Markets for Wire and Fiber from Waste Tires

CalRecycle

California Department of Resources Recycling and Recovery

September 2013

Contractor's Report
Produced Under Contract By:

SAIC®

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Publication # DRRR 2014-1513

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Prepared as part of contract number DRR 10032 ($3,562,742)

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Executive Summary

Under the California Tire Recycling Act of 1989 and subsequent amendments, the Department of Resources Recycling and Recovery (CalRecycle) is committed to expand market infrastructure for producing and using tire-derived products made from California-generated waste tires. This includes identifying and strengthening markets for steel wire and fiber components of waste tires, which can help strengthen the economics of crumb rubber production.

In 2003 CalRecycle published the "Assessment of Markets for Fiber and Steel Produced from Recycling Waste Tires" (2003 study). This current 2012 report was prepared to update the 2003 study and to identify the potential need and opportunities for CalRecycle to help further develop or expand markets for these by-products.

Key Findings

Whereas in 2003 only three of seven California processors surveyed were recycling some bead or belt wire from waste tires, recovery and marketing of steel by-products is now nearly universal across all processors, although pricing received varies significantly due to volume, contamination and marketing channels. California has one steel mill that purchases bead wire from some tire processors, and the global scrap steel market provides ample demand for the rest. Prices for scrap steel vary as do all recycling markets, with processors citing values of $35 to $325 per ton, depending on quality and prevailing global pricing, primarily.

In 2003 only one processor reported recycling tire-derived fiber for use as fuel at a California cement kiln. Currently, of six crumb rubber producers in California, three report they regularly recover and market fiber to cement kilns. Three dispose their fiber; however, all three said the cost is not a high percentage of overall disposal costs. Two of the three who dispose their fiber said they produce very small quantities of fiber due to their scale of operation and/or focus on using truck tires, which contain relatively less fiber than passenger tires. None said the cost of fiber disposal was a major issue for them. Total in-state demand for tire fiber is close to, or greater than, available supply. In 2012 two cement kilns had a demand in excess of 11,200 TPY and used approximately 7,800 tons of material out of a maximum, estimated supply of up to 12,000 tons. The two kilns using fiber are both in Southern California, however, resulting in very poor economics for processors in Northern California seeking to recycle fiber.

Opportunities to expand demand for tire fiber include:

- Encouraging the two California cement kilns that use tire-derived fuel but not fiber (including one located in Northern California) to investigate use of fiber ;
- Providing technical support to a tire processor investigating using fiber in asphalt with a university, and to a manufacturer that is reportedly developing a proprietary new product using tire-derived fiber as a feedstock. No additional information on these opportunities was available.
- Investigate the use of tire-derived fiber as a potential replacement for raw materials in manufacturing certain products (e.g., carpet backing, mattress pads, moving blankets, animal textiles), as it is highly absorbent and lightweight and it has low or no cost. However there are technical barriers to each of these uses. For example, a representative of L.A. Fibers, a

California firm that manufacturers carpet pads, said the fiber length of tire fiber is too short, and the material is typically too contaminated to be useful.

- Research potential uses for tire-derived fiber such as reinforcement in cement and in certain asphalt products. Examples of such uses were identified outside of California; however, because conventional raw materials for these products are so inexpensive, the incentive to use tire fiber is low.

Barriers to market development for tire fiber include, but are not limited to:

- Inconsistent quantity or low volume of generation;
- The cost of equipment needed to ensure clean, consistent supplies; and
- High cost of shipping very low-density material.
- Inherent material characteristics such as short fibers limit the usability of the material in some applications;
- Typically high contamination; and
- Difficulty in securing steady supplies of consistent quality.

Conclusions and Recommendations

The need for new market development activities focused on tire wire and fiber is mixed, and does not appear to merit shifting CalRecycle resources away from priorities such as expansion and diversion of markets for crumb rubber.

For wire, with very few exceptions California processors are now already recovering and marketing this material. Pricing varies significantly, but this is a result of both processor-specific factors and global factors outside of the control of processors and CalRecycle. Processors can invest in equipment and/or adjust practices to increase the value of marketed wire (within the boundaries or prevailing global prices). However, each processor must determine whether this is a priority need based on their unique circumstances. Information on how to do so is readily available from equipment vendors, and there does not appear to be a need for CalRecycle activities in this area.

For fiber, it appears that less than 33 percent of the amount generated is disposed, and market expansion appears to be a challenging proposition that would yield only modest benefits. Two in-state cement kilns consumed about 7,835 tons of tire fiber as fuel in 2012, about two-thirds of the rough, high-end estimate of fiber generation from current crumb producers of 12,000 tons per year. Based on this rough estimate, then, it appears that at most about 4,100 tons of tire fiber may be disposed each year. Moreover, total demand of 11,200 TPY nearly exceeds the upper estimate of tire fiber supply, although the two cement kilns using fiber are both located in Southern California, resulting in relatively poor economics for Northern California crumb producers to recycle fiber. Three of the six California crumb rubber producers are currently recovering and shipping most or all of their fiber to two of the four in-state cement kilns. There are opportunities to boost fiber demand, but they generally have associated barriers that could be challenging and costly to overcome. And, while a new market that could reduce costs and/or generate new revenue would be desirable, the remaining three crumb producers do not indicate that fiber disposal is a major concern to them compared to other priorities. Furthermore, CalRecycle is statutorily prohibited from promoting fuel-related uses for tires and tire-related materials, complicating support for that market niche for fiber.

CalRecycle has established a clear focus on expanding and diversifying markets for crumb rubber (along with tire-derived aggregate), which has a direct influence on the long-term viability and success of crumb rubber producers. Given that, and the above challenges related to wire and fiber market development, SAIC recommends that CalRecycle not redirect significant resources away from higher priorities to target wire and fiber. Rather, CalRecycle should continue to focus on expansion and diversification of waste tire markets generally, and especially for relatively high-value crumb rubber in new products.

Notwithstanding this recommendation, following are three relatively low-cost activities that CalRecycle could consider.

First, distribute this report to processors and encourage them to evaluate options to enhance their practices by evaluating equipment and practices to determine whether they can increase the value of wire or the marketability of fiber in a cost-effective manner. (Appendix B lists several equipment vendors who could provide advice and feedback).

Second, identify any California firms using scrap fibers and/or producing textile products that may be in a position to consider use of tire fiber, and provide low-level technical assistance to facilitate their evaluation. This should include providing a list of tire fiber suppliers and information on low-interest loans available through CalRecycle, for example.

One final action CalRecycle may wish to consider is adjusting the manner in which the tire diversion rate is calculated. Currently, all tires sent to an end use, including crumb rubber, "count" as diverted. This is similar to how most if not all other state and national tire studies are analyzed. Consistent with CalRecycle's current focus on "recycling" rather than "diversion," the agency could shift to a system in which disposed wire and fiber residuals are subtracted from the tons diverted prior to calculating the diversion rate. This would provide ongoing data to track progress in marketing wire and fiber. A challenge to implementing this approach would be the need for more accurate data from processors on disposed residuals, which has not been comprehensively gathered in the past. However, the data should be available from the firms, and SAIC believes such a shift in methodology could feasibly be implemented.

Introduction

Background

Under the California Tire Recycling Act of 1989 and subsequent amendments, the Department of Resources Recycling and Recovery (CalRecycle) is committed to expand market infrastructure for producing and using tire-derived products made from California-generated waste tires. CalRecycle's Five-Year Plan for the Waste Tire Recycling Management Program guides efforts to reach a 90 percent diversion goal by 2015. This goal was met in 2012, in large part due to a surge in exports of waste tires and TDF to Asia. CalRecycle aims to continue to expand and diversify in-state markets to ensure that high diversion is sustainable over the long term, including identifying and strengthening markets for steel wire and fiber components of waste tires, which can help strengthen the economics of crumb rubber production.

