Scrap Tire Recycling

A Summary of Prevalent Disposal and Recycling Methods
by Kurt Reschner

INTRODUCTION

The technology to turn a potentially hazardous waste product (i.e., scrap tires) into a valuable resource is available now. This article contains a concise summary of the most common scrap tire recycling methods, as well as a discussion of prevalent uses for recycled tire rubber.

Problems associated with uncontrolled or illegal scrap tire disposal

As a rule of thumb, the scrap tire generation in industrialized countries is approximately one passenger car tire equivalent (PTE, 20 lbs., 9 kg) per population and year. It is estimated that 2 to 3 billion scrap tires are stockpiled in illegal or abandoned piles throughout the U.S. This figure represents the cumulative scrap tire generation of approximately ten years. For EU member states, it is safe to assume illegal or semi-legal scrap tire piles in the same order of magnitude.

Figure 1: Tire Fire in Stanislaus Co. California (September 1999)

The most obvious hazard associated with the uncontrolled disposal and accumulation of large amounts of tires outdoors is the potential for large fires wich are extremely detrimental to the environment. Once a large pile catches fire, it is very hard, if not impossible, to extinguish.

In some instances, large tire piles have been burning for several months with the fumes being visible for many miles. Due to the intense heat and smoke generation, fire fighters have a hard time extinguishing these fires with conventional means. Also, air and soil pollution is even worse if attempts are made to extinguish the fire with foam or water. For this reason, scrap tire fires are often allowed to burn out in a more or less controlled manner until the entire pile is exhausted.

Even if large outside tire piles do not catch fire, they still pose a serious problem for human health and the environment: Disease carrying mosquitoes, find an ideal breeding ground in the countless little puddles which form in virtually each tire as it rains. Especially in areas with warmer climates mosquito-borne diseases like **encephalitis** and **dengue fever** have been reported around large tire piles.

In response to the environmental problems and health hazards caused the by countless illegal scrap tire piles around the globe, most industrialized countries have instigated legal guidelines addressing this issue. Regulations vary from country to country, but the main purpose of these regulations is to provide for an environmentally safe disposal, limit the amount of tires being stored at any given location, and to encourage the use of tire derived recycling products.

While grants and subsidies are sometimes instrumental for the implementation of a recycling project, it is ultimately up to the ingenuity of business community to come up with economically sound and market driven solutions. The key factors for a long term economic success in this field are:

- Sound marketing for the recycled product
- Judicious selection of the appropriate recycling technology
- Innovative product development
- A local and national government that is supportive of recycling

HISTORICAL PERSPECTIVE

It is commonly believed that recycling gained momentum only in the past decades. At least in the case of rubber recycling, this is not entirely true.

Figure 2: Advertisement of a Rubber Reclaiming Company from 1909

In the early 1900s, the average recycled content of all rubber products was over 50%. In fact, is fair to say that the rubber reclaiming industry is as old as the industrial use of rubber itself. Figure 2 shows the advertisement of a rubber recycling business in Leipzig, Germany dating back to the year 1909.

It reads: *"Grinding and separation of scrap rubber of all kinds. Low rates. The largest company in the industry. Custom grinding. Specialty: hard rubber dust"*

One reason for the flourishing rubber grinding and reclaiming industry lies in the comparatively scarce supply of rubber at that time. In 1910, one pound of natural rubber cost nearly as much as one pound of silver and it made perfect sense to reuse as much of this valuable commodity as possible.

By 1960, the recycling content in the traditional rubber manufacturing industry dropped to around 20%. Cheap oil imports, the more widespread use of synthetic rubber and the development of steel belted radial tires have led to a steady decline of rubber recycling. By the time the steel belted radial tire was introduced in the late 1960ies and early 1970ies, it became increasingly difficult to grind or slice old tires. As a consequence, the old infrastructure for regrinding and reusing waste tires has been almost completely lost. As of 1995, the traditional tire and rubber industry used only about 2% recycled material.

The low recycling content in conventional rubber products does not tell the whole story, however. Technical developments in the past decade (like effective ambient and cryogenic grinding methods and new environmentally friendly devulcanizing methods) make it very likely that the use of recycled tire materials will increase significantly. Many new uses for recycled tire rubber outside the traditional rubber manufacturing industry have become increasingly important. The author is of the opinion that rubber recycling not only has a long past, but also a bright future.

Scrap Tire Disposal Statistics

The publicly available information on scrap tire generation and disposal is fairly intransparent. Table 2 shows disposal and recovery data for scrap tires published by the European Tyre and Rubber Manufacturers Association.

