Life-Cycle Greenhouse Gas Emission Factors for Scrap Tires

May 2006

Executive Summary

This report provides life-cycle greenhouse gas (GHG) emission factors for scrap tires. The methodology used to develop these emission factors is consistent with those employed in the WAste Reduction Model (WARM) and in the U.S. Environmental Protection Agency (EPA) report entitled *Solid Waste Management and Greenhouse Gases: A Life-Cycle Analysis of Emissions and Sinks*.

Emission factors for tires were developed for three waste management practices: recycling (retreading), combustion, and landfilling. Recycling and the use of scrap tires for fuel results in GHG benefits while landfilling results in small net GHG emissions.

1 Scrap Tires

The markets for scrap tires have increased dramatically, with over 80 percent handled through the marketplace in 2003, compared to 17 percent in 1990.[1] About 290 million scrap tires are generated annually in the U.S., with fuel uses being the primary application (see Exhibit 1). An additional 27 million scrap tires are disposed in landfills, and another 16.5 million tires are retreaded (these are not considered to be "scrap" tires).

Exhibit 1. Scrap Tire Market (RMA 2004)

Application	Quantity (Million tires)
Fuel Uses	129.7
Cement Kilns	*53*
Pulp/Paper	*26*
Utility/Industrial Boilers	*40.7*
Dedicated Scrap Tire-To-Energy	*10*
Electric Arc Furnaces	0.5
Ground Rubber	18.2
Asphalt Rubber	10
Cut/punched/stamped products	6.5
Civil Engineering Applications	56.4
Exports	9
Agricultural use and miscellaneous	3
TOTAL scrap tire markets	233.3

Although recycling (retreading) and all of the scrap tire management techniques may have effects on GHG emissions, given the time and resource constraints for this project, we were able to collect data only on landfilling, recycling (retreading), and use as fuel. For use as fuel, we developed emission factors for scrap tires based on a weighted average of tires used in cement kilns, pulp and paper mills, and utility boilers. The methodology we applied is similar to the one developed for Environment Canada and

[1] Source: EPA Web Site, *Management of Scrap Tires*, http://www.epa.gov/epaoswer/non-hw/muncpl/tires/.

Natural Resources Canada for the report *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions: 2005 Update*, prepared by ICF Consulting (2005), but uses U.S. data where available.

Exhibit 2 summarizes the emission factors. Their derivation is explained in the following sections.

Exhibit 2. GHG Emissions from MSW Management Options for Tires (MTCE/ton)

	Net Landfilling Emissions	Net Retreading (Recycling) Emissions	Net Combustion Emissions
Tires	0.01	(0.50)	0.05

1.1.1 Landfilling

We assume that scrap tires do not degrade significantly in the landfill environment. As a result, the landfilling emission factor is 0.01 MTCE/ton, the same as the value used for inorganic materials disposed in landfills.[2] This emission factor takes into account the collection of tires and transport to a landfill facility. Exhibit 3 presents the emission factor for landfilling tires.

Exhibit 3. Landfilling Emissions for Tires (MTCE/ton)

	(a)	(b)	(c)	(d)	(e)
Waste Management Option	Waste Collection and Transportation	Net Landfill CH_4	Avoided Utility Emissions	Landfill Carbon Sequestration	Net Emissions (Post-Consumer) (=a + b + c + d)
Landfilling	0.01	0.00	NA	0.00	0.01

1.1.2 Recycling (Retreading)

Unlike most of the other materials, we were not able to collect full life-cycle emissions for the raw material acquisition and manufacturing stages, so we characterized an abbreviated life cycle, using several simplifying assumptions, as discussed below.[3]

According to a study of the energy and GHG implications of scrap tire management in Australia (Atech Group 2001), the average energy required to produce a new tire is 88.18

[2] For a detailed explanation of the landfill emission factor for inorganics, see EPA 2002, *Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks*, EPA530-R-02-006, Chapter 7.

[3] Crumb rubber used in rubber modified asphalt was not analyzed as a recycling option because it represents a diffuse percentage of total scrap tires recycled. Other structural uses for tires were also omitted due to lack of life-cycle data.

MMBtu/ton,[4] and the energy to produce a retread is 36.21 MMBtu/ton. The life-cycle boundaries for these estimates are not stated in the study, so it is not clear whether raw material acquisition or transportation are included. We made a series of assumptions:

- The energy intensity for tire production in the U.S. is similar to that in Australia.
- The fuel mix for new tires and retreads is the same, and can be approximated by the fuel mix reported for the U.S. rubber industry, seen in Exhibit 4 below (MECS 2002).
- The reported energy values pertain to passenger tires, which are assumed to have an average weight of 9.5 kg per new (or retreaded) tire.
- The effect of loss rates and the difference in mass (of a scrap tire compared to a new tire) are accounted for in the energy intensity values.
- The energy intensity and fuel mix required for passenger tire production is the same on a per ton basis as for truck and off-road vehicle tires.
- A retreaded tire has 75 percent of the use life of a new tire, and thus from a functional equivalence standpoint, the energy savings associated with producing a retread tire compared to a new tire should be counterbalanced by the shorter lifespan.