In 2003, CalRecycle (formerly the California Integrated Waste Management Board or CIWMB) issued the "Assessment of Markets for Fiber and Steel Produced from Recycling Waste Tires" (2003 Study). Appendix A summarizes technical findings from the 2003 study. Briefly:

- Of the 33 million passenger tire equivalents (PTEs) generated in California in 2001, 8 million (24 percent) were processed into crumb rubber.
- By-products of this crumb rubber production included an estimated 14,000 tons of wire and 9,000 tons of fiber, and if all of the waste tires generated in the state were processed into crumb, the by-products would include up to 61,000 tons of potentially recoverable steel and up to 39,000 tons of potentially recoverable fiber.
- Based on a worldwide survey of processors (with 206 respondents of approximately 800 surveyed):
    - 61 percent disposed of fiber, and 38 percent disposed of steel.
    - Fewer than 15 percent separated and recycled wire and steel, and fewer than 3 percent reported separating and recycling fiber.
    - The established scrap steel market provided a strong market for steel by-products from crumb rubber production, while markets for fiber were very limited.
- In California at the time, three of seven processors responding to the survey (43 percent) reported no markets for steel; three processors surveyed were recycling bead steel and two were recycling belt wire.
- Only one California processor indicated a market for tire-derived fiber, which was for tire-derived fuel at a cement kiln.
- If California waste tire processors employed better processing technology, it would result in cleaner steel, which would be more marketable and command a higher price.
- Data regarding quality demands for steel markets is limited, and additional information could assist processors.
- There are many barriers to the development of markets for fiber, including the fact that there are multiple resins, typically, included in the fiber of the tire. One market for which this is not a barrier is the fuel market.

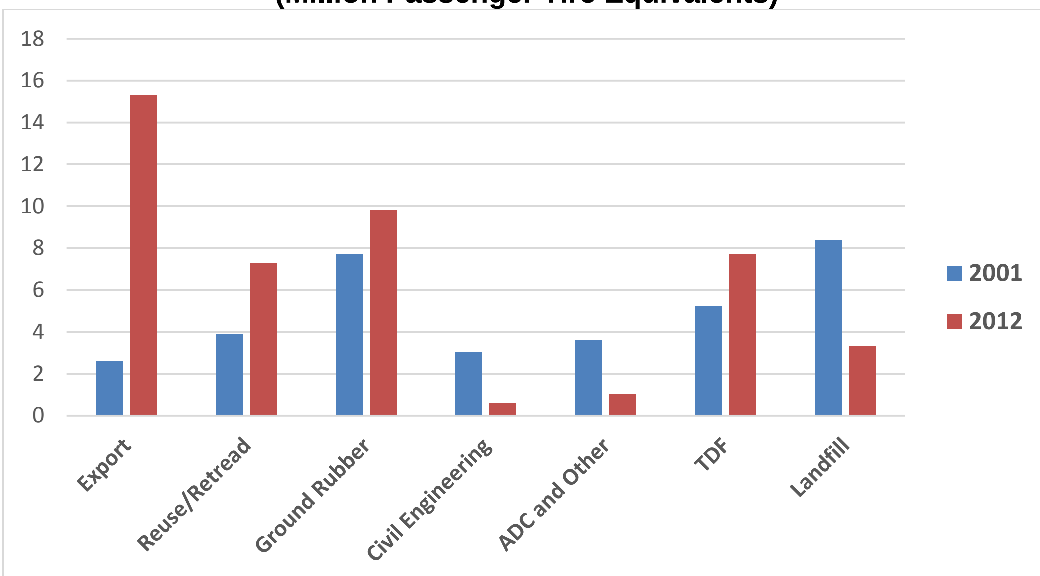
- There is little technical information available about the composition of tire fiber. Additional information could help processors market the material.
- There is a lack of standards/specifications for fiber material.

As described below, the situation has changed significantly in some ways over the past decade, with more crumb rubber produced in California and more processors recovering and marketing steel and, to a lesser degree, fiber by-products.

Current Waste Tire Market Conditions

It is estimated that in 2012, there were 45 million PTEs generated in California, 36 percent more than in 2001. As shown in Figure 1, approximately 9.8 million (or 21.7 percent) were used to produce crumb rubber.[1] This is 23 percent more than in 2001, but a lower percentage of total waste tire generation than in 2001.

Figure 1
Disposition of California Waste Tires 2001 vs. 2012
(Million Passenger Tire Equivalents)



Recovery and marketing of steel by-products is now nearly universal across all processors, although pricing received varies significantly due to volume, contamination, and marketing channels. Of six crumb rubber producers, three state they regularly recover and market fiber to cement kilns. Three dispose their fiber; however, all three said the cost is not a high percentage of overall disposal costs. Two said they produce very small quantities of fiber due to their scale of operation and/or focus on using truck tires, which contain relatively less fiber than passenger tires.

[1] Statistics in this section are from the 2012 California Waste Tire Market Report, available on the CalRecycle Web Site.

Purpose of Report

This 2013 Tire Recycling Wire and Fiber Study serves to update the 2003 study to identify whether the issues that existed in 2003 relative to the end markets for fiber and wire from waste tires have been adequately addressed, and what the potential need and opportunities are for CalRecycle to help further develop or expand markets for these by-products.

Research Approach and Organization of Report

The information and data in this Study were obtained through a variety of sources and methods. For the historical information, a review of the 2003 CalRecycle report and another study completed by the British Waste and Resources Action Programme (WRAP) "Markets for Steel and Fibre from Used Tyre Processing" dated June 2007 were completed. Both of these reports offered significant information on the recycling processes, the market demand (at the time of each report's respective publication), the potential markets, and information on tire recycling handlers, processers, equipment vendors, and other contacts.

SAIC also gained information from waste tire processors directly, both in and outside of California, and contacted industry organizations for input including:

- Institute for Scrap Recycling Industries (ISRI)
- Steel Recycling Institute
- Geosynthetic Materials Association
- Secondary Materials and Recycled Textiles Association (SMART)
- Rubber Manufacturers Association (RMA)
- Carpet and Rug Institute
- Carpet America Recovery Effort (CARE)

SAIC also conducted online research in an attempt to identify current and potential beneficial uses of these by-products, particularly of fiber from waste tires, and contacted potential end markets for fiber from waste tires to gain an understanding of the barriers to using this material. This report is organized as follows:

- Section 2 presents an overview of markets for steel derived from waste tires;
- Section 3 presents an overview of potential and identified markets for fiber derived from waste tires, including markets identified elsewhere, barriers, and the outlook for tire fiber markets.
- Section 4 presents conclusions and recommendations.
- Appendix A presents more in-depth technical information about wire and tire fiber from the 2003 report.
- Appendix B provides resources and references relative to wire and fiber, and liberating wire and fiber from waste tires.

