Understanding the environmental impact of our vehicles

For the better

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There are a number of upstream (e.g. mineral sourcing, manufacturing, fuel production) and downstream (e.g. recycling) activities associated with all vehicles, that not only affect emissions, but the broader environment. We must continue to develop our understanding and consider which powertrain[1] and fuel technologies are most capable at reducing the negative impacts of our vehicles.

Transport decarbonisation is a critical part of our transition towards a net zero-emissions future, and electrification of our road transport system is widely accepted as important to reduce the impact of mobility emissions on health and the environment.

In WA, in 2021, almost 18 per cent of carbon dioxide equivalent[2] (CO_2-e) emissions were from transport. Road transport contributed close to 75 per cent of transport emissions, with almost 48 per cent of road transport emissions coming from cars alone[3].

While it is clear that electric vehicle (EV) adoption will considerably reduce tailpipe emissions, a like-for-like swap of internal combustion engine (ICE) vehicles for EVs will not address the broader impacts from up- and down-stream activities. Minimising the impact of the entire value chain, for all vehicles, is key.

Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above [what it was in] 1850–1900 in 2011–2020.

- Intergovernmental Panel on Climate Change[4]

1 A vehicle powertrain encompasses every component that converts the engine's power into movement. This includes the engine, transmission, driveshaft, differentials, axles etc. Different vehicle types will have different components making up the powertrain (e.g. battery electric vehicles vs internal combustion engine vehicles).
2 Carbon dioxide equivalent (CO_2-e) is a measurement of the total greenhouse gases emitted, expressed in terms of the equivalent measurement of carbon dioxide. We use this to compare the emissions from gases on the basis of their global-warming potential, by converting amounts to the equivalent amount of carbon dioxide with the same global warming potential.
3 Department of Climate Change, Energy, the Environment and Water (2023). Australia's National Greenhouse Accounts. Retrieved from: https://ageis.climatechange.gov.au/
4 Intergovernmental Panel on Climate Change (2023). AR6 Synthesis Report of the IPCC Sixth Assessment Report (AR6). Retrieved from: https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf

