MARSDEN JACOB ASSOCIATES

blue environment pty ltd

Implications of the Transition to EVs for End-of-Life Tyre Recovery

Version 2 – updated October 2024

Prepared for

TyreStewardship AUSTRALIA

Australian Government Accredited Product Stewardship Scheme

Prepared for Tyre Stewardship Australia
Marsden Jacob Associates Pty Ltd
ABN 66 663 324 657
ACN 072 233 204

e. economists@marsdenjacob.com.au
t. 03 8808 7400

Office locations
Melbourne
Perth
Sydney
Brisbane
Adelaide

Authors

Dr Peter Kinrade	Marsden Jacob Associates
Kyle O'Farrell	Blue Environment
Ram Chandrasekaran	Marsden Jacob Associates
Emma Swann	Marsden Jacob Associates

LinkedIn - Marsden Jacob Associates
www.marsdenjacob.com.au

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Introduction

The expected transition of the Australian passenger vehicle fleet to electric vehicles (EVs) over the next 20 to 25 years has prompted Tyre Stewardship Australia (TSA) to seek research into better understanding new EV specific tyres entering the market and whether this poses a risk to end-of-life tyre (EOLT) recovery, recycling and end markets. This report presents outcomes of that research.

Background

In 2023, an estimated 8.4% of all new passenger and light commercial vehicles sold in Australia were EVs. This is an increase of 121% from the 3.8% share of sales in 2022. Strong growth in EV sales is expected to continue over the rest of this decade and beyond.

Central, High and Low growth scenarios were modelled for this study, drawing on similar scenarios modelled by the CSIRO. The scenarios indicate that EV sales could comprise between 36% and 60% of new vehicle sales by 2030. By 2030 the total stock of EVs on Australian roads could be between 2.1 million and 3.1 million vehicles, with about 2.7 million vehicles being on Australian roads under the Central scenario. This would represent about 16% of the total stock of passenger vehicles on Australian roads in 2030 or about 12% of the total stock of passenger and light commercial vehicles.

EOLTs from EVs could number between about 2.2 million and 3.2 million tyres each year by 2034, with the number of tyres being about 2.7 million under the Central scenario. This is equivalent to about 26,000 tonnes of tyres, which would represent about 12% of the total weight of EOLT tyres from passenger and light commercial vehicles and about 4.5% of the weight of all EOLTs in 2034. When EOLTs from EVs reach this level, this could start impacting on the cost of recovering tyres, a point noted in discussions with tyre recyclers.

Composition of EV tyres

There is a spectrum of tyre design, composition and performance property considerations, and ICEVs and EVs overlap on these design considerations. In fact, it is likely that EV marketed tyres are a completely contained subset within the compositional range of ICEV marketed tyres and will remain so. There are functional differences that EV related pneumatic tyres can have relative to ICEV tyres but improvements in most or all of these functional areas is also of benefit to many passenger ICEVs. These functional areas are:

- Lower rolling resistance – to reduce energy consumption and so increase EV range.
- Increased abrasion resistance – to allow for typically greater EV weight and maintain the EV tyre lifespan.
- Lower road noise generation / noise suppression.
- Stronger sidewalls – to allow for typically greater EV weight, particularly in cornering.

- Reduced overall tyre weight – to reduce energy consumption and so increase EV range.
- Self-sealing capability – to mitigate the issue of EVs not having a spare tyre.
- Run flat capability – to mitigate the issue of EVs not having a spare tyre.

Similarly, while the composition of tyres is being tuned for EVs, EV 'specific' tyres are, and will likely remain compositionally within the spectrum that already exists for passenger ICVs tyres. Two significant compositional elements influenced by the transition to EVs are noise reduction foams and self-sealing tyres. A minor new compositional element, that isn't EV tyre specific, is the future uptake of integrated sensors in tyres.

EV tyre wear

EVs are typically 20% to 30% heavier than equivalent ICEVs. This factor, combined with increased acceleration and a focus on tyre noise reduction mean that tyres on EVs have intrinsically higher wear rates than similar tyres on ICEVs. This has negative implications for non-exhaust PM emissions, with at least two reasonably recent studies establishing a link between higher tyre wear on EVs and higher non exhaust emissions. The evidence on this is not conclusive, however. Higher wear rates of tyres on EVs also have implications for tyre life and end-of-life tyre numbers

However, technological advancements to EVs and to EV tyres, already underway, mean that the implications of the transition to EVs for tyre wear (and associated emissions and EOLT generation) are less clear, especially in the longer term. Tyre durability features, such as increased abrasion resistance and stronger sidewalls, are especially significant developments. These features are likely to be further encouraged by the introduction of Euro 7 emissions standards.

EV tyre end-of-life processing, recycling and end markets

The increased uptake of passenger tyres incorporating a polyurethane noise reduction foam layer will not be particularly problematic for passenger tyre shredding or end-markets. However, reprocessing these tyres does result in some increased costs for recyclers.

The increased uptake of passenger tyres incorporating a self-sealing capability, much beyond the current low level of use, will be problematic for passenger tyre shredding. Reprocessing these tyres results in more significantly increased costs for recyclers.

Design modifications related to lowering rolling resistance and increasing abrasion resistance will generally not have any noteworthy impacts on either passenger tyre reprocessing or end-markets.

EV vehicle and tyre standards

At present there are no specific standards in Australia relating to EV's or EV tyres. Tyre standards, both in Australia and internationally are primarily focussed on tyre performance. EV standards in the EU and US are primarily focussed on safety standards, especially for batteries. For the foreseeable future therefore, government regulations are unlikely to directly affect the design and composition EV tyres and their recyclability, either positively or negatively. Indirectly however, there are emerging standards that could affect the design and composition of tyres, both generic tyres and EV tyres and, by extension, recycling of the tyres. The most significant of these trends is the introduction of Euro 7 emissions standards which, for the first time, will set emission limits and minimum durability requirements for tyres.

Conclusions

Significant changes to tyre composition and design are already underway. Many of these changes are not specifically linked to the transition to EVs, although that transition could be accelerating the changes. Some of the changes to tyre design and composition could, in turn, be increasing tyre recycling costs and, in the case of self-sealing tyres, making recycling more problematic. This is a challenge for tyre recycling generally though, and not one specifically for the recycling of EV tyres. Changes to tyre design and composition also represents an opportunity for the tyre recycling industry - an opportunity for recyclers to adapt and develop a competitive edge through adopting new and innovative recycling technologies and systems.

1. Introduction

1.1 Study purpose

After initially slow uptake in Australia, Electric Vehicle (EV) sales have experienced a surge in sales in recent years, with EV sales estimated by the Electric Vehicle Council (EVC, 2023) to have been 8.4% percent of all new car sales in 2023, up from 0.8% of sales in 2020. Pending Australian government policies, including a *New Vehicle Efficiency Standard*, are likely to further accelerate growth in sales. The EVC contends that for Australia to achieve its greenhouse gas emission targets, more than 50% of all new cars sold in 2030 will need to be EVs.

Available evidence indicates that the current generation of EVs are on average 20-30% heavier in comparison to equivalent sized internal combustion engine (ICE) vehicles. This extra weight, combined with the higher torque in EVs, could contribute to a higher rate of tyre wear compared to ICE vehicles (Carey 2023). Major tyre manufacturers, including Bridgestone, Goodyear, Michelin and Sailun, have responded by developing tyres they claim are EV specific, being more durable and improving range.

The expected transition of the Australian passenger vehicle fleet to EVs over the next 20 to 25 years has prompted Tyre Stewardship Australia (TSA) to seek research into better understanding new EV specific tyres entering the market and whether this poses a risk to end-of-life tyre (EOLT) recovery, recycling and end markets. This report presents outcomes of that research.

1.2 Study approach and report structure

The information presented in this report was compiled primarily through desktop research of published industry and academic reports and data. The desktop research was supported by information received through interviews with a small number of industry stakeholders, including tyre manufacturers and tyre recyclers, and with government agencies. Through the desktop research and stakeholder engagement we have sought to answer some key research questions including:

1. What is publicly known about the difference in material and compound composition between EV tyres and ICE tyres?
2. What is known about the influence or impacts of different compounds on EV tyre wear?
3. What impact could EV tyre composition and design potentially have on end-of-life tyre processing and recycling applications and end markets for tyre derived materials (TDMs)?
4. What are the current design rules for tyres and EV vehicles and are they expected to change?

Answers to these questions will help to provide TSA with a better understanding of the implications of the transition to EVs for the recovery of EOLT in Australia across the supply chain for EV tyres (Figure 1), noting that the aspects of the supply chain most relevant to the focus of the research questions are: design & manufacture (Questions 1 and 2); tyre use (Question 3); recycling, reuse and end markets (Question 4).

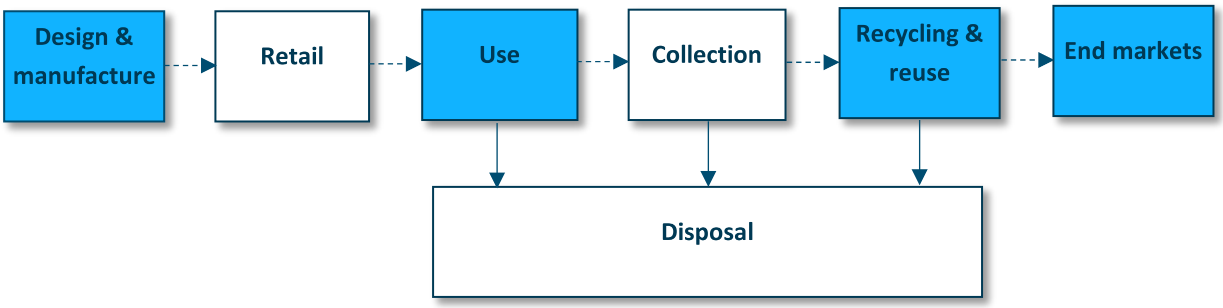

Figure 1: Supply chain for tyres with areas relevant to EV tyre recovery highlighted in blue

The remainder of this report is structured as follows:

- Section 2 provides background information on the EV market and market for EV tyres in Australia, including preliminary market projections.
- Sections 3 to 6 address the key research questions in turn.
- Section 7 provides conclusions.

2. Background

Key points

- EV sales have grown rapidly in Australia in recent years and are likely to continue grow rapidly over the remainder of this decade.
- Central, High and Low growth scenarios modelled for this study, drawing on very similar scenarios modelled by CSIRO, indicate that EV sales could comprise between 36% and 60% of new vehicle sales by 2030.
- Under these scenarios, by 2030 the total stock of EVs on Australian roads could be between 2.1 million and 3.1 million vehicles.
- Most of the major tyre brands are marketing tyres specifically for EVs. These have some different composition and design elements to generic tyres.
- Under the Central, High and Low growth scenarios, by 2034 2.2 million to 3.2 EOLTs could be generated each year from EVs. The number of EOLTs from EVs is likely to continue to grow rapidly through the remainder of the 2030s.
- This could have reprocessing, and end market implications for EOLTs.

2.1 Nature of EVs and EV tyres

There are currently four broad types of EV available in the market for passenger and light commercial vehicles:

- Battery Electric Vehicle (BEV). These cars are powered by rechargeable batteries with no secondary source of power. Most BEVs use a lithium-ion (Li-ion) battery, although many automakers are working on other chemistries and solid-state battery technology.
- Hybrid Electric Vehicle (HEV). These cars combine internal combustion engines with an electric propulsion system that is intended to achieve a better fuel economy. Most HEVs use a nickel-metal hydride (NiMH) battery.
- Plug in Hybrid Electric Vehicle (PHEV). Similar to a HEV, but usually with a larger battery that can be charged from the electricity grid.
- Fuel Cell Electric Vehicle (FCEV). These cars use a fuel cell (in combination with a battery or a super capacitor) to power its electric motor. These cars are generally not available to consumers in Australia yet.