Overview of Markets for Steel from Waste Tires

Current Practices

Practices vary depending on the type of tire being processed, the end products produced, volumes, market trends, and other factors. Bead wire is often removed from truck tires before further processing takes place. Some operations find this to be a cost-effective process for passenger tires also, although bead wire is often not removed from passenger tires before size reduction. Additional wire is removed as waste tires are processed into crumb rubber. Both wire and fiber residuals are mainly by-products of crumb rubber production, not other tire processing operations. When tires are processed into rough shreds, tire-derived fuel, or tire-derived aggregate, most or all of the wire and fiber generally remain in the chip. During processing the cutting action liberates the rubber from the steel, and generally the magnets remove the belt wire and any bead wire. The quantity and cleanliness of the steel removed is dependent on the type of equipment utilized. Some "mid-stream" processing equipment, for example, reduces a rough-shred chip to a ¾" chip, liberating at least 95 percent of the steel. Further granulation removes additional wire and fiber. Figure 2 presents a photograph of tire wire and fiber that has a fair amount of contamination. A variety of equipment for producing marketable wire from waste tires is available. Appendix B lists several sources as examples.

Figure 2
Tire Wire and Fiber with Contamination

All waste tire processors in California responding to SAIC's survey indicate that they have markets for steel wire that is removed from waste tires during processing. However, pricing varies significantly, both for individual firms over time and between firms, with a cited range of $30 - $340 per ton. Pricing can vary based on many factors, including: global market trends for scrap steel, quality, volume, packaging, market channels used, and location. Pricing is highly dependent upon quality in particular, – with higher prices offered for wire that has lower amounts of rubber contaminants. The Institute for Scrap Recycling Industries (ISRI) has developed specifications for such wire. They include:

Loose—Whole.

Loose—Chopped. If wire is chopped or shredded, parties may wish to specify the means of processing and/or characteristics of the final product (density, length of pieces, etc.).

Baled. Bales of wire should maintain their form during loading, shipment, unloading, storage, and handling typical of that done at a consuming facility, unless otherwise specified.

Baled—High Density. Hydraulically compressed, no dimension larger than 24", density of at least 75 pounds per square foot.

Baled—HRB/Low Density. Density of less than 75 pounds per square foot. Each bale secured with sufficient number of bale ties drawn tight to ensure a satisfactory delivery.

272 – Pulled Bead Wire (Truck)—Grade 1. Not chopped; made up of loops of wire. Less than five percent (<5%) rubber/fiber.

273 – Pulled Bead Wire (Truck)—Grade 2. Not chopped; made up of loops of wire. Five to ten percent (5-10%) rubber/fiber.

274 – Pulled Bead Wire (Truck)—Grade 3. Not chopped; made up of loops of wire. Greater than 10 percent (>10%) rubber/fiber.

275 – Pulled Bead Wire (Passenger)—Grade 1. Not chopped; made up of loops of wire. Less than five percent (<5%) rubber/fiber.

276 – Pulled Bead Wire (Passenger)—Grade 2. Not chopped; made up of loops of wire. Five to ten percent (5-10%) rubber/fiber.

277 – Pulled Bead Wire (Passenger)—Grade 3. Not chopped; made up of loops of wire. Greater than 10 percent (>10%) rubber/fiber.

278 – Processed Tire Wire (Ferrous)—Grade 1. Chopped. Less than 2 percent (<2%) rubber/fiber.

279 – Processed Tire Wire (Ferrous)—Grade 2. Chopped. Less than 5 percent (<5%) rubber/fiber.

280 – Processed Tire Wire (Ferrous)—Grade 3. Chopped. Five to 10 percent (5-10%) rubber/fiber.

281 – Processed Tire Wire (Ferrous)—Grade 4. Chopped. Ten to 20 percent (10-20%) rubber/fiber.

282 Processed Tire Wire (Ferrous)—Grade 5. Chopped. Greater than 20 percent (>20%) rubber/fiber.

Buyers and sellers may or may not reference the above specifications, and may agree on their own terms for what is acceptable. Generally, wire can be sold loose, baled, or briquetted. Baling and briquetting result in a denser commodity, which is more cost-effective to transport and has a higher value. One tire recycler in Texas indicates that for loose chopped wire he would receive $20 per ton, but if the same material were densified into briquettes he would receive $100 per ton for the wire. However, as is the case with California's one steel mill (Gerdau Ameristeel in Rancho Cucamonga, formerly known as TAMCO prior to a 2010 acquisition), some purchasers prefer to buy the material loose so they can see the quality of material more readily. Figure 3 shows a picture of clean wire derived from waste tires.

Figure 3
Clean Wire from Waste Tires

Specific machinery exists to separate clean wire from contaminated wire (e.g., clean wire separators), and to further remove contaminants (rubber and fiber) from the wire, allowing the processor to obtain higher revenues for the uncontaminated stream. (See Appendix B for examples of equipment vendors.)

According to the Rubber Manufacturers' Association, there are approximately 2.5 pounds of steel belts and bead wire in a passenger car tire. This material is made from high carbon steel with a nominal tensile strength of 2,750 MN/m2. Bead wire and steel belts have a slightly different material composition, which is summarized in Table 1.

Table 1
Composition of Bead Wire and Steel Belts

	Bead Wire	Steel Belts
Carbon	0.67 - 0.73%	0.60% min.
Manganese	0.40 - 0.70%	0.40 - 0.70%
Silicon	0.15 - 0.03%	0.15 - 0.30%
Phosphorous	0.03% max.	0.04% max.
Sulfur	0.03% max.	0.04% max.
Copper	Trace	Trace
Chromium	Trace	Trace
Nickel	Trace	Trace
Coating	66% Copper 34% Zinc	98% Brass 2% Tin

Source: RMA

In 2003, the Gerdau Ameristeel mill [2] reported that it was only accepting bead wire, due to the high cost of electricity (needed for processing scrap metal) in California. At that time, the quality of wire from processed waste tires was not as high as it is now. The 2003 Study suggested that thermolytic and pyrolytic technologies might enhance the liberation of rubber from steel. Since that time, however, processing technology has improved, and more processors are processing crumb rubber more thoroughly, liberating more rubber and fiber from the wire, rendering it more valuable in the marketplace.

Market Status and Trends

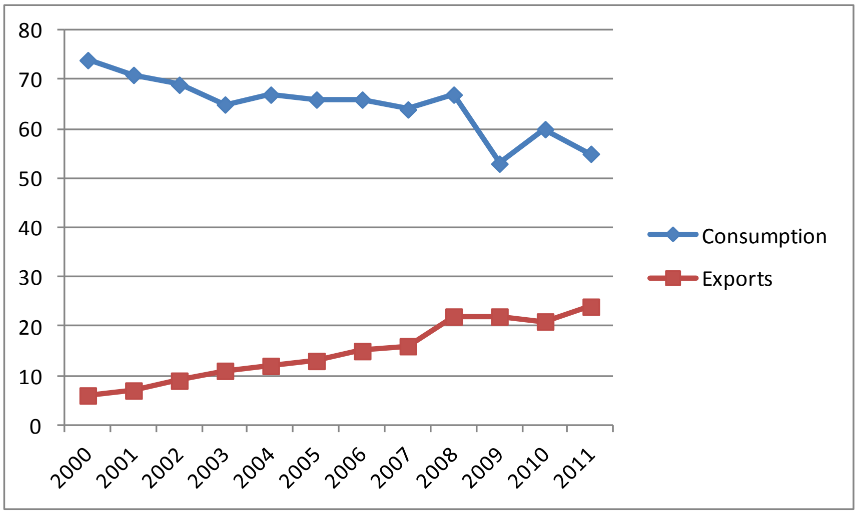
U.S. Market

The market for scrap steel has been relatively strong historically, in the sense that steel is a highly recycled commodity with generally strong global demand. According to the American Iron and Steel Institute, 88 percent of steel is recycled. Recycled iron and steel scrap is a vital feedstock in the production of new steel and cast iron products. Steel mills and foundries in the United States use technologies that are highly dependent upon scrap steel, which bolsters the markets for steel scrap. Pricing for scrap steel, however, can be somewhat volatile, reacting to economic factors such as demand for American steel, which is driven largely by the construction industry and durable goods manufacturing, as well as other countries' demand.

