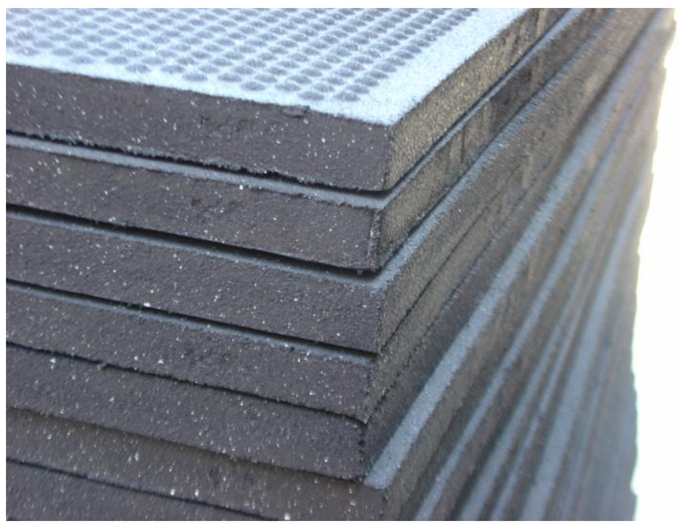
Institute of Scrap Recycling Industries, Inc.

Voice of the Recycling Industry

Carbon Footprint of USA Rubber Tire Recycling 2007



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The Institute for Environmental Research and Education

IERE

Institute for Environmental Research & Education

Executive Summary

The Institute of the Scrap Recycling Industries retained the Institute for Environmental Research and Education to perform a carbon footprint of rubber recycling. The analysis was performed in conformance with applicable international standards for life cycle assessment and carbon footprinting. Approximately 16 percent of the USA tire recycling industry was analyzed. The study found:

- The weighted average carbon footprint was 124 kilograms of CO_2 equivalent per metric ton of materials recycled back into commerce.
- The mean carbon footprint was 153 $\pm$ 92 kilograms of CO_2 equivalent per metric ton of material recycled. Larger tire recycling facilities tended to have lower carbon footprints than smaller tire recycling facilities.
- The use of recycled rubber in molded products provides a substantial carbon footprint advantage over the use of virgin plastic resins, having between four and 20 times lower carbon footprint.
- When used in road surfaces, recycled rubber had between three and seven times lower carbon footprint than asphalt on a materials basis.
- The carbon footprint was dominated by the processing of the tires followed by transport of the used tires to the processing facility.
- Electricity was the largest source of the carbon footprint, followed by the use of diesel fuel.
- When used in energy recovery, recycled rubber tires provided about a 20 percent carbon footprint advantage over coal, but tires had substantially more carbon emissions than other fossil fuels.

The upstream carbon footprint for the production of asphalt is 840 kgCO_2e per metric ton. In comparison, the carbon footprint for recycling tires is 124 kgCO_2e per metric ton. This reuse of rubber tires in roads is clearly highly favorable from a climate change perspective.

In summary, the reuse of rubber products from used tires has the potential to make a substantial contribution to reducing carbon emissions.

Rubber Tire Recycling Carbon Footprint

The Rubber tire recycling industry recycled almost 80% of the total production of rubber tires in the United States in 2007.[1] Most often, the tires were used for energy reclaim, but the rubber was also used in a diversity of products, as shown in the table below[2]

Rubber Tire End of Life North America 2007			
	million tires	million lbs	Percent
Fuel Markets Total	***133***	***2657***	***44***
Cement Kilns	56	1,119	19
Pulp & Paper Mills	33	661	11
Industrial Boiler	36	709	12
Tire-to-Energy Plants	7.5	150	2.5
Electric Arc Furnaces	0.9	18	0.3
Landfill	**65**	***1,292***	***22***
Crumb Rubber Total	***52***	***1029***	***17***
Molded Products	16.6	332	5.5
Surfacing/Ground Cover	14.8	295	4.9
Asphalt Modifications	9.3	185	3.1
Tires/Automotive	5.4	108	1.8
Animal Bedding	2.1	42	0.7
Plastic Blends	1.6	32	0.5
Surface Modification/Reclaim	1.5	30	0.5
Other Crumb Rubber	0.3	5	0.1
Civil Engineering Use	***42***	***839***	***14***
Export	***7***	***140***	***2***
Agriculture/Miscellaneous	***2***	***40***	***0.7***

