Scrap Tires: A Pricing Strategy for a Recycling Industry

BY KENNETH C. OWEN

The evolution of scrap tires from garbage, to environmental problem, to valuable resource has come about in little more than a decade. Although the technologies for tire recycling are starting to mature, there has been little agreement concerning the best uses for the 2.5 million tons of scrap tires generated annually in the United States alone. This calls for recycling strategists to develop an economic model that mutually benefits suppliers and users, a framework that will identify lucrative opportunities within the rubber recycling industry.

This model goes beyond the historic value of recycled material and is based upon the replacement value of virgin materials that are used in current processes. Replacement values are calculated using a database of products along with the volumes and grades of rubber and other additives consumed and acceptable percentages and specifications for inclusion of recycled material. The database also includes the volumes and prices for various virgin materials and current pricing by grade and quality for recycled crumb rubber. User sensitivities toward substitute and/or recycled materials are also taken into account. These sensitivities relate, not only to acceptable recycled content within each product, but comparative price sensitivity as well. A second database catalogs recycling methods.[1] The focus here is on using untreated crumb rubber to produce the various grades of recycled crumb rubber for the greatest profit. Surface treatments and devulcanizing processes are rapidly coming to market. They can and will effect the value of crumb rubber. However, these are so new to the market that prices are either unavailable or not yet stabilized.

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Synthetic rubber accounted for about 70 percent of total North American rubber consumption in 1993, according to the International Institute of Synthetic Rubber Producers (IISRP). Imports of natural rubber comprised the remaining 30 percent. The manufacture of tires accounts for about 60 percent of global synthetic rubber demand, while the production of other auto parts accounts for an additional 10 percent."[2]

The total U.S. rubber market exceeded three million metric tons for the first time in 1994. According to the Rubber Manufacturers Association (RMA) synthetic rubber consumption is expected to grow approximately one percent per year, and natural rubber consumption will be relatively flat through the end of the century. *(see* Exhibit 1, *right)*

Volumes, Prices, and Trends of Virgin Materials

Demand for synthetic rubber products has been growing steadily in major industrialized countries and at a rate greater than for natural rubbers. However, with total market growth forecast at only one percent per year, synthetic rubber producers have been unable to raise prices to keep pace with the increased cost of their major ingredients including "everything from ethylene to propylene and butadiene."[4] This "problem," for synthetic rubber manufacturers, is a potential opportunity for recyclers who may be able to fill some of the demand for raw material more profitably. The volatility of the natural rubber market may also provide manufacturers with an incentive to buy recycled materials, if recyclers can provide a consistent product at a stable price. ASTM standards are currently being developed. With these standards will come standardized grades of material which will be traded in the major commodity markets. As of 1997, the Chicago Board of Trade lists crumb rubber by polymer content, par-

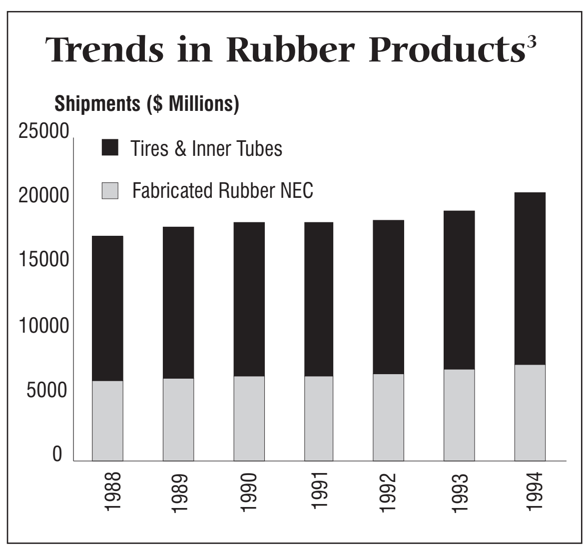

Exhibit 1

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ticle size and loose material, carbon black and contamination content, not by ASTM standards.

