Carbon Value Proposition: Resource Recovery using Tyre Derived Fuel (TDF)

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Overview of Key Points

There is widespread consensus that action needs to be taken to reduce greenhouse gas emissions, especially action that works to rebalance our systems of production and consumption with the ecology of the planet. Recovering resource value from 'wastes' serves to create both cyclical flows of materials and energy and reduce greenhouse gas emissions.

With an ever-increasing national fleet of on-road vehicles, there is an ongoing trend towards greater amounts of used tyres arising at their end-of-life. End-of-life tyres in Australia present as both a waste management challenge and an opportunity for resource recovery. One option for resource recovery of end-of-life tyres is through Tyre Derived Fuel (TDF). Tyre Derived Fuel provides an alternative energy resource to replace fossil fuels such as gas, coal or oil in industrial applications such as cement kilns, electricity generation or industrial process heat.

The overall environmental performance of energy recovery as TDF is important in assessing sustainable resource recovery options, and in particular, the greenhouse gas emissions from TDF. The calculation for greenhouse gas emissions from TDF is the greenhouse gas abatement of TDF use, less the impacts associated with the process of using TDF, gives the net greenhouse gas benefit, or 'carbon value' from TDF.

An analysis of the greenhouse emissions from using TDF as compared to three other fossil fuels was conducted using factors from the Australian Government's Emissions and Energy Reporting System (EERS). Information on the calorific value and emissions from the combustion of tyres was derived from tyre industry sources on an average of averages basis.

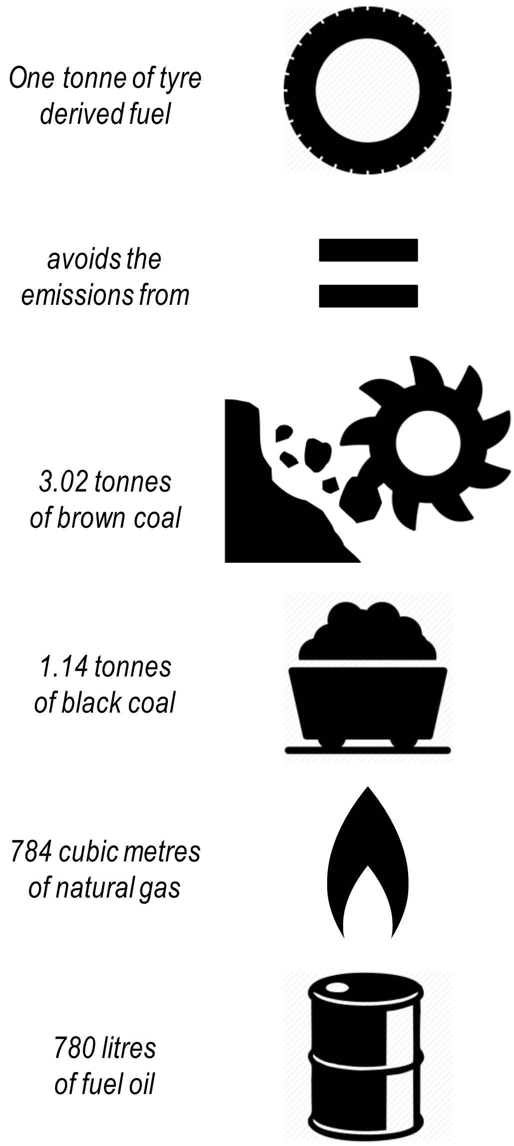

Figure 1 – The carbon value for Tyre Derived Fuel is based on the amount of fossil fuels replaced by the use of TDF

Based on this analysis, the use of one tonne of TDF would:

- replace 3.02 tonnes of brown coal and avoid 1.16 tonnes of carbon dioxide equivalent (tCO_2e), a reduction of around 40 per cent when compared to brown coal use
- replace 1.14 tonnes of black coal and avoid 1.05 tonnes of carbon dioxide equivalent (tCO_2e), a reduction of around 35 per cent when compared to black coal use
- replace 784 cubic metres of natural gas at a slight increase of 0.14 tCO_2e or 9 per cent when compared to natural gas use
- replace 780 litres of fuel oil and avoid 0.54 tCO_2e, a reduction of around 24 per cent when compared to fuel oil use.

