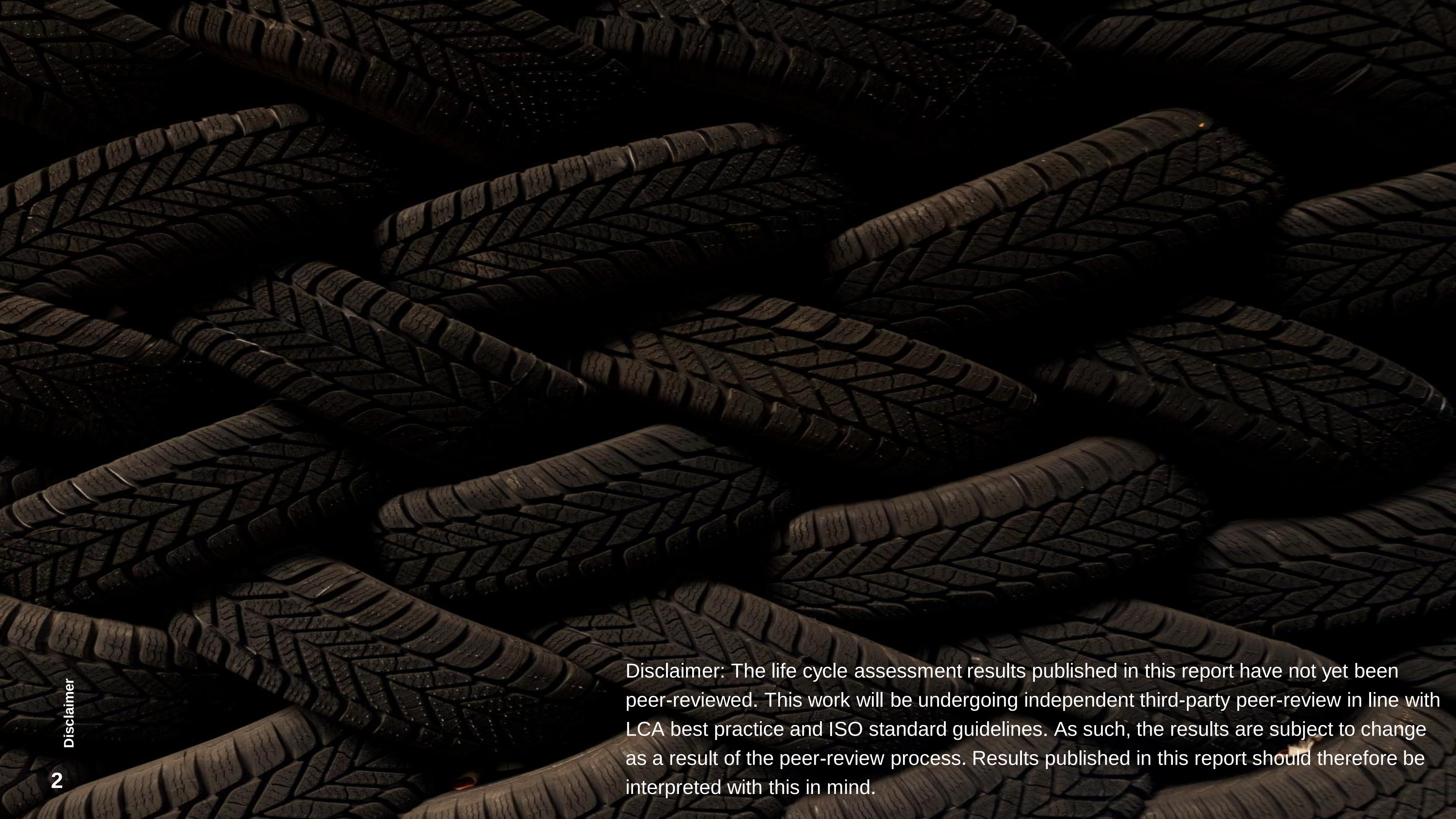
Greenhouse Gas Emissions Analysis of Waste Tyre Recovery

Key findings prepared for
Tyre Stewardship Australia
17 June 2022

EDGE



Disclaimer

Disclaimer: The life cycle assessment results published in this report have not yet been peer-reviewed. This work will be undergoing independent third-party peer-review in line with LCA best practice and ISO standard guidelines. As such, the results are subject to change as a result of the peer-review process. Results published in this report should therefore be interpreted with this in mind.