Tire Recycling

All tire recycling processes attempt to reduce old tires into smaller pieces for reuse or further processing. The first step is usually shredding to reduce overall volume to make handling and storage easier. For the most basic uses, such as tire derived fuel (TDF), this is all the processing required. However, for most other uses, the tire chips must be reduced further in order to produce more usable, higher value materials: crumb rubber, steel, and fiber. More value can be added by coating the crumb rubber to improve its bonding characteristics, or using pyrolysis to produce char[7], oil, and gas. Tires can also be reduced to reclaim rubber by chemical digestion. Because recycled rubber lacks some of the elasticity and other desirable characteristics and flexibility of virgin materials, it typically sells for 20 percent to 30 percent of the price of its virgin counterparts.[8] However, in some applications, suitable grades of recycled material can bring much higher prices, as long as their use does not increase the total process cost for the product.[9] Except for pyrolysis, all other methods of tire recycling have been on the increase.[10] *(see* Figure 2 *below)*

Shredding

Tires can be shredded by slow speed rotary shears

US Market for Tire Derived Crumb Rubber[6]

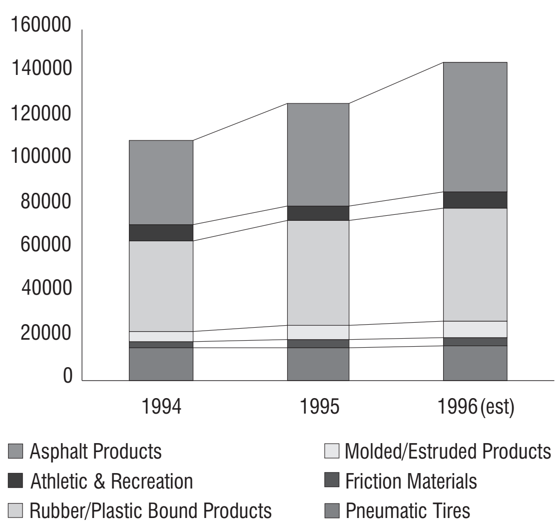

Exhibit 2

Products Currently Made from Recycled Crumb Rubber

Filler powder—tires, molded rubber products, hoses, brake pads, and mud flaps.

Construction—roofing, waterproofing, sound & vibration dampeners, sealants, caulking compounds, expansion joints, and thermal insulation.

Surfacing—arenas, amusement parks, livestock, playgrounds, jetty & sea wall coating, liners for landfills and reservoirs.

Highways—asphalt additive.

Energy—fuel for power plants, paper mills, and cement kilns.

Agriculture—soil aeration and de-toxification, golf course green liners, and mats.[5]

or hammermills. The former produces a cleaner cut that is more acceptable for applications where this is the only processing, such as for lightweight fill. Either method can be employed in plant, or in mobile units which can be taken to different sites to reduce whole tire transportation expense. Shredding costs, not including labor, transportation or site costs, are approximately $0.21 per tire, $0.28 per tire for wire-free TDF (or 1 cent to 1.3 cents per pound).[11] Often, these costs can be more than offset by tipping fees which average approximately $0.50 per tire (2.5 cents per pound). The end product of this process ranges from tire strips down to shreds, which can pass through a two-inch screen. This material is most often used as TDF, but is also suitable for some civil engineering applications. As TDF, its value is limited by the value of its competitor, coal, to approximately $30 to $50 per ton. To achieve higher value and finer grades, further processing, is required.

Adding Value

Tire chips, from shredding, can be reduced, and the steel and fiber removed by mechanical grinding methods. Highly efficient techniques, such as the use of serrated grinders, can produce crumb rubber ranging from 10 to 30 mesh, which currently sells at a price of $0.11 to $0.15 per pound. Mechanical grinding tends to produce rough edged particles with many hair-like appendages. Depending on the application, these can be either an advantage or disadvantage. The increased surface area provides a more intimate bond with virgin materials. However, it also raises potential blistering problems due to oxidation. Ambient grinding processes all generate heat, which can alter the properties of the recycled rubber. Regardless, ground rubber can only bond mechanically with the other materials in the blend, not chemically as virgin material can, unless it can be devulcanized, whereby the chemical links produced in the original material are delinked. Without this further processing, more demanding applications require increasingly smaller crumbs with ever increasing process costs.