Table 2: Scrap Tyre Statistics for Europe 2006

Scrap Tyre Generation in 1,000 t/a		Trade with Used Tyres			Recovery Disposal		
		Sale	Export	Retread	Material	Energy	Landfill*
Austria	55	-	-	4	16	35	-
Belgium and Lux.	82	-	2	3	28	35	14
Bulgaria	10	-	-	-	-	-	10
Croatia	15	-	-	-	-	-	15
Cyprus	5	-	-	-	-	-	5
Czech Republic	80	-	-	12	-	-	68
Denmark	45	1	-	5	38	1	-
Estonia	11	-	-	2	2	-	7
Finland	45	-	-	10	35	-	-
France	398	20	20	55	157	106	40
Germany	585	15	38	60	124	310	38
Greece	48	1	-	2	5	8	32
Hungary	46	-	-	5	18	16	7
Ireland	40	1	1	1	3	-	34
Italy	380	30	50	50	83	148	19
Latvia	9	-	-	2	-	-	7
Lithuania	9	-	-	2	-	-	7
Malta	1	-	-	-	-	-	1
Netherlands (car tires only)	47	-	13	-	13	21	-
Norway	47	-	1	7	23	16	-
Poland	146	1	1	21	10	56	57
Portugal	92	1	15	16	26	34	-
Romania	50	-	-	5	10	10	25
Slovakia	20	-	-	-	5	2	13
Slovenia	23	-	-	4	-	-	19
Spain	305	10	20	37	42	52	144
Sweden	90	1	7	16	32	34	-
Switzerland	54	1	13	7	-	25	8
U.K.	475	32	34	55	212	72	70
Total:	3,213	114	215	381	882	981	640

Source: European Tyre and Rubber Manufacturers Association 2006. Summary by Kurt Reschner
*) This figure also includes unknown means or disposal

Energy Recovery

The use of tire derived fuel (TDF) in cement kilns, paper mills or power plants is a perfectly reasonable use for scrap tires, *if recycling is not a viable option.* While uncontrolled fires cause substantial air and ground pollution, the incineration of whole tires or tire chips in a controlled furnace is environmentally safe. On average, the BTU value of scrap tires or TDF exceeds that of coal, while the sulfur content is in the same order of magnitude or even lower. Cement kilns are by far the largest users of TDF. Some cement companies have the capacity to incinerate whole tires, thus being able to omit the comparatively expensive size reduction process.

Rubber Recycling

A concise definition of recycling would be *the re-use of a material for its originally intended purpose, e.g. old aluminum cans are used to make new ones.* In the case of scrap tires, recycling would mean the use recycled tire rubber as a compounding ingredient for new tires.

In a broader sense, recycling is referred to as grinding scrap tires into crumb rubber while removing steel, fiber and other contaminants. In North America, the markets and applications for recycled tire rubber ("crumb rubber") have developed tremendously in the past decade. The different markets and uses for recycled tire rubber are discussed in greater detail in the section Products and Applications.

Landfilling

Most landfills accept whole scrap tires only at a hefty tipping fee because tires are awkward to handle and difficult to compact. In some instances, scrap tires have worked their way to the top of a closed landfill, causing costly damages to the landfill cover.

Nonetheless, a significant part of the current scrap tire generation still ends up in landfills. Since a ban on landfilling whole tires was implemented in most States, scrap tires are usually cut into pieces or shredded before landfilling in the U.S.

The EU Landfill Directive similarly bans whole tires from landfills by 2003. By 2006, tires in any shape or form will be banned from landfills in EU Member States. In order for the EU Landfill Directive to be implemented in a timely manner, new disposal routes for scrap tires need to be developed with great urgency in all EU Member States.

A variation of landfilling is **monofilling**, which means that scrap tires are not mixed with other waste materials, but stored at a dedicated, licensed location. Once the monofill has reached its capacity, it is covered like any other landfill to reduce the fire hazard and also prevent mosquito breeding.

Civil Engineering Applications

Tire derived products, mostly 1" tire chips are sometimes used to replace conventional construction material, e.g., road fill, gravel, crushed rock or sand. The benefits of using tire chips instead of conventional construction materials are amongst others: reduced density, improved drainage properties and better thermal insulation. The following are examples of projects where scrap tire chips have been successfully used in civil engineering applications:

- Lightweight fill for embankments and retaining walls
- Leachate drainage material at municipal solid waste landfills
- Alternative daily cover at municipal solid waste landfills
- Insulating layer beneath roads and behind retaining walls

Civil engineering applications of scrap tires are expected to become more widespread as more and more applications can be proven to be technically and economically viable.

Export and Miscellaneous

From an environmental standpoint, the use of a waste material for its originally intended purpose is the most preferential recycling method. The active international trade with used tires, mostly going from industrialized countries to in lesser developed countries, is a clear sign that this route of disposal is economically sensible well. It is a fair assumption that at least 10% of scrap tires generated in industrialized countries are sold as used tires, especially to in Eastern Europe, Africa and Latin America.

Figure 4: Waste bin made from an old tire (seen in Thailand)

The downside of exporting scrap tires is that the receiving countries end up with a disproportionate amount of scrap tires. At the same time, these countries usually do not have the legal framework and industrial infrastructure to address the issue of scrap tire disposal in an environmentally safe and economically sound manner. For this reason, some Eastern European countries (e. g. Poland) have issues laws that severely limit the cross-border transfer of waste tires.