Due to their large and heavy batteries electric vehicles (EVs) are typically about 20% to 30% heavier than equivalent petrol or diesel-powered vehicles (Recycled Rubber Coalition 2024, Timmers et al. 2016). EVs also reach maximum torque almost instantaneously. This increases tyre friction, contributing to increased tyre wear. Tyre manufacturers have responded by developing tyres that are suited to withstand the increased wear on tyres due to the increased weight and friction generated by EVs. Tyres are also designed to minimise rolling resistance, reduce noise and increase ride comfort. It is important to note that these tyre features (increased wear resistance, reduction in noise etc) can also be applied to traditional ICEVs. Nevertheless, the transition to EVs could be accelerating these design features, which could affect EOLT recovery and recycling, issues that will be explored at length in later sections.

2.2 The EV market in Australia

2.2.1 Current situation

EV sales have been growing rapidly in recent years but from a low base. In 2023, an estimated 8.4% of all new passenger and light commercial vehicles sold in Australia were EVs (EVC 2023). This is an increase of 121% from the 3.8% share of sales in 2022. In every state and territory in Australia EV sales doubled in 2023 compared to 2022. Along with substantial growth in sales was an observed shift in consumer preferences to BEVs over PHEVs. The top 5 EVs sold in Australia in 2023 were all BEVs and as at the end of 2023, BEVs represent over 90% of Australia's EV market. There are now approximately 180,000 EVs on Australia's roads made up of about 159,000 BEVs and 21,000 PHEVs.

2.2.2 Potential trends in EV sales and stocks

Strong growth in EV sales is likely to continue over the rest of this decade and beyond. Figure 2 and Figure 3 present 'Central', 'High' and 'Low' growth scenarios of EV sales in Australia out to 2030. The scenarios were modelled for this study drawing on scenarios of EV sales modelled by CSIRO (Graham 2022) but updated to reflect recent EV sales numbers. Nevertheless, the data presented in the figures should be regarded as indicative only.

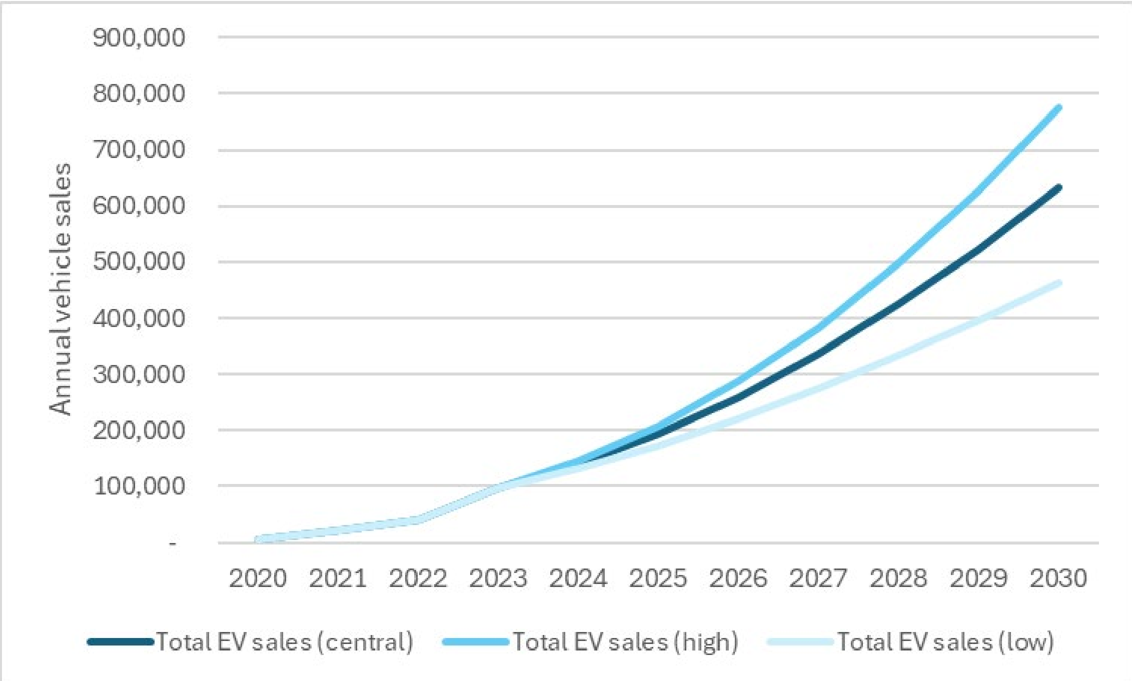

Figure 2: Potential sales of EV vehicles in Australia to 2030 - Central, High and Low Growth Scenarios

Source: Marsden Jacob analysis for this study drawing on Graham 2022, BITRE 2022, EVC 2023.

Under the High and Low growth scenarios, annual EV sales could range from about 460,000 to 775,000 by 2030, with sales under the Central scenario being about 630,000 by 2030 (Figure 2).

Under the Central growth scenario, EVs will comprise 49% of new vehicle sales by 2030 (Figure 3) but could be as low as 36% of new vehicle sales (Low growth scenario) or as high as 60% of new vehicles sales (High growth scenario).

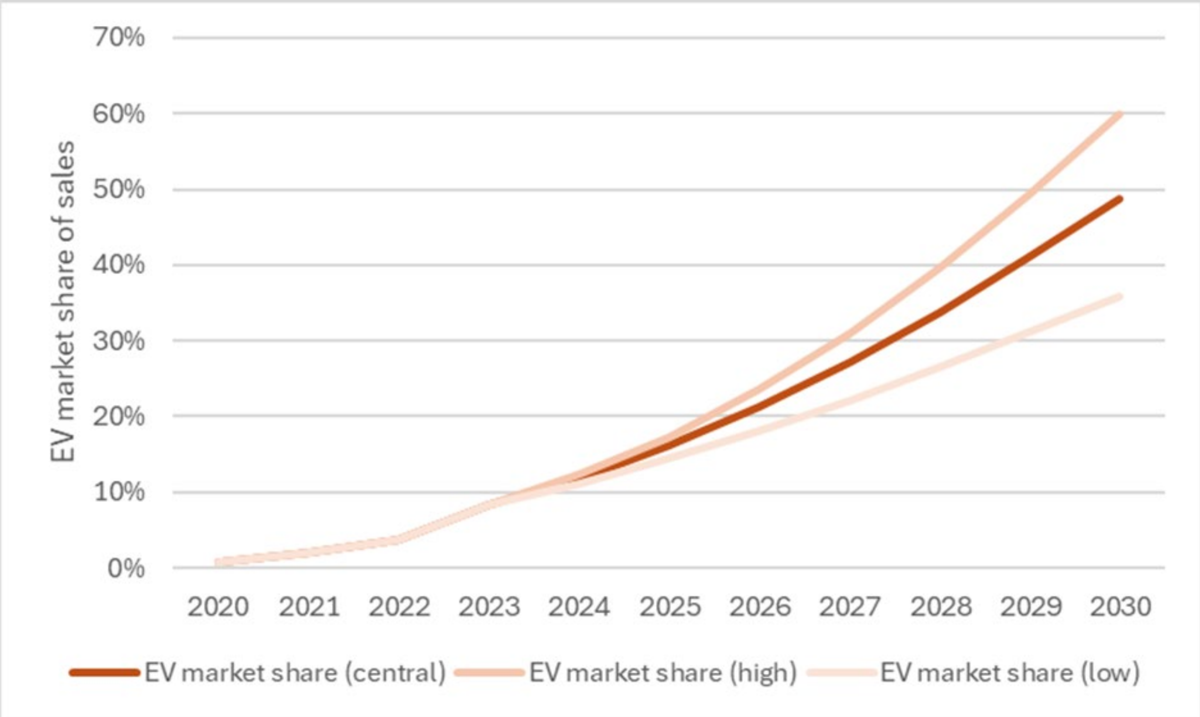

Figure 3: Potential EV share of total passenger and light commercial vehicle sales in Australia to 2030 - Central, High and Low Growth Scenarios

Source: Marsden Jacob analysis for this study drawing on EVC 2023 and Graham 2022

Recent data and developments provide some confidence that the Central scenario presented in Figure 2 and Figure 3 represents a realistic future for EV sales in Australia:

- First, international data compiled by the International Energy Agency (IEA 2024) shows that globally EV sales comprised about 17% of new car sales in 2023, about twice the proportion in Australia. While growth in EV sales in 2023 was lower than in the two previous years, the annual growth rate was still about 35%.
- Second, until now lack of a vehicle efficiency standard and nationally consistent EV policy has been a major contributing factor to the limited availability of EVs in Australia and is regarded a hindrance to the transition to EVs. Therefore, passing of legislation recently to introduce a New Vehicle Efficiency Standard (NVES) in July 2025 is likely to provide a significant incentive to vehicle suppliers to sell more EVs as part of the mix of low CO_2 vehicles (DITRDCA 2024).
- For Australia to achieve its national emission targets, and CO_2 targets established under the NVES

means that approximately 50% of all new cars sold in 2030 will need to be EVs (EVC 2023). Moreover, this trajectory also aligns with emission reduction targets set by state governments including in NSW (52%) and Victoria (50%). Given the urgency to meet these targets, almost all state and territory governments in Australia have implemented a range of incentives to encourage the purchase of electric vehicles, including rebates to reduce the upfront purchase price, zero-interest loans, and discounts on stamp duty and registration fees. In 2022, the Australian Government also introduced a fringe-benefit tax (FBT) exemption for EVs. This incentive benefits fleets and those consumers that can purchase an EV through salary sacrifice arrangements. The Australian Government also removed import duty for EVs made in countries without FTA agreements, namely EU and UK (EVC 2023).

With implementation of the NVES alongside incentives provided by states and territories, it is reasonable to expect that growth of EV sales will continue.

Drawing on the sales scenarios discussed above, indicative estimates have also been made of the stock of EVs driving on Australian roads by 2030. Under the Central scenario, the total number of EVs on Australian roads would grow to about 2.7 million vehicles by 2030 (Figure 4). This would represent about 16% of the total stock of passenger vehicles on Australian roads in 2030 or about 12% of the total stock of passenger and light commercial vehicles. Under the High and Low growth scenarios the stock of EVs on Australian roads would range from about 2.1 million vehicles to about 3.1 million vehicles in 2030.