Some companies are now producing surface treatments for ground rubber to make recycled crumb rubber perform more like its virgin counterpart.[12] Many of these treatments improve the utility of recycled rubber, but fall short of the goal of creating a recycled material comparable to virgin quality. The most recent development is a devulcanizing process developed by STI-K Polymers,[13] who has patents pending in 75 countries. STI-K and its U.S. subsidiary, STI-K Polymers America, are now commercializing this process worldwide, using a "three-pronged approach."[14] They will manufacture and sell delinked crumb rubber through an agreement with Baker Rubber Company in South Bend, Indiana, the largest scrap tire processor in the U.S. According to STI-K America President, Fred Seisseger, six parts Delink will be blended with 100 parts ground tires to produce a commercial material. Another avenue to commercialization is licensing. The third is toll processing whereby, according to Custom Cryogenic Grinding Corporation in Simcoe, Ontario, they will delink for a fee. It is believed that marketing of this patented process will be a:

> "…technical and commercial breakthrough allowing STI-K/CCGC to supply premium priced compounds at reduced prices to rubber product manufacturers, enabling them to have waste-free factories and make a significant contribution to cleaning up the environment worldwide."

Several other companies are developing devulcanizing processes based on the same body of Russian research as STI-K, including Cycletech, Inc., Hudson, New York.

> "Even the U.S. Air Force has a tire recycling project based on an experimental, micro-organism-based devulcanization process at the Department of Energy's (DOE) Pacific Northwest Laboratory in Richland, Washington. The process is in commercial trials at one recycling plant and at one shredder, according to a laboratory spokesman."[15]

Cryogenic Reduction

Cryogenic processing entails the cooling of the feed stock to approximately -325 degrees Fahrenheit using liquid nitrogen. The cooled material is extremely brittle, and is fed directly into a cooled closed loop hammermill/multi-state screener.[16] The whole process takes place in the absence of oxygen, so surface oxidation is not a consideration. Because of the low temperatures used in the process, the crumb rubber derived from the process is not altered in any way from the original material. Unlike ambient ground material, the crumbs are uniformly geometric in shape and the particle distribution for any given mesh size is very narrow. As with ambient grinding, this process generates a variety of material sizes, with yields dropping as required particle size is reduced.

Current Uses of Discarded Tires

Landfills, Monofills, and Storage. Traditionally, tires were simply buried in landfills. However, this method of disposal is now, for all practical purposes, no longer possible. Tires not only take up a lot of space, but they tend to work their way to the surface over time, damaging the surface layers of clay. They also cause leaching problems. Therefore, for both practical and environmental reasons, most municipalities in the United States no longer permit the inclusion of tires in regular landfills.

Monofills, landfills dedicated to shredded tires, are an effort to dispose of tires, rather than recycle them. While monofilling could potentially reduce some of the environmental problems of mixing tires with other landfill materials, it requires substantial expenditures for land, shredding and handling. It is also unlikely that monofilled tires will be reclaimed at a later date for fuel or any other worthwhile purpose. This is not a current practice, but rather one under consideration in a number of locations including Ohio and North Carolina.

