mandate was repealed as part of the Federal Highway Systems Act passed in late 1995. In its place was left an unfunded demonstration grant program.

During 1996, this market segment consumed around 168 million pounds of recycled rubber, mainly in states that have regularly utilized rubber modified asphalt. Since the repeal, the number of projects outside of these states has declined dramatically. Currently, the only states with any substantial asphalt rubber activity are Arizona, California, and Florida, with lesser activity in Kansas and Texas. In general, asphalt-rubber, or the "wet process," has proven to be the most successful product, representing approximately 95 percent of the RMA market.

Asphalt Rubber Research

The technical, environmental, and economic constraints associated with the use of scrap tire material in asphalt-paving applications have only moderately changed since 1992. The major issues with RMA are the lack of standard mix designs, continuing questions about its ability to be recycled, worker health and safety, and its cost. To address the worker safety issue, The Federal Highway Administration, (FHWA) has contracted with the National Institute of Occupational Safety and Health (NIOSH), to conduct research into the worker safety issues. NIOSH has conducted a series of field studies in several states and so far has found no major adverse health issues. The final report is expected soon. As for the recycling issue, several test were undertaken which revealed no difficulty recycling pavements containing rubber.

A multi-state cooperative research project was organized by the FHWA to conduct a comprehensive study of RMA performance and develop engineering guidelines and standardized application procedures. This is a 60 month study involving several engineering schools and research institutions, with a goal of providing detailed engineering criteria for use by all states. A separate major study of RMA is being conducted with federal funding at Texas A&M University. Its reports are also expected to shed additional light on RMA.

To a large extent, the acceptance of RMA by any state's department of transportation (DOT) will depend upon the results of these studies and their own field trials. Any large-scale increase in the use of RMA is dependent upon the state's DOT's acceptance of these test results and the willingness to begin their own state and local level programs. Even with some degree of acceptance by a DOT, the demand for size-reduced rubber will not explode over night. Rather, a more gradual increase over the next five years is expected.

One note for policy considerations. As stated earlier, the Scrap Tire Management Council believes that the use of scrap tire generated materials can provide benefit in a variety of applications. This is true for RMA as well. Having stated this, we see no benefit in forcing state DOTs to use RMA. RMA should be used where and when it can enhance or improve the performance of an asphalt pavement.

***Athletic and Recreational Applications*:** This market segment has been one of the fastest growing markets for ground rubber over the last two years. In 1996, some 24 million pounds of ground rubber was used in the wide array of products in this category. While the total poundage only equals six percent of the total ground rubber market, this total represents a 40 percent increase in its usage.

Examples of this market segment include, but are not limited to the use of rubber in running track material, in grass surfaced playing areas or for playground surfaces. Particulate rubber generally makes the playing surface and the running tracks more resilient and less rigid, while allowing the surface material to maintain traction and shape. One case in point is the running track at the White House which contains particulate rubber. Another example of this application is the use of particulate rubber as a soil additive combined with organic material in playing fields which are subject to soil compaction. The addition of this rubber-organic material compound has demonstrated the ability to allow grass to become better rooted, resulting in improved drainage and reduced hardening of the playing surface.

A new use that has emerged in the last two years is the use of ground rubber as a turf top dressing. Developed at Michigan State, this process is now patented as Crown Turf III. Ground rubber in a range of 4 to 10 mesh is applied to turf as a top dressing. The rubber granules fall through the grass leaves and remain on the soil surface. They will mound around the crown of the turf grass and will protect it from physical harm. In addition, it will insulate the grass plant and allow faster recovery in the spring. Principal applications to date have been in heavy wear areas of golf courses and on athletic fields.

The use of chipped tires as a loose laid playground cover has gained wide acceptance in the last two years. The use of chipped tires provides the highest level of shock attenuation of any competing material. The issues typically raised about the use as playground cover concern the toxicology of tire chips (what if a child swallows a piece), whether the chip will scuff clothes (black coloring) and whether there are any harmful emissions. To date, all test results have indicated that there are no adverse affects from the use of scrap tires in any of these applications. Tire chips have also been used in equestrian arenas where they provide a superior, non-compacting riding surface.

This market sector continues to have the potential to be a large growth area in the next several years. One of the more critical factors in this market's growth potential will be the school systems' budgets, since schools represent one of the largest potential markets.

Friction Material: Friction brake material uses particulate rubber in brake pads and brake shoes. This is a mature industry with little to no growth expected.

Molded & Extruded Plastics/Rubber: Particulate rubber can be added to other polymers (rubber or plastic) to extend or modify properties of thermoplastic polymeric materials. Examples of this application are injection molded products and extruded goods. There appears to be a significant market potential for this application due to the continuing research and development of products using a surface modified rubber.

Currently, 18 million pounds of particulate rubber is used in this market segment. There are indications that this market segment can increase considerably in 1997-1998, if certain technical restraints are overcome. While the market information suggests a significant potential market for molded and extruded co-polymeric products, there is not enough practical experience to suggest whether the inability to de-vulcanize rubber or other technical issues will impact the compounding and/or bonding ability of recycled rubber.

Automotive Parts As noted in the introduction to this section, the automotive industry has expressed strong interest in seeing rubber parts they purchase contain recycled content. Non-tire automotive rubber parts are the largest single rubber products market after tires. Every automobile contains literally hundreds of rubber based parts, from hose and belts, to weather-stripping, body and motor mounts, and tiny O-rings in fuel injectors. Already there are some parts containing recycled rubber that are being used as original equipment on new cars. With the automobile manufacturers asking for more recycled content, the rubber parts manufacturers are doing the testing and developmental work needed to incorporate recycled rubber without affecting the performance, durability or price of the part. Given the long lead time on qualifying new parts for installation as original equipment on new cars, it is unlikely that this application will result in any substantial ground rubber consumption much before the 2000 model year, if not later. Current consumption is limited to those few parts already qualified and being used, and to rubber parts manufacturers engaged in testing and development.