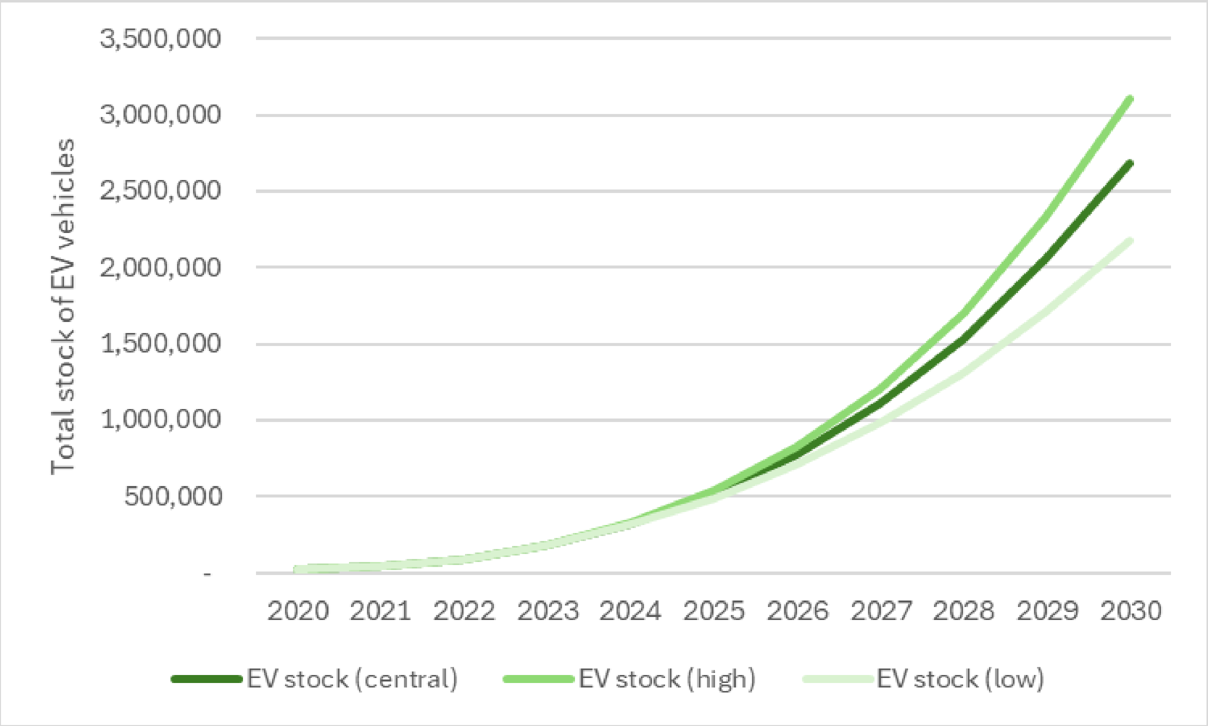

Figure 4: Potential stock of EVs in Australia to 2030, given High, Central and Low growth sales scenarios

Source: Marsden Jacob analysis for this study drawing on BITRE 2022, EVC 2023, Graham 2022

2.3 Implications of scenarios for EOLTs

Indicative numbers of end-of-life tyres (EOLTs) from EVs have also been estimated out to 2034. The estimates are based on the potential stock of EVs in Australia to 2030, given the High, Central and Low growth sales scenarios, and an assumed life of about 4 years for tyres fitted to EVs[1]. Under the High and Low scenarios, EOLTs from EVs could number between about 2.2 million and 3.2 million tyres each year by 2034, with the number of tyres being about 2.7 million under the Central scenario (Figure 5). This is equivalent to about 26,000 tonnes of tyres[2], which would represent about 12% of the total weight of EOLT tyres from passenger and light commercial vehicles and about 4.5% of the weight of all EOLTs in 2034. EV EOLT numbers would likely continue to increase rapidly through the remainder of the 2030s.

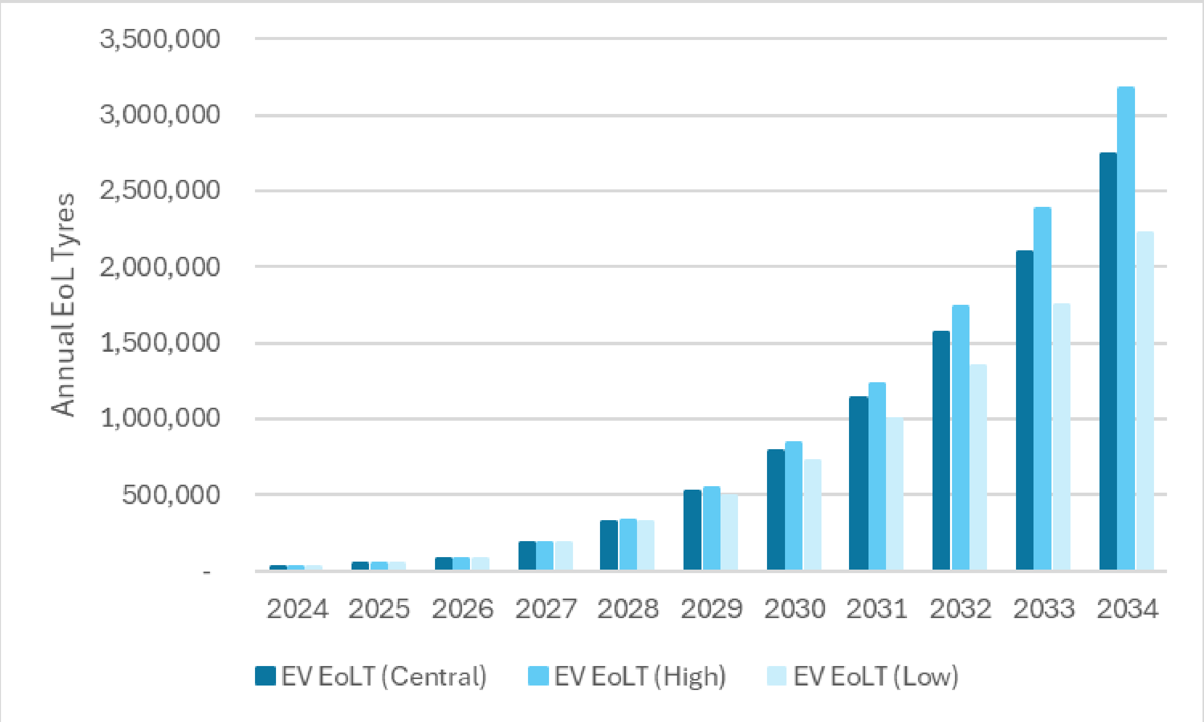

Figure 5: Potential numbers of EOLTs from EVs in Australia to 2034 under Central, High and Low Growth Scenarios

Source: Marsden Jacob analysis for this study drawing EVC 2023, Graham 2022, Randell EC et al. 2020

When EOLTs from EVs reach this level, this could start to impact on the feasibility and cost of recovery of tyres, a point noted by tyre recyclers. As outlined in Table 1, most of the major tyre suppliers are already marketing EV specific tyres or tyres that are targeting the EV and hybrid vehicle market. As discussed in detail in later sections of this report, many of these tyres have design and composition elements that are somewhat different to generic tyres. Representatives of the tyre

1 This estimate is based, in turn, on an average annual distance travelled by each vehicle of about 11,500 kilometres and an assumed life of each tyre of about 45,000 kilometres.

2 Based on an assumed average weight of an EV EOLT of about 9.5 kilograms.

recycling industry, for example, have indicated that tyres with a foam layer – features common in EV tyres – at present have to be manually separated from other tyres prior to the shredding process. While this is not a significant problem with the small numbers of these tyres at present, it might pose a significant problem if these types of tyres become a significant share of EOLTs.

The likely rapid increase in consumption of EV specific tyres, therefore, could have reprocessing and end market implications, issues that are also discussed in later sections of this report.

Table 1: Examples of EV tyres on the market[3]

Tyre make/model	Image	Vehicle types	Targeted vehicle market	Composition and differences to generic tyres	Reprocessing implications
Pirelli P ZERO E		Passenger	EV specific	- Higher usage of recycled and bio-based materials - Reinforced internal and external sidewalls.	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Hankook iON evo AS and SUV		Passenger	EV specific	- Higher Silica content. - Higher Silica dispersion.	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Hankook Ventus S1 evo3 EV		Passenger	EV specific	- Foam layer made from polyurethane. - Internal sealant layer. Adhesive could be polyvinyl acetate based (water-based), but not confirmed. - Higher silica content. - Tyre is vulcanised for twice as long as regular tyres.	- Additional sealant and foam insert may need to be removed or require additional sorting during recycling process.
Michelin Pilot Sport EV		Passenger	EV specific	- Foam layer made from polyurethane. - Thinner top belt compared to regular tyres (top belt is layer between tread and carcass often made of nylon).	- Additional foam insert may need to be removed or require additional sorting during the recycling process.
Michelin e.PRIMACY		Passenger	Not EV specific. But designed to target electric and hybrid cars sales.	- Thinner top belt compared to regular tyres (top belt is the layer between the tread and the carcass often made of nylon cord).	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Bridgestone TURANZA ECO		Passenger	Not EV specific. But designed to target electric and hybrid cars sales.	- 3mm sealant layer made from 50% natural rubber.	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Kumho ECSTA EV PS71		Passenger	EV specific	- Polyurethane foam layer. - Higher silica content. - New high-strength ultra-light hybrid components (possibly a mix of different textile layers).	- Additional foam insert may need to be removed or require additional sorting during the recycling process.
Kumho CRUGEN EV HP71		Passenger	EV specific	- Polyurethane foam layer. - Higher silica content.	- Additional foam insert may need to be removed or require additional sorting during the recycling process.
Kumho TX31 SUPERMILE EV		Passenger	EV specific	- Reinforced sidewalls.	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.

[3] Note, the information presented in this table is not exhaustive.

Continental EcoContact 6		Passenger	Not EV specific. But designed to target electric and hybrid cars sales.	- The adhesive is possibly polyvinyl acetate based (water-based), however, this is not confirmed. - Better dispersion of silica.	- Additional sealant and foam insert may need to be removed or require additional sorting during the recycling process.
Continental Conti.eContact EV tyre		Passenger	EV specific	(not stated)	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Continental SportContact 5		Passenger	Not EV specific but is often used on Tesla cars. Labelled as EV compatible.	- Polyurethane foam layer. - The adhesive is possibly polyvinyl acetate based (water-based), however, this is not confirmed. - Reinforced side walls.	- Additional sealant and foam insert may need to be removed or require additional sorting during the recycling process.
Yokohama ADVAN Sport EV A/S		Passenger	EV specific	- Higher silica content. - Reinforced sidewalls.	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Yokohama ADVAN dB V552		Passenger	Not EV specific. But designed to target electric and hybrid cars sales.	- Wider belt. - Reinforced side belt.	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Goodyear Eagle F1 Asymmetric 6		Passenger	Not EV specific. But design elements incorporated to target EV sales.	(not stated)	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Dunlop e.SPORT MAXX		Passenger	EV specific	- Foam layer (possibly a polyurethane).	- Additional foam insert may need to be removed or require additional sorting during the recycling process.
Falken e.ZIEX		Passenger	EV specific	- Polyurethane foam layer.	- Additional foam insert may need to be removed or require additional sorting during the recycling process.
Dunlop e. ENASAVE SP148		Truck/Bus	EV bus specific	(not stated)	- Tyre is composed of similar materials to regular tyres but there is greater reinforcement of steel and textile materials so may take more energy to break down.
Michelin UPTIS		Passenger	Not EV specific.	- No textile or steel reinforcement. - Tyre structure does not rely on pressurised air and so flats are effectively not possible.	- Less tyres are scrapped due to unrepairable punctures. - Traditionally non rubber components separated from rubber by magnetic properties or density. Since components are not magnetic or density doesn't different from rubber, new sorting process needed.
Pirelli Cyber Tyre		Passenger	Not EV specific. However, is available on tyres that have EV variants (e.g. Pirelli P Zero PZ4).	- Small electronic device and battery.	- Sensor may need to be removed or require additional sorting during the recycling process.

3. Composition of EV tyres

Key points

- EV marketed tyres do have modifications to rubber compositions and structural elements. However, these are not significant relative to the variability in tyre compositions that already exists in the market for ICEV tyres.
- EV marketed tyres are more likely to include a polyurethane layer for tyre and road noise reduction.
- Self-sealing tyres currently have a negligible market share and are not anticipated to take a noteworthy market share in the future.

3.1 Overview

This section of the report looks at the composition and structure of ICEV and EV marketed tyres, through the lens of likely compositional changes due to the shift to EVs, and the implications for the recoverability of passenger tyres as a result of these potential compositional shifts.

It is important to note that we have not identified any compositional shifts in EV passenger tyres composition that can be solely allocated to the market shift to EVs. That is, the functional features that have shifted the design parameters for EVs, are often just as relevant to ICEV tyre design and were already driving changes in ICEV tyre design, and the 'EV preferred' functional features were developed for pre-existing ICEV markets.