Data presented in Figure 4 shows the quantity of scrap iron and steel consumed and exported from 2000 through 2011. A small amount of scrap steel is typically imported into the United States annually as well, but this quantity is negligible.

[2] Available at:
http://www.steel.org/Making%20Steel/~/media/Files/AISI/Making%20Steel/2010_SteelPlant_NorthAmerica_HypocycloidVersion6.ashx

Figure 4
Annual U.S. Scrap Iron and Steel Consumption and Exports
2000 through 2011
(Millions of Tons)



Data Source: U.S. Geological Survey

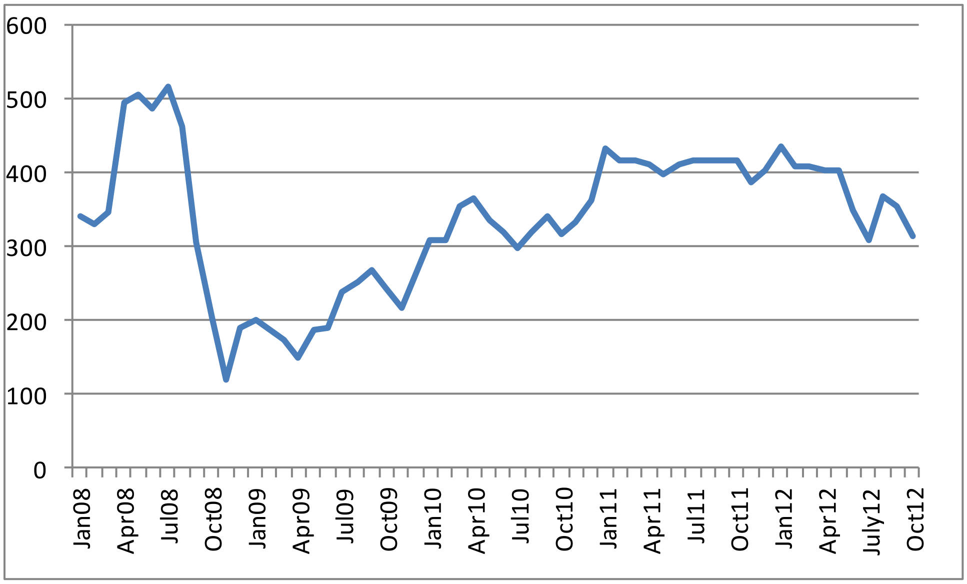
As Figure 4 shows, exports of steel from the United States have been increasing over time, particularly since 2007. This is due largely to economic growth in Asia, and in particular, China. The countries to which scrap steel was exported, in 2011 (in descending order) include Turkey, China, Taiwan, the Republic of Korea, and Canada. The United States is the leading exporter of scrap metal, including steel. Meanwhile, U.S. consumption of steel has declined, largely in response to the economic downturn.

Data presented in Figure 5 shows the U.S. average pricing for #1 heavy melt steel as reported by the Raw Material Data Aggregation Service (RMDAS™). RMDAS prices are a weighted average of the prices reported to them by steel producers from January 2008 through September 2012. The prices represent regional spot market prices for scrap commodities sold and "delivered" to domestic steel producers each month.

On the ferrous scrap demand side, domestic steel industry production figures were showing signs of weakness as of mid-October 2012. According to the American Iron & Steel Institute (AISI), in the week ending Oct. 13, 2012, domestic raw steel production was 1.736 million net tons at a capability utilization rate of 70.3 percent.

Adjusted year-to-date production through Nov. 3, 2012, was 82,811,000 tons, at a capability utilization rate of 76.2 percent. That is a 3.5 percent increase from the 80,011,000 tons during the same period last year, when the capability utilization rate was 74.5 percent.

Figure 5
U.S. Average Price for #1 Heavy Melt Steel
January 2008 – October 2012
($ Per Ton)



Source: RMDAS™

California Market

Most California waste tire processors that responded to the 2011 Market Analysis surveys indicated that they separate and have markets for steel by-products including wire and rims. Two respondents, however, said they do not always recover and market steel by-products. This is apparently due to occasional contamination issues in one case and unusually attractive disposal costs in another. Pricing varied from $30 per ton to $340 per ton. One processor indicated that it sold wire directly to a local steel facility (presumably the Gerdau Ameristeel mill) and that its revenues were relatively stable. Other processors, however, indicated that their revenues were highly variable, and that this was problematic. During the 2012 Waste Tire Market Study interview process, which took place in 2013, California waste tire processors indicated they received revenues of $40 per ton at the low end and $325 per ton at the high end for wire from scrap tire processing. This is an increase in market prices for wire over those identified in the 2003 study, which reported that prices for recovered steel were $55 per ton at the high end.

Variability in market pricing for wire is likely due to several factors, including:

- The level of contamination of the steel, which is determined primarily by the type of equipment utilized by the processor to separate the tire fiber and contamination from the steel;
- Ability/resources available to find the best possible market;
- Proximity to end market;
- Volumes; and

- External market drivers, such as export markets, which influence pricing.

Most processors that market wire appear to be exporting the wire through a broker; however, some processors located in close proximity to California's sold market sell directly.

SAIC interviewed the steel scrap buyer at the Gerdau Ameristeel (formerly TAMCO) mini-mill in Rancho Cucamonga. The mill consumes from 50,000 to 60,000 tons of scrap steel per month, and produces rebar. The scrap buyer at Gerdau Ameristeel indicated that the mill buys loose steel wire directly from two waste tire processors in California. The quantity ranges from one load per month to several hundred tons per month. The buyer prefers to purchase material loose, which helps him visually inspect the wire at the plant. The material the buyer has purchased from the California tire processors has a contamination rate of less than 3 percent. However, it is not uncommon to see contamination rates of 10 to 15 percent, and he says he has seen loads with contamination levels of up to 25 percent.

The buyer indicated that demand at his mill has been relatively steady in the past several years, albeit lower than in the early 2000s due to the economic downturn's impact on rebar demand. Prices can fluctuate, however, depending upon export markets. He said there is a relatively strong container export market. Historically, container shipping is more commonplace than bulk shipments due to the low cost of container transportation options going back to Asia. Other export markets include Mexico (Simec in Mexicali, Baja) and Canada (Alberta, Saskatchewan, and Manitoba each have one steel mill in operation).

California waste tire processors that are not selling directly to the Gerdau Ameristeel mill are likely selling to brokers who sell to out-of-state and export markets.

Pricing for scrap steel, as processors indicated, can fluctuate significantly. In California, long-term pricing changes are often due to changes in demand for rebar, however short-term pricing fluctuations are likely in response to export markets. Interestingly, when scrap pricing increases, this may help increase demand for lower-priced scrap (like tire wire) as mills try to keep their average costs low, and may switch from higher grades to lower grades in order to do so. Similarly, when rebar pricing goes down, for example by $30 per ton, scrap metal prices tend to go down by the same or similar amount across all grades, in which case lower grades may be impacted more significantly. Also, if buyers can purchase a higher-quality steel at a relatively low cost, they may decide to switch to higher-quality scrap metal, reducing demand for lower-quality steel.