A study by ICF (2006) calculated the greenhouse gas emissions saved by the recycling and energy recovery of rubber tires, by comparing the emissions with the fuels they displace. They concluded that there is a small greenhouse gas savings when rubber tires are recycled. However, this analysis did not collect primary data about the greenhouse gas emissions of the recycling process itself, assuming it to be negligible.

The Institute of the Scrap Recycling Industries retained IERE (the Institute for Environmental Research and Education) to calculate the carbon footprint of rubber tire recycling in order to have accurate publishable data on the US tire recycling industry.

Scoping

The goal of this study is to provide credible carbon footprint data on rubber tire recycling in the United States. The audience for the study is the ISRI membership, state, local and national public officials and members of the media. No comparative assertions are intended.

IERE performed this study in conformance with the ISO 14040 and ISO 14044 standards on life cycle assessment and the British Standards Institute PAS 2050[3] standard on Carbon Footprinting. Details of the scoping can be seen in the appendix.

Figure 1 System for Rubber Tire Recycling

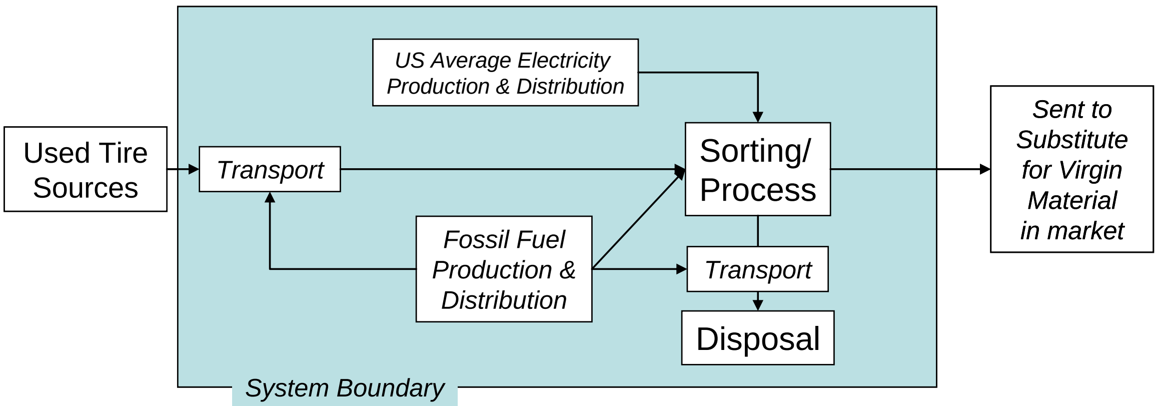


Figure 1 shows the rubber recycling system that was analyzed. The system starts at the point at which the rubber tires are discarded and ends at the facility gate where the material enters commerce as a substitute for virgin material. All upstream greenhouse gas emissions for the production and distribution of fossil fuels and of electricity are included. The US average 2007 grid is the basis of the calculation.

The functional unit chosen was one ton of material sold. Thus the emissions related to disposal were allocated on a mass basis to the material entering commerce. All allocations were based on mass. Emissions of gases at the landfill were assumed to be zero, per the US EPA WAste Reduction Model[4] (WARM).

Data Sources and Collection

The data was collected from eight separate locations throughout the United States, and represented five different recycling companies, all members of ISRI. This sample size was chosen to represent a sample likely to be able to distinguish between the sample mean and the mean carbon footprint of another material that was at least a factor of two different with 95% confidence.

The data cover the calendar year 2007. Participants in the study provided data on energy use for transport to the facility, within the facility and transport to the landfill, as well as information about the amount of material received, recycled (sold) and disposed.