Examination of the outlier estimates of calorific value and greenhouse gas emissions show that in all cases TDF has less greenhouse emissions than black coal and oil, and a small increase when compared to natural gas.

There are other benefits from using TDF, especially in the case of cement kilns. For example, the ash produced generally contains less heavy metals than the ash from coal combustion because in the cement kiln the rubber provides energy and iron and sulphur are incorporated into the cement matrix.

This study has shown that the use of TDF presents a better comparative greenhouse outcome over the use of fossil fuels such as black coal and fuel oil, are relatively comparable to the greenhouse emissions from the use of natural gas. In the Australian context the use of TDF has occurred in the past,[1] but has yet to be optimised, presenting an opportunity for increased resource recovery as well as lowering Australia's GHG emissions.

Introduction

Climate change is now widely recognised as a significant challenge to the future of civilised society. However, in many respects, climate change is primarily a symptom of the underlying problematic situation of production and consumption systems being out of sync with the ecology of the planet. In other words, the natural carbon cycle is unable to manage the current level of greenhouse gas emissions. Thus, a large part of the solution to climate change is delivered through rebalancing economy and ecology.

The recovery of resource value from waste materials is one activity that can create both cyclical flows of materials and reduce greenhouse gas emissions. This is in line with the vision for a waste free community that moves towards zero waste. And at a broader systemic level, the concept of zero waste is a key element of a sustainable 'biomimetic' economy using nature as a model – because 'nature recycles everything'.[2]

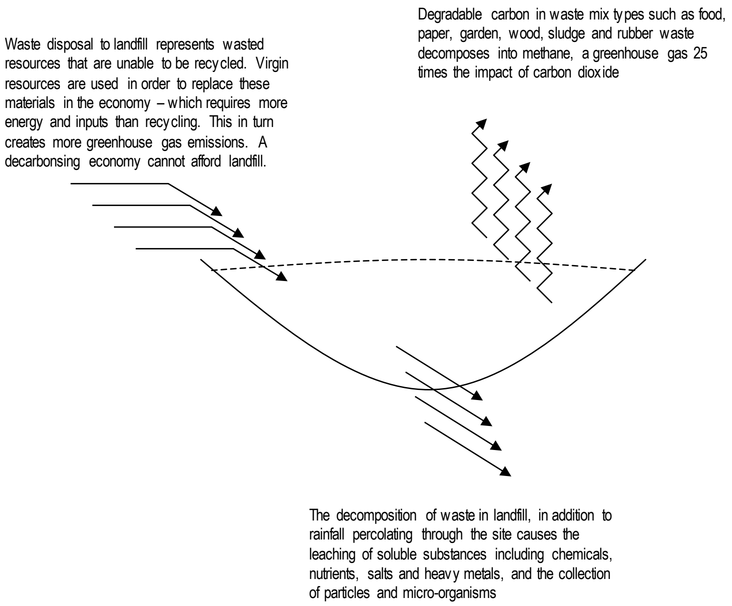

Figure 2 – Schematic showing the major impacts of landfill

The disposal of waste to landfill is a sustainability barometer indicating that change is required. There are many impacts of landfill, including land pollution, human health impacts, water pollution (leachate) and a loss of social amenity. There is also a significant greenhouse burden associated with the loss of resources wasted as inappropriate 'fill of land' (see Figure 2).

Used tyres arise at their end-of-life as a waste management and resource recovery challenge. The landfill of used tyres is problematic, as both an environmental issue, in addition to a lost opportunity to recover value from a potentially valuable resource.