Volume Characteristics

While the overall consumption of size-reduced rubber in 1996 was 400 million pounds, the STMC is only tracking the use of size-reduced rubber from scrap tires. Table 2.5 presents the various market segments, the 1996 consumption of each market segment and projected market demand for 1997 and 1998. From that estimated total, the use of size-reduced rubber from scrap tires is:

- Current Usage: 12.5 million scrap tires per year
- Within Two Years: 18 - 25 million scrap tires per year
- Within Five Years: 27 - 40 million scrap tires per year

The overall increase in the use of scrap tire rubber will be a function of the quantity of tire buffings and increased market demand for RMA, athletic/recreational applications and molded/extruded products. The factors that serve to benefit this increased demand are:

- Ability to enhance properties and characteristics of polymeric compounds (molded-extruded & RMA);
- Lower cost additive (molded/extruded); and
- Provides enhanced safety and performance (athletic/recreational)

The factors which currently impede the increased use of size-reduced rubber include:

- The generally negative attitudes of most state highway departments toward rubber modified asphalt;
- Competition from other recycled materials (molded/extruded products);
- Budgetary limits (athletic/recreational applications); and
- Environmental concerns (i.e., leachate relating to athletic/recreational applications)

Table 2.5 Market Demand for Sized-Reduced Rubber (in million pounds)

	1995	1996	1998*
Pneumatic Tire	33.5	48	140
Friction Materials	7.5	8	8.5
M/E Rubber Products	14	18	524
Rubber/Plastic Bound Products	105	134	160
Athletic & Recreation	16	24	50
Asphalt Products	102	168	200
TOTAL	274	400	582.5

**estimated*

New Technologies: There are two new technologies that may have an impact on the ground rubber industry; surface modification and devulcanization. Both of them attempt to deal with a basic problem encountered when trying to incorporate ground rubber into new rubber compounds: ground rubber is not a chemically active material. The original process of vulcanization makes rubber a temperature stable material by making largely irreversible chemical and physical changes to it. When vulcanized rubber is ground up, it retains these properties. Therefore, ground rubber is not bound into a new compound by the same chemical and physical bonds as will affect the virgin materials. Rather, it will be bound into the new material largely by mechanical adhesion, which is a relatively weak bond, and will affect the physical properties of the final product.

Devulcanization is the reversal of the sulfur-carbon bonding that makes rubber a stable material. There are several companies that report having technologies that can reverse, at least in part, the carbon-sulfur bond, and there are several researchers working on this issue Some of the more imaginative research involves the use of ultrasonics to break the carbon-sulfur bonds. Another researcher advocates a shear extrusion process. Of all these companies, there is one that is close to, if not already, commercially generating and selling a de-vulcanized scrap tire rubber. This technology uses a proprietary chemical agent mixed in an open mill. While this technology could assist the growth of this market segment and would indeed be a great technological advance, there remain several critical questions.

Perhaps the most significant question is the quantity of scrap rubber that will be consumed through this process. It appears that, currently, the majority of rubber that will be processed through this de-vulcanization process will be factory, non-tire scrap (pre-consumer material). While the importance of this application should not be diminished, the issue, for the purposes of this report, is the impact this technology will have on scrap tire rubber. It appears that this technology will likely only have a minimal impact on the scrap tire rubber market, although there could be some trickle-down effect.

This conclusion as to the limited effect on scrap tire rubber also is based on the composition of the tire itself. Today's tire is a combination of several types of polymers (rubbers). Even if de-vulcanization was possible, the resulting material would be a combination of the 3 - 4 polymers used in a tire. Add in several other types of tires, all of which containing various polymers, and you have series of de-vulcanized polymers, none of which have the characteristics or qualities of a virgin material, hence no applicability for new tire manufacturing.

In order for this devulcanized material to be successful, it will have to be engineered into a rubber formula and tested. At this point, it appears that there have been some successes with de-vulcanized, non-tire rubber. Although this technology will require more actual applications before its ultimate value can be decided.

Surface modification is a process in which size reduced rubber is treated to make it more reactive in new compounds. By its name, there is no attempt to alter the vulcanized material. There are two basic surface modification technologies. The first is to coat the rubber with a bonding agent that will make it more chemically active in a new compound. The second is to treat the rubber particle with a caustic gas to "activate" the surface of the rubber, allowing the material to bond with other polymers, usually urethane.

With respect to the coating process, there are several companies marketing either a pretreated particles or the coating material to treat your own ground rubber. With respect to the gas treatment, there is one company marketing such treated rubber. In either case, the resultant materials are used with various virgin polymers to manufacture new products. The major benefit of surface modification is that it can reduce the final cost of a finished product as the treated ground is used with high value virgin materials to make a finished product at a lower material cost without affecting, or perhaps even improving, product performance.

Producer Issues

Of all the market segments for scrap tires, the interest in entering the ground rubber business continues at a high level. While potentially a lucrative business, the current ground rubber market is facing some very significant issues. First, there are some 200 companies across the United States that are either producing, or claim to have the capacity to produce, ground rubber. Despite this high total number of processors, less than a dozen companies generate and sell some 80-85 percent of ground rubber. Hence, the majority of companies must struggle to capture the relatively small remaining market share.

Even if the market demand for ground rubber would double, the impact on the industry would be minimal. Currently, many companies are operating at less than half their production capacity, which drives up costs. These increased production costs can not passed along because: (1) the market for recyclable rubber is not elastic; (2) ground rubber supply greatly exceeds demand; and (3) the market forces are placing a downward pressure on prices. The result of all these factors is that many of the marginal producers have been or will soon be forced out of business.