There is interest, and progress being made, in the tire industry to develop lighter, longer-lasting, lower-maintenance, and more sustainable tires. It is possible that in the future, tires will contain less wire than they currently do. Cooper Tires, for example, is experimenting with lightweight belts, which could potentially replace some of the wire in tires. They are also experimenting with smaller, lighter bead wire bundles.[3]

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[3] Cooper Tires, "Improving Vehicle Fuel Efficiency Through Tire Design, Materials, and Reduced Weight," Tim Donley, May 13, 2013. Available at: http://www4.eere.energy.gov/vehiclesandfuels/resources/merit-review/sites/default/files/vss083_donley_2013_o%20.pdf

Overview of Markets for Fiber from Waste Tires

Current Practices by California Processors

The average passenger tire contains approximately 2.5 pounds of fiber, while truck tires may have much less. The fibers are a combination of polyester and nylon. Fiber is liberated from rubber and wire using different methods during processing. Mechanical vibrating screens and pneumatic systems can liberate fiber from other tire material when shreds are about ¾" in size; however, some material will re-pass through the system, as it is not yet liberated. The more the material is passed through, the shorter the fibers become. This can make the material less marketable for certain applications. Vibrating air fluidized beds are also used to separate fiber from rubber. The resulting fiber is "fluffy" in nature, resembling cotton, and is often referred to as "fluff." Because the material is low in bulk density, it may need to be baled for transport to market it successfully. Vacuum systems often collect the fiber material or convey it at its final destination due to its light nature. Figure 6 shows tire fiber from waste tires.

Figure 6
Tire Fiber

Of six crumb rubber producers surveyed, three said they regularly recover fiber and market it to cement kilns. Three dispose their fiber; however, all three of these said the cost is not a high percentage of overall disposal costs. Two of these said they produce very small quantities of fiber due to their scale of operation and/or focus on using truck tires which contain relatively less fiber than passenger tires. Tire derived fiber is largely an underutilized commodity. If markets were more readily available and offered a sufficient price, processors would likely be more prone to processing the tires in such a way as to remove the fiber and prepare it for market.

Market Status and Trends

It is difficult to estimate the exact amount of tire fiber generated annually. Assuming each PTE generates approximately 2.5 pounds of fiber, and that only processors manufacturing crumb rubber generate tire-derived fiber, a relatively high estimate would be that as much as 12,000 tons of tire-derived fiber could potentially be generated annually in California from existing crumb rubber producers.[4] As was the case in the 2003 study, the only market identified for tire fiber from processing waste tires is for use as fuel in cement kilns, with two California kilns currently using the material, both of which are located in Southern California. Based on survey responses SAIC estimates that in 2012 these two kilns used 7,835 tons of tire fiber, or about 66 percent of the estimated maximum total amount available.

In California the cement kiln market for fiber is generally non-paying, with the material being accepted for free, with shipment costs covered by the shipper. (Processors benefit from the cost savings compared to disposal.) One cement kiln has been using tire fiber for several years, and has made a significant investment in a blower and storage system to effectively utilize the fuel. The facility could potentially consume up to 8,200 tons of tire fiber annually, but used 4,635 tons in 2012. A second cement kiln in 2013 began using the material, and is able to do so without making an investment in handling equipment, by mixing it with other material such as wood chips. A kiln representative said, however, that it took time and effort to identify a source that could provide adequate quantities of the material at regular intervals. It is estimated that this facility used 3,200 tons of fiber in 2012. A third cement kiln had previously investigated use of fiber in combination with biomass, but determined at the time that it could not secure an adequate, steady supply. Although total demand of 11,200 TPY nearly exceeds the upper estimate of tire fiber supply, the two cement kilns using fiber are both located in Southern California, resulting in relatively poor economics for Northern California crumb producers to recycle fiber.

SAIC interviewed one California firm, L.A. Fiber, that had investigated use of tire fiber for use in carpet backing. A representative indicated that they found that the fibers from waste tires are too short to be of value to them. They also found that tire fiber had significant amounts of contamination in the fiber—including both rubber and wire—which made the material unsuitable for their purpose.

For this current study update, SAIC sought to identify and verify use of fiber in non-fuel markets outside of California, but found that such uses are very rare. One out-of-state manufacturer of asphalt products indicated that they use crumb rubber in their products, and include the fiber as well in some products, as it helps form a matrix that adds strength to the material. And, a vertically integrated waste tire processor and product manufacturer with locations in the United States and Ontario, Canada, uses tire-derived fiber in manufacturing some of its masticated rubber products. For example, the company manufactures mud flaps and rubber sheets and rolls that are fiber-reinforced with tire-derived fiber.

The amount of fiber that will be used in tire manufacturing in the future is uncertain, and changes in tire manufacturing practices could of course impact the quantity of fiber generated from waste tires. While safety is the first concern of tire manufacturers, they are also researching new tire construction technologies and materials to reduce the weight and increase the recyclability of tires, as well as ways to ensure proper tire pressure is maintained (enhancing safety as well as fuel efficiency). Several different technologies are being explored by tire manufacturers. One example is the AIRTEX Advanced Liner, which is an advanced material being developed by Yokohama. This liner would be a spray-on material, much lighter than fiber currently being used, and would prevent the loss of tire air pressure, promoting fuel efficiency. Other technologies being explored could result in lower rubber content, fewer petroleum-based feedstock vs. bio-based feedstock,

[4] This is a very rough estimate provided to illustrate the “high end” of current, potential tire fiber generation.

different types of fiber in tires (e.g., Kevlar), and less wire. For these reasons, it may not be advisable to develop uses for fiber that would be suitable only for fiber types included in tires currently.

Market Development Outlook

Opportunities

Given the established use in two California cement kilns, and the fact that the fiber has a relatively high btu value (similar btu value as TDF at 14,000 to 16,000 btu per pound, dry weight) one market expansion opportunity is to approach the two California cement kilns that currently do not use TDF to explore whether and how they could begin to use it to complement existing fuel sources. As mentioned above, one of these two mills had previously investigated its use, but representatives said they could not secure an adequate, consistent source at the time to justify the effort. As crumb rubber manufacturing in the state continues to evolve, conditions may change such that this barrier could be overcome.

Beyond use as fuel, tire-derived fiber is highly absorbent and lightweight and has low or no cost, potentially making it a possible replacement for materials in some other markets. The 2003 survey of processors internationally identified the following potential markets for fiber:

- Rubber (7 respondents)
- Concrete additive (4 respondents)
- Carpet (3 respondents)
- Soil amendment (3 respondents)
- Proprietary use (3 respondents)
- Sound deadening (3 respondents)
- Blanket (2 respondents)
- Insulation (2 respondents)
- Target backing (2 respondents)
- Recycled to plastics (1 respondent)
- Mulch (1 processor or 0.3 percent);
- Composite (1 respondent)
- Adhesive reinforcement (1 respondent)
- Asphalt strengthening (1 respondent)
- Toy stuffing (1 respondent)
- Packing (1 respondent)
- Flooring additive (1 respondent)
- Furniture stuffing (1 respondent)
- No market (17 respondents)

Apart from these 2003 examples of hypothetical uses, SAIC contacted a number of processors inside and outside California; most were not familiar with any high-volume use for tire fiber other than for tire derived fuel. However, two markets being pursued in California were identified:

- A waste tire processor is in discussions with a university to investigate the possibility of using the fiber material in asphalt; and
- A tire-derived product manufacturer says that he is in the process of developing a proprietary new product using tire-derived fiber as a feedstock.