Objectives

This summary report provides TSA stakeholders with a summary of the work conducted, some key results and the outcomes of the study.

Project Snapshot

Tyre Stewardship Australia (TSA) has commissioned Edge Environment to understand the potential greenhouse gas (GHG) contributions of end-of-life tyres (EOLT) and a range of tyre derived products (TDP). This includes the GHG implications of waste tyre recovery and any associated activities required to produce TDP.

TSA intends to use the results of this study to:

- Understand the potential GHG contribution that EOLT and TDP can have to a range of current and potential markets, including any risks and benefits.
- Identify initiatives that TSA and industry can undertake to support the expansion of current TDP markets and creation of new TDP markets, to avoid landfill and dumping.
- Develop rigorous and sound metrics on behalf of the sector to provide standardised factors and protocols to assess carbon and climate change factors via a consistent, sector wide approach.

Project Stages

The project was segmented into three stages.

Stage 1 – Desktop Review

Desktop review of the current Australian EOLT and TDP market.

Preliminary analysis of the GHG emissions of TDP supply chains.

Stage 2 – Detailed Assessment

Detailed assessment of the key TDP end markets, including consideration of any additional processing requirements or enhanced performance benefits the product may have.

Stage 3 – Evaluation + Recommendations

Evaluation of existing schemes, regulations and opportunities from the perspective of EOLT/TDP producers and purchases.

Recommendations to leverage GHG benefits of EOLT and TDP.

Stage 1: Desktop Review and Preliminary assessment

- An initial assessment of EOLT and TDP market impacts was conducted. This involved:
  - Understanding the calculation methods that are relevant to EOLT and TDP markets, and how the environmental benefit will be apportioned to EOLT/TDP.
  - Quantifying the GHG emissions of EOLT, including the collection and processing of EOLT into products as input into TDP end markets.
  - Comparing these products to conventional products they will replace as an initial indication of potential GHG savings.

There are three key frameworks used in Australia relevant to waste tyres.

These frameworks provide guidance on whether the environmental impact, or 'burden' of the virgin material prior to the EOLT recovery, must be included in the emissions calculation. Excluding this burden would reduce the overall emissions impact of EOLT/TDP.

Framework	Context	Method
Australian Renewable Energy Agency (ARENA) Life Cycle Assessment (LCA)	Renewable energy products	Zero burden for waste materials in subsequent life cycles
Environmental Product Declaration (EPD) (EN15804:2012+A2:2019)	Construction products	
National Greenhouse Emission Reporting (NGER) scheme	Energy production and consumption	Burden included for recycled tyres

GHG emissions of new tyres

- Emissions factors (kg CO_2 eq/ t new tyres) varied between tyre types, as per Figure 1. Passenger and off the road (OTR) tyres have the highest impacts due to relatively higher proportions of synthetic rubber and fabric (nylon/rayon).
- The overall biogenic carbon contribution was negligible, ranging from -0.01% to 0.4%.
- Note the impact of new tyres is only relevant if the assessment framework used requires a burden to be included.

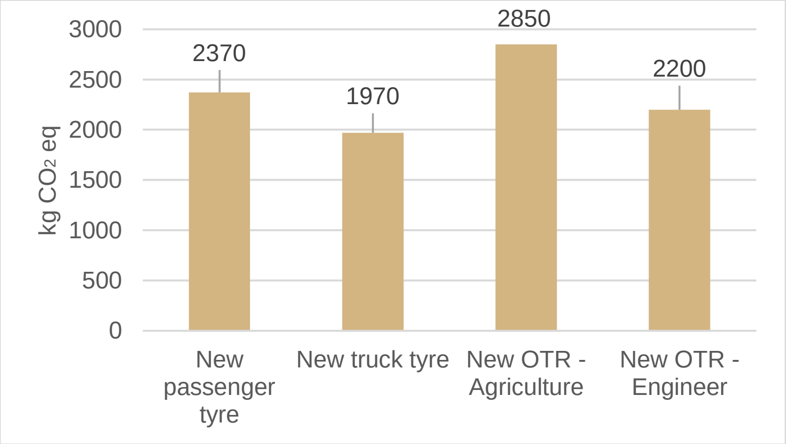


Figure 1 | Total GHG emissions per tonne of new tyre, split by tyre types.

GHG emissions of EOLT collection

- Transport emissions varied according to truck type and distance travelled. Larger trucks had a lower GHG emission factor than smaller trucks per tonne of EOLT transported over one km.