With tires being banned from landfills, they started to pile up. In 1991, the U.S. Environmental Protection Agency (EPA) estimated the size of scrap tire stockpiles to be two to three billion tires.[17] Of the roughly 240 million scrap tires generated annually in the United States, the quantity which are retreaded, burned as fuel or recycled, increased from just 10 percent in 1990 to 60 percent in 1995.[18] However, even with 60 percent of the tires being used, that still adds 96 million tires per year to stockpiles and, to a lesser extent, landfills. Storage is not a good long-term strategy for several reasons. First, tire piles can catch fire, and when they do, the fire is very difficult to extinguish and emits large quantities of unburned hydrocarbons and noxious fumes. Second, tires tend to collect rainwater and promote the breeding of mosquitoes. Third, tire piles provide ideal breeding grounds for rats and other pests. While various strategies have been developed to minimize storage problems any long-term solution to the tire recycling problem will have to make use of the billions of tires now in storage as well as the ongoing stream of new scrap. On the bright side, tire stockpiles can provide a steady source of materials for recycling companies as they develop their long-term tire acquisition strategies. Many states, such as Oregon, which provide subsidies to companies that make environmentally acceptable use of scrap tires, also require that these companies dispose of stockpiled scrap tires as a predetermined percentage of their total tire supply.[19]

Tire Derived Fuel (TDF). Scrap tires can be burned either whole or shredded into TDF. When burned at appropriately high temperatures (over 3,000°F), sulfur emissions are lower than coal, and particulate release can generally be maintained within an environmentally acceptable range. Tires also produce more heat than coal, approximately 13,200 Btu/lb. That means that a 20lb. passenger tire can generate approximately the same heat as 30 lb. of coal.[20] Three types of operations are currently burning tires: cement kilns, paper mills, and utilities. All face the same material handling and permitting problems, but the applications each have their own characteristics.

Cement Kilns. TDF use at cement kilns presents a number of advantages. These kilns operate at very high temperatures, keeping exhaust gasses in the burning zone for long periods of time. The high operating temperatures cause complete oxidation of the steel in the tire shreds, and the steel content provides supplemental iron, a requirement of the cement process. Since the Btu value of TDF is usually higher than coal, and the nitrogen, sulfur, and ash content is lower, it would seem that TDF is an ideal fuel for this purpose. However, there are several barriers to its use.

TDF's cost advantage over coal is marginal. Kilns that burn whole tires have a greater advantage. Either system requires plant modifications. In addition, modifications to air emissions permits are required, and these can be time consuming and costly to obtain. To make these costs bearable, there must be a reliable supply of TDF or whole tires. This reliability can only be assured when the tire recycling supply chain is more highly developed.

Paper Mills. Pulp and paper mills generate large amounts of wood scrap in the production of chips for the pulp digester. This waste is generally burned in a "hog boiler" which generates process steam. However, in order to burn the waste wood and maintain reliable boiler performance, supplemental fuel is required. Dewired TDF is very price competitive with coal for this application. It provides consistently high Btu content with uniformly low moisture content. It does require special handling equipment and environmental permits, but these problems have not proven insurmountable. As of 1992, pulp and paper mills were consuming 14 million tires per year.

Utilities. Utilities became involved with tire burning after the cement and paper industries. The economics are not as favorable, and the issue of reliability of supply is of utmost concern. Over the last decade, utilities and independent energy producers have experimented with mixing TDF with coal at dedicated tire to energy plants. While reports of financial performance are nominally favorable, widespread adoption of TDF for power generation has not occurred.

Paving. Following the passage of the Intermodal Surface Transportation Efficiency Act in 1991, interest in the use of old tires in paving increased sharply. The act "requires states to use crumb rubber in 5 percent of their asphalt tonnage laid in 1994. The percentage must rise to 10 percent in 1995, 15 percent in 1996, and 20 percent in 1997 and succeeding years."[21] While implementation of this act has been delayed by protests from the American