While the longer-term outlook for the ground rubber segment suggests a more stable market, there does not appear to be any overwhelming market or technological breakthrough that will radically alter the market dynamics in the short-term. The industry forecast is for continue and sustained growth, perhaps 10 to 25 percent annually. Furthermore, the larger. more established producers will continue to expand, while the marginal producers will likely be forced out of business. Even with this situation, there will probably continue to be new actors seeking to penetrate the production market. Finally, with the beginnings of a true market place for ground rubber the (CBOT), emphasis will be placed on the quality of the ground rubber. This development should cause prices to stabilize, giving the ground rubber market a more secure basis, albeit with a smaller number of producers.

One of the more discussed issues in this market segment is the differences between processing technologies: ambient versus cryogenic processing. Suffice it to say that both technologies can be performed in an efficient manner. The question asked is which processing system is the more desirable? The answer is, it depends. What it depends on is the market into which the processor is attempting to sell their material. Put in its simplest terms, the type of processing system needed will depend upon the characteristics wanted by the end user. If a rough surface particle is asked for, then the ambient system will be the logical choice. If a smooth particle surface is asked for, then the right move is to cryogenics. If it makes no difference, then the deciding factor will be the cost of processing.

Ground Rubber Market Limits

The U.S. produces around 3.3 million metric tons of scrap tires. If all scrap tires were made into rubber, it would produce around 2.3 million metric tons of rubber. The market for all ground rubber applications in 1996 consumed about 400 million pounds or about 7 percent of the total potential volume. In order for the ground rubber markets to consume all of the potential scrap tire derived ground rubber, the markets would have to increase more than 20 times.

This can be examined from a different perspective. The United States consumes about 3.119 million metric tons of virgin rubber, natural and synthetic combined, each year (1994 numbers) for both tire and non-tire applications. If ground, recyclable rubber could replace an average of 10 percent of all virgin rubber in all new rubber products, this would be a total market of 312 thousand metric tons, nearly 3 times the current market. However, this would still leave about 2 million metric tons of ground rubber needing markets. In time those markets might develop, in asphalt paving or as soil additives or in the manufacture of products not normally manufactured from rubber. But for the foreseeable future, all markets will be needed just to finish creating demand for all tires.

2.2.2 Cut, Stamped & Punched Rubber Products

There has been no change in this market segment since the 1994 report. The information supplied in this section remains the same as the previous report.

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

Examples of small die cut parts include muffler hangers and snow blower blades. Strips cut from tires have been used to make door mats as well as other types of mats for years; cut strips bonded together are used to make floor tiles for heavy traffic areas. Stamped shapes are also used to make wheel chocks, dock bumpers, support pads for back hoes and other construction equipment, commercial fishing equipment, blasting mats, solid tires for use on bush hogging equipment, wearing pads for front end loader buckets used in resource recovery facilities and a multitude of other uses.

One limitation of this market is that it generally uses only bias ply tires or fabric bodied radial tires. The steel belts in most radial tires and the steel body plies in an increasing percentage of medium truck radials are not desirable in these applications. As the number of bias ply and fabric bodied medium truck tires being produced decline, it appears unlikely that this market segment will increase substantially. In the meantime, the value of scrap tires which can be used for cutting or stamping will likely increase slightly.

Larger, bias ply tires are another possible raw material for this market, and thus it may provide a reuse opportunity for some of the large off-the-road tires which are otherwise difficult to handle. Another real challenge to this market segment is state laws which subsidize tire shredding without regard to other markets. The highest value for the scrap tire may be the money the state is willing to provide the tire shredder, even if the shreds have no markets.

Because of the demand in this market, virtually all of the scrap bias ply medium truck tires that are collected by major truck casing dealers are finding their way to a cutting or stamping operation.

The estimate of the size of this market segment is eight million tires (units), or three and one-half percent of the market, about the same as reported in 1994. This segment is expected to remain stagnant, since there is a (current) finite number of bias ply tires. If no new supply of bias ply tires can be secured, it is likely that this market segment will decrease slightly over the next five years as the supply of bias ply tires diminishes.

2.3 Scrap Tires in Civil Engineering Applications

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

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

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

ASTM Guidelines

One of the major difficulties in expanding the civil engineering use of tires is a general lack of published information about the physical characteristics of scrap tires as an engineering material, or the lack of any general guidelines for these uses. In order to rectify this situation, the Scrap Tire Management Council, working in conjunction with Professor Dana Humphrey of the University of Maine, one of the foremost researchers into the civil engineering uses of tires, approached ASTM committee D 34.15, and proposed a set of guidelines to fill this need. After nearly two years work, it is hoped that the Guidelines for the Use of Scrap Tires in Civil Engineering Applications will be approved by ASTM in late-1997 and be available for engineering professionals around the country and the world.

Heating Incidents

The growth of the civil engineering markets was substantially curtailed in early 1996 when three heating incidents involving deep scrap tire fills were detected. Two of the incidents were in Washington State and involved road embankment fills; the other occurred in Colorado and involved a fill over a rockslide area on a canyon wall. Although the cause of the heating was not initially known, the mere fact that they all involved tires used as fill material was enough to cause most planned projects to be canceled or postponed. All three of the projects were dug up and replaced with conventional fill materials.

Investigations undertaken by Washington State and by the Federal Highway Administration did not reveal a definitive cause for the incidents, although several factors are suspected. One of the first factors noted was that all three incident involved very deep fills: one Washington site had nearly 50 feet of tire fill, while the other two sites had more than 20 feet of tire fill. Other conditions that may have aided in the heating were the presence of water at some critical time, access to oxygen, presence of organic fill material, presence of rubber "fines", or small particulate matter, and the presence of large amounts of loose or exposed steel wire.