There is a spectrum of tyre design, composition and performance property considerations, and ICEVs and EVs overlap on these design considerations. In fact, it is likely that EV marketed tyres are a completely contained subset within the compositional range of ICEV marketed tyres and will remain so. For example, there are small relatively low powered EVs that have tyre requirements similar to a small ICEV passenger vehicle, and there are high-powered (and heavy) EVs that have similar requirements to large high-powered and heavy ICEVs.

It is worth summarising the areas of functional differences that EV related pneumatic tyres[4] can have relative to ICEV tyres. However, it is important to note that improvements in most or all of these functional areas is also of benefit to many passenger ICEVs. These functional areas are:

- Lower rolling resistance – to reduce energy consumption and so increase EV range.
- Increased abrasion resistance – to allow for typically greater EV weight, and so maintain the EV tyre lifespan at a similar level to an ICEV tyre.
- Lower road noise generation / noise suppression – Tyre noise contributes around 40% of passenger ICEV noise (Meneghelli, 2024, p. 69), which becomes highly noticeable in EV driving.

[4] The future of unpressurised tyres and alternative tyre systems, including foam filled 'no flat' tyres, is still uncertain, and is not considered in detail here.

- Stronger sidewalls – to allow for typically greater EV weight, particularly in cornering.
- Reduced overall tyre weight – to reduce energy consumption and so increase EV range.
- Self-sealing capability – to mitigate the issue of EVs not having a spare tyre.
- Run flat capability – to mitigate the issue of EVs not having a spare tyre.

The last 2 dot points above relate to most, if not all EVs currently on the market (in terms of number of sales) are sold without a spare tyre (and a dedicated storage space), due to the base of the vehicle being mostly allocated to the battery. However, it's important to note that many ICEV models are also sold without a spare tyre, and there is a continuing trend in the ICEV market towards the no-spare design approach, to maximise usable space in the vehicle volume (e.g. for increasing passenger space in the cabin). So, this vehicle design feature heavily overlaps between ICEVs and EVs.

It is also important to note that the weight disadvantage the BEVs currently have relative to an equivalent ICEV could potentially decrease over time as battery technologies advance. It is beyond the scope of this study to project improvements in EV battery energy densities over the next 5–20 years or so. However, the economic and market demand imperative to increase battery energy densities, which all else being equal also reduces battery cost, is significant.

3.2 Passenger tyres compositions

3.2.1 Major substances in passenger tyres

Over 200 substances can be used to produce a vehicle tyre including rubbers/elastomers, fillers, vulcanizing agents, process oils and softeners, as well as other additives like plasticisers and antioxidants (Ghaemi, et al., 2023, p. 3).

The major substances in passenger tyres in 2023 are summarised in Table 2. Also provided are approximate ICEV tyre material concentrations and indicative impacts on material concentrations in response to the functional performance characteristics related to EVs.

Table 2: Approximate average compositions of passenger tyres in 2023 and indicative impact on compositions for EV tyre related functional requirements

Substance	Function(s)	ICEV tyre approximate concentration range per kg of new tyre	EV tyre designed indicative impacts on concentration
Natural rubber	Primary elastomer matrix.	400–450 g/kg, split approximately 1:1 natural to synthetic	Down (minor)
Synthetic rubbers	Primary elastomer matrix.		Down (minor)
Carbon black	Reinforcing filler and antioxidant	280–290 g/kg	Steady
Steel cords	Steel belt and bead reinforcing.	110–120 g/kg	Down (minor)
Textile cords	Reinforcing layers, that can be made from nylons, PET and/or rayon	40–50 g/kg	Up
Silicon dioxide / Silica	Wet traction and rolling resistance.	40–45 g/kg	Up
Zinc oxide	Elastomer curing (polymer cross-linking) agents.	5–10 g/kg	No EV tyre related impact
Calcium carbonate	Reinforcing filler.	Unknown	Unknown
Adhesives	Steel belt, bead and textiles adhesives, and adhesives between tyre layers.	2–4 g/kg	Steady
Silanes	Wet traction and rolling resistance. Used to improve performance of silica.	2–3 g/kg	Up (but from very small usage base)
Phthalates	Plasticiser	0.12–0.25 g/kg	No EV tyre related impact
Diphenyl guanidine (DPG)	Elastomer curing (polymer cross-linking) agents.	0.06–0.12 g/kg	No EV tyre related impact
6-PPD	Antidegradant. Rubber oxidation protection during manufacturing and use.	0.08–0.12 g/kg	No EV tyre related impact
Processing oils	Manufacturing aids.	Unknown	Steady (probably)

Source: Marsden Jacob's synthesis of data from; Ghaemi, Enfrin, Giustozzi, & Mitchell (2023, p. 17) and Meneghelli (2024, p. 51)

In summary, while the composition of tyres is being tuned for EVs, EV 'specific' (or marketed) tyres are, and will likely remain, compositionally within the spectrum that already exists for passenger ICVs tyres given the large differences in the composition and structure of tyres manufactured for passenger ICVs.

3.2.2 Polyurethane noise reduction foams

Tyre noise contributes around 40% of passenger ICEV noise (Meneghelli, 2024, p. 69) when driving at higher speeds, which becomes particularly noticeable in EV driving due to the minimal noise generated by the electric motor. So, while tyre and road noise are not higher for EVs, the perception of increased tyre related noise is greatly increased for vehicle occupants when driving at higher speeds.

To mitigate this perception of increased tyre and road noise, a proportion of EV marketed tyres include an internal polyurethane (PU) foam layer. This foam layer is reported in tyre manufacturer marketing material to dampen tyre and road noise by up to 20%.

Figure 6: Passenger car tyre with a polyurethane noise reduction foam layer

Source: Meneghelli (2024, p. 69).

Tyres with foam layers have been sold for many years for use with ICEVs. For example, Volkswagen was an early adopter of this feature in VW OEM tyres for SUVs. However, it is understood that this type of tyre has had a negligible market share in Australia. See Section 6 for details on the end-of-life recovery impacts of PU foam layers in passenger tyres.

It is also worth noting that ICEV SUVs (in particular) have a significant degree of acoustic coupling of the rear wheels into the cabin space, and so at higher speeds the tyres can contribute a higher level of road contact and tyre noise into the cabin. This is recognised as an issue and was raised by tyre manufacturers during consultations, but as a tyre noise consideration related to ICEV SUVs, rather than EVs.

3.2.3 Self-sealing tyres

Self-sealing passenger car tyres are marketed as a solution for cars sold without a spare tyre. These tyres have a continuous pad (or similar) adhered to the inside of the face of the tyre containing a liquid adhesive. The adhesive types are not known with certainty but may be consist of a poly-vinyl acetate base, likely with other additives to provide enhanced functionally for this particular application. Silicone based adhesives may also be entering the market (Meneghelli, 2024, p. 70).

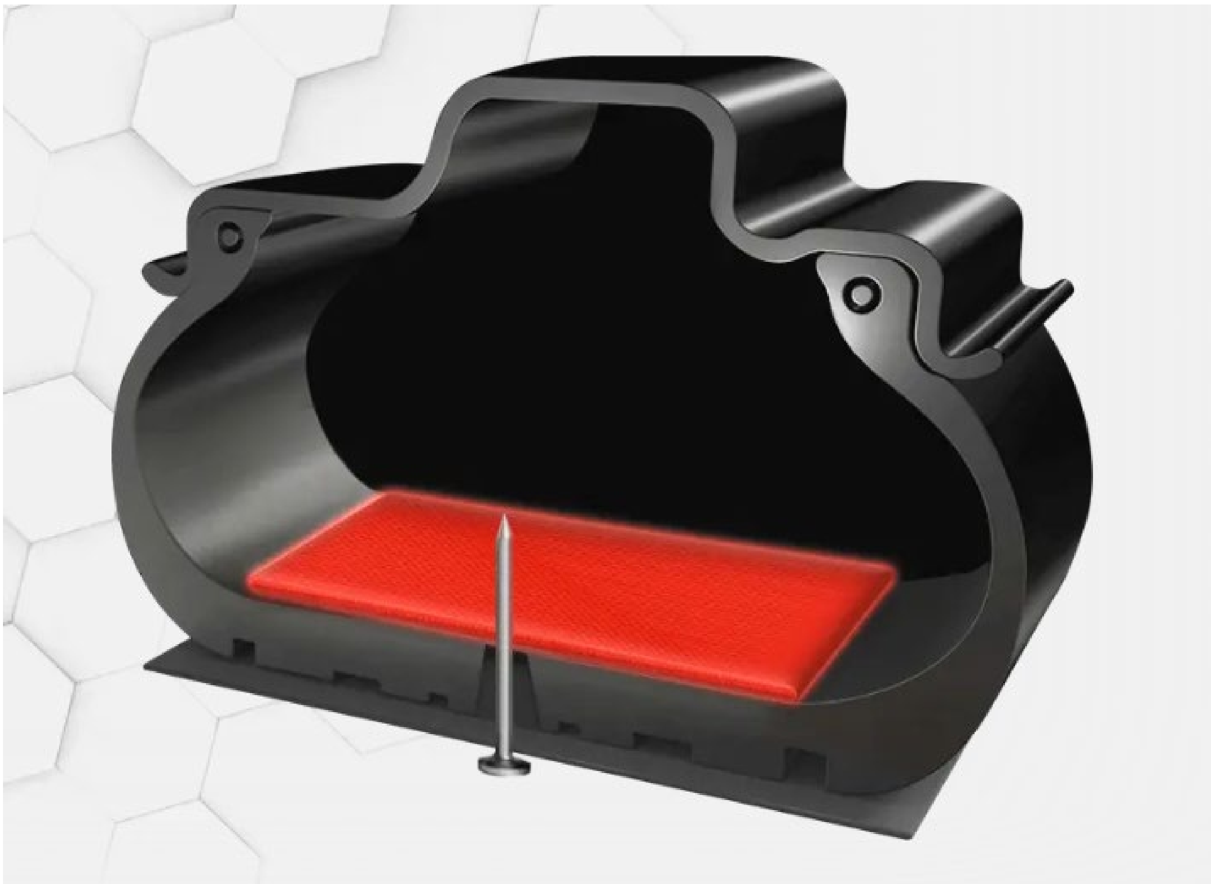

Figure 7: Passenger car tyre with a self-sealing adhesive layer

Source: Pirelli website (2024).[5]

Self-sealing tyres currently have a small market share in Australia, and the two tyre manufacturers consulted with for the project did not think that self-sealing tyres would take a noteworthy market share in the future. It was reported by one of the tyre recyclers consulted with that Tesla are selling some of their vehicles fitted with seal-sealing tyres.

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5 Available at: https://www.pirelli.com/tyres/en-ww/car/tech-and-knowledge/seal-inside

The tyre manufacturers both raised the likely issues that these tyres create for recyclers, which was seen as a significant negative. Some Chinese manufacturers may be now offering this technology in tyres. However, no specific examples could be identified.

3.2.4 Integrated sensors in tyres

Integrated tyre sensors are small sensors attached to the inside face of tyres to collect real-time data on tyre temperature, pressure, wear and movement (see Figure 8). Integrated tyre sensors are not specifically associated with EVs, and no EVs currently on the market are fitted with the sensors.

Figure 8: Pirelli passenger tyre with integrated sensor[6]

The specific components and materials used in the sensor could not be determined during this study. However, they will include a small integrated circuit board with surface mounted sensors, various plastic polymer types in the housing and attachment flange, and a small battery. Based on review of images of the sensors, they are glued to the inside of the tyre using an adhesive.

Currently, sensor equipped tyres have a tiny market internationally, with only a few compatible (high-performance) cars identified globally that can connect to the tyres.