[1] See for example, 'Alternative fuels use at Waurn Ponds, Victoria cement plant' Cement Concrete & Aggregates Australia accessed at http://59.167.233.142/sustainability/documents/concrete%20concepts%2004.pdf, December 2016.

[2] Benyus, J., 1997, 'Biomimicry: Innovation Inspired by Nature', William Morrow and Co., Inc., New York.

(Note that the Technical guidelines for the estimation of greenhouse gas emissions by facilities in Australia – 2016-17 reporting year (August 2016) identifies rubber as a waste mix type that contains degradable organic carbon).[3]

Since 2003 the Australian Tyre Recyclers Association (ATRA) has been committed to making sure used tyres are recycled in Australia, in order to minimise damage to human health, and the environment.

In 2015/16 ATRA members processed around 20.5M EPU's (Equivalent Passenger Units) representing 95 per cent of Australia's used tyre recycling activity and 86 per cent of the available market.

ATRA serves the tyre recycling industry in an advocacy role with the public, government and associated stakeholders; and promotes the use of recycled rubber in a range of consumer and industrial products. As part of this ongoing role, ATRA has commissioned Warnken ISE to review the carbon value proposition of resource recovery through Tyre Derived Fuel (TDF), and in particular the greenhouse gas emissions arising from the use of TDF as compared to other 'traditional' fossil fuels.

The Resource Recovery Challenge for Used Tyres

With an ever-increasing national fleet of on-road vehicles, there is an ongoing trend towards greater amounts of used tyres arising at their end-of-life. End-of-life tyres in Australia present as both a waste management challenge and an opportunity for resource recovery. A recent study found that approximately 51 million equivalent passenger units of end-of-life tyres are generated each year in Australia.[4]

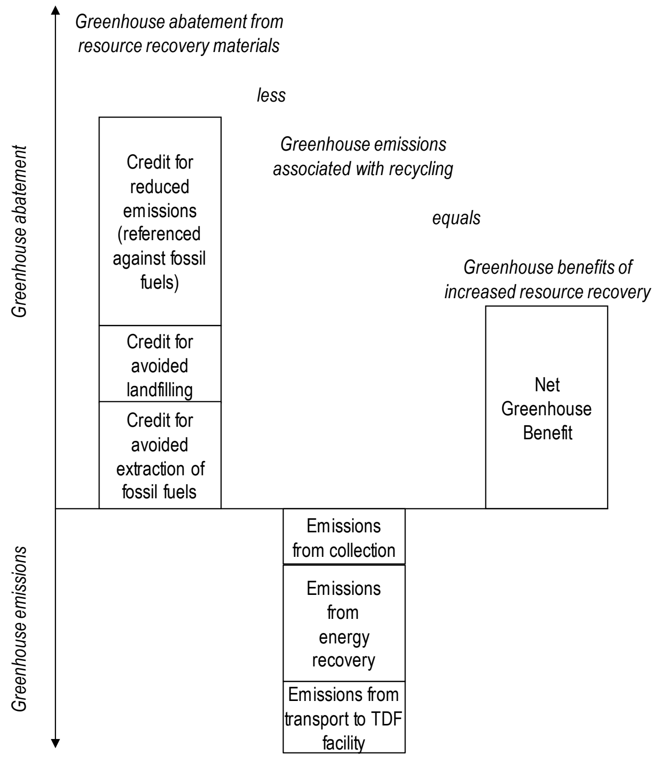

Figure 3 – Schematic showing the major elements of the carbon equation for energy recovery

Used tyres are broadly split three ways as passenger, truck and off the road (OTR – mine) tyres. Virtually all mine tyres are buried on site – though as this report outlines the material being buried may in fact have a higher CV than the material being extracted. There is some uncertainty as to the fate of all used truck tyres; and unfortunately some passenger tyres are still simply stockpiled, landfilled or exported whole in bales presenting a biosecurity risk to receiving countries.