In order to seek answers to the issues raised by these incidents, the Scrap Tire Management Council convened a meeting of interested parties that became the Ad Hoc Committee on Civil Engineering Applications. As a result of committee investigations, it was determined that there were more than 70 tire fill projects at depths up to 15 feet of tires across the country, and that none of them had ever experienced a similar heating incident. Accordingly the committee drafted a set of guidelines for the use of shredded tires in thin fill applications, that is in fills up to 3 meters (10 feet) thick. In addition, the committee is investigating conducting more extensive research in an effort to determine the exact causes of these thick fill heating incidents. The hope is that techniques of using tires in such applications can be identified that will eliminate the possibility of such a heating event taking place.

Still, with all the negative reporting and mis-information concerning civil engineering applications, some 10 million scrap tires were used in 1996. This amount is only 20 percent less than the quantity used 1995, which is far less of a decrease than originally predicted. The strength of the civil engineering market was concentrated in three states; Maine, Texas and Virginia. There were clearly other civil engineering applications in other states in 1996, but these three were the biggest single market areas. In general, the largest applications were landfill cover, leachate collection systems and road insulation material.

Description of Civil Engineering Applications

Subgrade Fill and Embankments

Work has been done in several states (i.e., North Carolina, Virginia, Vermont) using shredded scrap tires as a subgrade fill, in the construction of highway shoulders or other fill projects. The principal engineering advantage which scrap tire material brings to these projects is lighter weight. Scrap tire material can provide significant benefits where the use of a lightweight fill is indicated.

Projects using this feature of scrap tires include the construction of an interstate ramp across a closed landfill in Colorado; construction of mine access roads across bogs in Minnesota; and the reconstruction of a highway shoulder in a slide prone area in Oregon. Scrap tire material has also been used to retain forest roads, protect coastal roads from erosion, enhance the stability of steep slopes along highways and reinforce shoulder areas.

Research is also underway into the use of shredded tire material as backfill for retaining walls (Maine). Initial results suggest that the lower density of the scrap tire material significantly reduces the pressure on the retaining structure and permits substantial savings in the material used to construct it. This project is also of significant importance because it is the first major project to do field sampling of scrap tire leachate. While still in its preliminary stages, the reports have, to date, indicated that the leachate from scrap tires poses no health or environmental risks.

Landfill Construction and Operation

While the aim of most scrap tire market development efforts is to finds uses for scrap tires which keep them out of landfills, many landfill operators have found that scrap tires can be used beneficially in the construction and operation of the landfill, and can replace other materials which would have to be purchased.

Several operators have used whole or chopped scrap tires to assist in constructing leachate collection systems in new landfill cells (Texas, New York, Pennsylvania, Florida and Oregon). In addition, several states permit the use of shredded scrap tires as a partial daily cover material. The processed scrap tires are mixed with clean fill. This combination offers two advantages. First, processed scrap tires replace fill dirt which might otherwise have to be purchased. Second, the weight of the processed tires is effective in keeping the compacted material in the landfill. In landfills where the management wants to allow water to infiltrate the landfill, using a greater percentage of tires to fill allows a greater amount of water to enter the working face of the landfill.

Breakwaters and Artificial Reef Construction

Breakwaters are use to prevent coastal erosion and to provide boats protection from wave action. Scrap tire breakwaters are constructed by tying tires together with nylon bolts and rubber strips. Georgia and New Jersey have constructed scrap tire breakwaters and have reported no technical difficulties.

Artificial reefs are designed to prevent scouring, protect coastal roads and provide habitat for aquatic life. Tire reefs are made by bundling punctured tires weighted down with concrete and anchoring them to the ocean floor. Major artificial reefs have been constructed off the coasts of Florida, Maryland and New Jersey.

Septic System Drain Fields

Chopped or shredded scrap tire material can be used in small-scale, home-owner level civil engineering applications. Shredded tire material has been used in some areas as a drainage medium around house foundations. Shredded tire material is also used in several states to construct leaching fields for septic systems. The lower density of the shredded tire material greatly reduces the expense and the labor to construct these leaching fields, while the material provides equal performance of the traditional stone backfill material. South Carolina has issued specifications for the construction of tire shred leaching fields.

Volume Characteristics

In 1996, there were several large-scale civil engineering applications for scrap tires. Of these applications, some of the most noticeable are listed in Table 2.6.

Table 2.6 Selected Scrap Tire Civil Engineering Applications

QUANTITY	LOCATION	APPLICATION
2,500,000	Virginia	Landfill cover
500,000	Vermont	Leachate systems & road
500,000	Maine	Road base material
300,000	Florida	Leachate collection systems
300,000	New York	Landfill cover & leachate system
300,000	Pennsylvania	Landfills applications
3,500,000	Texas	Landfill cover
500,000	South Carolina	Landfill applications

While the use of scrap tires in this market segment have increased in the past two years, there are still impediments to the broader civil engineering use of scrap tires including:

- Unfavorable economics for some applications, such as artificial reefs;
- Mis-information on formation of hot spots; and
- Reaction of state Department of Transportation's to hot spot occurrences.

Even with these limiting factors, it is expected that the acceptance and use of civil engineering applications will continue its increase steadily over the next two to five years.

- Current Usage: 10 million scrap tires per year
- Within Two Years: 12-15 million scrap tires per year
- Within Five Years: 15- 25 million scrap tires per year

2.4 PRODUCT RECOVERY VIA PYROLYSIS

There is a continuing interest in thermal distillation or pyrolysis, of scrap tires as a strategy to manage scrap tires, even though there has been no success in the marketing of pyrolysis by-products. Pyrolysis is the use of heat in the absence of oxygen to decompose a material. As a basic chemical technology, it has existed since the time of the ancient Greeks. Broad interest in tire pyrolysis began as a result of the world-wide concerns for the availability of petroleum. Pyrolysis was thought to be a method to liberate the liquid hydrocarbons in the tire. A return to easier world access to petroleum at reasonable cost led most investigators to abandon their research on pyrolysis.