Truck size	Approx. capacity	GHG emissions
<10 t truck	300 equivalent passenger unit (EPU)	0.213 kg CO2-e/tkm
10-20 t truck	350 – 800 EPU	0.149 kg CO_2-e/tkm
>20 t truck	1200 – 1500 EPU	0.059 kg CO_2-e/tkm

Note: each EPU is 8-9 kg, so 300 EPU is equivalent to 2.4-2.7 tonnes of EOLT.

- For the scenarios assessed, the worst case was 500 km interstate travel in a <10 t truck (107 kg CO_2-e/ t tyres) and the best case 50 km urban travel in a >20 t truck (2.96 kg CO_2-e/ t tyres). This is due to the proportionally higher energy consumption required per tonne of goods for a smaller truck.
- Transport emissions are relatively small - these values are significantly smaller than the embodied emissions in the tyres.

Processing of EOLT into TDP

Preliminary analysis of TDP indicated that the GHG emissions factor (kg CO_2-e/t) varies depending on the processing technology.

- Shreds: 36.1
- Granules and buffings: 127
- Buffings: 356
- Crumb rubber: 413 – 473
- Pyrolysis process: 155

These preliminary GHG emissions results (per kg CO_2-e/t) are promising on comparison with conventional products.

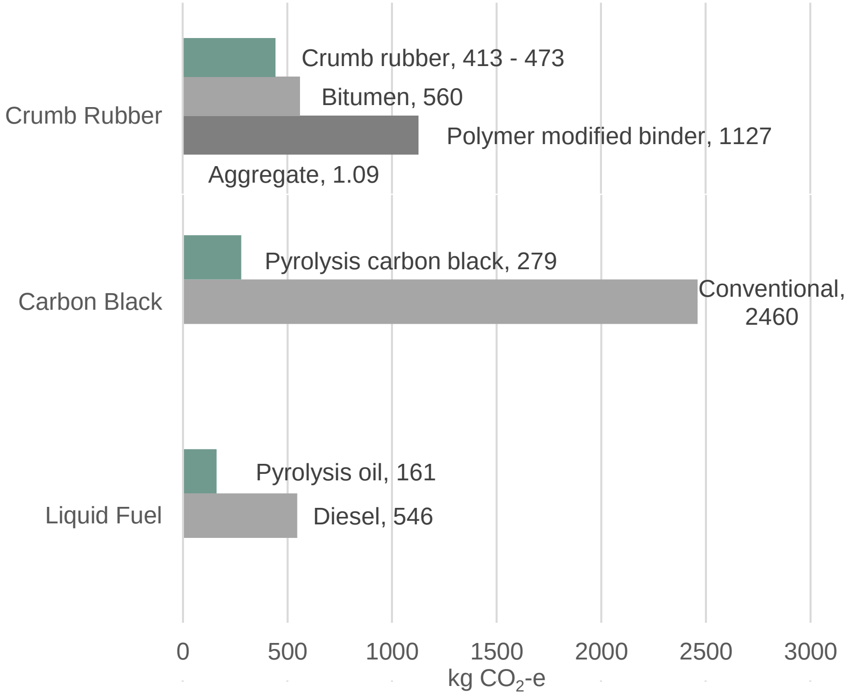


Figure 2 | Preliminary GHG emissions per tonne of product, accounting only for the processing stage of the TDP.

Stage 2: Detailed assessment of TDP end markets

This section extends the results of stage 1 by modelling the detailed TDP end markets, including consideration of any additional processing required and any performance benefits of replacing conventional products with EOLT.

The methodology used aligns with LCA methodology complying with ISO 14040:2006 and ISO 1044:2006+A1:2018. For consistency, the EPD methodology has been used to determine the environmental impacts of each scenario modelled.

The proportion of EOLT in each TDP scenario has been determined based on current best practice. More detail on these scenarios and the underlying assumptions used are in the detailed report.

General Methodology

The general process for modelling each scenario has been summarised into 7 steps. This process can be used to conduct similar analysis on new products and markets, noting that the methodology may require some adjustments for a specific scenario.