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[6] Available at: https://www.pirelli.com/tyres/en-ww/car/tech-and-knowledge/cyber-tyre

4. EV tyre wear

Key points

- EV tyres are required to handle increased weight, higher torque, noise reduction requirements and reduction in rolling resistance.
- All else being equal, these factors could be contributing to higher tyre wear rates in EVs at present.
- Higher tyre wear rates will in turn result in higher emissions of non-exhaust particulate matter (PM) than non-exhaust PM from comparable ICEVs. Available evidence on this is not conclusive, however.
- Higher tyre wear rates could also increase the generation of EOLTs.
- Technological advances in tyre design and/or EV design are likely to reduce the adverse impacts of the transition to EVs on tyre wear.

4.1 Characteristics of EV specific tyres

A general overview of the characteristics of EV tyres provided in Meneghelli (2024, p. 7) indicates that:

- Tyres are designed to minimise rolling resistance. This is achieved via rigid design patterns, tire profiles, and structural work in conjunction with the type of rubber compounds.
- Tyres are designed for enhanced grip and handling. This is achieved via a double-layer carcass made of strong polymers, silicon or silica.
- Tyres are designed to withstand increased weight and acceleration. This is achieved via thicker sidewalls and more robust compounds (nylon or heavier). The strain due to acceleration is offset by using stiffer tread patterns.
- Tyres are designed to reduce noise. This is achieved by using 'silent foam' or a polyurethane layer. The use of these does negatively affect the ability of the tyre to be recycled.

EVs are also typically 20% to 30% heavier than equivalent ICEVs (Timmers et al. 2016). Driver behaviour is also a factor that needs to be considered when looking at tyre wear. Driver behaviour relates to good management of tyres (tyre pressure), no rapid acceleration, safe braking practices etc. Driver assistant systems can influence driver behaviour to be more efficient. Sophisticated driver systems can include sensors for rotor temperature and tyre pressure, as they are important parameters for brake wear and tyre wear emissions, respectively. Research undertaken in OECD (2020) indicates that up to 30% of tyre wear could be attributed to driver behaviour.

4.2 Tyre Wear – EV vs ICE

This section compares tyre wear between EVs and ICEVs. This section analyses difference in tyre wear observed in EVs due to the following characteristics as opposed to their ICEV counterparts:

- Weight;
- Increased acceleration; and
- Noise reduction required from EV tyres.

4.2.1 Weight

There is very little direct research that links tyre wear to vehicle weight. However, there is significant indirect evidence for the positive relationship between weight, tyre wear, and non-exhaust PM emissions. Given that EVs are approximately 20 % to 30% heavier than equivalent ICEVs, Timmers et al. (2016) find that there is a positive relationship between weight, tyre wear and non-exhaust PM emission factors. Additionally, the following environmental agencies in the US, Europe, and Netherlands provide the following emission factors for heavier vehicles compared to lighter vehicles.

- European Environmental Agency (EEA) published in their Emissions Inventory Guidebook[7] emissions factors for different vehicle types. In this inventory, PM_{10} and $PM_{2.5}$ emissions factors for both tyre and brake wear were 57% higher for Light Duty Vehicles (defined as vehicles with a gross weight of up to 3500kg) compared to passenger vehicles (defined as vehicles carrying up to 9 passengers). Emissions factors for road and surface wear was the same for both.
- The U.S. Environmental Protection Agency in their emission inventory, MOVES2014,[8] they distinguish between passenger cars (<2720 kg) and passenger trucks (<3855 kg) and ascertain that the latter emit 67% more PM_{10} and $PM_{2.5}$ emissions due to brake wear but only 2% more due to tyre wear.
- The Pollutant Release and Transfer Register in the Netherlands (PRTR)[9] ascertain in their emission inventory that PM_{10} and $PM_{2.5}$ emissions are 40% higher for vans (gross weight around 2000 kg) than passenger cars (gross weight around 850-1050 kg).

Table 3 is adapted from Timmers et al. (2016).[10] Their study found that EVs emit more particulate matter from non-exhaust sources (tyre wear, road wear, and resuspension) than equivalent ICEVs. This can be attributed to increased weight of EVs compared to their ICEV counterparts. As a result, they concluded at the time that tyres on EVs experienced higher wear due to the higher weight of EVs compared with ICEVs. As discussed in section 4.3.1 however, a more recent study by the OECD (2020) is less clear on this. As the EV market progresses in the coming years, there is a strong chance of innovation within the industry relating to battery technology; as response to potential regulations on tackling non-exhaust emissions; and general efficiency gains in the industry. Due to this, a repeat

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7 Available at: http://www.eea.europa.eu/publications/emep-eea-guidebook-2013/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-road-transport

8 Available at: https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=527180&Lab=OTAQ

9 Referenced in Timmers et al. (2016). However, this register may have been updated since.

10 Table 5 and 6 from Timmers et al. (2016).

of the Timmers et al. (2016) study may provide different results. However, at this stage it is difficult to predict this.

Table 3. Comparison between non-exhaust PM emissions of EVs, gasoline, and diesel ICEVs

Comparison between expected PM_{10} emissions of EVs, gasoline and diesel ICEVs				
Vehicle technology	**Tyre wear**	**Brake wear**	**Road wear**	**Resuspension**
EV	7.2 mg/vkm	0 mg/vkm*	8.9 mg/vkm	49.6 mg/vkm
Gasoline ICEV	6.1 mg/vkm	9.3 mg/vkm	7.5 mg/vkm	40 mg/vkm
Diesel ICEV	6.1 mg/vkm	9.3 mg/vkm	7.5 mg/vkm	40 mg/vkm
Comparison between expected $PM_{2.5}$ emissions of EVs, gasoline and diesel ICEVs				
Vehicle technology	**Tyre wear**	**Brake wear**	**Road wear**	**Resuspension**
EV	3.7 mg/vkm	0 mg/vkm*	3.8 mg/vkm	49.6 mg/vkm
Gasoline ICEV	2.9 mg/vkm	2.2 mg/vkm	3.1 mg/vkm	40 mg/vkm
Diesel ICEV	2.9 mg/vkm	2.2 mg/vkm	3.1 mg/vkm	40 mg/vkm

Source: Timmers et al. (2016)

*Note: * - Timmers et al. assume a conservative estimate of 0 brake wear emissions due to regenerative braking in EVs and minimal literature investigating this topic.*

Note – vkm stands for vehicle kilometre.

4.2.2 Increased acceleration

Inputs from manufacturer stakeholders consulted for this study indicated that increased torque in EVs were expected to have a significant impact on tyres by increasing tyre wear. Recently, car manufacturers are implementing measures to electronically control the maximum amount of torque available to the driver. However, even with these controls, higher torque fundamentally leads to higher tyre wear.

Example

Consider two vehicles A and B. Both are comparable on weight, but vehicle A is an EV and vehicle B is an ICEV. Vehicle A will have more torque more available compared to B and this would result in higher tyre wear on tyres in vehicle A. This is because there is increased acceleration for the same level of input in A due to electric motors compared to B with an internal combustion engine.

4.2.3 Reduced noise

Noise reduction is an important aspect for EVs since the noise from tyres is exaggerated due to the absence of ICEs. EVs use sound-deadening layers made of polyurethane or silent foam in tyres to achieve this. The exact effect this has on tyre wear is currently unknown. However, use of sound-deafening layer does negatively impact the ability of tyres to be recycled.

4.3 Tyre wear implications for particulate emissions and EOLT numbers

4.3.1 Particulate emissions

Traditionally, vehicles emit particulate matter (PM) through exhaust (tailpipe) and non-exhaust pathways. Exhaust emissions were the main source of PM prior to the introduction of air quality standards. Since air quality standards have been introduced in Australia and other industrialised countries PM emissions via the exhaust pathway have been subject to increasingly stringent controls. Thus, the main source of PM emissions from both EVs and ICEVs are now non-exhaust emissions. Non-exhaust emission sources include tyre, brake and road surface wear, and resuspension of road dust.

Non-exhaust emissions, by mass, contain mostly PM_{10} (which represent particles with a diameter of less than 10 micrometres) but a significant proportion is made up of finer $PM_{2.5}$ particles. It is important to note that compared to mass concentration, which is conservative, particles are susceptible to processes that modify their number and size. Generally, non-exhaust emissions contain heavy metal (copper, iron, and lead) compared to exhaust emissions which are generally made up of hydrocarbons. OECD (2020)[11] and Kreider et al. (2010) indicate that while tyre wear particles are composed of plasticisers and oils, polymers, carbon blacks and minerals, special attention must be paid to elemental content (zinc and sulphur) and the abundance of polycyclic aromatic hydrocarbons (PAHs) due to their burden on public health and ecosystems. Timmers et al. (2016) also state that due to the chemical differences in non-exhaust emissions compared to exhaust emissions they are more likely to lead to secondary pollution such as the formation of inorganic aerosols. There are several toxicological studies that have found links between non-exhaust emissions and adverse health effects, such as lung-inflammation and DNA damage (Cassee et al. 2013, Gasser et al. 2009, Gualtieri et al. 2005, Mantecca et al. 2009). A review of epidemiological studies (Brunekreef, 2005) concluded that non-exhaust PM_{10} emissions increases mortality rates in exposed populations.

Since EVs tyres are designed to withstand heavier weight, minimise rolling resistance, and reduce noise, at present they might typically be expected to experience higher tyre wear than tyres on equivalent ICEVs, and therefore higher tyre wear emissions. As previously discussed in section 4.2.1, Timmers et al. (2016) support this conclusion. Similar findings were also made in a study by Soret et al. (2014). However, simulations undertaken as part of an OECD study (OECD 2020) conclude that the uptake of EVs will lead to marginal decreases in non-exhaust PM emissions (see Table 4). It is feasible that the main reason for the lower non-exhaust emissions from EVs in the OECD study is due to factors other than tyre wear, notably brake wear. Even so, the OECD study means that the link between EV weight, tyre wear and non-exhaust emissions is not conclusive.

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[11] Available at: https://www.oecd-ilibrary.org/sites/4a4dc6ca-en/1/3/2/index.html?itemId=/content/publication/4a4dc6ca-en&_csp_=681d016aff567eeb4efd802d746cdcc4&itemIGO=oecd&itemContentType=book

Table 4. $PM_{2.5}$ and PM_{10} non-exhaust emission factors across EURO-6-temp and BEV vehicle classes (in grams per vehicle km)

Passenger cars								
	$PM_{2.5}$				PM_{10}			
	Diesel	Gasoline	BEV 100	BEV 300	Diesel	Gasoline	BEV 100	BEV 300
Low	0.0121	0.0121	0.0100	0.0115	0.0296	0.0296	0.0243	0.0270
High	0.0165	0.0165	0.0147	0.0169	0.0296	0.0296	0.0244	0.0276
Sport Utility Vehicles								
	Diesel	Gasoline	BEV 100	BEV 300	Diesel	Gasoline	BEV 100	BEV 300
Low	0.0133	0.0133	0.0113	0.0135	0.0346	0.0346	0.0281	0.0317
High	0.0193	0.0193	0.0174	0.0206	0.0349	0.0349	0.0286	0.0333
Light Commercial Vans								
	Diesel	Gasoline	BEV 100	BEV 300	Diesel	Gasoline	BEV 100	BEV 300
Low	0.0165	0.0165	0.0134	0.0164	0.0404	0.0404	0.0326	0.0376
High	0.0226	0.0225	0.0200	0.0241	0.0404	0.0404	0.0326	0.0388

Source: OECD 2020. Table 3.4 and Table 3.5

Note – BEV 100 and BEV 300 denote EVs with battery packs enabling a range of 100 miles and 300 miles respectively.

A range of estimation techniques have been used to derive the values seen above (OECD, 2020, Section 3.3). This approach has been utilised because of a lack of quantitative evidence linking PM emissions from EVs.