Association of State Highway and Transportation Officials and the National Asphalt Pavement Association, among others, study of the potential benefits of tires in pavement and processes to realize those benefits have proceeded. Two major technologies have emerged: asphalt rubber, and rubber modified asphalt concrete (RUMAC). Asphalt rubber refers to the various methods for incorporating crumb rubber modifier (CRM) into hot mix asphalt (HMA) during manufacture. RUMAC refers to the use of tire chips in place of, or in addition to, other aggregates in the final asphalt mix. Both processes claim useful life up to double ordinary asphalt, but at roughly twice the initial cost. Due to the discounting of future costs, these processes appear to be more costly than traditional asphalt mixes. It also remains to be determined whether asphalt rubber or RUMAC can be recycled as traditional asphalt can. Provided that the cost and recycling issues can be overcome, potential use of old tires for paving could exceed the supply. However, if higher margin uses for recycled crumb rubber can be identified, pressure to keep rubber out of pavement would come not only from paving groups and municipalities, but from recyclers as well.

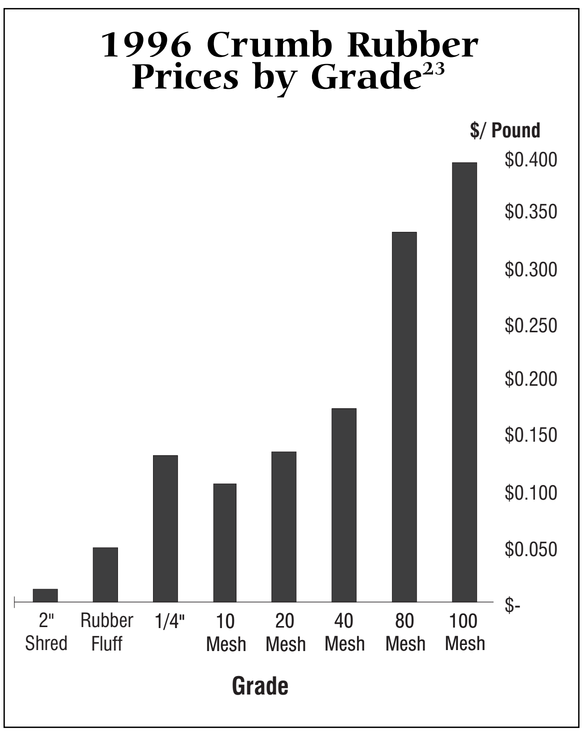

Exhibit 3

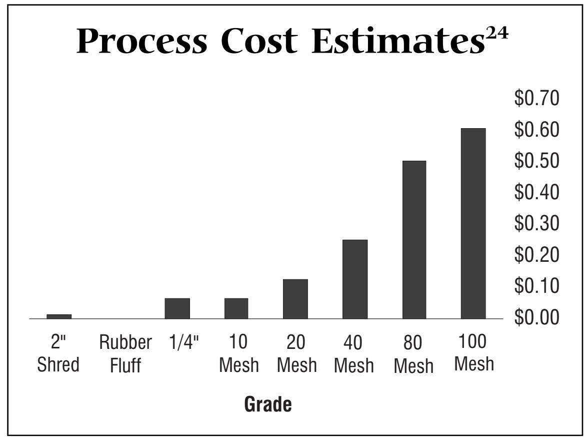

Exhibit 4

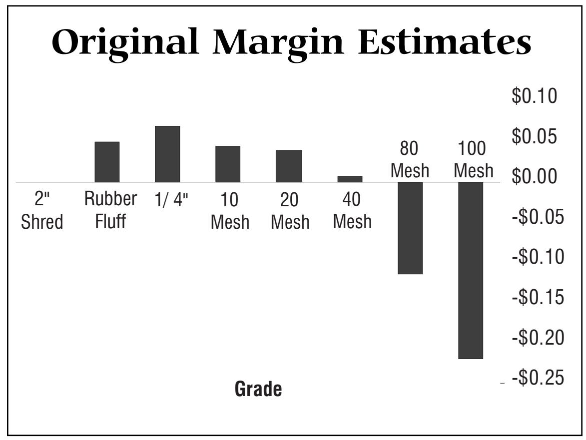

Exhibit 5

The Model

The value added in processing will ultimately determine the viability of any recycling effort.[22] According to Cycletech President, David Guido, "When this type of recycling becomes established, we are prepared to pay up to $20 per ton for scrap tires instead of collecting the $30 a ton tipping fee we get from tire collectors now to take the material off their hands."