1. Define the TDP and conventional product.
2. Consider appropriate system boundary.
3. Consider performance benefits of the TDP compared to conventional product and incorporate in the functional unit.
4. Confirm any additional manufacturing inputs required for the TDP compared to the conventional product (if modelling construction/installation impacts).
5. Collect inventory data on the additional materials and other inputs required, utilising the EOLT processing results as the raw material input for the TDP component.
6. Model in Simapro, following LCA principles, using the impact assessment methodology consistent with the EPD method used for midpoint impact categories.
7. Review and report on results.

Scenarios Modelled

	Use case	TDP	Conventional Product	Functional Unit
Scenario 1	Default	N/A	Landfill of EOLT	1 t of EOLT
Scenario 2	Road construction	Crumb rubber binder in asphalt for road construction (wet process)	Polymer modified binder (PMB) in asphalt for road construction	1 t of asphalt
Scenario 3	Road construction	Crumb rubber binder in asphalt for road construction (dry process)	Conventional asphalt mix with a straight bitumen binder for road construction	1 t of asphalt
Scenario 4	Sprayed seal	Crumb rubber binder in sprayed seal mix	PMB in sprayed seal mix	1 t sprayed seal
Scenario 5	Carbon black	Recovered carbon black (rCB) derived from pyrolysis	Conventional carbon black	1 t equivalent conventional carbon black
Scenario 6	Oil	Oil derived from pyrolysis, with no further processing	Conventional thermal oil	1 MJ of energy
Scenario 7	Diesel	“Renewable diesel” – standard diesel blended with oil derived from pyrolysis	Standard diesel	1 t of diesel
Scenario 8	Concrete	Crumb rubber replacing sand as an aggregate in concrete	Conventional concrete mix	1 m^3 of concrete
Scenario 9	Concrete	Rubber granules replacing gravel as an aggregate in concrete	Conventional concrete mix	1 m^3 of concrete
Scenario 10	Permeable pavement	Rubber granules to replace gravel as an aggregate in permeable pavement	Conventional permeable pavement	1 m^2 of paved surface
Scenario 11	Combustion	Shredded rubber used in co-combustion at a cement kiln	Coal-derived fuel for combustion at a cement kiln	1 MJ of energy

Key findings (1/3)

Key findings from the detailed assessment of the 11 end market scenarios revealed 9 scenarios demonstrated an overall reduction compared to the conventional product.

Scenario 1 - Landfill

Emissions from landfill are potentially quite significant, ranging from 671-1,008 kg CO_2 eq per t EOLT.

Scenario 2 – Asphalt binder (wet process)

Crumb rubber used as 15% of an asphalt binder in the wet process has a **10% improvement** in GHG emissions compared to PMB, assuming the same service life. This increases to a 40% improvement if the improved service life is considered (Figure 3).

Scenario 3 – Asphalt binder (dry process)

Crumb rubber used as 27% of an asphalt binder in the dry process has a 12% **improvement** in GHG emissions compared to conventional asphalt, assuming the same service life. This increases to a 41% improvement if the improved service life is considered (Figure 3).

Scenario 4 – Sprayed Seal

Crumb rubber used as 15% of a bitumen mix sprayed seal has a **21% improvement** in GHG emissions compared to PMB sprayed seal, from 604 kg CO_2 eq to 769 kg CO_2 eq respectively.

Scenario 2 and 3 comparison

These scenarios provide an illustration of the potential GHG emission reductions that TDP can have compared to the conventional product. Crumb rubber can be added to asphalt mix for road construction. Initial research suggests the addition of crumb rubber can increase the service life of the road from 6 years to 9 years.

Figure 3 compares the crumb rubber mix to a polymer-modified binder (PMB) (scenario 2) and a conventional asphalt (scenario 3). In the uncorrected scenarios, where this performance benefit is ignored, there is already some reduction in GHG emissions. Adjusting for the service life improvement shows the significant potential that TDP has to reduce GHG emissions compared to the existing conventional products.