Miscellaneous uses for scrap tires include a wide range of applications like the ubiquitous silo covers, playground swings, woven door mats from scrap tire strips, handicrafts, shoe soles, die cut products, etc.

Figure shows a fairly inventive use for a scrap tire. First, the beads of a light truck tire were removed. Then, the tire was turned inside out and shaped into barrel-like container. Two small segments serve as bottom and lid, while the beads are used as a support. Two small strips are attached to serve as handles. A blue coat of paint gives it a fresh, clean appearance. These waste bins can be seen all over Thailand.

Environmental Assessment of Different Disposal Methods

When referring to incineration, some people use the term "energy recovery" or even "thermal recycling". While this sounds more impressive that "incineration" or "burning", the fact remains that the use of a material for its originally intended purpose more preferable, both from an environmental and from an economic standpoint. This becomes obvious when we take a closer look at the typical energy consumption to produce tire rubber and compare it to the energy gained by burning a tire:

Energy needed to manufacture a tire	32,0	kWh/kg
Energy needed to produce tire rubber compound	25,0	kWh/kg
Thermal energy released when incinerating scrap tires	9,0	kWh/kg
Energy consumed in the process of grinding scrap tires into crumb rubber (0.5 to 1,5 mm)	1,2	kWh/kg

Table 3: Specific energy values. Sources: W. Dierks: Incorporating the Use of Recycled Rubber, Robert Snyder: Scrap Tire Disposal and Reuse, compilation by Kurt Reschner.

As shown in the table above, it takes 3 – 4 times as much energy to produce tire rubber, compared to the energy recovered by "thermal recycling". Consequently, the use of recycled tire rubber for its originally intended (or related) purpose makes by far more sense than incineration, both environmentally and economically. The following list shows the main scrap tire disposal and recycling methods, classified hierarchically, by environmental and economic preference.

Rank	Application/Processing Method	Examples
1	Use **PRODUCT** for its originally intended purpose for as long as possible.	Design rubber compound and tire geometry for maximum durability. Keep tire properly inflated at all times to ensure maximum service life. Reuse partly word tires. Regroove or retread tire casings.
2	Use **MATERIAL** for its originally intended purpose.	Grind scrap tires into crumb rubber, separate steel and fiber. Sell rubber as raw material.
3	Use whole scrap tires for energy recovery.	Burn whole scrap tires as fuel supplement in cement kilns.
4	Use mechanically processed tires for energy recovery.	Tire chips added to coal as fuel supplement in power plants, paper mills, cement kilns, etc.
5	Alter the chemical structure of scrap tires and use the products for energy recovery.	Pyrolysis, Supercritical Extraction.
6	Storage for possible recovery at a later time.	Monofilling.
7	Disposal without any current or future use.	Landfilling.

Table 4: Scrap tire disposal methods, ranked by environmental preference.

Some might argue that the preference list shown in **Table 4** is the result of an environmentalist agenda with little footing in the real world. In fact, the vibrant international trade with partly worn tires and retreadable tire casings shows that market participants world wide-have similar priorities. Market forces have a clear verdict on the next two options as well: recycled tire rubber (crumb rubber) sells for 200 – 400 US$ per ton, whereas tire derived fuel (TDF) fetches one tenth of that price. This is a clear indication that, sound environmental practices and market forces are not necessarily opposites when it comes to tire disposal.

Size Reduction Technology

As discussed in the previous section, processing scrap tires into rubber granules is one of the most useful disposal options, provided that there is a local and regional market for recycled rubber. In this section, I will discuss the most common size reduction technologies for scrap tires.

Tires are built to be tough and durable. The very properties that ensure a long service life and a safe ride, make size reduction both difficult and costly. Since the steel belted radial tire has become commonplace in the 1970ies, grinding scrap tires into steel and fiber free crumb rubber requires fairly complex machinery.

The purpose of size reduction is two-fold:

- Liberate and separate steel and fiber from rubber
- Process the rubber fraction into a sellable particle size

The typical product yield from scrap tires is as follows:

Product Yield from:	Truck Tires	EM Tires	Car Tires
Crumb Rubber	70%	78%	70%
Steel	27%	15%	15%
Fiber and Scrap	3%	7%	15%

Table 5: Typical product yield from scrap tires.

Shredding

Nearly all processors first shredded the scrap tire into chips, mostly 2” in size. By shredding, the volume of scrap tires can be reduced to about ¼, thus reducing space requirement and shipping costs. At the same time, tire chips are easier to handle with standard equipment like front end loaders or bobcats.

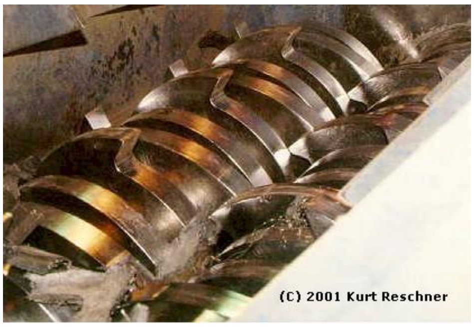


Figure 5: View inside the cutting chamber of a shredder for scrap tires

The most common machines used for pre-shredding scrap tires are rotary shear shredders with two counter-rotating shafts. The machines are designed to work at low RPMs (20 to 40 RPM) and high torque and can easily handle all sorts of tires, including truck tires, super singles and farm equipment tires.

