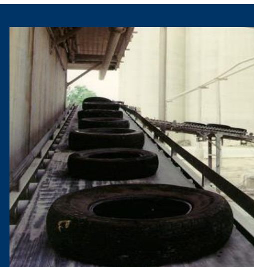
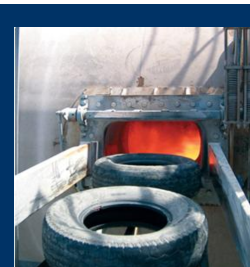
TIRE DERIVED FUEL STUDY





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Prepared for:

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Glossary of Terms

Auto Fluff	Auto fluff is the nonmetallic material that remains after junked automobiles are stripped and then shredded to recover their metal (primarily ferrous) and other valuable components
Chipped Tires	Pieces of rubber usually one inch by one inch by one inch (1ôX 1ö) or two inches by two inches (2ôX 2ö)
Chopped Tires	Tires cut into usually four or more large pieces
Crumb Rubber	Particles of rubber from about one-eighth inch to about one-half inch in size
Cryogenic Granulate	The technology of using liquid nitrogen to freeze tire rubber to a brittle state and hammering it into granulate
Cyclone	A pollution control device used to reduce the amount of particulate matter exhausted to the atmosphere by using conical shaped ducts to separate most of the larger particles
Hog Fuel	Chipped wood waste generated from lumber operations, pulp manufacturing, and other chipping operations which contains substantial moisture content
Scrap Tire	A pneumatic tire that is no longer suitable for its original intended use or for repair due to wear, damage, or defect
Tire Derived Fuel	A uniformly shredded product produced from whole scrap tires for use as a fuel

Nomenclature

BDt	Bone dry tonnes
BOMA	Building Operators and Managers Association
BTU	British thermal unit
EC	Environment Canada
USEPA	United States Environmental Protection Agency
EU	European Union
MW	Megawatt
NOx	Nitrogen Oxides
PM	Particulate Matter
PTE	Passenger Tire Equivalent
RWDI	Rowan Willians Davies & Irwin Inc.,
SOx	Sulfur Oxides
TDA	Tire derived aggregate
TDP	Tire derived products
TDF	Tire derived fuel
TSM	Tire stewardship Manitoba

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1.0 INTRODUCTION

Tires at the end of their purposeful life that are no longer suitable for further use on road end up as scrap tires. Scrap tires have been land filled or stockpiled in most jurisdictions until the late 60ȍs and 70ȍs though they were a known environmental hazard. After the Hagersville, Ontario tire fire in Feb. 1990, Governments and tire industries have realized the potential risk associated with scrap tire piles and have dealt with them through stewardship and industry funded programs to promote recycling and other end uses of scrap tires. Since then, most scrap tires are being turned into useful value added products to extend the life of the material by making them into various products for road construction, blast mats, recreational uses and crumb products which have found suitable consumer markets. One particular use of scrap tires is using them as fuel in industry known as (TDF) Tire Derived Fuel. This is the focus of the report. Scrap tires are chipped into pieces of 1ȏX 1ȏto 2ȏX 2ȏ size chips and are co-fired with coal and other industrial fuels like hog fuel (from 5% up to 20% by weight) in thermal power generating stations, paper and pulp industries across North America. Also, whole tires are also used in cement industry, the metal in the tires is required as part of the process in clinker formation. This study congregates different views on use of TDF in Manitoba from various groups and individuals and attempts to draw conclusions on the current situation.

2.0 PRESENT SCENARIO

According to Canadian Association of Tire Recycling Agencies (CATRA), of the various scrap tire markets in Canada, 33% are molded manufactured products form the largest sector followed by crumb at 24%, shredded rubber at 17%, die cut manufactured products at 11% while TDF forms 13%. In Manitoba, currently 5% of scrap tires collected are exported as TDF replacing fossil fuels, the reminder of 95% are recycled in Manitoba into products such as aggregate, crumb rubber, blast mats and other moulded products. The present ratio of **TDP : TDA : TDF** is **7:12:1** *(TSM 2008 Annual Report)*. I.e. for every 100 scrap tires generated 5 are used as TDF (exported) and the rest 95 become tire derived products and tire derived aggregates. Figure 1 shows the sector wise end use markets for scrap tire in Manitoba for the year 2008 (for 9 months).