Some researchers have persisted however, and there is a continual, but limited, flow of news stories about "new" pyrolysis technologies. Some of the new technologies seek to distance themselves from the negative image of pyrolysis by insisting that they are something else. For example, one promoter says it is reversing the polyimerization process through the application of microwave energy. The fact is that the application of heating energy to tires in the absence of oxygen generally results in three end products - a liquid, a solid, and a gas - and each of these by-products in turn needs end markets. Also, related stories have surfaced about potential new commercial ventures to construct pyrolysis or gasification facilities to deal with tires.

The fact is that pyrolysis technology does work, in the sense that tires can be rendered and converted to three by-products. The key to whether pyrolysis can be more than a technological curiosity is the potential markets for the by-products.

The gas is methane and can be used to provide the heat necessary to run the operation. There is, however, not normally enough produced to make it economically feasible to sell, so any excess gas is flared off.

The solid fraction is often incorrectly referred to as carbon black. The proper term is carbon char. While it does have a high carbon content, that is the only thing it has in common with carbon black, a highly engineered form of carbon used to reinforce rubber. Pyrolytic carbon char, after extensive refining, has found limited markets as a filler in some materials and as a coloring agent for some plastics. In these markets it faces strong competition from, among other things, off-specification carbon black which cannot be sold to primary carbon black markets.

The liquid fraction is a hydrocarbon material variously presented as being comparable to a home heating oil or a diesel fuel. While synthetic rubber is manufactured from petroleum, contaminants resulting from the processing of the material and its pyrolysis render the liquid generally unfit to use directly, except as a waste fuel or as a feedstock for further refining. Its acceptability in either application depends on the receiving facility's ability to handle the material. To date, even experimental pyrolysis facilities have had limited success in identifying end-users for the liquid fraction.

There has been some research conducted both at universities and at private facilities to seek uses for, or to upgrade the pyrolysis by-products. At the current time, none of this recent work appears to be commercially successful. While the possibility always exists that a significant, economically viable use can be found for the pyrolytic by-products, it must be assumed that based on current information and technology, pyrolysis has no substantial role to play in long term scrap tire management.

The principal barriers to the use of tires in pyrolysis applications are:

- Technology has yet to be proven over short or long-term basis;
- Questionable economics; high capital expenditures for plant construction and start up;
- Virtually nonexistent demand for pyrolitic products, especially char; poor perception of product quality.

Volume Characteristics

It is our contention that virtually no scrap tires were consumed by the U.S. pyrolysis facilities in 1996. Extensive investigation indicated that there were no commercially viable facilities in the United States. The majority of the activities associated with this technology has been focused around the sale of pyrolytic equipment or the acquisition of companies. This has given rise to the perception that progress has been made in this market segment.

Given the highly questionable economics and speculative nature of pyrolysis, it is difficult to estimate any future growth in the use of this technology as a means to address the scrap tire situation.

Table 2.7 Known Pyrolysis Facilities in the United States

FACILITY	LOCATION	STATUS
Conrad Industries	Concordia, WA	Demonstration Facility
Omni	Windgap, PA	Operational on limited basis
ECO^2	Hawthorne, FL	Shut down
Texaco	Montebello, CA	Gasification research
Titan	Alburequqe NM	Sale of Equipment only
Wolfe Industries	Brazil, IN	Closed
Colinas Tire	Cooledge, AZ	Facility never built, lost county contract

2.5 EXPORTS OF TIRES

Export of sound used tires constitutes a major market for tires removed from initial service. As discussed earlier, many tires when initially removed from a vehicle are still sound and have adequate tread depth to be used as tires. In addition, many tires without proper tread are usable as candidate casings for retreading. Both categories of tires have ready markets both within the US and North America and in many other parts of the world and are regularly sold into these markets. Virtually all tire producing countries also participate in this world trade in used tires. Used tires and casings exported from the United States are assumed not to return to the U. S. for ultimate disposal.

In 1996, this market faced a major international challenge when an effort was made in the Technical Working Group of the Basel Convention to have used tires listed as a hazardous waste. The Basel Convention is a major world wide treaty regulating the flows of hazardous waste materials between developed and developing nations, and is designed to limit the dumping of hazardous and toxic waste from developed countries in less well developed countries. A few South and Central American countries sought to use the Basel Convention to limit the imporation of used tires into their countries, in part because of internal market competition for tires. The mechanism for this action under the Basel Convention is a listing on the so called "A" list of banned materials. A concerted effort by the major tire manufacturing countries of the world has so far been successful in having tires instead placed on the "B" list, which identifies materials which are safe for international trade.

The export market routinely ships slightly more than one million units per month, or more than 15 million tires per year, based on the estimates of participants in those markets. This constitutes about five percent of the annual volume of discarded tires.

2.6 Agricultural Uses

Scrap tires are regularly used in agriculture in a variety of ways. Used tires not legally fit for highways may be used on low speed farm equipment. Tires are also used to weigh down covers on hay stacks, over silage, or for other purposes where an easily handled weight is needed. Tires can be used as feeding stations, to construct stock feeders, or to protect fence posts and other structures from wear and damage by livestock. Tires may also be used in erosion control and other land retention purposes.

It is estimated that about two and one-half million tires are used in agricultural applications each year, or about one percent of the total volume of scrap tires in the U.S.