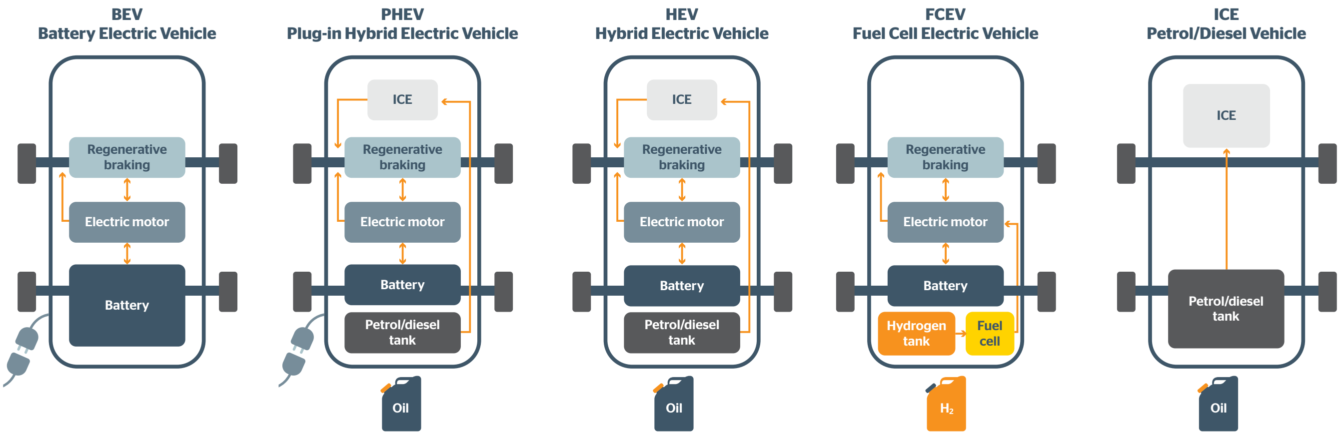

Figure 1 - Vehicle powertrain types

The emissions impacts

Modelling for a WA specific context[5] shows only battery EVs (BEVs) and fuel cell EVs (FCEVs) have the potential to come close to the magnitude of life-cycle[6] greenhouse gas (GHG) emissions reductions from road transport to help achieve Paris Agreement commitments[7] (Figure 2). Beyond GHGs, BEVs and FCEVs still contribute other life-cycle emissions, such as particulate matter (e.g. $PM_{2.5}$ and PM_{10})[8], which arises from wear and tear on brakes and wheels. Therefore, improvements in air quality will also require a reduction in the number of kilometres travelled by vehicles on our roads, as well as increased active and public transport use.

Internal combustion engine vehicles

An ICE vehicle is powered through the ignition and combustion of fuel within the engine. The engine then partially converts the energy from combustion to work and move[9].

As a category of both road transport and the broader transport system, cars are the largest emitter of CO_2-e[10] - this will likely continue while fossil fuels (e.g. petrol and diesel) are their primary energy source. In addition, vehicles also release noxious emissions which are harmful to our health, with diesel fuelled vehicles in particular producing a disproportionately higher level of noxious emissions than petrol and electric vehicles. While currently there is limited potential for further reducing ICE vehicle emissions, reductions can be achieved through, for example, the introduction of fuel efficiency and tightening of noxious emissions standards for new vehicles.

Battery EVs

A BEV is powered directly by electricity rather than fossil fuels[11].

Operating on WA's existing grid mix, BEVs produce less life-cycle CO_2-e emissions than ICE vehicles, and as the electricity mix continues to decarbonise, the life-cycle emissions gap between BEVs and ICE vehicles will increase.

- » Operating on WA's mixed grid[12], the life-cycle emissions of BEVs are already lower than a comparable petrol vehicle by 55 per cent.
- » Operating on a fully renewable grid, the life-cycle emissions of a BEV would be 86 per cent lower than a petrol equivalent.

Plug-in hybrid EVs

A plug-in hybrid EV (PHEV) is powered chiefly by an electric motor and will only use its ICE as a back-up[13,14].

PHEVs can support the transition towards lower-emission road transport, however provide a smaller but significant contribution towards the achievement of Australia's emissions reduction targets.

- » The life-cycle emissions of PHEVs are lower than a comparable petrol vehicle by 43 per cent.
- » Operating on WA's mixed grid, the life-cycle emissions of BEVs are already 21 per cent lower than a PHEV.
- » Operating on a fully renewable grid, the life-cycle emissions of a BEV would be 76 per cent lower than a PHEV.

5 Modelling undertaken by consultancy firm Aurecon. Modifying the International Council on Clean Transport research/modelling for the Western Australia context in 2023. Using average vehicle characteristics, and accounting for the tailpipe emissions, fuel and electricity production and consumption, and vehicle and battery manufacturing. Scenarios considered the South West Interconnected System emission factors for 2021 grid mix (which is 0.68kg CO_2-e/kWh) sourced from Clean Energy Regulator EERS release (https://www.cleanenergyregulator.gov.au/OSR/EERS/Archived-EERS-releases/EERS-release-2021-22), and a potential future where only renewable energy is used for electricity supply and hydrogen production.

6 Assumptions include 'lower medium' size vehicles as defined by the European Commission (e.g. Volkswagen Golf, Honda Civic etc.), average vehicle lifetime of 240,000km; fuel economy; and emissions. Inputs include: fuel/electricity production; fuel/electricity consumption; maintenance; and vehicle, hydrogen tank and battery manufacturing.