Background data sources include the US LCI Database[5], data from GREET 1.7[6] and data from the Energy Information Agency[7].

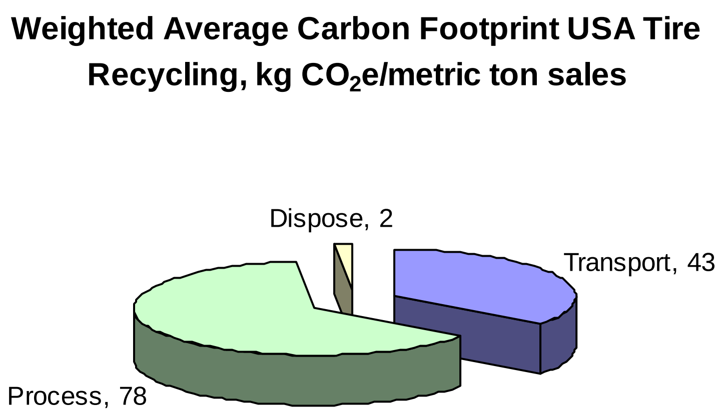
Impact Assessment

The carbon footprints were expressed as 100-year horizon CO_2 equivalents based on the most recent guidance from the Intergovernmental Panel on Climate Change (IPCC).[8] This is the model recommended in PAS 2050.

Results

The sample weighted average carbon emissions for recycling scrap tires was 124 kg CO_2 equivalents per ton sold. The sample mean and standard deviations were 153 $\pm$ 92 kg CO_2 per metric ton sold (N = 8). Most of the greenhouse gas emissions occur during the processing of the tires, although a significant amount of emissions are due to transport of the tires to the facility. A small amount of emissions come from the transport to landfill of tires, as can be seen in Figure 2 and Table 1 below.

Figure 2 Unit Process Sources of Greenhouse Gases in Tire Recycling



This weighted average represents 16% of the total tire recycling industry in the USA.

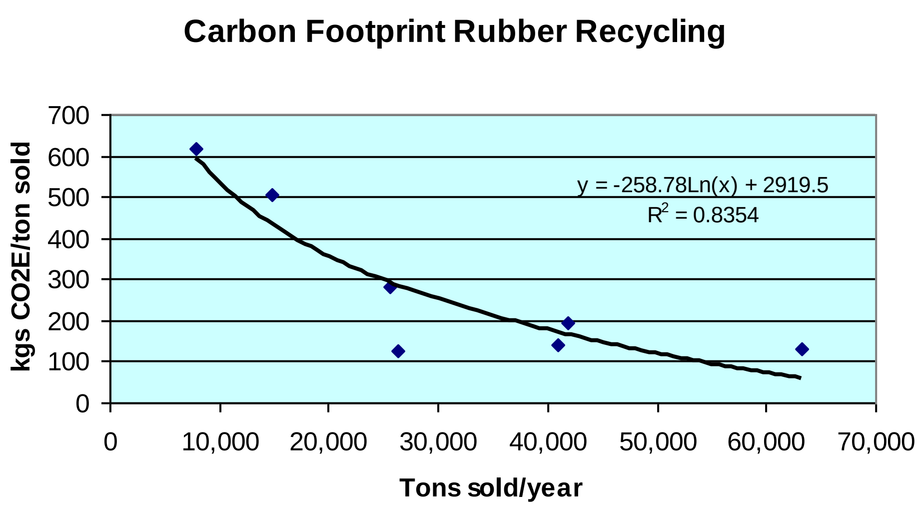
During recycling tires are processed and different components separated for recycle. Typically crumb rubber of different sizes, steel wire and fiber are the products created. Approximately 33 percent of the mass taken in for recycling eventually was landfilled, either at a commercial landfill or on site, but the variability of disposal by site was very large, ranging from two to 50 percent. In general, portions of the tire for which no markets existed at the time of the processing were landfilled. On occasion, entire tires were landfilled due to lack of markets, but this was the exception, not the rule.