2.7 Miscellaneous Uses

There are a wide variety of uses for scrap tires which do not fit neatly into any of the preceding categories, which ranges from one of the most popular uses as a scrap tire swing, to more exotic uses such as an artistic medium for a few artists. Flower pots, fences, horse jumping barriers, shock absorbers for construction demolition cranes, boating dock bumpers, driveway markers, and crash barriers on racing tracks -- the uses are limited only by imagination and necessity.

One of the most interesting of these may be the use of tires to make houses. In this use tires are stacked up like bricks and used to contain compacted earth or other recyclable materials. The odd spaces between the tires are filled with cans and bottles and the entire structure is covered with stucco or adobe. The developer of this construction intends them to be highly ecological buildings, using recycled materials and taking maximum advantage of the mass of the structure both for insulation and for passive heating.

In terms of volume, however, these uses do not consume any substantial quantity of scrap tires. We estimate there are about 1.5 million tires used in all of these innovative applications.

3.0 Regional Markets & Flow

One of the more common questions asked within this industry pertains to the flow of scrap tires. The following section will describe the general and current trends regarding the destination of scrap tires. The intended approach is to define the flow by dividing the country into a series of regions and analyzing the market demand for scrap tires, and how this demand is satisfied. We have attempted to group states into a reasonable region, typically using the USEPA regional definition as a guideline. While this may not have always been the case, the issue should not be the actual groupings, but the flow of scrap tires.

One point that should be understood is that the STMC is not suggesting that there is or should be, any type of artificial flow control. It is our considered opinion that the only factor that should "control the flow" of scrap tires is the market place.

The **New England region** is generally regarded to contain the states **of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.** Within this six state region, virtually all scrap tires are going to one of two major markets: the Exeter Energy Limited partnership facility in Sterling, Connecticut or the pulp and paper mill boilers in Maine. The combined market demand for TDF exceeds 20 million scrap tires annually. There are two smaller markets in this region as well: civil engineering applications and the fabrication of punched rubber products. Scrap tires are being used in civil engineering applications in Maine and Vermont, while there is one large-scale manufacturer of punched rubber products ins Massachusetts.

The six states in this region do not generate 20+ million scrap tires annually. Consequently, scrap tires are imported from New York, primarily from three distinct areas: the entire Hudson Valley region, the New York City metropolitan area and Long Island. Some tires from New Jersey and a few from Virginia also find their way to New England, but these numbers are relatively small.

The **Mid-Atlantic region** is defined as **New York, New Jersey, Pennsylvania, Delaware and Maryland**. Eastern New York's scrap tires, as defined in the previous section, are currently going to New England, although this may change when any of three cement kilns begin using TDF. The only current TDF user in New York (NYSE&G) draws their supply from the central part of the state. Scrap tires in Western New York are being used in landfill applications and are being processed into TDF. While no TDF markets currently exist in western or central New York, there is at least one large-scale potential TDF user that has been going through trial runs. At present, the majority of scrap tires in New York appear to be going to stock piles. To complicate the situation, scrap tires from Ontario are being disposed of in New York.

The majority of New Jersey's scrap tires are going to one of three destinations: TDF market in New Jersey (Atlantic Electric or the Camden resource recovery facility), Pennsylvania or New England. It would appear that these markets are using the majority of tires since the stock piled scrap in New Jersey do not appear to be growing. In Pennsylvania, there is a strong TDF market in the Lehigh Valley, which draws its supply from metropolitan Philadelphia, New Jersey and the eastern/central part of the state. The Lehigh Valley is the area where the U.S. cement industry began, and still maintains a strong presence. Pennsylvania also has a relatively strong ground rubber market, consisting of both several producers of and several end users of ground rubber. Pennsylvania's markets also receive scrap tires from Delaware.

Delaware has no markets for scrap tires, but does have one large-scale producer of ground rubber. It appears that their feed stock come out of Maryland. Maryland, as it turns out, has three cement kilns, which have the capacity to consume every tire generated in that state. This capacity proves markets for the annually generated scrap tires, and has allowed Maryland to have a successful stock pile clean up program.

In the **Atlantic Coast region (Virginia, North Carolina, South Carolina and Georgia)**, there is a considerable level of movement between states. Starting at the top of the region, scrap tires from Virginia are being shipped to the cement kilns in Alabama and the TDF markets in New England. This movement is a function of the subsidy that Virginia gives for using Virginia generated scrap tires. In addition to the out of state markets, Virginia has developed a series of TDF users and uses a very considerable number of scrap tires in civil engineering application, particularly as daily cover in landfills. North Carolina has a series of large-scale processors, who in addition to processing the majority of in-state tires, pulls tires from South Carolina. There are no TDF markets in North Carolina, but tires are processed and used for land reclamation projects or processed and landfilled. South Carolina, which has one TDF user, finds many of their tires being taken not only to North Carolina, but to Georgia as well. This out of state movement of tires is having an impact on their internal markets. There is another cement kiln in South Carolina that would like to use TDF, but is having difficulties securing a consistent flow of tires. Scarp tires in Georgia are being processed and sent to any of a series of TDF markets in state. Furthermore, Georgia has two companies that are using ground rubber to manufacture a series of products.

In the **Gulf Coast region (Florida, Alabama, Mississippi, Louisiana)** there are three options for scrap tires. The first is TDF, which has a strong presence in Florida and Alabama. The second option is ground rubber, which is mostly happening in Florida, and the third option is landfilling or monofilling processed scrap tires, which is occurring in Mississippi and Louisiana. As with the strength of the markets, so goes the flow. Scrap tires are being sent from Florida to the TDF markets in Georgia. Tires from Florida are also being sent to Alabama, although not always to the TDF markets. Ground rubber which is processed in Mississippi is sent to the rubber modified asphalt market in Florida. In Florida, there is a growing production capacity for soil amendments, playgrounds and other ground rubber applications. These finished products are being sent to markets not only in Florida, but to the surrounding states as well. In Alabama, the relatively low population can not truly support the market demand for scrap tires. Furthermore, there tires are being landfilled in the state as well. Scrap tires arrive from Virginia, Illinois, Florida and Mississippi. In Louisiana and Mississippi, there appears to be few tires brought in from other states, and the majority of in state generated scrap tires are being land disposed.