The collection of process costs has proven difficult. Processors guard their costs, considering them to be highly sensitive proprietary data. Equipment manufacturers have proven similarly sensitive to the release of data. Therefore, the costs shown here are an aggregation of proprietary data received under non-disclosure requirements and projections based on yield curves and cost relationships provided by equipment suppliers. (*see* Exhibits 3, 4, *and* 5)

These charts make evident that the process cost for producing finer and finer grades of crumb increases faster than the current market prices for recycled rubber, suggesting that the greatest margins can be achieved with relatively coarse grades (4 to 10 mesh).

However, current market prices do not reflect potential market prices. The lack of uniform quality standards and continuity of supply both serve to discount market prices. As ASTM standards are finalized and fine grind crumb becomes more uniform and plentiful, prices should improve. Furthermore, the more advanced, and potentially profitable applications such as tire manufacturing, are currently examining the use of 10 to 30 mesh crumb either delinked or surface treated in place of the finer mesh materials. Therefore, to judge the available opportunities, a model is required to value recycled crumb based on the standard cost of the material it replaces. *(see* Exhibit 6, *below)*

Using the ingredient prices published in the March 1997 issue of *Rubber World* magazine in conjunction with the recipes for the rubber compounds for the products under consideration, as described in the 1996 *Vanderbilt Handbook*, standard costs are calculated. Each product is then assigned an acceptable recycled content percentage and an acceptable price limit is calculated. As stated above, the range of acceptable pricing is wide, ranging from 30 percent of virgin cost to as high as 100 percent. The process cost for the appropriate grade of recycled material is subtracted from the acceptable price limit to indicate the potential gross margin available per pound of material for each product. This is presented as a revision of the margin chart, showing how these products have affected the margin curve.

In a determinate market, where the supply of crumb rubber far exceeds the potential for a given product, it would make sense to multiply the gross margin per pound times the available market volume for the product to show total potential. However, in the case of all three applications selected here, the potential market for each product could consume more recycled crumb rubber than the scrap tire market can supply. Therefore the decision to pursue any of them is determined by feasibility and margin per pound.

Starting with the lowest grade material use, we can look at tire derived fuel (TDF). Usually delivered as 2" or 1" shred, TDF requires little processing, but must compete with coal on price. For most applications, a steady supply of TDF must be available in order to justify necessary modifications to material handling equipment. Therefore the price of coal becomes a limiting factor and high volume contracts a necessity. These parameters are well established in the current market, and are unlikely to change dramatically in the near future. From our data above, the market price for 2" shred is 1.22 cents per pound, the cost is 1 cent per pound, yielding a margin of 0.22 cents per pound.

Rubber Modified Asphalt (RMA) appeared to be a dominant use for recycled tires following the passage of the 1991 Intermodal Surface Transportation Efficiency Act. However, as discussed above, price considerations and industry opposition slowed implementation and in 1995, Congress eliminated the funding for enforcement and administration. Therefore, RMA is only going ahead where it can stand on its own merit, without government mandate or funding. However, since RMA is inherently more costly than the asphalt it replaces, there is consistent downward pressure on the price of the crumb rubber used. In fact, the National Asphalt Paving Association looks at the additional price of RMA in terms of the cost to dispose of each tire ($5 to $10), rather than the value of the material.[25] Therefore, for this model, a cost ($0.133/lb.) and selling price based on the current market ($0.1562/lb.) interpolated between the 20 mesh and 40 mesh figures can be used. This yields a margin for RMA of $0.0232/lb.