Table 1 Mean and Standard Deviations of the Tire Recycling Unit Processes

	Transport	Process	Dispose	Total
Mean	48	103	2	153
SD	17	98	2	92

There was a wide range of values for the carbon footprint of tire recycling, from 87 to 341 kg CO_2e per ton recycled. There was a correlation of carbon footprint to the size of the facility doing the recycling, with larger facilities being more energy efficient. Figure 3 below shows this trend*. Note that any improvements in efficiency decrease rapidly above 30,000 tons sold per year.

Figure 3 Effect of Scale on Tire Recycling Carbon Footprints



Similar kinds of results of eco-efficiency as a function of size have been observed elsewhere, notably in the works of Schlich.[9]

The carbon footprint of rubber tire recycling is dominated by the electricity used in processing, followed by the use of diesel, primarily in transport.

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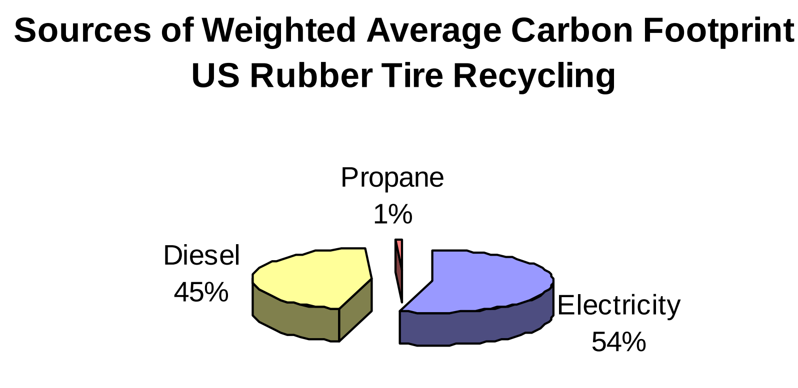
* A single outlier was removed from this graph.

Figure 4 Fuel sources of rubber tire recycling



Comparison with Other Studies and Materials

Ideally, one would like recycled materials to be recycled in closed loops, so that the same materials can be used over and over for the same purposes. However, this is not always possible and in many cases it is not desirable. In the case of rubber tires, a certain proportion of the used tires are re-used or re-treaded for an extended life, but this represents only about two percent of the total market. The rubber from tires is typically not returned to the tire market, but finds use in many other applications.

Energy

The most common use of recycled tires is as an energy source. In order to compare the carbon footprints of different uses, we have modeled the life cycle emissions of greenhouse gasses of fossil fuel used to make electricity and compared that to the creation of electricity from used tires, using the following assumptions:

1) Electricity production was based on the US average grid in 2007, per the Energy Information Agency (including 8% line losses)
2) Data from GREET was used to model the greenhouse gas emissions on a life cycle basis
3) We assumed that only the rubber portion of the tire was burned, and that typical heat values for rubber were appropriate (i.e. 15,000 btu/lb)[10]
4) The recycled rubber was 95% hydrocarbon, and the remaining 5% on combustion did not recreate greenhouse gases.
5) Efficiency at the plant was 30% (2908 kWh/ton rubber)
6) Transport distance to the power plant from the tire recycling facility was 50 miles via 20-ton truck.

Modeling the energy use as electricity generation implies the highest value energy, but not the highest energy recovery. However, the relative greenhouse gas emissions of the different fuels will increase or decrease in lockstep in different energy recovery systems and so any conclusions based on electricity generation will have general applicability.

Table 2 Carbon Footprint of Fossil Fuels

Energy Source	Grams CO_2 Equivalents/kWh
Coal	1,300
Gas	450
Nuclear	16
Recycled Rubber	1,072

As Table 2 shows, energy from recycled rubber has a lower overall carbon footprint than coal, but higher than all other fossil fuel resources. In the USA, about half of the electricity is generated from coal, so there is some scope for rubber tires to decrease the overall carbon emissions of the nation.