[3] DEE 2016, 'National Greenhouse and Energy Reporting Scheme Measurement: Technical Guidelines for the estimation of emissions by facilities in Australia - Applies to the estimation of emissions in the 2016-17 reporting year', Department of the Environment and Energy, Canberra, accessed November 2016 at https://www.environment.gov.au/system/files/resources/95cf8d59-dcf8-40c7-8bfc-5ceacc221700/files/nger-technical-guidelines-2016-17.pdf. It is noted that the decomposition of used tyres in landfill is likely to occur over long periods. However, used tyres in landfill also remain as a potential source of fuel for underground landfill fires.

[4] Hyder 2015, 'Stocks and Fate of End of Life Tyres - 2013-14 Study—Final Report', Hyder Consulting, Sydney, accessed at http://www.nepc.gov.au/resource/stocks-and-fate-end-life-tyres-2013-14-study, November 2016.

Appropriate disposal options include:

- direct recycling into rubber value chain as crumbed rubber
- energy recovery tyre derived fuel (TDF)
- civil work applications

The overall environmental performance of resource recovery activity need to be assessed when considering these options. This paper looks at one aspect of this for energy recovery as TDF, namely greenhouse gas emissions or the carbon equation.

Understanding the Carbon Equation of Energy Recovery

The equation for determining the carbon benefits (or impacts) of energy recovery is presented in Figure 2. Broadly speaking it is the greenhouse gas abatement of a given activity, less the impacts associated with the process of delivering those benefits, that gives the net greenhouse gas benefit. In the case of TDF there is a 'credit' for avoided extraction of fossil fuels, the avoided landfilling of rubber materials (no landfill gas generation to the extent that any of the natural rubber content in landfilled tyres dissimilates into landfill gas which contains methane, a potent greenhouse gas),[5] and the avoided emissions referenced against the fossil fuels that are displaced by TDF.[6] Emissions from used tyre resource recovery arise from the collection of tyres, energy and industrial emissions from processing and emissions from transport to end markets.[7]

Tyre Derived Fuel

Tyre Derived Fuel refers to the use of end-of-life tyres to replace fossil fuels such as gas, coal or oil, and provide an alternative energy resource for several industrial applications. For example, of the 117 million end-of-life tyres used as fuel per year in the US (48 per cent of total arisings), cement kiln usage accounted for 39 per cent, pulp and paper mills used 32 per cent, and electric utilities 29 per cent.[8]

Several steps are required to prepare TDF. While whole tyres can be used as a fuel in some applications, specialist handling systems are required and whole tyres may contain water becoming a breeding ground for mosquitos and the diseases they carry. Also, whole tyres are bulky to transport.

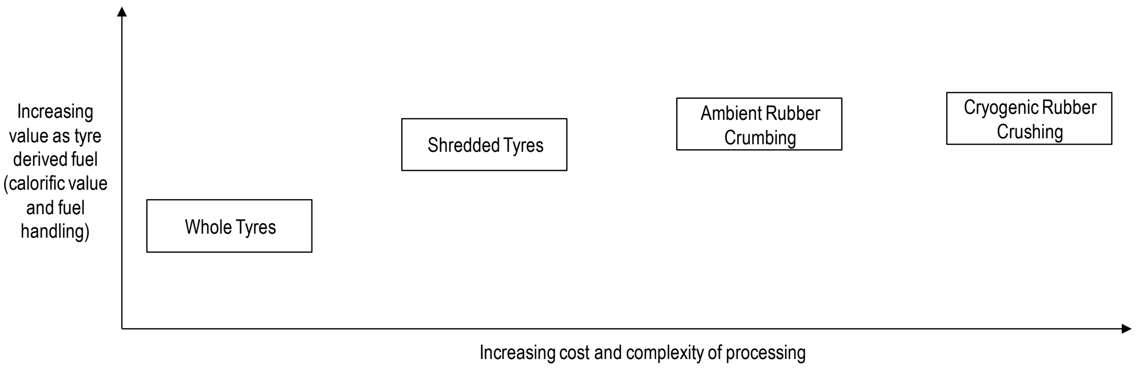

Figure 4 – Relationship between additional processing of end-of-life tyres and added value as a fuel. Highly processed material such as rubber crumb has higher order applications such as sports fields, soft fall surfaces and adhesives.