Some operators use a debeader to remove the steel beads from truck tires prior to shredding. Debeading significantly reduces wear and tear on the shredder and consecutive size reduction machines. While the steel bead represents only 10 – 15 % of the weight of a truck tire, it is probably safe to state that the 1” thick circular steel cables are responsible for 70% of the wear and tear in the shredder as well as in the consecutive grinding machines.

Tire shredding can be considered a mature technology and reliable machines are being offered by a number of reputable companies throughout North America and Western Europe. Most shredders are powered by electric motors (approx. 200 – 300 HP) and have a capacity of 2 – 6 tons per hour, depending on the input material and the size of the chips produced.

Ambient Scrap Tire Processing

The schematic in Figure 6 is an example of a typical ambient scrap tire recycling plant. The process is called ambient, because all size reduction steps take place at or near ambient temperatures, i.e. no cooling is applied to make the rubber brittle.

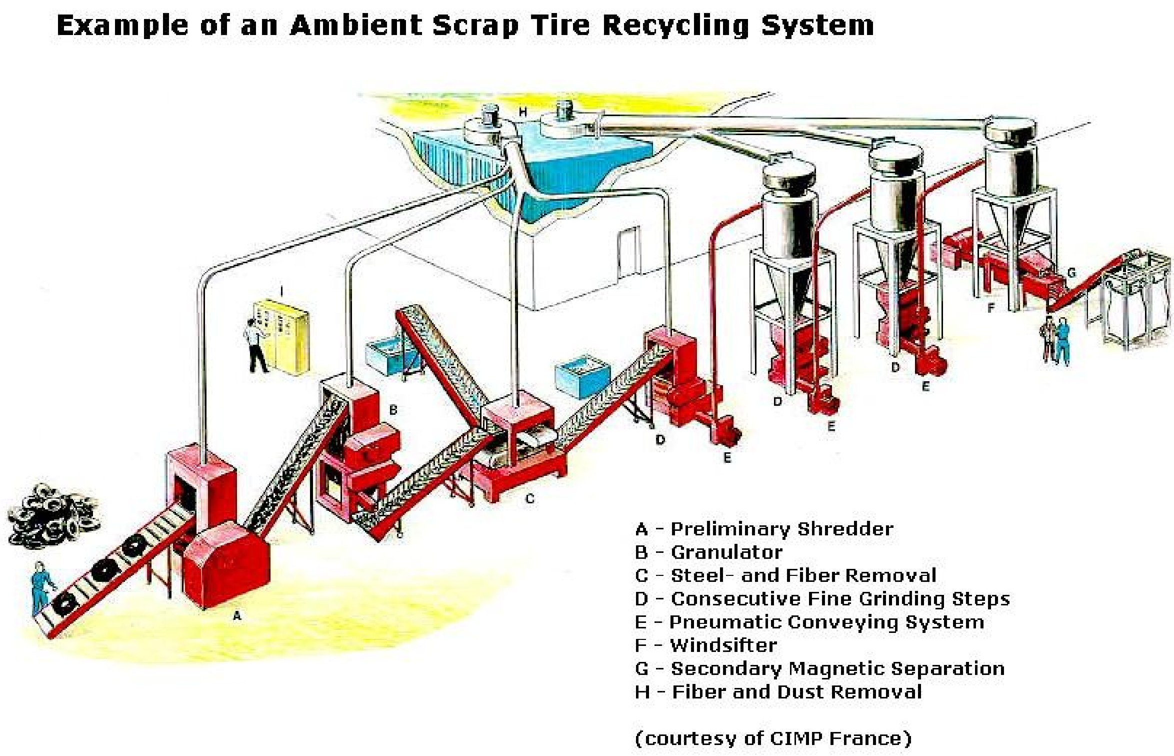


Figure 6: Schematic of an Ambient Scrap Tire Processing Plant

In this plant layout, the tires are first processed into chips of 2" (50 mm) in size in a preliminary shredder (A). The tire chips then enter a granulator (B). In this processing step the chips are reduced to a size of smaller than 3/8" (10 mm), while liberating most of the steel and fiber from the rubber granules. After exiting the granulator, steel is removed magnetically and the fiber fraction is removed by a combination of shaking screens and wind sifters (C).

While there is some demand for 3/8" rubber granules, most applications call for finer mesh material, mostly in the range of 10 to 30 mesh. For this reason, most ambient grinding plants have a number of consecutive grinding steps (D). The machines most commonly used for fine grinding in ambient plants are:

- Secondary granulators
- High speed rotary mills
- Extruders or screw presses
- Cracker mills

Ambient grinding can be operated safely and economically if the bulk of the rubber output needs to be relatively coarse material, i.e., down to approximately 20 mesh material.