Margin Calculation for Each Product

Standard Cost x *Acceptable Replacement Percentage* – *Production Cost* x *Process Change Allowance* = *Potential Margin*

Exhibit 6

Potential Margin for Crumb Rubber Used in New Tire Components

Passenger Car Tire Component	Virgin Component Cost/lb.	30 Mesh Crumb Process Cost	Potential Margin	Margin After Process Cost Allowance
Tread	$ 0.7409	$ 0.1330	$ 0.6078	0.51666
Sidewall	$ 0.7465	$ 0.1330	$ 0.6135	0.521492
Apex	$ 0.5869	$ 0.1330	$ 0.4539	0.385793
Bead	$ 0.6862	$ 0.1330	$ 0.5532	0.470198
Inner Liner	$ 0.5761	$ 0.1330	$ 0.4430	0.376572
Plys				
Wire Belt Coat	$ 0.5615	$ 0.1330	$ 0.4285	0.364228
Carcass	$ 0.6095	$ 0.1330	$ 0.4765	0.405014
Composite	$ 0.6439	$ 0.1330	$ 0.5109	0.43428

Exhibit 7

Next comes the consideration of tire components. Two basic approaches can be taken here. Recycled crumb can be used either as a direct replacement for carbon black or natural or synthetic rubber, or it can be used as a filler, displacing all other components of the material mix up to a given percentage. In this model, the second approach is used. The acceptable price for crumb rubber in tire components will be considered equal to the price of the material it replaces less an allowance for the cost of process changes. The price equity assumption is based on the assertion by Clarence Hermann, Vice President of Product Engineering at Michelin, that incorporating recycled material should be "cost neutral." He also stated that, "The recycled rubber will be in all of the tire's components, the sidewall and the tread, for example, and the replacement factor will actually be a bit more than 10 percent…We require a material that's finer than 20 mesh." The process change allowance is arbitrarily set at 15 percent. The actual allowance for any end user would be based on an appropriate amortization schedule of actual process change costs. The following pricing is based on the *Vanderbilt Handbook* recipes and *Rubber World* component prices. *(see* Exhibit 7, *above)*

The value of the material as calculated here ranges from four to five times the composite current market price for 30 mesh material and up to twice the market price for 100 mesh material in *Exhibit* 8.

By calculating the material value for additional products which make use of other grades of crumb, a more complete composite curve depicting the optimum margin for each grade can be obtained. New products can be judged against the curve to determine their desirability. Products which improve on the margin curve at any grade point become the new benchmarks for later products. Using this pricing model, the grades with the most potential are 20 to 40 mesh.

Opportunities & Risks

All of these calculations are based on the use of untreated recycled crumb rubber. Surface treated or devulcanized crumb, as mentioned above, could provide additional opportunities, either for the use of coarser grinds at higher prices or for expanded market potential due to their suitability for use in higher percentages. As the market develops, these processes will in all likelihood become embedded in the standards for some of the higher grades of material. In the short term, the greatest opportunities for high value crumb rubber markets lie in joint or cooperative ventures with major potential users, such as tire manufacturers and plastics compounders, to produce high grade materials at a stable cost which meets the varied design requirements and business needs of original equipment manufacturers and end users.

Recommendations

To realize the higher potential value in products such as tires, recyclers must move as rapidly as pos-