7 Limiting global warming to below 2°C, preferably below 1.5°C, on pre-industrial levels. United Nations Climate Change (n.d.) The Paris Agreement. Retrieved from: https://unfccc.int/process-and-meetings/the-paris-agreement

8 Timmers, V. & Achten, P (2016). Non-exhaust PM emissions from electric vehicles. Atmospheric Environment. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S135223101630187X

9 Office of Energy Efficiency & Renewable Energy (2013). Internal Combustion Engine Basics. Retrieved from: https://www.energy.gov/eere/vehicles/articles/internal-combustion-engine-basics

10 Department of Climate Change, Energy, the Environment and Water (2023). Australia's National Greenhouse Accounts. Retrieved from: https://ageis.climatechange.gov.au/

11 Australian Renewable Energy Agency (2023). Electric Vehicles. Retrieved from: https://arena.gov.au/renewable-energy/electric-vehicles/

12 Assumptions based on 2021 grid mix (which is 0.68kg CO_2-e/kWh) sourced from Clean Energy Regulator EERS release.

13 U.S. Department of Energy (n.d.). Plug-in Hybrid Electric Vehicles. Retrieved from: https://afdc.energy.gov/vehicles/electric_basics_phev.html

14 Aurecon did not model the GHGs of hybrids that are not plug-ins. In a hybrid, the vehicle is powered by both an internal combustion engine and a battery-powered electric motor that can work either independently or simultaneously.

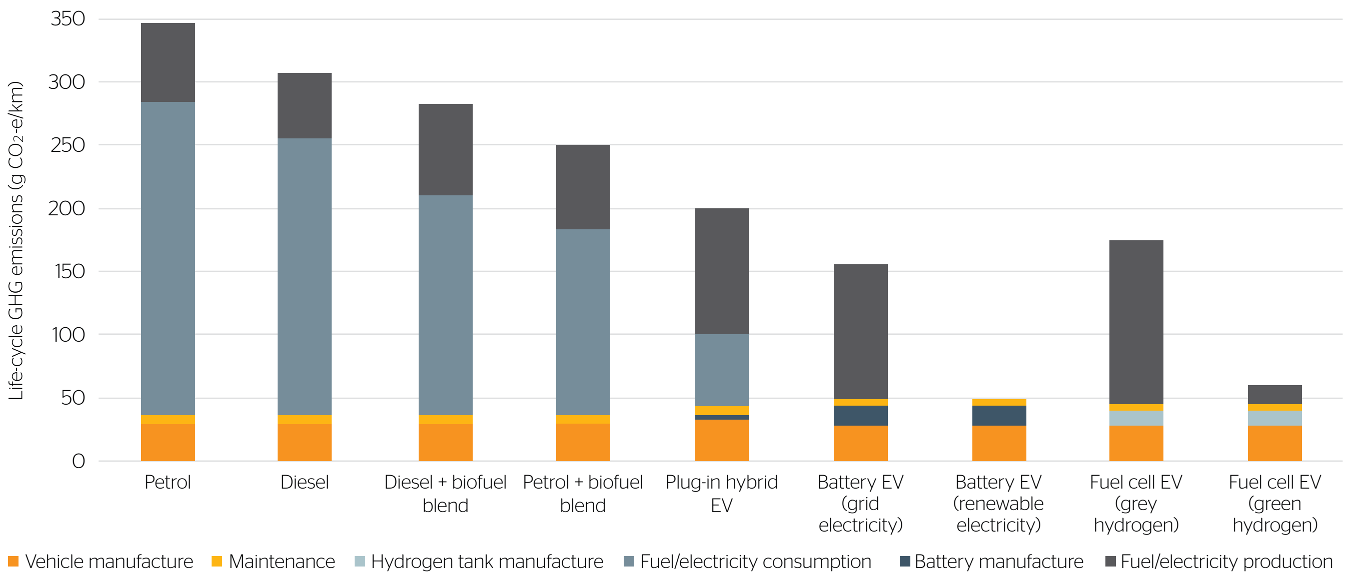

Figure 2 - Life-cycle emissions of petrol, diesel, biofuel blend ICEVs, PHEVs, BEVs, and FCEVs in Western Australia (Source: Aurecon)

Fuel-cell EV

A FCEV is powered by a fuel cell fuelled by hydrogen, rather than drawing electricity from only a battery. The power of the vehicle is determined by the size of the fuel cell and battery combination[15].