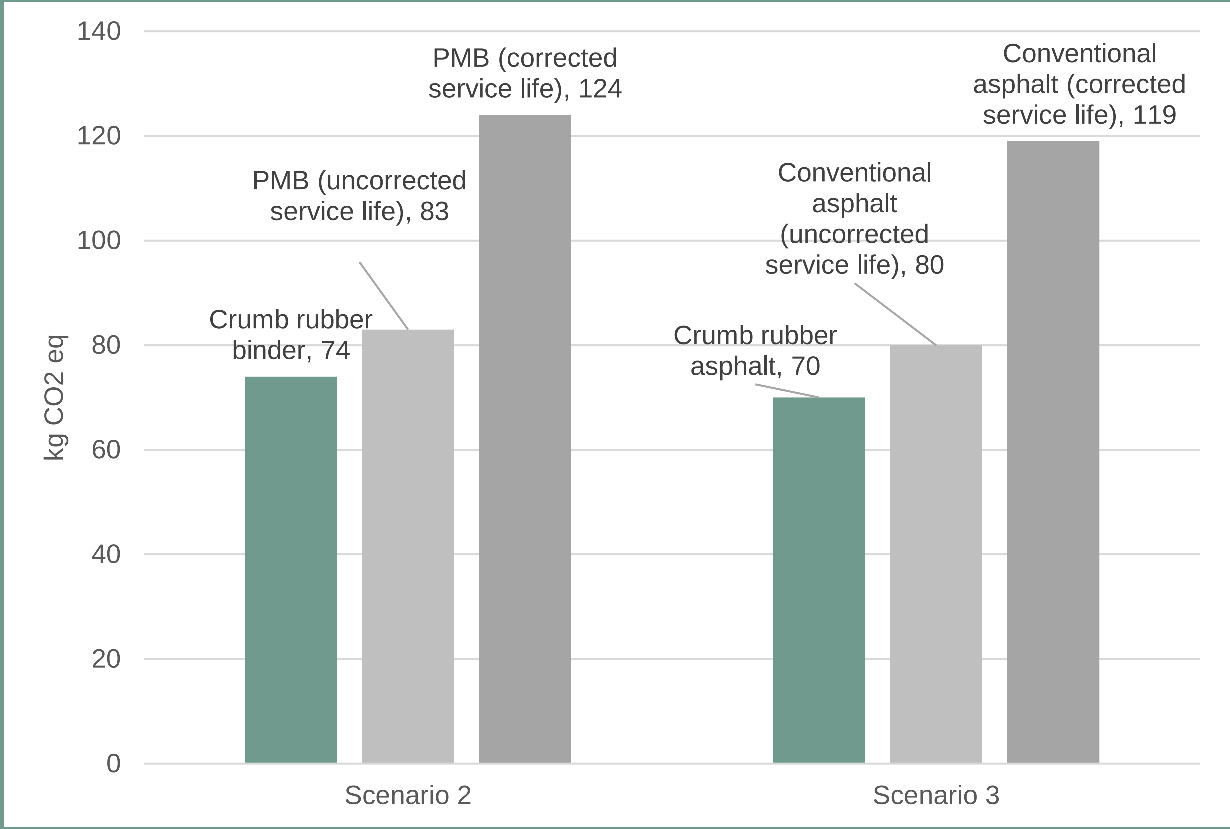


Figure 3 | Total GHG emissions for 1 tonne of asphalt mix. Scenario 2 shows a wet-process crumb rubber binder compared to PMB, scenario 3 shows a dry-process crumb rubber asphalt mix compared to conventional asphalt mix.

Key Findings (2/3)

Key findings from the detailed assessment of the 11 end market scenarios revealed 9 scenarios demonstrated an overall reduction compared to the conventional product.

Scenario 5 – Carbon black

Carbon black produced from pyrolysis has a **77% improvement** in GHG emissions compared to the conventional product if the replacement ratio is assumed to be 1:0.5, from 564 t to 2,458 kg CO_2 eq respectively. This increases to an **89% improvement** if the replacement is assumed to be 1:1.

Scenario 6 – Thermal oil

Unprocessed thermal oil produced from pyrolysis of EOLT used to replace conventional thermal oil has a **96% improvement** in GHG emissions if the replacement ratio is assumed to be 1:1, from 0.096 kg CO_2 eq to 0.004 kg CO_2 eq respectively. However, the used of pyrolysis derived products is still relatively unknown and extra processing may be required for the thermal oil. This has not been modelled and could reduce the benefit.

Scenario 7 – Diesel

Unprocessed thermal oil produced from pyrolysis of EOLT used to blend with conventional diesel has an **improvement** in GHG emissions of **3%** for a 5% blend, **13%** for a 20% blend and **34%** for a 65% blend. However, the blended diesel is of a reduced quality which may have other impacts. Similar to Scenario 6, additional processing may be required that has not been modelled but may reduce the benefit.

Key Findings (3/3)

Key findings from the detailed assessment of the 11 end market scenarios revealed 9 scenarios demonstrated an overall reduction compared to the conventional product.