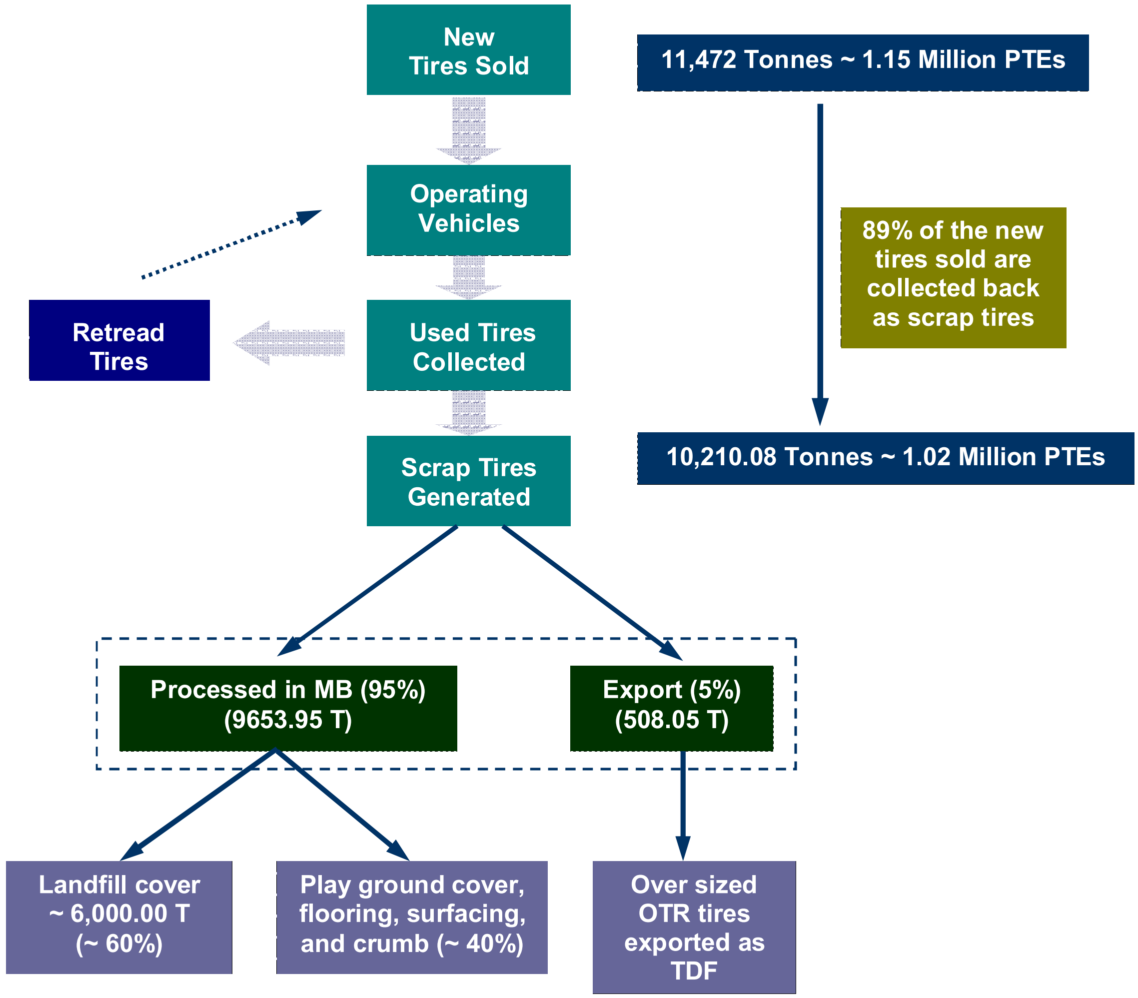

Figure 1. Scrap Tire Generation and Use in Manitoba for 2008

**1 PTE (Passenger tire equivalent) = 10 Kilos*

Note: For a full 12-month period the annual recovery rate would be higher than shown here at about 90%

2.1 4-R Hierarchy

The four R **(Reduce, Reuse, Recycle and Recover)** order currently promotes operations that reduce the scrap tires to a highly processed form, typically to a crumb rubber and powder from for use in producing new products with recycled rubber content (particle size up to 5/16ôto 40 mesh and lower) followed by fabricated products that are made at least 75% from scrap tires (e.g. ï blasting mats, traffic cone bases, etc) and Tire shred with particle size of normally 2 to 4 inches produced as an alternative to granular material. TDF has been recognized as the lowest end-use priority for scrap tires. Of the 95% scrap tires that are processed in the province ~60% of that is used as daily cover at local landfill.