[5] There is debate around the timeframes for decomposition of natural rubber in landfill and the timing of landfill gas generation. The benefits of avoided landfilling have not been modelled here.

[6] There is also a credit from material displacement where TDF is used as a cement kiln alternative fuel. The steel belts displace the need for ferrous oxide and because the ash is incorporated into the cement matrix, less demand is placed on material input requirements. However, these benefits could add cost where TDF is not used in cement kilns. These additional benefits and potential impacts have not been modelled here.

[7] Note that in some cases emissions from collection of waste for disposal may be reduced because of shorter and more effective trip times achieved through recycling. These benefits have not been modelled here.

[8] RMA 2016, '2015 U.S. Scrap Tire Management Summary', Rubber Manufacturers Association, Washington DC, accessed at https://rma.org/sites/default/files/RMA_scraptire_summ_2015_0.pdf November 2016.

Shredding end-of-life tyres improves materials handling for the end-user and improves the efficiency of transport. Shredded tyres therefore present a useful balance between materials handling and the cost of processing (see Figure 4 above).

While the use of TDF for electricity generation and industrial process heat is common around the world, use of TDF in cement kilns is a resource recovery option with an additional variety of benefits. For example, the extremely high temperatures (over 1,500°C) and long residence time of TDF combustion in cement kilns ensure that any complex organic compounds are destroyed, in addition to neutralising any potentially harmful mineral elements. Furthermore, concrete made from cement manufactured using alternative fuels has the same safe construction and environmental properties as if it had been made using traditional fossil fuels.

The key value of TDF is the energy content (calorific value)[9] of the tyres. Different sources present different calorific values (CV) for used tyres. For example, a detailed study by Japan Automobile Tyre Manufacturers Association was used to estimate TDF calorific value at 33.2 GJ/t.[10] This compares favourably with the range of 32 – 34 GJ/t found in a recent used tyre technology review.[11] However, there are also lower ranges presented. For example, data from a European Tyre & Rubber Manufacturers' Association report provide a 15 per cent lower CV for TDF of 28.3 GJ/t.[12] An average of these two averages gives a calorific value of 30.8 GJ/t of TDF.

Estimating the Greenhouse Benefits

An analysis of the greenhouse emissions from using TDF as compared to three other fossil fuels was conducted. Greenhouse gas emissions were sourced from the Australian Government's National Greenhouse and Energy Reporting (Measurement) Determination 2008 for the 2016/17 reporting year.[13] The energy content and emissions from used tyres was sourced from data in the Japan Automobile Tyre Manufacturers Association and European Tyre & Rubber Manufacturers' Association recent reports.[14]

The results of this comparison are presented in Table 1. End-of-life tyres have a higher energy content than coal, while having a slightly lower energy content than natural gas and fuel oil. Greenhouse gas emissions are significantly lower than coal and fuel oil on a per unit basis, while being

Table 1 – Energy content and emissions from tyres, coal, natural gas and fuel oil

Material Type	*Energy Content*	*GHG Emissions*	*Relative Savings*
End-of-Life Tyres	30.8 MJ/kg	56.2 gCO_2e/MJ	- kg CO_2e/t
Brown coal	10.2 MJ/kg	93.9 gCO_2e/MJ	1,163 kg CO_2e/t
Bituminous coal	27.0 MJ/kg	90.2 gCO_2e/MJ	1,049 kg CO_2e/t
Natural gas distributed in a pipeline	39.3 MJ/m^3	51.5 gCO_2e/MJ	-143 kg CO_2e/t
Fuel Oil	39.7 MJ/L	73.8 gCO_2e/MJ	544 kg CO_2e/t