Exhibit 4. Fuel Mix Distribution for Virgin and Recycled Tires

Net Electricity	Residual Fuel Oil	Distillate Fuel Oil	Natural Gas	LPG and NGL	Coal	Other	Total
12%	0%	0%	54%	0%	10%	23%	100%

Combining these assumptions, the GHG emission reduction associated with recycling (i.e., retreading) 1 ton of tires is about 0.50 MTCE/ton. The net emission factor for recycling tires is shown in Exhibit 5.

Exhibit 5. Recycling Emissions for Tires (MTCE/ton)

	(a)	(b)	(c)	(d)
Waste Management Option	Process Energy	Transportation Energy*	Process Non-Energy*	Net Emission Factor (=a + b + c)
Recycling	(0.50)	NA	NA	(0.50)

* Transportation energy and process non-energy data were not available for this analysis. We are not aware of any process non-energy emissions.

[4] Note: throughout this document, values originally reported in metric units are reported in corresponding units used in the US.

1.1.3 COMBUSTION

A major scrap tire market in the U.S. is for use as fuel. Due to their high heating value, tires can supplement or replace a fraction of coal, natural gas, or wood in a variety of industries. The three main end-use applications for tires used as fuel include cement kilns, utility boilers, and pulp and paper mill boilers. To develop combustion emission factors, we used a weighted average of emissions from these three end-use scenarios based on the number of scrap tires used in each application.

We assume that scrap tires substitute for coal when burned in cement kilns and utility boilers, and can substitute for the average fuel mix of coal, natural gas, and wood at pulp and paper mills. The following section discusses the derivation of the combustion emission factors for each of the three end-use applications for tires used as fuel.

Cement Kilns

For combustion of tires in cement kilns, we assumed tires displaced coal that would have otherwise been consumed. The Australian tire study (Atech Group 2001) reports that the energy content per passenger tire is about 0.25 MMBtu, and that the carbon content per unit energy (carbon coefficient) is 0.08 $MTCO_2$/MMBtu. Again, assuming an average tire weight of 9.5 kg, this implies that for every ton of tires combusted for use as fuel, 25.95 MMBtu of energy is yielded, and 2.05 MTCE is emitted.[5] The emissions associated with burning enough coal in cement kilns to yield 25.95 MMBtu, and it is estimated that at 2.39 MTCE is emitted. The emissions benefit of using tires in place of coal in cement kilns is thus 0.34 MTCE/ton, shown in Exhibit 6.

Exhibit 6. Net Emission Change for Replacing Coal with Tires in Cement Kilns

Scenario 1 Tires Used as Fuel		**Scenario 2: Coal Used Instead of Tires**		
Total Energy (MMBtu/ton)	Emissions from 1 ton of passenger tires (MTCE/ton)	Replacement of Tire energy with equivalent heat energy of Coal (MMBtu)	Emissions from Coal Use (MTCE)	Net Emission Change (MTCE/ton)
25.95	2.05	25.95	2.39	(0.34)

Utility Boilers

For the combustion of tires in utility boilers, we used the same procedure as cement kilns to determine the emissions benefits of displacing coal that would have otherwise been consumed. The emission benefits for using tires as fuel in utility boilers is 0.34 MTCE/ton, calculated in the same way as for cement kilns. Unlike cement kilns, where the whole tire is added to the combustion chamber and the remaining steel and ash is

5 An alternate energy value of 29.42 MMBtu/ton was suggested by a commenter during review, however the value of 25.95 MMBtu/ton used in this analysis is based on a more recent reference for the energy content of scrap tires.

incorporated into the clinker/aggregate mixture, before tires are consumed as fuel in utility boilers, steel is separated from tires for recycling. The avoided emissions from steel recovery are estimated based on the average steel content of tires (15%), the average ferrous recovery at facilities that separate ferrous from ash (98%), and the change in emissions from recycling, rather than landfilling steel (0.49 MTCE/ton of steel).[6] Note that the tire shredding and steel separation process consumes energy, but we did not find information on this process, and assumed the energy and associated GHG emissions are negligible. Thus, the avoided emissions due to steel recovery at utility boilers are estimated to be 0.07 MTCE/ton of tires. As seen in Exhibit 7, the overall emissions benefits of using tires for fuel in utility boilers is 0.41 MTCE/ton.