The **South-Central region of Arkansas, Tennessee, Kentucky** find tires, mostly, staying within the state boundaries. In Arkansas, there are two basic end uses: TDF and landfills. In Tennessee, there is a significant, potential TDF market, although many scrap tires are being landfilled. Due to the geography of the state, TDF markets in the eastern portion of the state are being satisfied by companies in Virginia, who are benefited by the state's subsidy program. A major TDF market in western Tennessee is being applied with Texas generated tires. In Kentucky, there is one processor who has developed markets for the tires they take in. However, this represents a relatively small percentage of the annually generated scrap. The remaining annually generated scrap tires are generally landfilled or stock piled. In 1996 there were several large-scale stock piles that were abated, with the abated tires sent to TDF markets in Illinois. The State is currently attempting to develop a TDF market, although it does not appear that this effort will offer any short-term relief to their situation.

West Virginia, which has not been assigned to any region, currently stock piles the majority of its scrap tires.

The **North Central region**, consists of **Ohio, Indiana, Illinois, Michigan and Wisconsin**. Scrap tires generated in Wisconsin are used in Wisconsin, although some have been transported to Illinois. End users of Wisconsin scrap tires enjoyed the benefits of a users subsidy of $20 per ton. However, this program ended at the end of 1996. At the time of this printing, there was no clear indication on the impact of this change. We would expect that the instate markets of Wisconsin will continue using TDF, while some of the out-of-state markets may switch to a supplier closer to their facilities. Illinois has develop a very, very significant TDF market. The state generates some 12 million scrap tires annually and has a market capacity of 19 million. Even with the demise of a dedicated scrap tires to energy facility with a capacity of six million scrap tires a year, the state imports tires from Kentucky, Wisconsin, Iowa, Indiana and Michigan. Of further interest is that there are still several major, potential markets that could be developed in Illinois, which would further impact the flow dynamic of the region.

The flow of scrap tires in Ohio, if not to Illinois, are to one of three options: stock piles, monofills, or fuel. Currently, there is one TDF user and one potential market in state. Ohio also allows monofills to accept scrap tires, and has at least two monofills operating. There are also a significant number of scrap tires going to a stock pile in the Northwest section of the state. In Indiana, those tires not going to Illinois, are, typically going to stock piles, although there are numerous processors in the state, suggesting a wide distribution of tires though out the state, with some being processed. Michigan has one TDF end user being supplied by in state sources, with another potential TDF market in the permitting process. Michigan also has one large-scale processor of ground rubber and products containing ground rubber and several smaller-scale producers of products containing tire derived materials. However, the sum of the scrap tire markets in Michigan is not sufficient to consume all the tires generated annually. Consequently, there are some tires that are being stock piled.

The **Northern Plains states region (Minnesota, South Dakota, North Dakota, Montana)** has the characteristic of large land mass/small population density. Consequently, the concentration of scrap tires, which is usually needed for market development, is generally a concern. In general, scrap tires are being sent from Minnesota to a large-scale TDF user in South Dakota. Some tires in Minnesota are being used for civil engineering applications, as well as for ground rubber applications in state. Minnesota's annually generated scrap tires all have markets. Eastern South

Dakota finds its tires going to the TDF market, while the Western part of the state typically landfills them. The current rate of usage at the South Dakota facility is six million scrap tires annually. This exceeds the population of Minnesota, North and South Dakota and Montana combined. Tires for the TDF market in South Dakota also come from Iowa and Nebraska. North Dakota has a similar division as South Dakota, where a percentage of the tires are going to TDF market, with the rest being landfilled. Since the TDF market in North Dakota just come on line, its full impact on the market dynamics has yet to be felt. Montana's scrap tires are typically landfilled due to the sparseness of its population and the distances between population centers.

In the **Central Plains states region (Iowa, Missouri, Nebraska, Oklahoma and Kansas)**, scrap tires from Iowa are bound for any of three TDF markets (in Illinois, South Dakota or in state), some are processed into products, with the reminder being landfilled. Missouri sends some tires to Illinois to be processed, and then receives them as processed TDF. Tires are sent to Illinois and Kansas for use as TDF. Additionally, there are several TDF markets in Missouri, which primarily use in state generated scrap tires. The State's scrap tire program has been encouraging the use of size reduced rubber for playground applications, and has funded a significant number of projects. In Kansas, the eastern half of the state finds their tires being used for TDF, while the western portion of the state finds their tires being monofilled. There is one producer of products from tires (in the eastern part of the state). In Nebraska, scrap tires are being stock piled, since the TDF user in eastern Nebraska stopped using the material. However, we anticipate that the TDF market will be revised if/when a cement kiln begins using TDF. The instate destinations in Nebraska consist of a ground rubber producer and civil engineering applications. Some tires in the northern part of the sate are sent to South Dakota as TDF. Oklahoma's scrap tires are either sent to the TDF market or to civil engineering applications. However, there a ground rubber processor is active in Oklahoma that could soon draw tires away from other uses.