Scenario 8 – Sand in concrete

Crumb rubber used to replace 5% of the sand in a concrete mix showed a **13% increase** in GHG emissions from 200 kg CO_2 eq to 223 kg CO_2 eq respectively. Note there may be other benefits of TDP compared to conventional sand.

Scenario 9 – Gravel in concrete

Rubber granules used to replace 30% of the gravel in a concrete mix showed a **15% increase** in GHG emissions from 200 kg CO_2 eq to 231 kg CO_2 eq respectively. Note there may be other benefits of TDP compared to conventional gravel.

Scenario 10 – Permeable pavements

Rubber granules used at 15% of an aggregate mix for permeable pavements showed a **16% improvement** in GHG emissions compared to conventional aggregate for permeable pavements, from 9 kg CO_2 eq to 10 kg CO_2 eq respectively.

Scenario 11 – Cement clinker

TDF used in the cement clinker process showed a **98% improvement** in GHG emissions compared to bituminous coal, from 0.0019 kg CO_2 eq to 0.0963 kg CO_2 eq respectively. This is the most substantial saving of all the scenarios assessed.

Stage 3: Producer & Purchaser Considerations, Opportunities & Requirements

Existing schemes and programs evaluated:

- **Reporting (Mandatory & Voluntary)**
- **Certification Opportunities**
- **Compliance Considerations**
- **Carbon credits Opportunities**
- **Funding Opportunities**

This stage puts the detailed GHG results of Stage 2 into the context of existing reporting and regulatory schemes.

- These schemes may present an opportunity to market the GHG benefits of EOLT/TDP and encourage the uptake of these products.
- Producers and purchasers of EOLT/TDP will also benefit from understanding the regulatory benefits or hurdles for using these products.
- Schemes may be either mandatory or voluntary, and span emissions quantification and certification schemes, reporting programs and initiatives, and standards and regulatory frameworks.
- There is an opportunity to leverage carbon trading and funding (e.g., government grants) mechanisms to realise benefits in producing or purchasing EOLT & TDP products and pursue further development of these products.

Evaluation Criteria

The following criteria was used to evaluate how well each scheme aligns to the strategic objectives of TSA and industry members.

Robustness: Does the scheme require third-party verification or is compliance to certification requirements self-declared?

Uptake: Does the scheme demonstrate breadth and depth of uptake by producers/purchasers at a national scale? E.g., multiple large-scale organisations, or uptake across multiple industries.

Impact: Is the reporting based on transparency in reporting, or does it promote impact reduction initiatives?

Eligibility: Are producers/purchasers eligible to become accredited against the scheme, and is it accessible to acquire (e.g., applicable fees are reasonable).

Criteria	Greater Outcome (1)	Lesser Outcome (0)
Robustness	Third-party verified	Self-declared
Uptake	Widespread uptake of scheme	Minimal demonstrated uptake of scheme across industry
Impact	Impact reduction	Transparent reporting only
Eligibility	Eligible & accessible	Not eligible and/or accessible

Summary of Schemes

	Criterion			
	Robustness	Uptake	Impact	Eligibility
1	★	★	★	★
0	☆	☆	☆	☆

Type	Category	Key schemes	Rating				Recommendation for TSA action
Reporting and certification schemes	Environmental Labels	GECA ecolabel	★	★	★	★	TSA should consider developing sector-wide EPD. This encourages the use of TDP as a product category, but also supports members to develop their own EPDs. EPDs recognised by a range of schemes including GECA, Climate Active and the IS Rating Scheme. TSA can also develop an industry wide tool to allow comparison of existing products with TDP alternatives. The tool allows producers to understand how to market their products and gives purchasers confidence in the products they buy. The voluntary reporting standards are more relevant at the organisation and product level and provides opportunity to educate TSA members on how to position their TDP products.
		EPD	★	★	☆	★	
		ANZ EPD Climate Declaration	★	★	★	★	
		Climate Active	★	★	★	★	
	Other tools and schemes	AfPA LCA Calculator for Asphalt	★	☆	☆	★	
		IS Rating Scheme	★	★	★	☆	
	Voluntary reporting	Science Based Targets	★	★	★	★	
		Carbon Disclosure Project	☆	★	★	★	
		MECLA	☆	★	★	★	
		GHG Protocol	★	★	☆	☆	
		Declare Product Labelling	☆	★	☆	★	
		GRI Standards	☆	★	☆	★	
		SASB	☆	★	☆	☆	

*Note additional information for these schemes is available in the detailed report.