Asphalt

We also looked at the carbon footprint of asphalt, for recycled tires are increasingly being used to displace a portion of the asphalt in rubberized asphalt mix roads. The upstream carbon footprint for the production of asphalt is 840 kgCO_2e per metric ton. In comparison, the weighted average carbon footprint for recycling tires is 124 kgCO_2e per metric ton. This reuse of rubber tires in roads is clearly highly favorable from a climate change perspective, creating almost 7 times less carbon emissions than asphalt.

Rubber is not simply a passive replacement material in asphalt roads: road surfaces made from rubberized asphalt are typically half the thickness of conventional asphalt roads[11]. This provides additional potential improvement in the carbon footprint, but was not evaluated in this study. Using recycled rubber in asphalt in roads also has the potential to reduce the rolling resistance of tires, thus reducing the energy consumption of all vehicles using the road[12,13]. This is likely to be a much more important source of carbon reduction than simple displacement of the upstream asphalt emissions as calculated here.

Molded and Plastic Products

Recycled rubber is also being used in molded products. Here the material can be used to substitute for virgin plastic or as a filler.

The American Chemistry Council has recently performed life cycle assessments of the US average resin production.[14] The table below shows the cradle-to-gate carbon footprints for some of the more common plastic resins.

Table 3 Carbon Footprint of Virgin Resins

Virgin Plastic Resins	
Resin	**kg CO_2e/metric ton**
Low Density Polyethylene	1,477
Linear Low-density Polyethylene	1,479
Polypropylene	1,373
Polyethyl Terephthalate	2,538
General Purpose Polystyrene	2,763

Here again, the recycled rubber product is preferable from a climate change perspective. The carbon footprint of recycled rubber is between four and 20 times lower than the carbon footprint of virgin resins.

Conclusions

The carbon footprint of USA rubber tire recycling in 2007 was 153 $\pm$ 92 kilograms of CO_2 equivalent per metric ton of material recycled. The weighted average carbon footprint was 124 kilograms of CO_2 equivalent per metric ton of material recycled. The footprint is dominated by the electricity use in the processing facilities, followed by the diesel use for transport to the facilities. As the USA electric grid becomes greener, the carbon footprint of the recycling facilities will decrease even in the absence of internal rocess improvement.

Larger tire recycling facilities tended to have lower overall greenhouse gas emissions, and this implies that consolidation in the industry will tend to have a beneficial effect on the environment, although this effect is small above a modest operations size of 30,000 metric tons of material sold per year.

As noted above, about 80% of all rubber tires were recycled in 2007. About a third of the total mass of tires sent to recycling facilities ends up in a landfill, but the range in the different operations is from 2 to 50 percent. This implies that the markets for the recycled products are not fully developed, and there is a substantial scope for growth in the recycled rubber markets.

The carbon footprint of tire recycling is relatively low when compared to that of most virgin materials for which it can substitute. These applications, e.g. asphalt displacement or use in molded or plastic products, appear to offer the largest opportunity for the recycled tire industry to provide a real reduction in greenhouse gas emissions. In some cases carbon footprint reductions of up to 95% are possible. There are about 53 million tons of plastic resins produced annually in North America[15], and globally, a total of 23 million tons of rubber annually[16]. The opportunities for recycling are clear.

In contrast, the only fossil fuel that has a higher carbon footprint than recycled tires is coal. The industry is trying to move away from energy recovery as a use for tires, and this trend should be encouraged.

Perhaps the most interesting growth opportunity for the industry is the increased use of recycled rubber in asphalt mixes. In the USA about 70 Billion lbs (over 30 million metric tons) of asphalt is used annually [17]This is much more than the approximately 2 million tons of tires recycled annually, so it is unlikely that recycling tires will ever replace more than a fraction of the asphalt used in roads. Nevertheless, use of recycled rubber in key high-traffic locations may have a substantial positive environmental impact through reduced fuel use. Further studies could be useful in indentifying the best applications of this technology.