4.3.2 Tyre wear implications for tyre life end-of-life tyre numbers

As with emissions, tyre wear also has implications for tyre life and end-of-life tyre numbers. As previously noted, EVs can typically be expected to experience higher tyre wear than tyres on equivalent ICEVs. If this is the case, this will result in vehicle owners having to replace tyres more often. Specific evidence to support this conclusion could not be found.

4.4 Technological advancements

4.4.1 Implications for emissions and EOLT generation

Technological advancements to EVs and to EV tyres, already underway, mean that the implications of the transition to EVs for tyre wear (and associated emissions and EOLT generation) are less clear, especially in the longer term. Electronically limiting torque, possible innovation in battery technology around energy densities, which will reduce the weight of EVs, and the design of more durable tyres for EVs, could all have the effect of reducing tyre wear, EOLT numbers and non-exhaust emissions.

Tyre durability features, such as increased abrasion resistance and stronger sidewalls, are especially significant developments. These features are likely to be further encouraged by the introduction of Euro 7 emissions standards (see section 7.2).

Tire Industry Project (TIP) recently released a white paper produced by World Business Council for Sustainable Development titled "Tire Industry Project commitment to Addressing Tire and Road Wear Particles".[12] The document outlines the current state-of-play of tire industry efforts to mitigate the potential impacts of TRWP. The table below outlines the nine TRWP mitigation measures that are a priority for TIP. The measures are broken down into two categories:

- Mitigation by prevention: and
- Mitigation after release.

Table 5. The 9 priority TRWP mitigation measures outlined in TIP's white paper

Mitigation by prevention	
Vehicle technologies	Utilising on-board electronic devices to monitor and provide feedback in real time on abrasion generation to drivers.
EV abrasion reduction	A better understanding of interactions between weight, torque, and regenerative braking in EVs could promote better decision making to support reduced TRWP.
Driver awareness	Utilising existing knowledge on impact of driving behaviours on tyre wear to increase awareness of drivers and encourage change in driving behaviours.
Road surface design	Confirming understanding of road surface designs to minimise tyre wear without compromising safety, performance, and environmental features.
Mitigation after release	
Vehicle capture devices	Utilising on-board devices to capture particles before disposal into the environment.
Runoff/stormwater systems	Investigating which runoff/stormwater systems (open retention ponds, basins, subsurface treatment units etc.) are effective in treating TRWP and implementing them at scale.
Street cleaning techniques	Investigating which types of vehicles and cleaning technologies are effective in removing TRWP from roads and then promote implementation.
Street cleaning management	Deployment of street cleaning – when, where and frequency – can have an impact on TRWP removal. Understanding optimal removal strategy can play a key role.

12 Available at: https://tireindustryproject.org/news/tire-industry-project-commitment-to-addressing-tire-and-road-wear-particles/

Mitigation by prevention	
Wastewater treatment plants	Wastewater treatment plants collect runoff from roads. Understanding what type of treatment is effective in treating TRWP can be a useful mitigation solution.

Source: Table 1, Page 14 from Tire Industry Project Commitment to Addressing Tire and Road Wear Particles.

Additionally, the European Tyre & Rubber Manufacturers' Association (ETRMA) indicate that European tyre manufacturers have taken steps to ensure circularity within the tyre manufacturing industry. The following key points are mentioned in relation to tyre wear and EOLT generation[13]:

- During tyre use, new vehicle technology assists drivers to ensure optimal tyre maintenance by providing alerts for low tyre pressure and sub-optimal load.
- Steps have been taken to ensure that tyres are designed to facilitate repair and remanufacturing, increasing tyre lifetime, and reducing environmental impact. For example, truck tyres are designed to be re-treaded up to three times (see Box 2).
- At the end-of-life, tyres are collected, and their treatment is organized through EOLT management companies across the EU.

Box 2. Retreading in Europe

In Europe, retreading is being increasingly implemented to increase tyre life, reduce waste, and limiting the use of resources. Retreading reduces approximately 160 kg of waste for each tyre re-treaded twice and saves 104 kg raw materials, all whilst achieving CO2 savings (EY, 2016). European Tyre & Rubber Manufacturers Association (ETRMA) claim that truck tyres in Europe are designed to be re-treaded up to three times.

4.4.2 Tyre manufacturer perspectives

A limited number of tyre manufacturers were consulted during the research to gain perspectives on the current status of EV tyres and on likely technological advancements. The tyre manufacturers' responses indicate that the current transition to EVs both presents challenges in terms of tyre wear but that manufacturers are taking tyre design measures to reduce wear.

13 Available at: https://www.etrma.org/key-topics/circular-economy/

5. EV tyre end-of-life processing, recycling and end markets

Key points

- The increased uptake of passenger tyres incorporating a polyurethane noise reduction foam layer will not be particularly problematic for passenger tyre shredding or end-markets. However, reprocessing these tyres does result in some increased costs for recyclers.
- The increased uptake of passenger tyres incorporating a self-sealing capability, much beyond the current low level of use, will be problematic for passenger tyre shredding. Reprocessing these tyres results in more significantly increased costs for recyclers.
- Design modifications related to lowering rolling resistance and increasing abrasion resistance will generally not have any noteworthy impacts on either passenger tyre reprocessing or end-markets.

5.1 Overview

This section of the report looks at the potential impact of EV marketed passenger tyres composition and design changes on EoL tyre processing and recovered material end-market applications, including tyre derived products (TDP) and tyre derived fuels (TDF).

The EoL issues explored include:

- What are the potential impacts of differences in 'EV specific' tyre rubber compositions (relative to ICEV tyre rubber compositions), and self-healing tyre and tyre repair sealants, on tyre shredding and crumbing equipment, and how can these impacts be managed?
- Will changes in the composition of EV tyres have a notable impact on the feasibility or cost of using shredded passenger vehicle tyres in recycling applications (including spray seals, asphalt, playing fields)?
- Will changes in the composition of EV tyres have a notable impact on the feasibility or cost of using shredded passenger vehicle tyres in energy recovery or pyrolysis applications?
- If necessary, will manufacturers of these products be able to respond by fine-tuning formulations over time if needed, to maintain the required functional performance of products?
- What influence or impact could EV tyre composition and design potentially have on end markets for tyre-derived products (TDP) and tyre derived fuels (TDF)?

5.2 Reprocessing and end-market impacts of EV tyres

Provided in Table 8 are the EV marketed tyre functions and the related compositional or structure changes, mapped to potential reprocessing and end-market impacts.

Table 6: EV marketed tyre function mapped to potential reprocessing and end-market impacts

EV tyre function	Related design change(s)	Related compositional change	Potential reprocessing impacts	Potential end-market impacts
Lower rolling resistance through reduced tyre weight	• Lighter tyres, with less material mass to deform.	• More complex tyre structure (e.g. more supporting layers) with potentially a lower proportion of rubbers making up the tyre mass. • However, there is a limit to the minimum percentage of rubber in a tyre for it to perform, assuming current tyre designs.	• Possible minor reprocessing cost increase as unit (per tyre) reprocessing costs are unchanged, but the weight of recovered tyre material is decreased.	• TDP – Possible lower proportion of natural and synthetic rubber in the tyres, further reducing the viability of reprocessing passenger tyres for tyre crumb. • TDF – Minimal TDF related impact.
Lower rolling resistance through modified rubber chemistry	• Modified rubber composition to provide both improved rolling resistance and abrasion resistance. • Note that it is reported that breakthrough lower rolling resistance technology is possible but considered unlikely.	• Increased use of silica and silica/silane combinations. • Potential modifications to concentration and/or grade of carbon black.	• None identified.	• TDP – Probably negligible. • TDF – Minimal TDF related impact. Possible reduced energy content.
Increased abrasion resistance	• As above (row 2) • Note that greater tread depth also provides increased abrasion resistance but the increased weight increases rolling resistance.	• As above	• As above	• As above
Lower road noise generation	• PU noise reduction foams.	• PU foam layer adhered to the inside face of the tyre. [Note that non-bonded PU foam inserts, which are removable prior to shredding, are also reported as a design possibility in the future, but no tyres were identified as being currently on the market with this design feature].	• Possible increased risk of fires in equipment and increased fire risk management costs, if processed other than 6-inch shredding only. • Increased OHS risks associated with PU layer and additives (e.g. through exposure to smoke from smouldering events).	• TDP – Possible reduced average potential sale value of incoming tyre mix, as foam lined tyres can only be sent to TDF. • TDP – Possible poorer environmental outcome as foam lined tyres can only be sent to TDF, and not go to TDPs.

EV tyre function	Related design change(s)	Related compositional change	Potential reprocessing impacts	Potential end-market impacts
			• Increased labour costs for segregation. • Increased management costs. • Increased labour and equipment (unit) costs due to requirement to separately reprocess tyres with PU foam layer.	• Low density PU foam increasing TDP/TDF transport costs. • TDF – Probably negligible.
Stronger sidewalls / Run-flat capability	• More structurally complicated reinforced sidewalls.	• Changes in (non-rubber) related structure	• Potentially increased energy requirement for shredding. • Potentially increased losses to landfill if tyre reprocessed for TDP.	• TDP – Lower proportion of natural and synthetic rubber in the tyres, further reducing the viability of reprocessing passenger tyres for tyre crumb. • TDF – Minimal TDF related impact. Possible reduced energy content.
Self-sealing capability	• Continuous pad (or similar) adhered to the inside of the face of the tyre containing a liquid adhesive.	• The adhesive types are not known with certainty but may be consist of a poly-vinyl acetate base, likely with other additives to provide enhanced functionally for this particular application. Silicone based adhesives may also be entering the market.	• Possible increased risk of fires in equipment and increased fire risk management costs, if processed other than 6-inch shredding only. • Increased labour costs for equipment cleaning. • Lost processing time cost for equipment cleaning. • Increased labour and equipment (unit) costs due to requirement to separately reprocess tyres with self-sealing layer. • Possible increased landfill costs if sefl-sealing tyres can only be sent to landfill after shredding. • Possible increased OHS risks associated with employees	• TDP – Possible reduced average potential sale value of incoming tyre mix, as self-sealing tyres can only be sent to TDF (or possibly landfill in some cases). • TDP – Possible poorer environmental outcome as seal-sealing tyres can only be sent to TDF, and not go to TDPs. • TDF – Possible increased handling costs due to adhesive contamination.

EV tyre function	Related design change(s)	Related compositional change	Potential reprocessing impacts	Potential end-market impacts
			coming into contact with the adhesive. • Increased labour costs for segregation. • Increased management costs.	
Integrated sensors	• Small electronic device adhered to the inside face of the tyre.	• The specific components and materials used in the sensor could not be determined as part of this study. However, they will include a small integrated circuit board, various plastic polymer types in the housing and attachment flange, and a small battery. The sensors appear to be glued to the tyre using an adhesive.	• Possible increased risk of fires in equipment and increased fire risk management costs. • Increased labour costs for possible segregation and attempted sensor removal. • Increased management costs.	• TDP – Possible reduced average potential sale value of incoming tyre mix, if sensor cannot be removed. • TDP – Possible poorer environmental outcome if sensor equipped tyres cannot go to TDPs. • TDF – Minimal known TDF related impact.

5.3 Reprocessing and end-market impacts of polyurethane noise reduction foams

The tyre reprocessing stakeholders consulted with, did not consider that an increasing prevalence of PU foam layers as particularly problematic for passenger tyre shredding, and would have minimal impact on tyre shredding. Although, as can be seen in Table 6, a number of actual and potential reprocessing impacts were identified during the consultation.