Cryogenic Tire Recycling

This process is called "cryogenic" because whole tires or tire chips are cooled down to a temperature of below –80 C (-112 F). Below this "glass transition temperature", rubber becomes nearly as brittle and glass and size reduction can be accomplished by crushing and breaking. This type of size reduction requires less energy and fewer pieces of machinery when compared to ambient size reduction. Another advantage of the cryogenic process is that steel and fiber liberation, is much easier, leading to a cleaner end product. The drawback, of course, is the cost for liquid nitrogen (LN2).

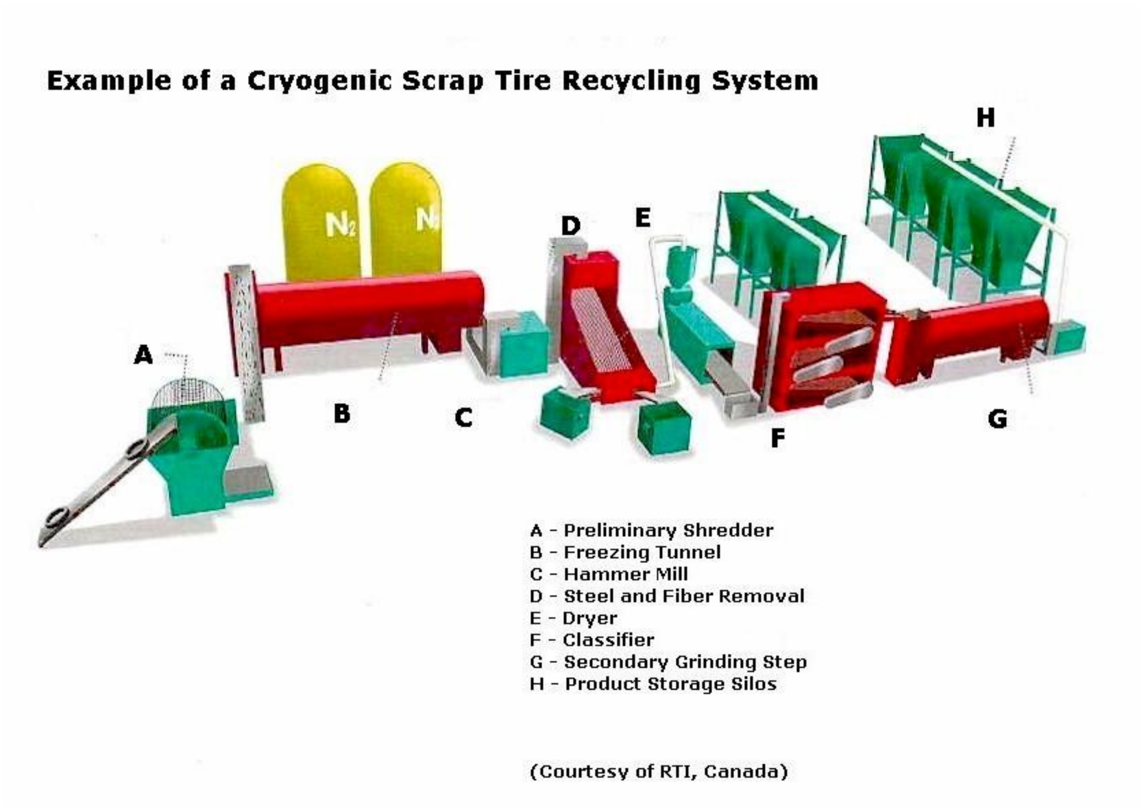


Figure 7: Schematic of a Cryogenic Scrap Tire Processing Plant

The preliminary treatment of scrap tires (debeading, pre-shredding) is pretty much the same as in ambient plants. In the cryogenic process, the 2" (50 mm) tire chips are cooled in a continuously operating freezing tunnel (B) to below –120°C and then dropped into a high RPM hammer mill (C). In the hammer mill, chips are shattered into a wide range of particle sizes, while, at the same time, liberating fiber and steel. Because the rubber granules may still be very cold upon exiting the hammer mill, the material is dried (E) before classification into different, well defined particle sizes (F). Generally speaking, cryogenic scrap tire processing is more economical if clean, fine mesh rubber powder is required.

Comparison between Ambient and Cryogenic Technology

The question, which is "the best" processing technology for scrap tires, is often discussed in the industry. As you may imagine, the answer to this question depends on a multitude of factors.

It must be emphasized that, **crumb rubber is not a standard commodity** and is rarely sold solely based on specifications submitted in writing. In most cases, buyers of crumb rubber require samples for field tests before purchasing larger batches. Some buyers are very specific about what type of material (ambient or cryogenic) they require, whereas others do not have such preferences. Thorough knowledge of the local and regional market requirement is a must before

The table below compares some of the most important parameters in cryogenic and ambient grinding.