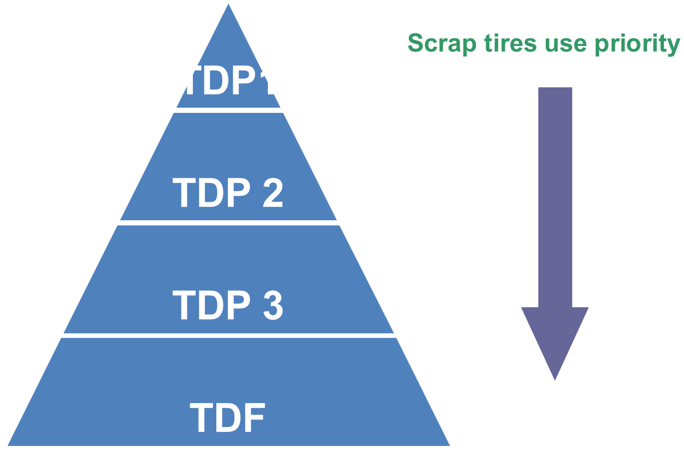

Figure 2: Current order of preference for use of scrap tires in Manitoba. TDP1 followed by TDP2, TDP3 and TDF

TDP 1 ï Includes operations that reduce the scrap tire to a highly processed form, typically to a crumb rubber and powder from for use in producing new products with recycled rubber content (particle size up to 5/16ôto 40 mesh and lower)

TDP 2 ï Fabricated products that are made at least 75% from scrap tires (e.g. ï blasting mats, traffic, cone bases, etc.)

TDP 3 ï Tire shred with particle size of normally 2 ï 4 inches produced as an alternative to granular material

TDF ï whole tires used as tire derived fuel (TDF) to supplement other fuels in industrial applications

* According to the TSM business plan proposed to the government.

3.0 ECONOMIC

TDF is a high quality readily available fuel with about 13,000 to 15,000 BTU/lb, (in other words 7,200 to 8,300 kcal/kg) which is same as high quality coal. Provincially, there are three companies that burn large amounts of coal:

- Tembec's pulp and paper mill at Pine Falls, which was built in 1917
- The Graymont lime plant at Faulkner built in 1976 (uses pulverized coal and PET coke)
- Manitoba Hydro's Brandon power plant, (which is to be phased out shortly and used only on an emergency basis)

Other large facilities that can potentially use TDF:

- Tolko Kraft Papers (uses Hog fuel for its operations)

Source: CBC News, http://www.cbc.ca/canada/manitoba/story/2008/04/11/mba-carbon-tax.html Accessed on June 25, 2009 at 10.50am

Note: The province is planning for a coal emission tax of $10 per tonne of CO_2 equivalent emission from July 2011 in a bid to move away from coal. Industries can explore opportunities by co-firing coal/TDF at their plants and mitigate coal consumption and as a result reduce potential carbon tax.

3.1 TDF Processing and Co-firing

All tires are designed for toughness and durability; hence tire shredding, chipping, and grinding processes require substantial amounts of energy. On average, the shredders are capable of processing about approx. 1,500 - 2,000 tires per hour which works out to be approximately 500 BTU/tire. As tire size specification of the shred or chip is decreased, the energy requirement increases substantially *(Refer Table 1)*. The energy requirements can be compared to the energy equivalent of a tire, at about 250,000 BTU/tire. Estimated energy requirement values for several size specifications are shown below:

Table 1. Estimated values for several TDF tire shred size specification

Process	Energy Required (BTU / tire)
Coarse Shred	**500**
2ôX 2ôchip	**2,500**
1ôX 1ôchip	**15,000**
Crumb Rubber (1/4ôï ½ô)	**35,000 – 50,000**
Cryogenic Granulate	**> 100,000**

Source: Columbus McKinnon Corp., 1990; Sladrk, et al., 1989

In terms of energy recovery from tires the most efficient way is to transport them as coarse shred. However, most TDF users want smaller and more uniform chip size which requires more processing machinery and energy input.