Tyres with a PU foam layer can (currently) only be shredded to a 6-inch size profile and then exported as TDF. Shredding to smaller size profiles has resulted in 'smouldering events' in those shredders. For context, only 7% of passenger EOLTs in Australia in 2021–22 were sent to crumbing related fates and less than 1% into the retreads and seconds market. However, 78% were sent to export, which almost entirely goes to energy recovery (TSA, 2023). So, the requirement to send this type of tyre to TDF is not an issue for the foreseeable future, as the fate (end-market) of most shredded passenger tyres is to export as TDF and will continue to be so.

5.4 Reprocessing and end-market impacts of self-sealing tyres

One tyre recycler consulted with reported that approximately 2–3% of passenger tyres in the gate were self-sealing tyres, and that this level of receival was manageable. These tyres are manually segregated and only processed through 6-inch shredders, with the 6-inch shredders largely tolerating this level of contamination with the adhesive, with only a minor increase in the shredder cleaning requirement.

However, it was also estimated by this stakeholder, that if the share of these tyres increased to ~10% then they would create a significant cleaning problem in the 6-inch shredders as well.

As with the PU foam lined tyres, self-sealing tyres can only be shredded to 6 inches and then exported as TDF. Shredding to smaller size profiles has resulted in 'smouldering events' in those shredders, along with a significant cleaning requirement impact.

5.5 Reprocessing and end-market impacts of integrated sensors in tyres

The specific components and materials used in integrated tyre sensors could not be determined under the scope of this work. However, the negligible numbers of these tyres currently in circulation in Australia means any potential effect on tyre reprocessing was not uncovered during the completion of this report. This tyre feature was not raised by tyre reprocessors as an issue that is currently of concern during stakeholder discussions. It is also important to note, that the few identified passenger vehicle models that can receive and use the data transmitted by the sensors are currently all ICE vehicles.

However, there are some general reprocessing implications worth discussing here. As the sensor is electronic and wireless, it is likely powered by a battery, which when shredded may present a new fire risk for reprocessors.

In terms of materials recovery, given the small size of the sensors and as they are bonded to the tyre, there is no realistic possibility that the sensors could be removed from the tyres and segregated into an e-waste recovery stream. The fate of the materials in the sensors in Australia, for the foreseeable future, would be landfill. Likewise, the removal of the sensor from EOL tyres, and reuse/reattachment on new tyres, is highly unlikely to be economically, technically or practically feasible.

6. EV vehicle and tyre standards

Key points

- At present there are no specific standards in Australia relating to EV's or EV tyres.
- Tyre standards in Australia and internationally are primarily focussed on tyre performance.
- EV standards in the EU and US are primarily focussed on safety standards, especially of EV batteries.
- There are emerging standards that could affect the design and composition of tyres, both generic tyres and EV tyres and, by extension, recycling of tyres.
- The most significant of these are Euro 7 emissions standards which, for the first time, will set emission limits and minimum durability requirements for tyres.

6.1 Current and proposed standards for tyres and EVs

6.1.1 Australian Design Rules

National standards for road vehicles sold in Australia are set out in the Australian Design Rules (ADRs). Development and review of ADRs is overseen by the Commonwealth Department of Infrastructure, Transport, Regional Development, Communications and the Arts (DITRDCA). The ADRs are reviewed every 10 years to ensure that they remain relevant. The last review resulted in the Third Edition of ADRs being implemented in July 2021.

The main standards relating to passenger car tyres are set out in *ADR 23/03 – Passenger Car Tyres, 2018*[14], which sets out the overarching administrative requirements for new pneumatic tyres that are fitted to passenger cars and other light vehicles (including light trailers) in Australia. All design and technical requirements relating to light vehicle tyres, however, are detailed in UNECE Regulation 30, which is attached to ADR 23/03 as an Appendix (see section 6.1.2 for further discussion).

Additionally, there is a separate ADR - ADR 95/00 - relating to the installation of tyres. The main installation requirement in the standard relating to passenger vehicle tyres is that each tyre fitted to a passenger vehicle must comply with the current version of ADR 23 and, by extension, technical specifications for tyres detailed in UNECE Regulation 30.

There is no specific requirement relating to fitting or design of tyres on EVs. In discussions held with DITRDCA for this project, a DITRDCA official advised that while the Department is aware that some EVs benefit from tyres that have been designed specifically for EVs, it stressed that "the national road vehicle standards aim to be performance based rather than prescriptive" [15]. In the case of tyres therefore, the standard allows a manufacturer to specify tyres for a vehicle that will ensure vehicle

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14 Note a separate standard relating to commercial vehicle tyres is set out in ADR 96/00.

15 Tim Hicks, Assistant Director, Road and Safety Vehicle Division, Department of Infrastructure, Transport, Regional Development, Communications and the Arts, *Email* 8 April 2024

safety and other performance requirements of that vehicle will be met, rather than requiring that a particular type of vehicle (e.g. an EV), be required to be fitted with a tyre of a particular design, composition or size.

Thus, at present the only ADRs specifically for EVs relate to Electric Power Train Safety Requirements, the latest version of which are set out in ADR 109/01, 2023. Moreover, as discussed further in section 4.2.2, there are no plans in Australia to make any amendments relating to performance and other standards for tyres to specifically accommodate EVs.

6.1.2 United Nations Economic Commission for Europe (UNECE) Regulations

The ADR Harmonisation rule facilitates automatic acceptance of United Nations Economic Commission for Europe (UNECE) vehicle regulations that are adopted as alternative standards within the ADRs through Australia's participation in the World Forum for Harmonisation of Vehicle Regulations. The World Forum includes a working group on vehicle noise and tyres.

An initial review of the UNECE vehicle regulations has been undertaken including UNECE Regulations and UNECE Global Technical Regulations (GTR)[16]. Box 2 contains an overview of the relevant regulations.

In summary, various regulations relating to EVs have been adopted and are in the process of being introduced through the UNECE. While none of the UNECE regulations relate specifically to EV tyres, they are indirectly relevant to EV tyres, notably UNECE Regulations 30 and 54 relating to tyre performance for light vehicles (passenger and light commercial) and commercial vehicles respectively. As previously noted, UNECE Regulation 30 is attached to ADR 23/03 as an appendix and sets out all technical requirements applying to new pneumatic tyres fitted to passenger and light commercial vehicles in Australia.

6.1.1 USA Regulations

The National Highway Traffic Safety Administration (NHTSA) is the U.S. federal agency tasked with regulating vehicle design. They enforce the Federal Motor Vehicle Safety Standards (FMVSS)**,** which specify design, construction, performance, and durability requirements for motor vehicles and related safety components.

There does not appear to be any FMVSS specifically relating to EV tyres, nor is it apparent that the NHTSA is considering regulations specifically aimed at EV tyres.

Box 3 provides a summary of key US standards relating to EVs and tyres. As with UNECE regulations, The US standards make no specific reference to EV tyres, but some are relevant to EV tyres, notably FMVSS standards 109 and 139 relating to tyre performance and endurance.

[16] UNECE Regulations are a more established system historically focused on the European region, while UNECE GTRs are a newer approach aimed at global application.

Box 2. UNECE regulations relating to EVs and tyres

UNECE Global Technical Regulations and UNECE Regulations specifically relating to EVs

- *GTR No. 20: Electric Vehicle Safety:* Introduces performance-oriented requirements that address potential safety risks of EVs while in use and after a crash event, including electrical shocks associated with the high voltage circuits of EVs and potential hazards associated with lithium-ion batteries and/or other Rechargeable Electrical Energy Storage Systems (REESS) (in particular, containing flammable electrolyte.)
- *GTR No. 21: Determination of Electrified Vehicle Power:* Provides a worldwide harmonized method to determine a system power rating for electrified light-duty vehicles that is comparable to traditional measures of system power applicable to conventional vehicles.
- *GTR No. 22 In-Vehicle Battery Durability for Electrified Vehicles:* Sets minimum performance requirements for battery durability and introduces a method to monitor battery health over time. A proposal to introduce a similar regulation pertaining to in-vehicle batteries for electric vans has been submitted for adoption in June 2024[17].
- *UNECE Regulation No. 100 (R100):* Addresses the safety requirements specific to the electric powertrain of road vehicles, including rechargeable battery systems**.** This has an important role in ensuring safety of electric vehicles by setting out comprehensive standards and specific tests for lithium batteries installed in electric vehicles.

UNECE Global Technical Regulations and UNECE Regulations specifically relating to tyres

The regulations below cover tyres in general:

- *GTR No. 16: Tyres*: Establishes provisions for new radial pneumatic tyres equipping passenger cars and light truck (commercial) vehicles. The regulation works to harmonise technical provisions related to tyres, making them acceptable for type approval and self-certification compliance assessment systems. The regulation covers numerous aspects related to tyres, including rolling resistance, wet grip, dimensions, load capacity, speed rating and noise emission.
- *UNECE Regulation No.30:* Establishes uniform provisions for the approval of pneumatic tyres used on passenger and light commercial vehicles and their trailers. Requirements of the standard cover various aspects of tyre design including:
  - tyre dimensions, such as section width, outer diameter and height;
  - load and speed ratings;
  - tread patterns and tread depth;
  - tread wear indicators (with a focus on indicating when tread depth falls below 1.6 mm); and
  - labelling (i.e. how information on tyre markings is to be arranged and presented).

  The standard also establishes technical requirements for various aspects of tyre performance such as wet grip performance, rolling resistance and load capacity/speed rating and includes a procedure for load/speed performance testing and a method for measuring pneumatic tyres.
- *UNECE Regulation No.54*: Establishes uniform provisions for the approval of pneumatic tyres used on commercial vehicles. The requirements of the standard cover similar aspects to UNECE Regulation 30.
- *GTR 16 and UNECE Regulation 30:* These do not make any reference to self-sealing or self-repair tyres. They do refer to 'run flat tyre' and 'self-supporting tyres' which is a similar, albeit different technology. 'Run flat tyre' and 'self-supporting tyres' provide support to a deflated tyre (through reinforced sidewalls), allowing the driver to continue traveling in the vehicle for around 80km and not change the tyre immediately.

Box 3. US standards relating to EVs and tyres

FMVSS specifically relating to EVs

US standards relating EVs relate to some specific safety aspects of EVs. These include:

- *FMVSS No. 141: Minimum Sound Requirements for Hybrid and Electric Vehicles:* This standard requires EVs to emit an audible sound at low speeds (typically under 30 mph) to improve pedestrian awareness.
- *FMVSS No. 305 - Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection*: This standard aims to enhance safety during and after crashes involving electric vehicles. It addresses risks related to electrolyte spillage**,** intrusion of energy storage devices, and electrical shock**.**

FMVSS specifically relating to tyres

US tyre regulations having most relevance to EV tyres are FMVSS No. 109 and FMVSS No. 139. Importantly though, they do not make any specific reference to either EV tyres or self-sealing tyres:

- *FMVSS No. 139 New pneumatic radial tires for light vehicles:* establishes requirements for tire dimensions, performance testing (including endurance, strength, high-speed performance, and low inflation pressure performance), and labelling.
- *FMVSS No.109: New pneumatic and certain specialty tires:* This standard specifies requirements for new pneumatic tires for use on motor vehicles to ensure their structural integrity, endurance, and performance under various conditions.

Other US tyre regulations also make no specific reference to EVs or EV tyres. They include:

- *FMVSS No. 110: Tire selection and rims:* This standard applies to motor vehicles with a Gross Vehicle Weight Rating of 10,000 pounds (4536 kilograms) or less. The standard specifies requirements for tyre selection to prevent tyre overloading. *FMVSS No. 119: New pneumatic tires for vehicles other than passenger cars:* applies to new pneumatic tires of motor vehicles with a GVWR of more than 4,536 kilograms and for motorcycles.
- *FMVSS No. 117:* This standard applies to *retreaded pneumatic tires for passenger cars manufactured after 1948.* It ensures that retreaded tires meet minimum safety standards through performance testing and quality control procedures.
- *FMVSS No. 129: New non-pneumatic tires for passenger cars:* specifies tire dimensions and laboratory test requirements for lateral strength, strength, endurance, and high-speed performance; defines the tire load rating; and specifies labelling requirements for non-pneumatic spare tires.