Additional information on these potential uses was not available. As mentioned above, SAIC also spoke with representatives of LA Fibers, a California firm that produces carpet backing using recovered fibers. The firm had rejected using tire fiber, however, as the fibers were too short to be of value to them. Contamination can also be an issue with fiber. LA Fibers indicated that that tire fiber had significant amounts of contamination in the fiber – including both rubber and wire – which made the material unsuitable. L.A. Fibers indicated that if the fiber could be processed to be free of wire and rubber, and in such a way that the fibers were at least 1.5 inches in length, then there might be some opportunities to use the material in manufacturing new products. It appears that many in the textile industry, even those that customarily use recycled fibers, are unaware of current processing capabilities. There may be waste tire processors that can produce tire-derived fiber to their specification, though no specific opportunities were identified in California. Ideally, of course, value-adding markets providing a new revenue source would be developed. But given the characteristics of tire fiber, it may be more useful to focus on finding beneficial uses that are feasible to simply keep fiber out of landfills, providing a cost savings to processors who are disposing the material. Potential fiber markets that merit further investigation include those that:

- Do not require significant capital expenditure;
- Are not specific to particular resin types (as these may change, and it is not likely that specific resins can be separated cost effectively);
- Have the potential to divert significant amounts of fiber;
- Do not have overly strict specifications (e.g., that are challenging for processors to meet); and
- Can be developed in relative close proximity to the processor locations.

Potential uses for tire-derived fiber such as reinforcement in cement and in certain asphalt products may have some potential to meet some of these criteria. The uses are not specific to particular resin types, so would likely remain a practicable market if tire manufacturers change the type of fiber used in their tires in the future. Also, some of the other barriers that exist for other applications (mixed resins, potential contamination, and short fibers) do not appear to be as problematic for these applications. If shown to be viable, these markets could potentially consume a large amount of material in California. However, raw materials for these products are already inexpensive, and it is by no means clear that California processors would be interested in shifting supplies away from current fuel markets, and/or investing in the ability to send adequate quality fiber to such new uses.

Outside of California, as noted above, one company in Ontario, Canada, was identified that manufactures mud flaps and rubber sheets and rolls that are fiber-reinforced with tire-derived fiber. Another company, North American Wool, located in Montreal, manufactures mattress pads and carpet padding. The company would consider using tire fiber, but would require the fabric to be completely free of rubber, as it damages the equipment; however small amounts of metal would be relatively easy to manage. The company's minimum requirement for fabric length is ¾-inch, and it would require that the material be baled. The company location, of course, precludes use of California-generated fiber. And, one additional company not located in California says it uses tire fiber in certain asphalt products. Although several academic papers have been written regarding the potential to use tire-derived fiber in manufacturing cement, none of the authors contacted knew of any real-world application. Two technical reports, for example, were identified that investigate the use of tire fiber as reinforcement in concrete.[5] The reports found there was a

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[5] "Concrete Reinforcement with Recycled Fibers." By Youjiang Wang, H. C. Wu, and Victor C. Li. Journal of Materials in Civil Engineering. Nov 2000. http://deepblue.lib.umich.edu/bitstream/handle/2027.42/84900/youjiang_JMCE_00.pdf?sequence=1.

noticeable decline in the compressive strength of the concrete; however, there was an increase in the toughness of the concrete. SAIC did not identify any commercial examples of tire fiber being used in concrete. Again, given the low cost of concrete raw materials and the expense of shipping tire fiber, economics may play a role in constraining such uses, in addition to lack of familiarity or sufficient technical testing results.

Barriers

As described above, there are theoretically several potential uses for tire fiber, but also a number of critical barriers that constrain such uses. Following is a consolidated summary of these barriers:

Barriers to Recovery and Marketing by Processors

- Inconsistent quantity or low volume of generation. Crumb producers may generate only a few truck loads per year or less in some cases.
- Costs associated with equipment to ensure clean, consistent supplies of tire fiber
- High cost of shipping very low-density material
- The fact that for some crumb rubber producers, the cost of disposing fiber is a very small percentage of total disposal costs, providing only a weak incentive to prioritize expanding fiber recovery and marketing

End Use Barriers

- Short fibers limit the usability of the material in some applications
- Crimped fibers limit the usability of the material in some applications
- The "dirtiness" of the fiber limits the usability of the material in some applications
- Contamination from rubber or wire. (Some potential fiber markets would be intolerant of any metal included in the material, due to potential damage to equipment as well as consumer safety concerns)
- Lack of knowledge about relatively recent advances in liberation technology that can potentially help secure clean fiber material
- Dual resins (nylon and polyester) in the fiber stream may limit the marketability of the fiber
- Tire fiber can absorb water, and in most applications a high moisture content is not desirable
- The low density or "fluffiness" of the material can make it difficult or costly to manage, contain, transport, and feed into systems. Even baled fiber can be problematic in some feed systems
- Variability in fiber sources, as fiber length, contamination and other factors can vary depending on equipment used and type of tires being processed

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And: Analysis and Testing of Waste Tire Fiber Modified Concrete. Gregory Garrick. Thesis submitted to Louisiana State University, 2005. http://etd.lsu.edu/docs/available/etd-04112005-154524/unrestricted/Garrick_thesis.pdf

- Alternatives for the fibers are often inexpensive (e.g., recycled PET or other polymers, other textiles, waste tire chips (for fuel)) etc. , which limits the pricing for tire-derived fiber
- Tire fiber can be challenging to keep evenly dispersed throughout the mixture in the manufacturing process
- Fiber uses can be very specific, and tire-derived fiber may not be suitable for many needs
- There are no specifications for tire-derived fiber, making it less marketable.

Some of the above barriers can potentially be addressed through modified practices by tire processors and/or potential fiber end users. However, most options are also problematic. For example, the low-density issue can potentially be overcome by densifying the material into a briquette. This allows for more cost-effective transportation and could possibly reduce the need for special equipment at the site of final use. However, the equipment needed to produce the briquette is expensive. Individual processors would need to evaluate whether the cost of purchasing, maintaining, and operating the equipment is worthwhile for the quantity of fluff they produce, relative to the revenue received and disposal costs avoided. One major equipment manufacturer in the Midwest has experimented with densifying tire fiber into briquettes (about 200 pounds can be processed per hour); however, the company does not currently have any customers using the briquetting machine for that purpose.

The cost-effectiveness of purchasing, maintaining, and operating such equipment would have to be weighed against the increases in revenue/decreases in disposal costs derived from marketing a higher-quality fiber product. In the end, each processor must assess whether purchasing, maintaining, and operating the equipment is a cost-effective option for them, given the potential market for the fiber and the alternative disposal cost or other outlet for the fiber. It is important to remember too that, while processing of waste tires has improved in recent years, the primary goal is not to develop clean fiber, but rather to process rubber into high-value crumb rubber and other products, with fiber and wire as by-products. To most crumb rubber producers, fiber appears to be viewed as a relatively low-volume annoyance that does not significantly impact their profitability or long-term success.

Other barriers are a result of the fundamental characteristics of the fiber contained in tires. For example, the fibers are relatively short compared to those that may be needed for some end products like carpet backing. While improved processing equipment and practices may be able to yield cleaner, longer fibers, such investments would not be contemplated if the reward were not sufficient, as noted above. And, while end-users could potentially adjust their practices to accommodate shorter fibers, the low quantity available and lack of urgent need may not provide sufficient motivation for them to explore such options.

Conclusions and Recommendations

The need for new market development activities focused on tire wire and fiber is mixed and does not appear to merit shifting CalRecycle resources away from priorities such as expansion and diversion of markets for crumb rubber.

With very few exceptions, California processors are now already recovering and marketing wire and appear to be generally well equipped to determine whether and how to invest in equipment and/or to adjust practices to increase the value of their marketed wire. Given the relatively strong situation for tire wire, this report focuses primarily on fiber market development.