The potential for FCEVs to reduce GHGs depends in large part on the source of energy - if the electricity is produced with renewable energy (green hydrogen[16]), the emissions are substantially reduced[17].

» The life-cycle emissions of a FCEV powered by green hydrogen would be 83 per cent lower than a petrol equivalent.

» The life-cycle emissions of a FCEV powered by grey hydrogen[18] would be 50 per cent lower than a petrol equivalent.

The environmental impacts of vehicle and fuel manufacturing

Vehicles are produced using a range of materials – some of these include steel, aluminum, magnesium, copper, plastics, composites, rubber, and glass[19]. The vehicle industry has a major impact on the mining industry, as the mining industry provides many of the components used to build a vehicle. EV batteries in particular require lithium, nickel, cobalt, manganese, and graphite[20], and increased EV sales will necessitate a scale up of all elements of the battery supply chain. The process of extracting the metals and minerals used in vehicles and batteries has multiple and significant environmental impacts. These include the use of large quantities of water; generation of pollution and waste; contamination of waterways; deforestation; and biodiversity destruction[21,22].

Unearthing, processing, and moving underground oil, gas, and coal deposits so we can use fossil fuels to power our vehicles also has an impact on our landscapes and ecosystems. The fossil fuel industry requires large amounts of land for infrastructure, such as wells, pipes, and access roads, as well as facilities for processing, waste storage, and waste disposal. During extraction or transport, it's also possible for oil to spill or leak, potentially polluting our water sources and systems[23]. Given the demand for fossil fuels, offshore drilling, where petroleum is extracted from reserves located beneath the sea, has become more common. Drilling undersea is more challenging than drilling on land, and the extraction, transportation, and environmental protection considerations are all comparatively more difficult[24].

15 U.S. Department of Energy (n.d.). How do fuel cell electric vehicles work using hydrogen? Retrieved from: https://afdc.energy.gov/vehicles/how-do-fuel-cell-electric-cars-work

16 Green hydrogen is powered entirely by renewable energy, so produces no emissions and is the cleanest and most sustainable hydrogen. While green hydrogen production does not generate greenhouse gas emissions, hydrogen combustion, like any combustion reaction that heats air to high temperatures, creates harmful pollutants called nitrogen oxides. World Wildlife Fund (n.d.). What is green hydrogen, and how can it help tackle the climate crisis? Retrieved from: https://www.worldwildlife.org/stories/what-is-green-hydrogen-and-how-can-it-help-tackle-the-climate-crisis

17 Commonwealth Scientific and Industrial Research Organisation (2021). Green, blue, brown: the colours of hydrogen explained. Retrieved from: https://www.csiro.au/en/news/all/articles/2021/may/green-blue-brown-hydrogen-explained

18 Grey hydrogen is created from natural gas, or methane, typically using steam reformation. Emissions during this process are not captured or stored, and are released into the atmosphere. Nationalgrid (2023). The hydrogen colour spectrum. Retrieved from: https://www.nationalgrid.com/stories/energy-explained/hydrogen-colour-spectrum). Production of grey hydrogen was assumed to be 58.3g CO_2-e/km, compared to 14.6g CO_2-e/km for green hydrogen, based on figures presented by the International Council on Clean Transport.

19 Mayco International (2019). What are cars made of? 10 of the top materials used in auto manufacturing. Retrieved from: https://maycointernational.com/blog/what-are-cars-made-of/

20 Natural Resources Defense Council (2022). Electric Vehicle Battery Supply Chains: The Basics. Retrieved from: https://www.nrdc.org/bio/jordan-brinn/electric-vehicle-battery-supply-chains-basics

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24 Energy Education (n.d.). Offshore Drilling. Retrieved from: https://energyeducation.ca/encyclopedia/Offshore_drilling

There are alternative fuels with lower tailpipe emissions compared to fossil fuels including: liquid petroleum autogas[25]; ethanol-based fuels[26]; and bio-fuels and syn-fuels[27]. While these may have a role in specific use cases (e.g. heavy vehicles on mine sites, classic cars etc.), they cannot be relied upon for industry-wide transport decarbonisation[28]. As climate change continues to progress, land for farming and water will become more scarce, which will make ethanol fuels a potentially impractical choice. In addition, the production of bio- and syn-fuels is typically not carbon neutral, particularly once distribution and the broader supply chain is factored in.