3.2 TDF Feeder Mechanism Implementation Cost for Industry

For scrap tire fuel system implementation at an industry, the primary on-site improvement includes a tire feeding system and on-site space for tire-storage. It is very difficult to provide an exact cost of implementation for this project as every company must have custom built system. The cost depends on variety of factors such as design and complexity of the feeding system and type of kiln or boiler. Scrap Tire Management Council estimates that typical implementation cost for a tire fuel system would be between $ 200,000.00 up to $ 500,000.00. The following example considers an average scrap tire fuel system implementation cost of $ 350,000.00.

Simple Payback Period (SPP) and Return on Investment (ROI) are calculated as follows:

<u>Simple Payback Period (SPP)</u>: Implementation cost ($) / Cost saving ($/yr)

Implementation cost: $ 350,000.00

Assuming a facility consuming 15,000 tonnes of coal per year, if burns TDF at a rate of 15%.
Fuel Saving = 15% x 15000 tonnes of coal

= 2,250 tonnes of coal / yr

Cost Saving = Fuel Saving x J (Where, J is the cost of coal per tonnes assuming $50/tonne)

= 2,250 tonnes of coal / yr X $50 / tonne = **$ 112,500.00 / yr**

Simple Payback Period (SPP): 350,000 / 112,500 = 3.88yrs

SPP = 3.88yrs

Return on Investment (ROI): Cost saving ($/yr) x 100 / implementation cost ($)

= $ 112,500/yr x (100 / $ 350,000)

= 32.14 % /yr

ROI = 32.14 % / yr

Table 2. presents the varying TDF from 5% to 15% with 5% increments and compare it with implementation costs of $200,000 $350,000 and $500,000. The calculations used in this table are identical to the method used above.

Table 2. Variable Percent TDF and Variable Implementation Cost

Fuel Consumption (Tonnes of coal / year)	Percent TDF	Fuel Savings (Tonnes of coal /yr)	Cost savings ($/yr)	Implementation cost ($)	SPP (yrs)	ROI (% / yr)
	5%	750	37,500		5.33	**18.75**
15,000	10%	1500	75,000	200,000	2.66	**37.5**
	15%	2250	112,500		1.77	**56.25**
	5%	750	37,500		9.33	**10.71**
15,000	10%	1500	75,000	350,000	4.66	**21.42**
	15%	2250	112,500		3.11	32.14
	5%	750	37,500		13.33	**7.5**
15,000	10%	1500	75,000	500,000	6.66	**15.0**
	15%	2250	112,500		**4.44**	**22.5**

3.3 Shipping and Tipping fee

For an industry which uses the following the cost for shipping is calculated as follows:
Tons of coal per year = 15,000 tonnes

Energy of coal = 25 MMBtu / tonne

Energy of TDF = 15,000 Btu /lb

Cost of Diesel fuel = $ 3.00 /gal

Full truck load weight = 30,000 lbs

Tipping fee = $150 per ton (Average)

Shipping Cost

= Distance x [(Fuel cost x No. of truck loads / M_1) + (Fuel cost x No. of truck loads / M_2)]

Where,

No. of truck loads = Number of trips per year (estimated at 10, 20 and 30)

M_1 ï Loaded fuel efficiency, 5 miles/gal

M_2 ï Unloaded fuel efficiency, 6 miles/gal

= 100 miles x [($ 3/gal x 10 trips/yr / 5 miles/gal) + ($ 3/gal x 10 trips/yr / 6miles/gal)]

= $ 1,100.00 (for 100 miles)

3.4 Fuel and Cost Savings

For a facility that consumes 15,000 tons of coal annually on an average, the fuel cost savings by introducing 5% TDF are estimated as follows at $50 /ton of coal:

Fuel Savings (FS): FR X TC

Where,

FR = Fuel saving rate, 5%

TC = Total yearly coal usage

Therefore,

FS = 5% X 15,000

= 750 tonnes of coal / year

Energy Savings (ES): Fuel Savings X C

Where,

C = conversion constant for coal 25,000,000 Btu/ton

ES = 750 tons of coal /yr X 25,000,000 Btu/ton

= 18,750 MM Btu/yr

Cost Savings (CS):

CS = Fuel savings X J

Where,

J = Cost per tonnes of coal $50 /tonne

Therefore,

CS = 750 tons of coal / yr X $50/tonne

= $37,500 / yr

3.5 Energy Recovery from Scrap Tires

In order to calculate the recoverable energy from scrap tires, we need to know the energy require to produce a tire and the energy that can be derived from it after itċs been used.