It appears that less than 33 percent of the tire-derived fiber generated in California is disposed, and it appears that at most about 4,100 tons of tire fiber may be disposed each year. Total current demand of 11,200 TPY nearly exceeds the upper estimate of tire fiber supply, although the two cement kilns using fiber are both located in Southern California, resulting in relatively poor economics for Northern California crumb producers to recycle fiber. Three of the six California crumb rubber producers are currently recovering and shipping most or all of their fiber to two of the four in-state cement kilns. And, while a new market that could reduce costs and/or generate new revenue would be desirable, the remaining three crumb producers do not indicate that fiber disposal is a major concern to them.

There are potential opportunities to boost demand for fiber outside of fuel markets, and this could be a focus in future efforts. For example, fiber could potentially be beneficial in manufacturing carpets, asphalt, cement, textiles, carpet pads or hot mix asphalt either as a fundamental raw material or as filler. Many in the textile industry appear to be unaware of the existence of this material, and processing technologies have changed significantly in the past 10 years or so. Other low-tech options would be using tire-derived fibers for filling/stuffing in furniture manufacturing. However, this market is likely to have a more stringent specification (e.g., longer fibers and no rubber).

Promoting such fiber uses could be done by providing technical assistance and financial support, as CalRecycle has done with crumb rubber market development. However, CalRecycle is legislatively prohibited from promoting fuel-related uses for tires and tire-derived materials. Alternatively, promoting such market expansion this could be conducted as a low-effort "matching" of waste tire processors with by-product users. However, few candidate firms operate in California: Only one specific potential California user was identified in California in this study (L.A. Fibers).

CalRecycle has established a clear focus on expanding and diversifying markets for crumb rubber (along with tire-derived aggregate), which has a direct influence on the long-term viability and success of crumb rubber producers. Given that, and the above challenges related to wire and fiber market development, SAIC recommends that CalRecycle not redirect significant resources away from higher priorities to target wire and fiber. Rather, CalRecycle should continue to focus on expansion and diversification of waste tire markets generally, and especially for relatively high-value crumb rubber in new products.

Notwithstanding this recommendation, however, CalRecycle should consider undertaking the following relatively low-resource activities:

- Distribute this report to processors and encourage them to evaluate options to enhance their practices by evaluating equipment and practices to determine whether they can increase the value of wire, or the marketability of fiber to non-fuel users in a cost-effective manner (Appendix B lists several equipment vendors who could provide advice and feedback).

- Identify any California firms using scrap fibers and/or producing textile products that may be in a position to consider use of tire fiber, and provide low-level technical assistance to facilitate their evaluation. This should include providing a list of tire fiber suppliers and information on low-interest loans available through CalRecycle, for example.

Beyond these relatively low-cost steps, SAIC concludes that CalRecycle's scarce resources would be best applied to expanding and diversifying markets for rubber products made from crumb rubber, rather than the fiber and wire by-products which are largely recycled already, and for which market development is less critical to their long term success.

One final action CalRecycle may wish to consider is adjusting the manner in which the tire diversion rate is calculated. Currently, all tires sent to an end use, including crumb rubber, "count" as diverted. This is similar to how most if not all other state and national tire studies are analyzed. Consistent with CalRecycle's current focus on "recycling" rather than "diversion," the agency could shift to a system in which disposed wire and fiber residuals are subtracted from the tons diverted prior to calculating the diversion rate. A challenge to this approach would be the need for more accurate data from processors on disposed residuals, which has not been comprehensively gathered in the past. However, the data should be available from the firms, and SAIC believes such a shift in methodology could feasibly be implemented.

Appendix A
Technical Summary of the 2003 Tire Wire/Fiber Study

Following is a brief summary of select findings from CalRecycle's 2003 study, "Assessment of Markets for Fiber and Steel Produced From Recycling Waste Tires," which is available online at: http://www.calrecycle.ca.gov/publications/Detail.aspx?PublicationID=1033.

Wire

The 2003 study provides a good description of the two sources of steel found in waste tires: bead wire and belt wire. The bead is composed of many wraps of thin wire that is used to add structural stability to the tire as well as serving as the mechanism to allow the tire to form a tight leak-proof hold on the wheel rim. The bead can be separated by any of the shredding and grinding operations that recover rubber, as well as by a debeader or puller. Bead wire is generally lower carbon steel than belt wire and has a thicker wire gauge. Some tire companies use the same grade of steel for both components. Chopping into small length and compacting bead wire into blocks is the most saleable steel from tires. However, processed bead wire is a difficult material to package because of its springiness and resistance to compaction or to forming into a bundle.

Belt wire is comprised of cords of very thin, high-tensile wire that has been wrapped and twisted. The belt wire provides stability and strength to the tire tread and sometimes, particularly in trucks, to the body of the tire. Ambient grinding or cryogenic processing can be used to free wire from rubber.

When the 2003 study was conducted, wire was generally still fairly contaminated, and it was suggested that future processing technologies using thermal processing or pyrolytic processing might be beneficial means of cleaning the wire more thoroughly. In addition, when the 2003 study was conducted, the specifications for wire derived from waste tires were relatively new. Lack of specifications (and/or familiarity with new specifications) likely hampered the marketability of the steel. Processor surveys indicated that the most common technologies used to recover steel from waste tires included belt magnets (34 percent), bead magnets (27 percent), screens (14 percent), and debeaders (11 percent). Less commonly used equipment included belts (6 percent), gravity (2.5 percent), post-processing (2.5 percent), granulators (2 percent), and compactors (2 percent).

Results of the survey conducted for the 2003 study (including national and international processors and other industry members) indicated that 38 percent of processors' wire was not being recycled. For some, however, this may have been because they did not generate wire separately, as 25 percent of respondents processed tires into TDF.

Survey responses pertaining to by-product end markets indicate that it was more common for steel to be sold directly to steel mills rather than through brokers by 2:1. Processors generally sold mixed steel wire, which typically was comprised of shreds no greater than 2 inches in length, unless a debeader was used. The primary market was remelt to form new iron or steel. The report indicated that there was variability in demand by region, as there were some regions where perfectly clean wire had to be landfilled, and some regions where contaminated wire had a market. Sixty percent of processors indicated that their recovered wire was at least 90 percent steel (less than 10 percent contamination). Thirty percent of processors indicated that their wire was at least 99 percent steel (less than 1 percent contamination). Marketability primarily was dependent upon three characteristics:

Bulk density—a higher bulk density is preferred, as it is easier to transport, results in less loss of steel through vaporization at mills, and poses a reduced risk to equipment at the mill.

Alloy content—there is some bronze coating on the bead wire and brass on the belt wire. Some foundries may have very tight specifications regarding alloys, and therefore will not use tire-derived wire.

Contamination level—The degree to which rubber is included in the wire can reduce its marketability; however this can be a loose relationship, dependent upon other factors such as proximity to mill and specific mill specifications (reportedly specifications among the survey respondents varied from virtually no contamination to 20 percent). Also, attempts to remove rubber through heating can alter the characteristics of the steel, also reducing its value.

Distance to market—If the generator is located far from the market, the net revenues will likely be reduced due to transportation costs. (Markets can be up to several hundred miles away, potentially).

The 2003 study author did not identify steel markets in California and concluded that the three processors that were recycling tire-derived wire were sending to scrap metal processors/brokers that eventually exported the material. Scrap steel dealers were interviewed and indicated that if the wire were free of rubber (less than 5 percent contamination), they would be open to trying to find markets for the wire. They indicated that if the wire were also compacted, they could find markets in California, the Pacific Northwest, Mexico, or overseas. They indicated that California had six foundries – all potential markets for steel.