Exhibit 7. Net Emission Change for Replacing Coal with Tires in Utility Boilers

Scenario 1: Tires Used as Fuel		**Scenario 2: Coal Used Instead of Tires**				
Total Energy (MMBtu/ton)	Emissions from 1 ton of passenger tires (MTCE/ton)	Replacement of Tire energy with equivalent heat energy of Coal (MMBtu)	Emissions from Coal Use (MTCE/ton)	Net Emission Change (MTCE/ton)	Steel Recycling Benefits (MTCE/ton)	Net Emission Change w/Steel Recycling (MTCE/ton)
25.95	2.05	25.95	2.39	(0.34)	(0.07)	(0.41)

Pulp and Paper Mills

For the combustion of tires in pulp and paper mills, we determined the emissions benefits of displacing the average fuel mix of coal, natural gas, and biomass that would have otherwise been consumed. The weighted average fuel mix for coal, natural gas, and biomass in pulp and paper mills is 11.6%, 25%, and 63.4%, respectively (MECS 2002). The net emission change of using tires to replace this average fuel mix is an emission *increase* of 1.45 MTCE/ton. The increase is due to the fact that tires have higher emissions per unit energy than natural gas and biomass.

Before tires are consumed as fuel in pulp and paper mills, steel is separated from tires for recycling. Identical to steel recovery in utility boilers, the avoided emissions from steel recovery are based on the average steel content of tires (15%) and the average ferrous recovery at facilities that separate ferrous from ash (98%). The avoided emissions due to steel recovery at pulp and paper mills are 0.07 MTCE/ton of tires. As seen in Exhibit 8, the net emissions of using tires for fuel in pulp and paper mills is +1.38 MTCE/ton.

[6] The derivation of the emission benefit of recycling steel as compared to landfilling is described in EPA 2002, *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*, EPA530-R-02-006, Chapter 4.

Exhibit 8. Net Emission Change for Replacing Coal, Natural Gas, and Biomass with Tires in Pulp and Paper Mills

Scenario 1: Tires Used as Fuel		**Scenario 2: Coal, Natural Gas, and Biomass Used Instead of Tires**				
Total Energy MMBtu/ton	Emissions from 1 ton of passenger tires (MTCE/ton)	Replacement of Tire energy with equivalent heat energy of Coal, Natural Gas and Biomass (MMBtu)	Emissions from Coal, NG, and Biomass Use (MTCE/ton)	Net Emission Change (MTCE/ton)	Steel Recycling Benefits (MTCE/ton)	Net Emission Change (MTCE/ton)
25.95	2.05	25.95	0.61	1.45	(0.07)	1.38

Combustion Emission Factors

The combustion emission factor is based on the weighted average of net emissions from cement kilns (52%), utility boilers (25%), and pulp and paper mills (23%).[7] This weighted average was applied to the avoided utility emissions, and the avoided emissions due to steel recovery. The final combustion emission factor for tires used as fuel, is 0.05 MTCE/ton, as seen in Exhibit 9. Note that this is the weighted average of two negative (emission reduction) components for cement kilns and utility boilers and a positive component for pulp and paper mills; to the extent that users of these emission factors can distinguish which combustion situation is applicable, they may want to use the appropriate components rather than the "blended" factor.

Exhibit 9. Combustion Emissions for Tires in Cement Kilns, Utility Boilers, and Pulp and Paper Mills (MTCE/ton)

	(a)	(b)	(c)	(d)	(e)
Waste Management Option	Combustion Emissions	Transportation Energy	Avoided Utility Emissions*	Avoided Emissions due to Steel Recovery	Net Combustion Emissions (=a + b + c + d)
Combustion	2.05	0.01	(1.98)	(0.03)	0.05

*Avoided utility emissions represent direct fossil fuel displacement (primarily coal).

[7] At the end of 2003, cement kiln facilities in the U.S. consumed 53 million scrap tires, pulp and paper mills consumed 26 million scrap tires, and utility boilers consumed 23.7 million scrap tires (RMA 2004).

1.1.4 REFERENCES

Atech Group (2001) *A National Approach to Waste Tyres.* Prepared for Environment Australia, June 2001.

CIEEDAC (2005) Canadian Industrial End-Use Energy Data and Analysis Center. Fuel mix for rubber products (NAICS 326200). Available online at <www.cieedac.sfu.ca/CIEEDACweb/mod.php?mod=NAICSdatabase>

FAL (1994) *The Role of Recycling in Integrated Solid Waste Management to the Year 2000* (Stamford, CT: Keep America Beautiful). pp. I-27, I-30, and I-31. Franklin Associates, Ltd. September 1994.

MECS (2002) *Manufacturing Energy Consumption Survey*. Energy Information Administration. Table 3.2 :Fuel Consumption, 2002 for Synthetic Rubber.

RMA (2004) *U.S. Scrap Tire Markets 2003 Edition.* Rubber Manufacturer's Association, July 2004.