Parameter	Ambient	Cryogenic
Operating Temperature	ambient, max. 120° C	below - 80° C
Size Reduction Principle	cutting, tearing, shearing	braking cryogenically embrittled rubber pieces
Particle Morphology	spongy and rough, high specific surface	even and smooth, low specific surface
Particle Size Distribution	relatively narrow particle size distribution, only limited size reduction per grinding step	wide particle size distribution (ranging 10 mm to 0.2 mm) in just one processing step
Maintenance cost	higher	lower
Electricity Consumption	higher	lower
LN2 Consumption	N/A	0.5 – 1.0 kgLN2 per kg tire input

Table 6: Comparison between Ambient and Cryogenic Processing

In the next section, I will discuss the most common applications for recycled tire rubber, commonly referred to as crumb rubber or ground tire rubber.

Products and Applications

Especially in North America, commercial applications of recycled tire rubber ("crumb rubber") have experienced an enormous growth in the past decade. The Table below shows a market summary for North America (United States and Canada) for 2001 classified by the main markets and applications.

Application/Market	million lbs.	metric tons
Rubber Modified Asphalt (RMA)	292	132,727
Molded Products	307	139,545
Athletic Surfaces	141	64,091
Tires/Automotive	112	50,909
Devulcanized and Surface Modified Rubber*	36	16,364
Plastic/Rubber Blends	38	17,273
Construction and Miscellaneous	70	31,818
Total	**996**	**452,727**

Table 7: Markets and applications for recycled tire rubber in North America in 2001. The figures include buffings from retreading plants. *This category includes imported products. Source: Recycling Research Institute.

Crumb Rubber as a Filler in Virgin Rubber Compound

Since the tire industry consumes about 65% of all rubber compounds produced world wide, using crumb rubber as a compounding ingredient for new tires is the most obvious application for this recycled product. As the quality and supply of crumb rubber has become more reliable and predictable in recent years, an increasing number of tire manufacturers add recycled material into their compounds. If mixing and processing methods are chosen properly, substantial savings can be achieved without compromising quality, safety or performance characteristics. Aside from lower material cost, adding some crumb rubber (5 – 15%) to the virgin rubber compound offers the following advantages:

- Better mixing properties and improved form stability of uncured parts
- Improved degassing during the vulcanization process
- Improved mold release
- Increased plant efficiency due to reduced cure times
- In some applications, abrasion resistance is also significantly improved

Based on these benefits, some tire manufacturers routinely use crumb rubber as a filler, especially for tread compounds and whenever speed and high performance is not crucial, e.g. for farm equipment or solid rubber tires. The growth potential in this market segment is substantial.

Devulcanization

In chemical terms, devulcanization means reverting rubber from its thermoset, elastic state back into a plastic, moldable state. This is accomplished by severing the sulfur bonds in the molecular structure. With the proper devulcanization method, a much higher percentage of crumb rubber old tires can be used as compounding.

Traditional devulcanization methods involved exposing cured rubber to elevated temperatures for an extended period of time. However, this "thermal reclaim process" not only severs the sulfur bonds in the polymer matrix, but also breaks the polymer chains, causing a significant decrease in physical properties. Because of questionable economics and environmental concerns, thermal devulcanization is rarely used today.

The current price increase of virtually all types of polymers, including natural rubber, means that for most rubber manufacturers, reprocessing rubber scrap is no longer an interesting alternative, but an **economic necessity.**

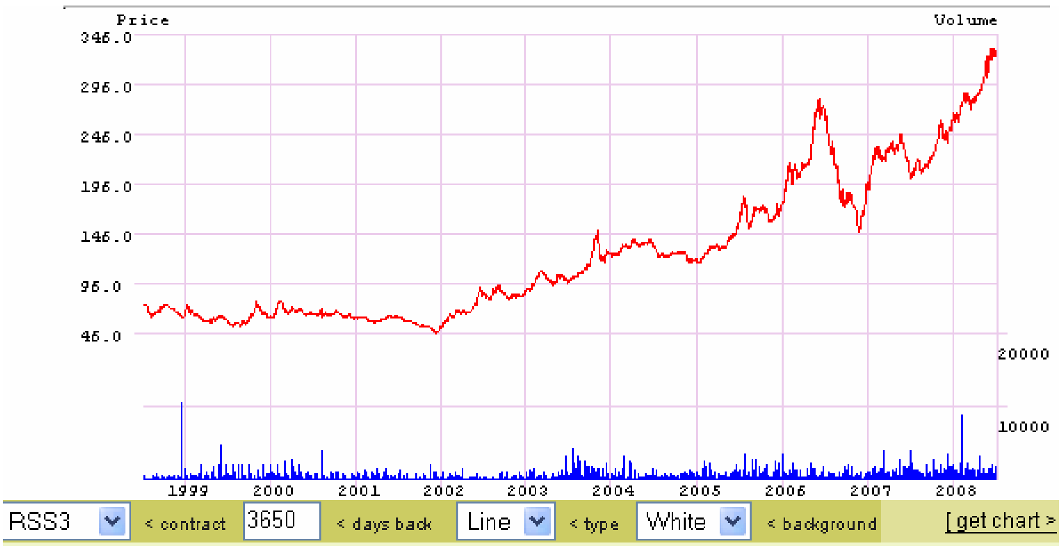


Figure 8: Ten year price chart for Natural Rubber (RSS3) in US$ per kg.
Source: Singapore Commodity Exchange, www.sicom.com.sg

The following Table lists the most common devulcanization methods.