Fiber

The 2003 study indicated that recovered fiber from waste tires is described by some processors as fibrous “fluff,” with the appearance of cotton or dirty cotton. The fiber is normally collected using screening systems, air classification systems, or both. Due to the methods of processing waste tires and of segregating product streams, rubber and steel particles tend to snare themselves in the fiber fraction.

Survey results indicated that the markets for reprocessing fiber were extremely limited and that there was no attempt to process fibers back to basic resins or to separate the fibers by resin type. Further, the respondents indicated that there was no research being funded to separate resin types from tire-derived mixed fiber fractions. Waste fiber dealers are generally not aware of tire-derived fiber and, therefore, are not looking for outlets. The waste fiber and textile scrap business is focused almost exclusively on clean, single resin, long-length fiber for reuse in textile applications. In contrast, tire fibers typically are composed of a mix of resins and are dirty, crimped, and short (although some cryogenic operations reportedly can remove the fiber as a fabric, not individual strands).

Tire-derived fiber has many limited markets (e.g., filling for targets and furniture), but few substantial ones. Processors selling TDF generally include the fiber in with the TDF. Of the processors providing tire-derived fuel commercially, two processors added back in the recovered fiber, while a third did not separate the fiber from the rubber. Baling the fiber increases its bulk density, making it more practical to ship greater distances. Baling also helps the material absorb less water, which makes it a more valuable fuel. Either in loose or baled form, the fiber can cause problems with existing feeding systems of utilities, or of paper or cement companies. Some processors reported that fuel users resisted or are likely to resist installing new feed systems for small quantities of low-cost fiber. The average distance for shipping fiber, according to the survey, was 200 miles. A significant amount of fiber is landfilled due to its limited marketability (e.g., supply exceeds demand).

According to the study, one potential market that might be worth pursuing further is tire-derived fiber as reinforcement in cement. In the 2003 study, two respondents (not located in California) indicated that they were selling tire-derived fibers for this purpose. Polyester fibers may not be useful in this application, however, because they can have an alkaline reaction with the cement mixture. Also, the presence of adhesion coatings could be problematic in this application.

The 2003 study also indicated that another potential market for tire-derived fibers is in erosion control – either blended with soil directly or formed into erosion control mats. The report indicated that "In the Midwest, tire-derived fiber was reported to be used in an architectural landscaping project, and mats of single-resin polyester and other natural and synthetic fibers are being used elsewhere for hillside, riverbed, and shoreline projects, railroad track beds, and other erosion-control projects." The report indicates that several companies sell fiber products that are used for erosion control. The fibers are not from waste tires, but they include polyester fibers. Fiber length is important: The fibers used by the companies described are from 1.25 inches to 5 inches in length. Some are spray-on applications, which would be intolerant of any rubber (as it would block the nozzles).

Some survey respondents also indicated that they had heard of tire-derived fiber being used for manufacturing mats and blankets (such as moving blankets) and as a packaging material. Of course, it would be important for fibers used in such applications to be free of debris, especially of wire, due to liability/injury issues. Rubber can also cause be problematic for manufacturing equipment.

Similarly, respondents indicated that the material could feasibly be used as stuffing/filling material, insulation, and as a filter medium, and for sound-dampening applications. The report indicates that "Although the total market for waste polyester exceeds 100 million pounds per year in the United States, most markets such as retail stuffing for hobbies and sewing projects, rope, or reuse in primary applications are not suitable for tire-derived fiber. The tire-derived fiber's short length, lack of purity, steel inclusions, and other quality issues preclude many potential applications."

Carpet underlay is another suggested use presented in the 2003 study, based on survey results. The study indicates that "Tire-derived fiber has been tried unsuccessfully in this application due to the quality and contamination issues mentioned above. The presence of metal is unacceptable, and the presence of rubber can form uneven blotches when heated and break needles in needle-punch joining systems. Moreover, dealing with moisture buildup in the fiber adds to the manufacturing cost."

Another potential market for tire-derived fibers mentioned in the 2003 study is as an additive in asphalt production. Fiber can be added to asphalt products to improve material integrity and flex strength. Direct addition of fiber to paving has reportedly been tried; however, it is not widely practiced. Caltrans and others also question whether the addition of fibers to the asphalt pavement provides measurable improvements in road durability, and tests do not indicate that fibers enhance the performance of asphalt. However, there are several different types of asphalt products, some of which would be better suited for tire derived fiber than others. Also, the limitations of fiber in other applications would not apply to most asphalt applications. Survey respondents, however, were not aware of any current uses of tire-derived fiber being used in asphalt production.

Equipment used to separate fiber from waste tires and process it for marketing, according to the survey, included air classification (81 percent), cotton gin (6 percent), baler (6 percent), density separator (3 percent), and scalper/screen (3 percent).

General

The 2003 study author indicated that California processors enjoyed lower pricing for steel than the rest of the country's processors, based on survey results ($16.60 per ton, on average, as opposed to $33.80 for the rest of the nation). Fiber pricing averaged $19.40 in the rest of the country, vs. no revenue, on average, in California. The study authors thought this was indicative of lower-quality processing in California at the time compared to the rest of the country. California's tip fees for disposing of by-products was cited as lower, however, at $23.90 per ton vs. $33.00 in the rest of the country. However, the study also indicates that the price for recovered steel is naturally higher in the steel belt region of the country. The study showed that processors in California were less likely to recover by-products than processors in the rest of the country, and those larger-scale processors (those processing more than 3,000 PTE per day) were more likely to recover wire and fiber.

Appendix B
References and Resources

Processing Equipment Manufacturers

The following list is not exhaustive, but is intended to provide some starting points for firms interested in investigating equipment needed to process wire and fiber in waste tire processing operations. The firms listed are not necessarily recommended or endorsed, nor are any equipment manufacturers or vendors not listed herein excluded intentionally. SAIC attempted to identify equipment manufacturers that supply equipment that liberates wire and/or fiber from rubber in processing scrap tires.

Amandus Kahl USA

Website: http://www.akahl.de/akahl/de/home/index.php

http://www.akahl.de/akahl/en/products/recycling_industry/waste_tyre_recycling_plants/

Bimetal Corporation

Website: http://www.bi-metalrecycling.com/clean_wire_system.htm

Columbus McKinnon (CM)

Website: http://cmtirerecyclingequipment.com/

Eldan Recycling

Website: http://www.eldan-recycling.com/

http://www.eldan-recycling.com/content/tyre-recycling

Global Recycling Equipment

Website: http://www.globalrecyclingequipment.com

Granutech

Website: http://www.granutech.com

http://www.granutech.com/tire-recycling-equipment.html

Pallman Industries

Website: http://www.pallmannindustries.com

http://www.pallmannindustries.com/Recycling%20of%20Tires.htm

Vecoplan Midwest

Website: http://www.vecoplanmidwest.com/

Relevant Organizations

Institute of Scrap Recycling Industries, Inc. (ISRI)

ISRI, among other things, develops standards and specifications for scrap materials, which helps develop expectations and allows for more standardized pricing.

Website: http://www.isri.org/

Rubber Manufacturers Association (RMA)

The Rubber Manufacturers Association (RMA) is the national trade association for tire manufacturers that make tires in the United States.

Website: http://www.rma.org/

Secondary Materials and Recycled Textiles (SMART)

An international trade association that aims to strengthen opportunities for members by promoting the interdependence of industry segments and providing a common forum for networking, education, and trade.

Website: http://www.smartasn.org/