A typical composition of passenger and truck tire composition (by weight) are shown in below:

Passenger Tire

Natural rubber	14 %
Synthetic rubber	27%
Carbon black	28%
Steel	14 - 15%
Fabric, fillers, accelerators, antiozonants, etc.	16 - 17%
Average weight:	New 25 lbs, Scrap 22.5 lbs.

Source: Rubber Manufactures Association, 2009

Truck Tire

Natural rubber	27 %
Synthetic rubber	14%
Carbon black	28%
Steel	14 - 15%
Fabric, fillers, accelerators, antiozonants, etc.	16 - 17%
Average weight:	New 120 lbs., Scrap 110 lbs

Source: Rubber Manufacturers Association, 2009

Table. 3 shows the break down of total energy required to produce one kilogram of tire.

Table 3. Energy usage for production of 1 kg of rubber tire

	Material usage (Kg/Kg of production)	Energy usage (MJ / Kg of product)	Total Energy usage (MJ/Kg)
SBR (Styrene-Butadiene)	0.59	55.79	32.92
Carbon Black	0.30	126.50	37.95
Steel	0.03	27.80	0.83
Fabric	0.08	43.49	3.48
Manufacturing		11.70	11.70
Total	**1.00 Kg**		**86.88 MJ/Kg**

Source: T. Amari et. al, 1999

Typically for a tire the energy required to manufacture is:

= 86.88 x 10kg (Avg. weight of a tire) = 868.80 MJ/tire

Using the typical value for recoverable energy from tires as 32 MJ/kg of tire (derived from 15,000.00 Btus/lb) **or** 320.00 MJ/tire, the energy recovery from scrap tires is:

= (320.00 MJ/tire / 868.80 MJ/tire) X 100

= 0.368 X 100

= 36.8% (approx.)

Therefore, approx. 37% of the energy embedded in scrap tires is recoverable as fuel energy.

4.0 ENVIRONMENTAL

Environmentally, TDF is much similar to coal and better in some aspects like sulfur content. Typically, TDF has 0.5% to 2.0% sulfur; this is same as superior quality coal and less than most coal and coke types.

4.1 TDF CHRACTERISTICS

Used tires or TDF are one of the most readily useable and highest heat content non-hazardous wastes available. TDF can be provided in a number of forms depending on its use in the type of industry. A typical passenger tire contains 30 different types of synthetic rubber, eight types of natural rubber, eight types of carbon black, steel cord, polyester, nylon, steel bead wire, silica and 40 different kinds of chemicals, waxes, oils and pigments. They typically contain 85% hydrocarbon, 10-15% iron (in the bead wire and steel belts) and a variety of chemical components *(Practical Environmentalist 2009)*.

Air Pollution from using Tire Derived Fuel

The chemical composition of tires needs to be examined in order to determine the impact of using them as fuel. Tires have less sulfur than many eastern coals, means lower SO_x emissions, but many western coals have less sulfur than tires. TDF has lower carbon-to-hydrogen ratio theoretically reducing the CO_2 emissions, which is a GHG. Similarly lower nitrogen content of tires can marginally decrease NO_x emissions. *(Terry Garry, 2004, First Northeast Regional Scrap Tire Conference, Albany, NY)*. It is common knowledge that burring tires in the open is extremely harmful to human health and environment. The fumes emitted in an open fire contain many toxic chemicals that tires contain that are inorganic compounds such as benzene, metals such as lead, polycyclic aromatic hydrocarbons. The major toxic chemical compounds are dioxins and furans.