Devulcanization Process	Description
Thermal Reclaim Process	Rubber is exposed to elevated temperatures over an extended period of time in order to break the sulfur bonds as well as the polymer back bone. This process was first patented by H. L. Hall in 1858, but is rarely used today due to environmental concerns and relatively severe degradation of the material.
Mechanical Devulcanization	Vulcanized rubber is exposed to intense mechanical work (mastication) in order to selectively break the sulfur bonds in the polymer matrix. The machines used are two roll mills, high shear mixers and extruders. Mechanical devulcanization method leads to good results and may be economically viable in the near future.
Devulcanization with Ultrasound	Technically speaking, this is a special form of mechanical devulcanization. First research results on this subject are encouraging.
Bacterial Devulcanization	Fine rubber powder is exposed to an aqueous suspension with bacteria that consume sulfur and sulfur compounds, e.g., thilbacillus, rodococcus und sulfolobus. Technically viable, but questionable economics due to the complexity of the process.

Table 6: Important Devulcanization Methods

Surface Activation

Surface activation increases the adhesiveness of crumb rubber particles. The increased adhesiveness makes it possible to use a larger percentage of recycled material without the detrimental effects commonly experienced when untreated fillers are added. This method may prove to be a good compromise between using crumb rubber as a mere filler versus complete devulcanization. In some applications, surface activated crumb rubber can be molded by itself, without binders or other additives. Like with devulcanized material, the economic viability of surface activated crumb rubber depends to a large extent on the market price of virgin rubber compound.

Molded Products

In the past few years, the increasing supply of crumb rubber and a newly developed moisture-curing urethane binder has led to a rapid increase in the number of products made by simple compression molding. Typically, this method is used to produce high-volume, low-tech products, such as livestock mats, railroad crossings, removable speed bumps and athletic mats.

Using crumb rubber in combination with urethane binder to produce molded products enables manufacturers to significantly reduce the processing time and material costs. However, this application is limited to products where only moderate tensile strength and abrasion resistance is required.

Pyrolysis

Pyrolysis is the thermal decomposition of an organic material under the exclusion of ambient oxygen. The typical products of scrap tire pyrolysis are:

- hydrocarbon gases (mostly used to fuel the process itself)
- pyrolysis oil (properties similar to that of heavy fuel oil)
- carbon black (may be used as pigment or filler)
- scrap steel

While pyrolysis of scrap tires has been proven to be technically viable, the author is not aware of any company in the world that has operated a pyrolysis plant for a sustained period of time.

Wet Poured Layers

Playgrounds and athletic surfaces are frequently covered with a layer of rubber granules in order to help prevent injuries. Many stadiums throughout the industrialized world have running tracks that consist of recycled material. Most commonly, a moisture- curing urethane is mixed with 4-10 mesh crumb rubber and applied in a similar way as other poured pavements. These layers are usually softer than hot cured, compression molded mats. In most cases, the top layers of poured in place athletic surfaces are made of UV-resistant, colored EPDM granules.

Thermoplastic-Elastomer Compounds

Combining crumb rubber with a thermoplastic binder at high temperatures yields a material that can be processed more like a thermoplastic compound, but still has some of the elasticity of rubber. This is a very cost effective method of producing high volume products such as acoustic insulation in cars, pallets, railroad crossings, etc.

Sprayed Layers of Crumb Rubber

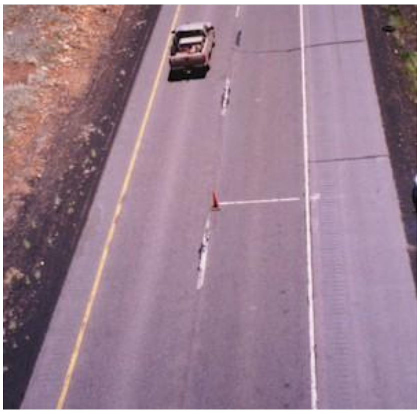
In combination with a moisture curing urethane binder, crumb rubber can be sprayed onto surfaces where elastic, waterproof, corrosion resistant or vibration and impact dampening properties are desirable. This method has a wide range of possible application and has a good potential for growth.

RUBBER MODIFIED ASPHALT (RMA)

Rubber pavements date back to around 1870. At that time, the area around St. Pancreas Station in London was paved with a rubber compound. This rubber pavement was widely praised because “the horses’ hooves were silent”, it also was reported to be durable and easy to keep clean.

More widespread commercial applications of rubber modified asphalt (RMA) pavements date back to the 1960ies and were first introduced by Charles McDonald in Arizona. Apart form recycled tire rubber, SBS block co-polymers (thermoplastic elastomers) are often added to the hot bitumen to improve the performance characteristics of asphalt pavements. Experience with thousands of highway miles paved RMA prove the engineering merits as well as the economic benefits of using recycled tire rubber in asphalt.