[9] Calorific value refers to the amount of energy released during the combustion of a fuel. Known also as the heating value or inherent energy of a material, calorific value is measured in units of energy per amount of material. For example, giga-joules per tonne (GJ/tn). Most working references to heating energy are presented as the net calorific value (also known as the lower heating value) on an as received basis. This measurement accounts for the moisture content of a fuel material and the energy used to 'drive' this moisture from the fuel (latent heat of water vapourisation). Calorific value is contrasted against embodied energy as an alternative approach to measuring energy content.

[10] JATMA, 2012, 'Tyre LCCO2 Calculation Guidelines Ver 2.0', Japan Automobile Tyre Manufacturers Association, Tokyo, accessed at http://www.jatma.or.jp/english/tyrerecycling/pdf/lcco2guideline_en.pdf, November 2016. The breakdown of passenger and truck tyres was taken from Hyder 2015, 'Stocks and Fate of End of Life Tyres - 2013-14 Study—Final Report', Hyder Consulting, Sydney, accessed at http://www.nepc.gov.au/resource/stocks-and-fate-end-life-tyres-2013-14-study, November 2016. This, in combination with an assumed 50:50 split on general and fuel efficient tyres in the Australian market was used to calculate CV and emissions per GJ.

[11] Ramos, G., Alguacil, F.J., López, F.A., 2011, 'The recycling of end-of-life tyres: technological review', Revista de Metalurgia, 47 (3), Mayo-Junio, 273-284, accessed at http://digital.csic.es/bitstream/10261/112830/1/The%20recycling.pdf, November 2016.

[12] ETRMA 2011, 'End of life tyres - A valuable resource with growing potential - 2011 edition', European Tyre & Rubber Manufacturers' Association, Brussels, accessed at http://www.etrma.org/uploads/Modules/Documentsmanager/brochure-elt-2011-final.pdf, November 2016. The same approach was used to estimate the CV of TDF as for JATMA data.

[13] Australian Government, 2016, 'National Greenhouse and Energy Reporting (Measurement) Determination 2008', Federal Register of Legislation, Canberra, accessed at https://www.legislation.gov.au/Details/F2016C00691, November 2016. Prepared 1 July 2016 - next update anticipated July 2017. Greenhouse gas emissions include Carbon dioxide, methane and nitrous oxide and are presented in units of carbon dioxide equivalents.

[14] Derived from JATMA, 2012, 'Tyre LCCO2 Calculation Guidelines Ver 2.0', Japan Automobile Tyre Manufacturers Association, Tokyo, accessed at http://www.jatma.or.jp/english/tyrerecycling/pdf/lcco2guideline_en.pdf, November 2016.

comparable to emissions from natural gas. (Note too that in the case of brown coal, around three tonnes are required to achieve the same energy content).

This relative advantage compared to fossil fuel emissions is presented in Figure 5. Here the relative greenhouse gas emissions arising from combusting the equivalent amount of energy content found in one tonne of end-of-life tyres (30.8 GJ) is graphed.