Table 4. Emission Data from US and Canadian Facilities using TDF

Data From	TDF Content (% TDF compared to 100% coal)	Dioxins/Furans
5 Canadian Cement Kilns		Increased 37% and 247% in two tests Decreased 54% and 55% in two other tests
Victorville, CA Cement Kiln	24.6%	Dioxins increased 139-184% Furans increased 129%
Cupertino, CA Cement Kiln		Increased 30%
Davenport, CA Cement Kiln	30%	Dioxins increased 398% and 1,425% in two tests Furans increased 58% and 2,230% in two tests
Davenport, CA Cement Kiln	20%	Increased 25%
Lucerne Valley, CA Cement Kiln	20%	Dioxins and some dibenzofurans increased
U Iowa, Iowa City, IA Industrial Boiler	4%	Decreased 44%
U Iowa, Iowa City, IA Industrial Boiler	8%	Decreased 83%

Source: Energy Justice Network, 2009

Energy Justice is the grassroots energy agenda, supporting communities threatened by polluting energy and waste technologies. Taking direction from our grassroots base and the Principles of Environmental Justice, we advocate a clean energy, zero-emission, zero-waste future for all.

Referring to Table.5 above, the emission results are mixed. However, low percentages of TDF between 4% to 20% seem to be environmentally beneficial. Like any other fuel, tires also have both environmental advantages and disadvantages. Compared to coal, the desirability of using tires depends on the application. A number of emission studies exist with varying conclusions for using TDF. According to EPA, testing has shown that TDF produces emissions that are comparable or in some cases better than conventional fuels. The change in emissions when using TDF depends on the type of facility configuration, air-pollution control equipment and type of fuel being replaced by TDF.

Public Perception

Public/employee opposition to using TDF is an important disincentive. It is partly due to the well publicized uncontrolled open tire fires from the past. The process of burning tires has poor reputation because of peopleǒs observation and perception of tire yard fires. Tire fires can last for long durations; emit a gigantic quantity of smoke and generate inordinate amounts of pollution. Tire fires occur in open air, burn at relatively low temperatures and do not have complete combustion. However, in an industrial set-up, TDF is used in highly controlled environment with required air-fuel ratio and at significantly higher temperatures to ensure complete combustion not only to prevent clouds of black smoke and particulate emissions but also to ensure that maximum recovery of available energy.

In general, the common belief is that using tires as fuel is environmentally unacceptable method of managing scrap tires; however, this study finds that TDF has been successfully co-fired with coal and hog fuels in cement kilns, pulp and paper industry and power utilities for over 20 years in US and Europe while meeting all necessary emission and pollution standards. Many governments including Norway, Sweden, and California which has some of the stringent air quality and stack emission standards allow TDF use in their jurisdiction. In the United States, more than 30 states have adopted legislation recognizing TDF as an acceptable industrial fuel source. Based on over 15 years of experience with more than 80 individual facilities, *"EPA recognizes that the use of tire-derived fuels is a viable alternative to the use of fossil fuels"* and it recognizes that using scrap tires as fuel is not recycling, but should be considered a beneficial use.

5.0 LEGAL

TDF Permitting in MB

To date, there are no facilities with TDF permits in the province. For four years between 2001 and 2005, Government of Manitoba has permitted "Experimental Usage" of TDF in the paper mills in the province. The trails have shown that the air emissions were within the air quality and regulation standards. The air emission results were monitored and reported by Paprican® and BOMA. Manitoba Conservation's Environmental Assessment and Licensing branch mostly follows USEPA guidelines in issuing licenses and monitoring air quality emissions for industries within the province. In Manitoba, TDF permits (both for processors and end users) follow USEPA guidelines on stack emissions and ambient air quality standards.

6.0 ISSUES

Some current and potential issues on using TDF in Manitoba:

Tolko Pulp and Paper Mill

The issue with feeder mechanism at Tolko Pulp and Paper mill *(Refer Image.1)* was that the TDF was getting into the feeder mechanism and interrupting its operation and because of this the feeder had to be stopped to clear the TDF before continuing. Also the wires in the TDF were a cause of concern as they were catching other objects on their way to the mill and on the conveyer.