Summary of Schemes

	Criterion			
	Robustness	Uptake	Impact	Eligibility
1	★	★	★	★
0	☆	☆	☆	☆

Type	Category	Key schemes	Rating	Recommendation for TSA action
Compliance considerations	Compulsory standards and regulations	State-based and national standards	N/A – mandatory	TSA should explore the need and potential to lead the development of state/territory-based or Australia-wide standards for pyrolysis fuels to ensure quality of this new stream and generate confidence in the new market entrant to foster strong uptake by industry.
		European Parliament PEF	★ ★ ★ ★	
		ISO 14064-1 GHG specification	★ ★ ☆ ★	
		NGER scheme	N/A - mandatory	
		IPCC Guidelines for National GHG Inventories	N/A - mandatory	
Fiscal opportunities	Carbon trading mechanisms	VCUs	★ ★ ★ ★	While TSA should not be providing financial advice, TSA can provide some general information on schemes relevant to producers.
		VERs	★ ★ ★ ☆	
	Funding mechanisms	State-based grants	N/A – consider eligibility and availability at time of application	TSA can proactively seek funding grants that producers may be eligible for and use their knowledge and resources to support their applications.

*Note additional information for these schemes is available in the detailed report.

Recommendations (1/2)

Based on the findings in this analysis, the following actions are recommendation to accelerate and support the uptake of EOLT/TDP by industry and end-users.

1. Develop a **tool** to assist companies, which can include Marginal Cost Curves, similar to the tool developed for a local council (for roads and buildings). This will allow the comparison of existing products in the markets with TDP alternatives, to provide an indication of the GHG saving.
2. Develop a **sector-wide EPD** on selected TDPs using input data from member companies. A verified sector-wide EPD would help encourage the use of the TPD compared to alternatives in the same category. It can also be provided to TSA members who provided the input data to allow development of their own specific EPDs.
3. Undertake a **feasibility study** to assess the current market capacity to collect & process EOLT, and manufacture and produce TDP across Australia. This will identify gaps in capacity, and/or areas of inefficiency to be addressed.
4. Commission a **comparative LCA** of TDPs in typically cementous applications, against new carbon neutral/ low carbon concrete products, such as ECOPact – Low carbon concrete by Holcim, to understand the GHG emissions and cost comparison of these two alternatives to traditional materials. This will proactively address queries from producers/purchasers who may be considering emissions-reducing initiatives, however, are unsure which alternatives are most appropriate for their business activities.
5. Prioritising the EOLT/TDP applications with the largest potential demand (e.g. crumb rubber), undertake a **cost-benefit analysis** of the EOLT/TDP life cycle, to calculate the cost savings (and potentially, a different cost distribution profile) of recycled content over virgin materials. This will allow producers/purchasers to present a business case for transitioning to EOLT/TDP and inform discussions with key business stakeholders.

Recommendations (2/2)

Based on the findings in this analysis, the following actions are recommendation to accelerate and support the uptake of EOLT/TDP by industry and end-users.

6. Translate GHG emissions data into **public-facing marketing and communications collateral** to allow industry and community to rapidly digest the benefits of EOLT/TDP applications. This will accelerate the transition to EOLT/TDP by mitigating effort required by producers/purchasers to create buy-in from end-users. This public-facing summary report forms part of this recommendation.
7. Establish further **partnerships** with national and international research institutions and circular economy associations such as CSIRO, and the Victorian Circular Activator, to understand future direction of pyrolysis technology and potential application to new TDP products in the energy and thermal use sectors.
8. Explore potential to **apply blockchain technology** to create digital ledgers of EOLT/TDP outputs to establish transparency of supply chain, product/ content and quality, and contribute to improving the collection and management of data in the circular economy in Australia.
9. Develop or commission **training material** for the internal TSA team to educate them on the content of this project and its outcomes, to improve their understanding and empower them to communicate the outcomes to stakeholders.
10. Explore the need and potential for TSA to lead development of state/territory-based or Australia-wide **standards for pyrolysis fuels and materials** to ensure quality of this new stream, and confidence in the new entrant to the market to foster strong uptake by industry. As TDP markets become more established across Australia, the TSA should proactively liaise with authorities across all markets (e.g. roads authorities, EPA) to update regulations as necessary.