Increased resistance to rutting, reflective and thermal cracking are the main benefits of RMA. Other advantages include better de-icing properties, reduced traffic noise and, most importantly, a significantly increased service life and thus a lower life cycle cost.

	
Figure 9 a: I 40 near Flagstaff, AZ paved with conventional Asphalt	**Figure 9 b:** I 40 near Flagstaff, AZ paved with RMA

Images 9 a and 9 b show two stretches of I 40 near Flagstaff, AZ. Both pavements were laid in 1990, the pictures were taken in 1998. While the conventional pavement (left image) is already severely cracked, the RMA pavement (right image) is in much better shape. (Photos Courtesy of Mr. George Way, of the Arizona Department Transportation).

The main advantages of Rubber Modifies Asphalt can be summarized as follows:

- Reduced thermal cracking (due to cold temperatures) and rutting (usually caused by hot temperatures) can be reduced with one and the same asphalt mix. RMA is specifically useful in areas with extreme climates, i.e. high temperatures in summer and severe frost in winter.
- Severely cracked pavements can be paved over with RMA or with a stress absorbing membrane interlayer (SAMI) because the more elastic properties of RMA or SAMI significantly reduces reflective cracking.
- Due to lower maintenance costs and increased durability, the live cycle cost of RMA is significantly lower when compared to conventional asphalt pavements.
- Other advantages include increased traffic safety due to a better deicing property, increased skid resistance and fewer construction sites.

Based on the proven technical and economic advantages of RMA, the use recycled tire rubber nearly doubled from 1995 to 1999 in North America. It is very likely that this growth rate will continue world-wide.

Frequently Asked Questions

Q: Who buys my scrap tires?

A: Unless you have retreadable truck tire casings or car tires in good condition, nobody will take your tires for free, let alone "buy" them.

Typically, scrap tire haulers and processors charge a tipping fee of 65 to 150 US$ per ton. Actual tipping fees vary depending on volume, transportation costs and a number of other factors. For example, if you have purchases a piece of land and find an abandoned pile of scrap tires filled with dirt, disposal may become fairly expensive.

To find out who hauls scrap tires in your region, please contact your local Environmental Protection Agency or Department of Environmental Control. The entity may have a different name where you live, but they should have a list of licensed tire haulers and processors.

Q: Which is the best way to process scrap tires?

A: As you may imagine, the answer to this question depends on a wide range of factors. First and foremost, you should have a pretty good idea of the market demand in your area. Only after you have decided what products you intend make, should you approach the question of technology selection.

For example, it would make little sense to set up a cryogenic plant and produce fine rubber powder if the demand in your area is mostly for coarser rubber granules. Also, there could be some particular circumstances at your location that may favor one specific technology and impede another. Thorough market research and prudent technology selection are the two key factors to success in this industry.

Q: How much do I need to invest for a scrap tire recycling plant if I want to produce crumb rubber?

A: As an order of magnitude, expect an investment volume 5 Million US$ for a complete turnkey plant with a capacity approx. 2 - 3 tons of tires per hour. Actual numbers vary widely depending on supplier, type of equipment, quality of end product, etc.

Q: I want to keep my investment at a minimum in the initial phase. Does it make sense to purchase equipment with a lower capacity?

A: Not really. Most shredders and subsequent grinding machines are built to process tires at a rate of 2 - 4 tons per hour. Even if you purchase a smaller plant with a lower hourly throughput, you still need a building, ancillary equipment like conveyors, screens, magnetic separators, a dust collection system, etc. In other words, a substantially downgraded plant capacity will only moderately reduce the overall investment sum. You may be able to source used equipment for far less money, but it is extremely important to find out why this equipment is for sale.

Q: Where do I obtain information about grants and business development loans?

A: Since each country, state, or province has a host of different programs, I am not in the position to answer this question exhaustively. The best place to obtain preliminary information is your local or state government, specifically the Department of Economic Development and the Department of Environmental Control.

Q: I intend to start a scrap tire recycling business. Why should I retain the services of a consultant?

A: In the past decade, there have been numerous start-up ventures and this industry has been blessed with a multitude of "revolutionary" technologies. However, only a small fraction of these new businesses survive long term. If one accounts for the investment moneys lost in ill-fated ventures, it is a fair statement that in this industry as a whole, there is more money being lost than made.

Investing in overpriced and/or inadequate equipment is a prime reason for business failure in this industry. Because of the many innovative but not always viable technologies and applications, thorough due diligence is crucial for every lender or entrepreneur who intends to become active in this industry.

Based on my in-depth knowledge experience in this industry I can help my clients stay away from proposals with questionable economics. By the same token, I have a solid track record of facilitating the implementation of economically viable projects world-wide. I provide the following services:

- General due diligence on behalf of lending institutions, investors or entrepreneurs.
- Feasibility studies for scrap tire recycling projects.
- Independent advice on technology selection.
- Market studies and assistance with initial marketing in the region where the plant is to be built.
- Product development
- Assistance with disposal and/or reprocessing of factory scrap rubber

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