Photo: Tamsin Patience, 2009

Image 1: Mill's Feeder Mechanism

Image 2: Enlarged Feeder mechanism image showing TDF and Hog fuel mix

Photo: Tamsin Patience, 2009

Image 3: TDF stock pile on site at Tolko mill

Photo: Tamsin Patience, 2009

Photo Source: Tamsin Patience, 2009

Images 4 and 5: TDF size. The chips are approx. 2' x 2' in size

The feeder mechanism problems could be addressed by better tire processing equipment suitable to produce high quality TDF. Better tire processing equipment can clean-cut the tires with no hanging wires and better control over the size of TDF. The equipment suitable to produce such high quality TDF can cost as much as 1.5 ~ 2 million dollars. The mill also faced strong opposition from the mills employee union on using TDF at their site because of which and the mill had to stop further trails and abandoned the use of TDF at its site. The process engineer at Tolko said *"the idea of using TDF is more political than any other*ò commenting on their future prospects of using TDF.

Currently, Tolko consumes 130,000 tonnes of Hog fuel along with 9.5 million liters of bunker oil (No. 6 Grade) and 6 million liters of waste fuel oil (No. 2 and 4 Grade). Hog fuel has an energy content of 12.6 GJ/ton while TDF has 32.7 GJ/ton. TDF has apporx. 2.5 times the energy content of hog fuel, replacing merely 1% of hog fuel with TDF would redirect 1,300 tonnes of scrap tires from landfill daily cover to energy recovery.

Greymont Lime Plant

Speaking to mid level management employee at Greymont its known that the lime plant at Faulkner consumes about 15,000 tonnes of coal and about 4,000 tonnes of coke annually for its operations. With the government likely to impose a carbon tax of $10/tonne on coal usage Greymont is looking at opportunities to mitigate its coal consumption. Ideally, lime plants can burn TDF from 5% up to 20% by weight without breaching the air quality standards. However, Greymont lime plant at Faulkner is less inclined to introduce TDF in their plants for the following reasons:

- Lime contamination
  - Lime tends to capture sulfur and other heavy metals that are released from TDF combustion
- Greymont plants in the US have tried TDF and had problems with material handling and feeding that lead to flame instability that impact the quality of lime
- Unavailability of high quality TDF (100% wire removed from TDF, 1/8ô grain size)
- Other significant issue is the cost. The cost of TDF raises sharply as the size reduces thus prohibiting its use for lime industry

Overall, lime plants in the US donöt use TDF, which indicates that TDF is not best suited for lime plants. However, the Manitoba plant located at Faulkner has told that if provided with TDF they are open to perform sample test and can determine its applicability for their plant. The requirements of TDF are 100% metal free, and a chip size of 1/8th of an inch.

The other facility is Tembec (Pine Falls Operations); it was unavailable for their input.

Other trial and Utility Boilers

Shredded tires can be used efficiently in utility boilers in units that offer adequate time to get complete combustion and with proper mixing with other fuels. TDF must be less than two inches in all dimensions with an average size of one inch or less to get complete combustion and fit most coal-handling systems.

BFI Landfill

When talked to the BFI manager, he said that using shredded tire as daily cover is most attractive to BFI because it works out to be cheap and effective. Alternatively, Auto Fluff (which can also be used as daily cover) cannot be accepted at the landfill because of high amounts of mercury and lead in it.

7.0 CLOSING THOUGHTS

In conclusion, the study finds that in Manitoba some portion of scrap tires is potential TDF resource that currently is being dealt with in a low energy value process like using them as landfill cover. Use of tires as fuel may represent the optimal strategy for value recovery considering the environmentally responsible combustion of tires for energy and is preferable to the health and aesthetic problem resulting from their accumulation in landfills. The role that energy recovery will play in scrap tire disposal now and in the future is highly dependent upon development of other options like rubberized-asphalt. However, on the other hand rubberized-asphalt is not thoroughly tested for northern climate and there are issues with its performance. (See Appendix - A). Apporx. 10% to 15% of the 6,000 tonnes of scrap tires going to the landfill cover can be diverted as energy recovery resource for use within the province thus allowing for holding onto the existing scrap tire markets and at the same time exploring new TDF opportunities.

SWOT Analysis

SWOT is a study tool used to evaluate the Strengths, Weakness, Opportunities and Threats in regard to the use of TDF in Manitoba. This tool is used to provide the concluding thoughts for this study.