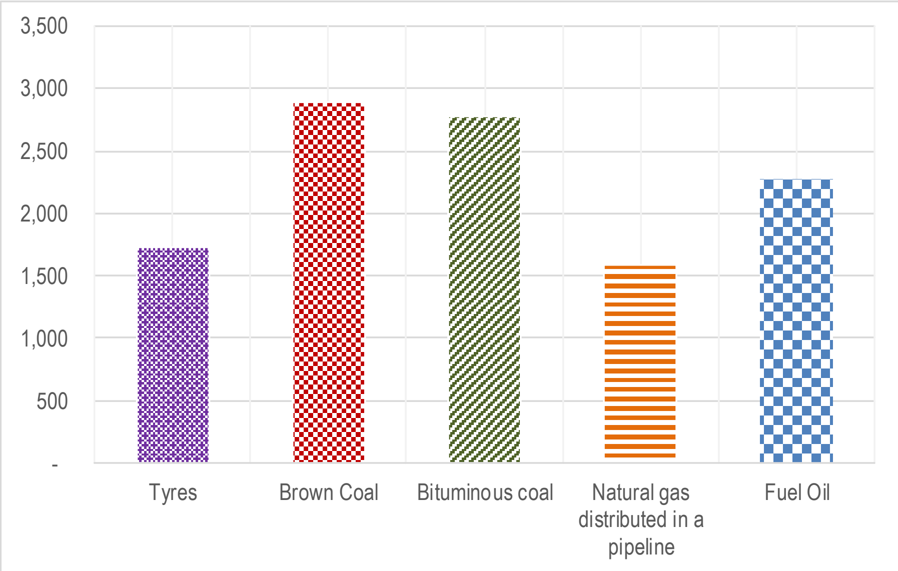

Figure 5 – Comparison of the greenhouse gas emissions from tyres, coal, natural gas and fuel oil as measured in kg of CO_2e per tonne of tyre equivalent energy combusted

Based on this analysis, TDF releases approximately 60 per cent of the greenhouse gas emissions as coal, offers a reduction of around 25 per cent when compared to oil and releases a small excess (9 per cent) when compared to the equivalent emissions released from natural gas.

It should be noted that the analysis involves estimated emissions from tyred derived fuel and the calorific value of that TDF on an average of averages basis. The outliers in the range present two boundaries of less greenhouse gas emissions and higher greenhouse gas emissions. However, even the lower range of CV and higher range of emissions presents lower emissions outcomes for the use of TDF when compared to coal and fuel oil, while only being 25 per cent more greenhouse intensive than the use of natural gas.

This analysis excludes the impacts of transport and processing.[15] However a previous analysis of greenhouse benefits from recycling, based on energy savings from resource recovery found that the impacts of transport were relatively minor in comparison to the benefits that were produced from increased resource recovery.[16]

Methane emissions from decomposition in landfill have not been taken into consideration. This is a function of the rubber content of the tyre and the decomposition of tyres in landfill. While the actual benefit of these avoided emissions may accrue slowly over long periods of time, it would reduce the overall emissions from a 'full life cycle' assessment of the use of TDF.

[15] However, note too that the greenhouse gas emissions from reference fossil fuels also excludes these additional impacts.

[16] Warnken ISE, 2007, 'Potential for Greenhouse Gas Abatement from Waste Management and Resource Recovery Activities in Australia', Waste Management Association of Australia, Sydney, accessed at http://s3.amazonaws.com/zanran_storage/www.wmaa.asn.au/ContentPages/46233201.pdf, November 2016.

Realising the Potential of Tyre Derived Fuel

End-of-life tyres in Australia present as both a waste management challenge and an opportunity for resource recovery. One option for resource recovery of end-of-life tyres is through Tyre Derived Fuel (TDF). This study has shown that the use of tyre derived fuel presents a better comparative greenhouse outcome over the use of fossil fuels such as coal and fuel oil, and is broadly comparable to emissions from natural gas. For example, the use of one tonne of TDF to replace coal results in a reduction of one tonne of greenhouse gas emissions.

While the actual relative greenhouse gas advantages of using TDF will vary on a case-by-case basis according to the replacement counterfactual, its potential should be given due consideration. TDF has been used in several applications within Australia over the last decade, however the opportunity is to optimise TDF use to deliver commercial and sustainable outcomes.

Figure 6 – Tyres have previously been used as fuel in Australia at the Gladstone clinker production facility operated by Cement Australia in Queensland, however this potential has not been optimised at a national level.

Further Information

This paper has been prepared for Australian Tyre Recyclers Association (ATRA): For further information please contact Robert Kelman :: Mob: 0423 573 278:: Email: robertkelman@iinet.net.au.

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