The states of **Texas, New Mexico, Colorado, Arizona**, which make up the **Southwestern region** all have different programs. In Texas, the Texas Natural Resource Conservation Commission has been actively developing markets, and are now to a point where there is almost an equal market capacity to the annual rate of generation (18 million a year). The major markets are TDF and civil engineering applications. A relatively small amount of in state tires are being made into ground rubber. A relatively small amount of tires from Texas are shipped out of state, due to the nature of their state scrap tire program. Those tires shipped out go as TDF and are destined for Tennessee, with some tires being sent disposal in Alabama. The flow of scrap tires to stock piles has been all but ended, however, there remains a very large inventory of stock piled tires in Texas. New Mexico only imports a relatively small amount of tires, mostly the larger-sized tires, and mostly from Arizona. The majority of scrap tires generated in state go to landfills, where they wait to be baled. The State plans to develop applications/markets for these baled tires, which would divert them from land disposal. In Colorado, the majority of scrap tires remain in state. There doesn't appear to be many out of state tires going to Colorado. There is one TDF market instate, and one significant producer of products containing tire-derived material. Scrap tires are also being used in landfill applications. Arizona, however, does have a significant number of tires going out of state. Some tires are shipped to Southern California, to a land reclamation project, while others, especially the larger, earth mover tires, are shipped to New Mexico for processing. In state markets consist of TDF and ground rubber, which is used in rubber modified asphalt. Arizona has one of the largest ground rubber producers in the region, who's finished product is shipped to Texas, New Mexico and California.

The **Mountain region of Nevada, Utah and Wyoming** have two means of dealing with their tires: TDF and landfilling. In Nevada and Wyoming, almost all the scrap tires generated in state are landfilled. Few tire, if any, are either shipped out or into either state. Tires from Utah, however, are used for TDF both instate and out of state. Due to the $65 per ton subsidy, scrap tires from Utah are shipped to TDF markets in California, Idaho and Oregon. The sum of all the TDF markets consume all the annually generated scrap tires in Utah.

In the **Northwest region (Washington, Oregon, Idaho)**, scrap tires flow between all the states involved. Scrap tires in Washington are used for TDF and are stock piled in state. Some Washington scrap tires are processed in Oregon, and used as TDF in Washington, Oregon or California. Scrap tires in Eastern Washington can also be shipped to a TDF market in Idaho. In Idaho, the TDF market consumes most of the in state tires, but there are tires arriving from Utah and Oregon and Washington. Scrap tires in Oregon are used in Oregon, Washington and California TDF markets.

California, which in itself has two regions (north and south) has a unique market infrastructure. The state generates some 26 millions scrap tires annually, and has market demand for some 65 percent of those tires. However, almost 90 percent of the instate generated scrap tires are landfilled. The market demand for scrap tires is satisfied by importing tires from Utah, Arizona, Oregon and Washington.

The remaining two states, **Alaska** and **Hawaii**, for obvious reasons, neither import nor export their in state generated scrap tires.

Conclusions:

The movement of scrap tires is a function of two primary factors; market demand and economics. Clearly, where there is a significant demand for scrap tires, such as in Illinois and New England, and the regional supply of scrap tires is insufficient to satisfy demand, tires from outside the region will be imported. Thus tires are finding their way from New Jersey and Delaware to Connecticut. Furthermore, where there is greater competition for scrap tires, the tip fees paid to have the tires removed goes down. Once again New England and Illinois have seen this happen.

The other critical factor is economics. Clearly, tires will flow to the least cost (hopefully legal) disposal option. The point to be made is that even where there are significant markets, scrap tires may still go to a lesser cost, and lesser utilitarian application. For example, there is a flow of tires from Florida to Alabama, or Ohio to West Virginia. In these cases, tires are taken to certain locations solely due to the lax nature of the scrap tire regulations and enforcement. The end result is that tires are either landfilled, stock piled or just dumped.

4.0 CONCLUSION

This market survey has presented information on the various markets for scrap tires. In general, there continue to be three major markets that form the basis of the demand for scrap tires. These markets are tire-derived fuel, products, and civil engineering applications. The market survey also reported on several additional markets for scrap tires which include export, agricultural uses, thermal distillation (pyrolysis) and miscellaneous uses, which account for less significant, long-term growth potential.

The results of the past two years have demonstrated a continuation of the increases in the number of markets for scrap tires. In 1990, 11 percent of the annually generated scrap tires had markets. In 1992, 38 percent of the annually generated scrap tires had markets. By the end of 1994, 55 percent of the annually generated scrap tires had markets, and by the end of 1995 some 69 percent of all the annually generated scrap tires had markets. This report concludes that 75.9 percent, or 202 million of the 266 million scrap tires generated in 1996 had a market. The STMC is projecting continued increases in all the major markets for scrap tires, and consistent markets for all others reported. While the factors which impact the markets suggest that the number of scrap tires with markets should continue to increase, it is unlikely that the market will sustain the same rate of increase it sustained over the last six years. The ultimate goal of having markets for 110 percent of the annually generated scrap tires is within sight. With the presumption that there are no major disruptions to the market place, it is reasonable to conclude that by 2002, our goal could be met.

The rationale for this assessment is that the majority of the readily available market, i.e., potential fuel users, have already begun their use of TDF. While there are still a significant number of potential fuel users seriously considering or already in the permitting process, their numbers will

not equal the new entrants to the TDF markets in the past two years. Furthermore, many of these potential fuel users are in states which have arduous permitting processes.

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

The use of scrap tires in civil engineering applications, even with its major problems well publicized, did not decrease that significantly. We are cautiously optimistic that this market niche will regain the lost market share, and increase over time. The development of industry guidelines and construction practices should assist greatly to this end.

The use of size-reduced rubber from scrap tires remains on the verge of becoming a larger market segment. The reasoning is two fold. First, there is a finite limit to the quantity of tire buffings which are available, and that limit is rapidly being approached. Second, the markets for the various uses for size-reduced rubber could increase dramatically over the next two to five years.

Of the other markets for scrap tires, the indications are that export, cut, stamped and punched products, agricultural and other uses will not increase to any great extent over the next two years.

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

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

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

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

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