Appendix A. Scoping of the Rubber Tire Recycling Carbon Footprint Project

Required Point for ISO 14040/44	Scoping Decisions	
The intended application 14040: 5.2.1.1; 14044:4.2.2	Develop Carbon footprinting of rubber material recycling in the USA: as a first step towards a more comprehensive LCA	
The reasons for carrying out the study 14040:5.2.1.1; 14044:4.2.2	To provide credible information for the members of ISRI in policy discussions.	
The intended audience, i.e. to whom the results of the study are intended to be communicated 14040: 5.2.1.1; 14044:4.2.2	ISRI members; state, local and national public officials; media	
Whether the results are intended to be used in comparative assertions intended to be disclosed to the public. 14040:1.2.1.1; 14044:4.2.2	No comparative assertions are intended.	
Product system to be studied 14040:5.2.1.2; 14044:4.2.3.1	Recycling of rubber tires	
Functions of the product system 14040: 5.2.1.2; 14044:4.2.3.1	Substitutes for virgin material in commerce	
Functional unit 14040: 5.2.1.2; 14040:5.2.2; 14044:4.2.3.1; 14044:4.2.3.2	Tons of recycled material	
System boundary 14040: 5.2.1.2; 14040:5.2.3; 14044:4.2.3.1; 14044: 4.2.3.3.1	From the point where the decision to recycle is made to the point where the recycled material substitutes for virgin material in commerce.	
Unit Process Descriptions 14044: 4.2.3.3.2	Includes collection, transport, sorting/grading/cleaning, processing & disposal	
Allocation procedures 14040: 5.2.1.2; 14040:5.3.4; 14044:4.2.3.1	Allocation via mass allocation.	
Impact categories selected and methodology of impact assessment, and subsequent interpretation to be used; 14040: 5.2.1.2; 14044:4.2.3.1; 14044:4.2.3.4;	**Impact Category**	**Model**
	climate change	IPCC 2007 factors, 100 year horizon
Interpretation 14040: 5.2.1.2; 14044:4.2.3.1	Data should be compared relative to published virgin material LCAs	
Types and sources of Data 14044:4.2.3.5	Where possible, US LCI database, otherwise the Ecoinvent database.	
Data quality requirements 14040: 5.2.1.2**;** 14044:4.2.3.1; 14044: 4.2.3.6.2		
age	No data over five years old, unless it can be documented that the unit process has not changed.	
geography	USA	
	Cutoff values: 97% of the mass and energy in the system	
technology coverage	Addressed statistically	
precision:	Addressed statistically	
industry coverage	Statistically valid sampling of all relevant unit processes for packages where the final conversion step is in the USA or Canada	

Required Point for ISO 14040/44	Scoping Decisions
representativeness	Data collected over January to December 2007
reproducibility	Reported on statistical sampling
sources of the data	Primary data or peer-reviewed published data preferred. US LCI Database backed by the Eco-invent Database
uncertainty of the information	Reported in mean, standard deviation, number of samples and tests of normality
Assumptions: 14040: 5.2.1.2; 14044:4.2.3.1	Material sent to landfill is inert, per the US EPA WARM Model
Value Choices: 14044:4.2.3.1	Focus is on climate change; international activities ignored
Limitations 14040: 5.2.1.2; 14044:4.2.3.1; 14044:4.2.3.1	Analysis is based on industry averages in the USA only
Initial data quality requirements 14040:5.2.1.2; 14044:4.2.3.1	Data no more than 5 years old; published peer-reviewed data where possible, data sets where not possible: sources should be disclosed.
Type of critical review, if any 14040:5.2.1.2; 14044:4.2.3.1; 14044: 4.2.3.8	Per ISO 14040:7.3.3, at least a 3-person review panel
Type and format of the report required for the study 14040:5.2.1.2; 14044:4.2.3.1	A single report for all recycled materials
	Where possible, Data from the US LCI database should be used.
	Reports should be in metric units.

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