End-of-life-cycle considerations: Recycling and disposal of vehicle parts, powertrains, and home charging infrastructure

To reduce the life-cycle emissions and environmental impact of vehicles, end-of-life recycling and disposal represents both a significant challenge and opportunity. In WA and Australia there is a lack of regulation for vehicle recycling. Without regulation, an increased amount of material waste will be sent to landfill to breakdown, potentially leaking into soil and water, affecting humans, flora, and fauna.

A circular economy[29] is well suited to dealing with issues of materials supply risks[30]. To strengthen the resilience and sustainability of automotive supply chains and reduce primary resource requirements, government and industry have recognised the importance of working towards this. For example, in 2023 the Australian Government established the Circular Economy Ministerial Advisory Group to advise on opportunities and challenges in making the transition to a circular economy by 2030[31].

Currently end-of-life vehicle recycling is generally financially motivated (e.g. reusing vehicle parts, income from scrap metal etc.) and there are no national product stewardship schemes in place. Product stewardship schemes support the environmentally sound management of products and materials over their life - they can help hold manufacturers accountable for the materials they use during the manufacturing of the product, and also ensure there are re-use and recycling opportunities available[32]. These schemes reduce waste and prevent harmful materials from ending up in landfill; increase recycling and recovery of valuable materials; and accelerate a circular economy[33]. To address end-of-life vehicle and battery waste across all vehicles, the Australian Government has provided funding to develop Australia's first collective vehicle stewardship scheme to investigate the automotive supply chain in Australia and make recommendations for its improvement[34].

In Australia, most of the materials recovered from a vehicle are steel, plastics, glass, and rubber. However, the recovery rate could be increased through stewardship and mandatory targets. For example, Belgium has mandatory requirements for the recycling of end-of-life vehicles, including the amount of mass that needs to be captured from the recycling process. A recent report has found that in Belgium, on average more than 97 per cent of a vehicle can be recovered and recycled[35].

Vehicle hulks

When separated from their powertrains, vehicle hulks are recycled in the same manner (e.g. hulks from ICE vehicles, BEVs, PHEVs, FCEVs etc. undergo the same process). Only some components and materials are regulated, which means it is possible for a scrap yard to incorrectly and inadequately separate vehicle components to save money and then sell the bodies for scrap[36].

Vehicle shredding involves crushing the car body for ease of transportation and logistics. The crushed hulks are then transported to a mechanical shredder, which breaks the hulk down to a fibre like material for sorting. The material is then passed over magnetic rollers to remove the salvageable metals which can be sold for scrap recycling. The remaining material, called automotive shredder residue (ASR) is then sent to landfill. As we continue to see a shift in the composition of the materials used to manufacture vehicles (e.g. using more complex and unique materials to keep larger vehicles light weight and efficient), without regulation an increased amount of ASR will be dumped.