Strengths: • the notion energy from waste, better utilization of scrap tire • opportunity to use a safe alternative fuel • no end-of-life handling issues - 100% diversion from landfill (ash from burnt tires can be used in construction) • MB is not first, environmentally advanced nations like burn scrap tire as fuel • processors need not continuously look for TDA, TDP markets • higher economic value when compared with existing TDA and TDP	**Weakness:** • public awareness - needs change of perception, appears that using TDF is environmentally unacceptable • air emission results from using TDF are mixed • opposition from environmental groups, sections of public and other players
Opportunities: • can help Manitoba reduce its coal consumption • can reduce fuel cost to industries • can help industries reduce the potential carbon tax from July 2010 • in future, a ban on tires in any form going to landfill is a possibility (including daily cover)	**Threats:** • other emerging uses of scrap tires in MB like for road construction (rubberized-asphalt) esp., with the Government of Manitoba investigating rubberized asphalt with interest on doing a performance trial • government is promoting bio-mass use to offset coal in the province, this is a potential conflict of interest • keeping in context with governmentôs push for bio-mass to offset coal, in future, TDF may also be taxed as itôs a product derived from fossil source (crude oil)

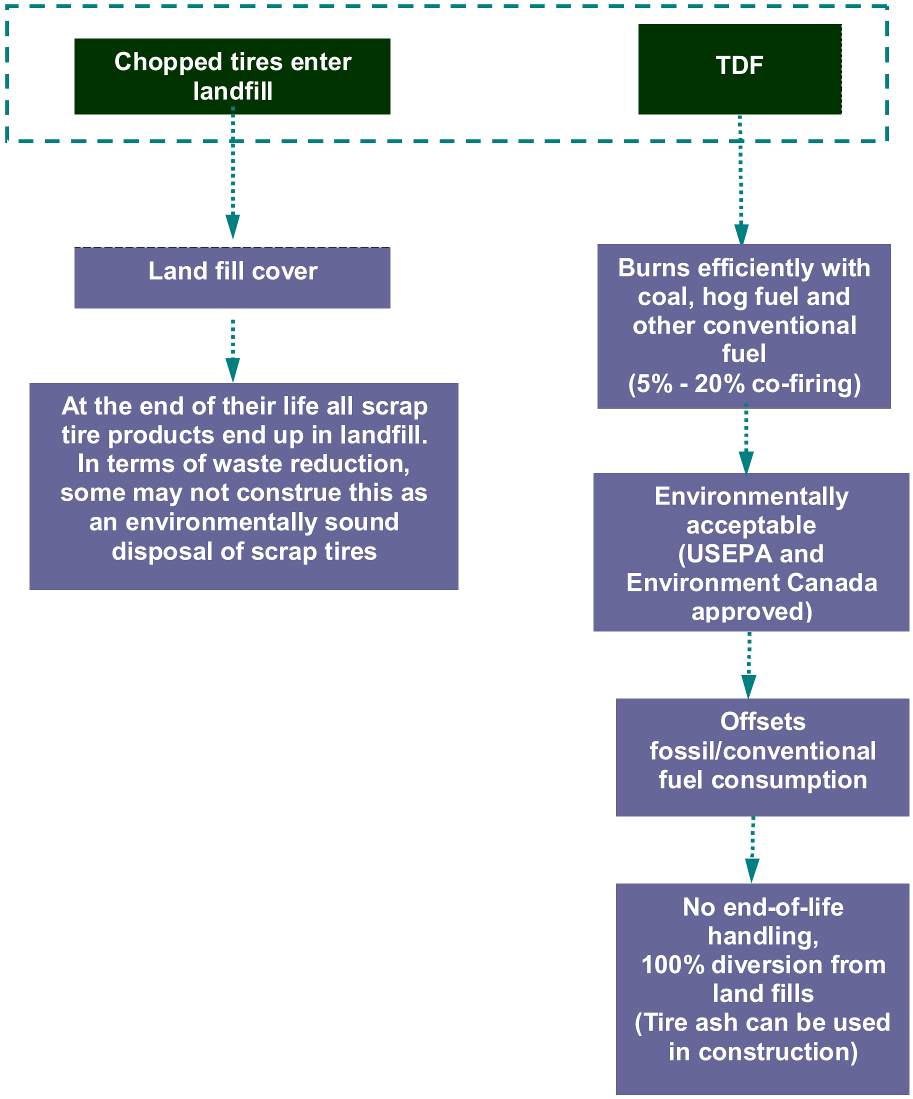

Figure. 3 Comparative Analysis of TDA/TDP and TDF at various stages of processing and end of life handling issues

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