6.1.2 Recovery of end-of-life tyres – current regulations in the EU and USA

European Union

The European Union (EU) regulates the recovery of end-of-life tyres through various directives, although Member States are responsible for implementing and enforcing the regulations. Key Directives are:

- *End-of-Life Vehicles Directive (2000/53/EC):* addresses the management of waste generated from vehicles, including tyres. The Directive set targets for all economic operators in the life cycle of cars and light vehicles to increase reuse, recycling, and recovery of material. It requires member states to takes steps to implement the directive goals including sustainable design and production of vehicles, establishing collection and treatment centres, introducing extended producer responsibility schemes and setting recovery and recycling[18].

- *European Standard UNE-EN 14243*: relates to materials produced from end-of-life tyres. Its purpose is to promote recycling and recovery of end-of-life tyres through standardization.[19]

There do not currently appear to be any EU directives that specifically target end-of-life tyres from electric vehicles.

USA

The US approach to end-of-life tyre management relies on state regulations and EPA guidance.

The recovery of end-of-life tyres is guided by the US EPA under the *Resource Conservation and Recovery Act 1976.* The Act provides a framework for the US EPA's waste management program, which includes tyres (see for example US EPA 1993).

States in the US enact legislation and/or regulation to specifically manage the recovery of end-of-life tyres. The EPA estimates that approximately 48 states have laws or regulations in place to address scrap tyre management[20].

California, for example has implemented the *California Tire Recycling Act 1989* which authorized the creation of the 'Tire Recycling Program' and the 'California Tire Recycling Management Fund'. *CalRecycle* is the state agency responsible for waste management, and regulates the collection, storage, handling, and disposal of waste tyres[21].

6.2 Tyre particulate emissions

6.2.1 European Union

The EU does not currently have regulations that specifically focus on particulate emissions from motor vehicle tyres. However, in December 2023, the European Parliament and the Council of the European Union (EU) reached an agreement on new emission standards for light-duty vehicles (Euro 7) and heavy-duty vehicles (Euro VII). Euro 7 will represent a significant shift in the regulation of emissions from vehicles in that, for the first time, emission limits will be set not only on tailpipe emissions but also emissions from tyres and brake systems. The regulatory framework for tyres will:

- stipulate emission limits;
- set emission-relevant minimum durability (tyre wear) requirements; and
- define requirements for on- and off-board compliance verification methods.

Tyre regulations will apply to tyres of vehicle classes C1 (passenger cars and vans), C2 (light commercial vehicles) and C3 (heavy commercial vehicles).

18 Available at: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en
19 Available at: https://www.en-standard.eu/search/?q=UNE+14243
20 Available at: https://archive.epa.gov/epawaste/conserve/materials/tires/web/html/laws.html
21 CalRecycle. Tire Management. Available at: https://calrecycle.ca.gov/tires/

The Euro 7 standards are expected to be finalized and implemented (enter into force) by 2025[22], with the standards to apply to all new vehicle models, including their brake systems and tyres, 2.5 years later and to all new vehicles 3.5 years later (Figure 6).

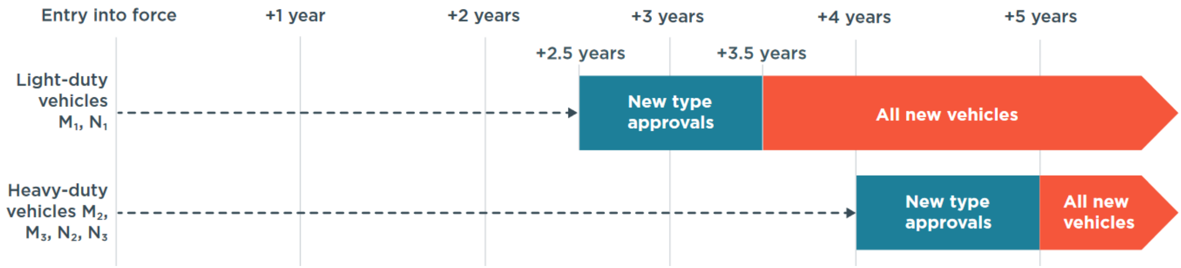

Figure 9: Pathway for implementation of Euro 7 standards

Source: Dornoff and Rodríguez 2024

Work has already begun on developing methods by which to assess tyre abrasion (and therefore particulate emissions) for the purposes of the Euro 7 regulation. In February 2024, The UNECE adopted a proposal under UN Regulation No. 117 (UNECE 2016) which introduced 2 ways to measure tyre abrasion:

- Vehicles drive a distance of 8,000 km on open roads in vehicle convoys. This method assesses tyre abrasion in real-world conditions.
- In laboratories, tyres undergo testing on an abrasing rolling drum for a distance of 5,000 km. This method gives precise measurement of abrasion in a controlled environment.[23]

Measurement methods will be used in a market assessment exercise to gather abrasion data from different tyre brands, sizes and patterns. Results from the data will inform the tyre abrasion limits to be set in UN Regulation No. 117 by September 2025 for tyres fitted to passenger cars.

When these abrasion limits are in force, tyre manufacturers will need to ensure that all tyres sold comply. Manufacturers will be required to make changes to their manufacturing process or material composition for any tyres that exceed the set limits.

The methods in this proposal will become the reference methodology of the Euro 7 proposal of the European Union.

[22] News European Parliament, 2023. Euro 7: MEP's back new rules to reduce road transport emissions. Available at: https://www.europarl.europa.eu/news/en/press-room/20231009IPR06746/euro-7-meps-back-new-rules-to-reduce-road-transport-emissions

[23] UNECE to introduce the first ever methodology to measure particle emissions from tyres. Available at: https://unece.org/environment/press/unece-introduce-first-ever-methodology-measure-particle-emissions-tyres

6.2.2 USA

At the Federal level, the Biden-Harris Administration has recently finalized the Multi Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles. These standards build on the US EPA's existing emissions standards for passenger cars and light trucks for model years 2023 through 2026. The standards aim to reduce emissions and primarily target emissions from vehicle exhausts. They do not specifically mention particulate emission from motor vehicle tyres.[24]

At the state level, there do not appear to be regulations specifically targeting particulate emission from motor vehicles. California has investigated the issue through the California Air Resources Board, which has conducted various research projects. The main aims of these projects were to gain a better understanding of factors affecting the emissions from non-exhaust sources (including tyres), and to understand the impact of this pollution on communities living near roadways[25].

While this research has been undertaken, particulate emissions from tyres does not currently appear to be the subject of regulation in California or in any US State.

The State of California has indicated that it could potentially regulate the use of chemical 6PPD in vehicle tyres given its link to marine wildlife fatalities. Tyre manufacturers could be required to develop an alternative to chemical 6PPD, which is used to preserve tyres[26].

6.2.3 Australia

There are no specific plans in Australia to amend vehicle emission standards to include emissions from tyres. Amendments to vehicle emissions standards for light vehicles (ADR 79/05) were legislated in Australia in April 2024[27]. The amendments are based on Euro 6 standards, which do not set emission standards for tyres. However, officials from DITRDCA consulted for this research have indicated that the Department is aware of concerns regarding particulate emissions from tyre abrasions and "… is monitoring international developments in this area. If and when an international vehicle regulation on tyre abrasion is agreed, the Department will consider the case for mandating equivalent requirements in Australia[28]."

Given this, it is reasonable to assume that Australia will eventually regulate in line with any new EU and UNECE standards relating to tyre abrasion and particulates.

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24 US EPA. 'Biden-Harris Administration finalizes strongest-ever pollution standards for cars that position U.S. companies and workers to lead the clean vehicle future, protect public health, address the climate crisis, save drivers money'. Available at: https://www.epa.gov/newsreleases/biden-harris-administration-finalizes-strongest-ever-pollution-standards-cars-position

25 California Air Resources Board. 'Brake and Tire Wear Emissions'. Available at: https://ww2.arb.ca.gov/resources/documents/brake-tire-wear-emissions

26 Reuters. 'Insight: Tyre-makers under pressure as too much rubber hits the road'. Available at: https://www.reuters.com/business/autos-transportation/tyre-makers-under-pressure-too-much-rubber-hits-road-2023-05-17/

27 See https://www.legislation.gov.au/F2024L00443/latest/text

28 Tim Hicks, Assistant Director, Road and Safety Vehicle Division, Department of Infrastructure, Transport, Regional Development, Communications and the Arts, *Email* 8 April 2024

6.3 Concluding comments

At present there are no specific standards in Australia relating to EV's or EV tyres. Tyre standards, both in Australia and internationally are primarily focussed on tyre performance. EV standards in the EU and US are primarily focussed on safety standards, especially for batteries. For the foreseeable future therefore, government regulations are unlikely to directly affect the design and composition EV tyres and their recyclability, either positively or negatively. Indirectly however, there are emerging standards that could affect the design and composition of tyres, both generic tyres and EV tyres and, by extension, recycling of the tyres. The most significant of these trends is the introduction of Euro 7 emissions standards which, for the first time, will set emission limits and minimum durability requirements for tyres.

7. Conclusions

Electric vehicle (EV) sales have grown rapidly in recent years and are likely to continue to grow rapidly over the coming decade. By 2030, EV sales could feasibly comprise about 50% of new vehicle sales and 12% or greater of the total stock of passenger and light commercial vehicles on the road. Along with this growth, there are likely to be changes to the durability, design and composition of tyres. Many of these changes are linked to changes already underway with generic tyres but the transition to EVs is likely to be accelerating them. Changes that are occurring include:

- tyres incorporating a polyurethane noise reduction foam layer;
- tyres incorporating a self-sealing capability;
- tyres incorporating integrated sensors; and
- design modifications related to lowering rolling resistance and increasing abrasion resistance.

While there are currently no standards in Australia or internationally relating specifically to EV tyres, it is likely that relevant standards will eventually be implemented. Noteworthy is the introduction of Euro 7 emission standards which, for the first time set emission limits and minimum durability standards for tyres, including EV tyres. As a consequence, the durability of tyres in Europe is likely to improve, especially at the low-price end of the tyre market. When this trend becomes more widespread, it could counter any adverse effect that the transition to EVs might currently be having on tyre wear.

There are currently no standards or programs in place that are specifically focussed on increasing the recyclability of tyres, either generic or EV specific tyres.

In summary, significant changes to tyre composition and design are already underway. The move to heavier and AWD vehicles, increasing recognition of the importance of circularity and the need to reduce the impacts of tyre wear are all influencing tyre design and composition. Many of these changes are not specifically linked to the transition to EVs, although that transition could be accelerating the changes. The impact of the transition to EVs on tyre wear and therefore on non-exhaust emissions and the numbers of EOLTs being generated is also uncertain.

Some of the changes to tyre design and composition could, in turn, be increasing tyre recycling costs and, in the case of self-sealing tyres, making recycling more problematic. This is a challenge for tyre recycling generally though, and not one specifically for the recycling of EV tyres. Changes to tyre design and composition also represents an opportunity for the tyre recycling industry - an opportunity for recyclers to adapt and develop a competitive edge through adopting new and innovative recycling technologies and systems.

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MARSDEN JACOB ASSOCIATES

Contact us

Peter Kinrade
Associate Director

pkinrade@marsdenjacob.com.au
+61 0432 636 086

Rod Carr
Director

rcarr@marsdenjacob.com.au
+61 0418 765 393

Marsden Jacob Associates Pty Ltd

03 8808 7400
economists@marsdenjacob.com.au
Marsden Jacob Associates
www.marsdenjacob.com.au

TyreStewardship AUSTRALIA

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TSA0369/10.2024