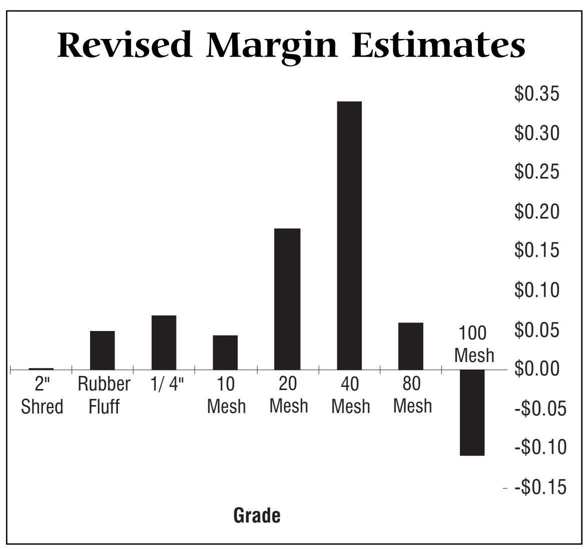

Exhibit 8

sible toward a commodity market for crumb rubber. As long as no two suppliers can or do provide identical material, manufacturers will be wary of plans to incorporate crumb rubber in any meaningful quantity in their processes. As the market is currently structured, each recycler is, for all practical purposes, marketing a proprietary product which requires customers to be totally dependent on a single supplier for material. While this can be an acceptable arrangement, it is restrictive enough to stymie large-scale market development.

The fact that all publicly quoted commodity prices for crumb rubber as of this writing are specified as #1, indicates that true standards have yet to be achieved. Still, the current movement toward ASTM standards and the acceptance of crumb rubber on commodities markets should serve to drive this market rapidly over the next few years.

Endnotes

1. The decision to implement any recycling method must include an evaluation of the required capital investment, optimal plant size, utilization rates, and access to a consistent supply of raw material. These elements are beyond the scope of this model.
2. Standard & Poor's, 1/19/95.
3. U.S. Department of Commerce: Bureau of Census, International Trade Administration.
4. Reisch, M. "Rubber consumption is rising, but producers' profits are squeezed," *Chemical & Engineering News*, Vol. 73 No. 33, August 14, 1995, pp. 11-14.
5. RW Industries, Inc. "Markets for crumb rubber," http://www.rwindustries.com.
6. Rose, P. "Tyre recycling comes of age in North America," *Rubber Trends*, Summer 1995, pp. 34 ff (9).
7. Char is a black residue that can be recycled as low quality filler.
8. Klingensmith, W. "Recycling, production, and use of reprocessed rubbers," *Rubber World*, Vol. 203 No. 6, March 1991, pp. 16-21.
9. Steuteville, R. "Puncturing the scrap tire program," *BioCycle*, Vol. 36 No. 10, October 1995, pp. 51-52.
10. *Id.*
11. Blumenthal, M. "Tires," *Recycling Handbook*, McGraw Hill.
12. Fesus, M. & Eggleton, R. "Recycling Rubber Products Sensibly," *Rubber World*, Vol. 203 No. 6, March 1991, pp. 23-27.
13. Samdani, G. "Chemical treatment devulcanizes rubber crumbs for recycling," *Chemical Engineering*, Vol. 102 No. 11, November 1995, pp. 17-19.
14. Rose, P. *supra note* 6.
15. *Id.*
16. Leyden, J. "Cryogenic processing and recycling," *Rubber World*, Vol. 203 No. 6, March 1991, pp. 28-29.
17. Environmental Protection Agency "Markets for Scrap Tires," EPA/530-SW-90-074B, September 1991.
18. Augenstein, D. "Disposal of Scrap Tires," *Fleet Equipment*, May 1995, pp. 12-13.
19. Oregon Dept. of Environmental Quality, 340-64-005.
20. Tesla, M. "Scrap tire process turns waste into fuel," *Power Engineering*, May 1994, pp. 43-44.
21. Ichniowski, T. "Noises in the House over rubber in the road," *ENR*, Vol. 230 No. 21, May 24, 1993, pp. 24-25.
22. The first stage of the model looks at current margins for recycled crumb rubber by grade. By taking current market prices for various grades of recycled material, and subtracting process costs, we can generate a chart illustrating gross margin per pound after process cost. In this calculation, and in those that follow, the cost of collection is ignored, since it is related to tires in general and its influence on profitability is the same per pound of material, regardless of grade.
23. *Composite: 1996 Scrap Tire Users Directory and Recycler's World* 7/31/96.
24. Aggregated proprietary data from processors & equipment manufacturers.
25. Hughes, C. *Scrap Tire Utilization Technologies*, National Asphalt Pavement Association, Information Series 116, 2/93.