25 Liquid petroleum autogas is a petroleum derived gas that can be used in modified engines to power vehicles.
26 Ethanol based fuels blend petrol with ethanol.
27 Bio- or synthetic fuels are typically produced from a mix of resources including vegetable oils, animal fats and recycled cooking oil, with the feedstock and processing method applied determining the resulting fuel.
28 Aurecon (2023). Exploring Clean Energy Futures. Report prepared for RAC.
29 A circular economy is an economic system designed with the intention that maximum use is extracted from resources and minimum waste is generated for disposal. A circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible.
30 Bleicher, A. & Pehlken, A. (2020). The Material Basis of Energy Transitions. Retrieved from: https://www.sciencedirect.com/book/9780128195345/the-material-basis-of-energy-transitions
31 Australian Trade and Investment Commission (2023). Circular economy. Retrieved from: https://www.globalaustralia.gov.au/industries/net-zero/circular-economy
32 Department of Climate Change, Energy the Environment and Water (2021). Product stewardship in Australia. Retrieved from: https://www.dcceew.gov.au/environment/protection/waste/product-stewardship
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34 Department of Climate Change, Energy, the Environment and Water (2023). National Product Stewardship Investment Fund. Retrieved from: https://www.dcceew.gov.au/environment/protection/waste/product-stewardship/national-product-stewardship-investment-fund
35 Febelauto (2023). Key figures. Retrieved from: https://www.febelauto.be/jaarverslag2022/kerncijfers-afgedankte-voertuigen.html
36 National Motor Vehicle Theft Reduction Council (2020). Reform of the Scrap Metal Laws in Western Australia Regulatory Impact Statement. Retrieved from: http://carsafe.com.au/assets/WA_Scrap_Metal_Reform_RIA_Final.pdf

Electric drive motors and batteries

Electric drive motors (EDMs) are used in all powertrains, excluding ICE vehicles. While vehicle hulks may be recycled in the same way, EVs present more of a challenge than ICE vehicles due to the complexity of their batteries which contain a range of raw materials. Given the finite supply of these materials and environmental impact of mining, it is critical to promote responsible and sustainable sourcing[37]. As demand for EVs increases, so too will the potential battery waste. If recycled, potentially 95 per cent of battery components can be recovered for alternative use, or may even be turned into new batteries[38]. Re-use opportunities exist in the form of batteries being rearranged in arrays to provide small battery energy storage systems for communities. Irrespective of stewardship schemes, it is possible that vehicle manufacturers will still pursue recovery of the vehicle's batteries as the materials are difficult to source.

Only 10 per cent of Australia's lithium-ion battery waste was recycled in 2021, compared with 99 per cent of lead acid battery waste.

- CSIRO[39]

FCEV batteries are not as large as BEVs. In a small way, this reduces the amount of complex materials to be recycled, however does not reduce the complexity of the process. Recycling a hydrogen fuel tank is difficult and energy intensive. Recycling hydrogen fuel cells is not yet happening in Australia, though it has begun in other parts of the world. For example, German company Voith Composites and their partners are developing recycling solutions for hydrogen storage tanks, and manufacturing methods to produce automotive parts from the recycled materials[40].

Following mechanical or manual disassembling, batteries need to be chemically treated and dismantled to recover the valuable materials inside. The emissions released during recycling EV batteries is unclear - it is possible for these processes to be done using predominantly renewable energy, thereby reducing emissions. The European Union (EU) has recently introduced a new law to ensure that batteries are collected, reused and recycled. The new regulations will ensure that, in the future, batteries have a lower carbon footprint, use minimal harmful substances, need less raw materials from non-EU countries, and are collected, reused and recycled to a high degree[41]. While battery recycling is not yet commonplace in Australia, the importance of a pro-recycling policy has been recognised in the WA Government's *Future Battery Industry Strategy*[42]. In 2023, Australian battery recycling start up, Renewable Metals, raised $8 million in investments to help scale and commercialise its lithium-ion battery recycling technology. This initial funding will be used to develop a pilot plant in Perth, paving the way for a larger scale demonstration plant anticipated of being able to process up to 1,500 tonnes of battery waste annually[43].

37 International Energy Agency (2022). Global Supply Chains of EV Batteries. Retrieved from: https://www.iea.org/reports/global-supply-chains-of-ev-batteries
38 Commonwealth Scientific and Industrial Research Organisation (2023). Lithium-ion battery recycling. Retrieved from: https://www.csiro.au/en/research/technology-space/energy/energy-in-the-circular-economy/battery-recycling
39 Commonwealth Scientific and Industrial Research Organisation (2023). Lithium-ion battery recycling. Retrieved from: https://www.csiro.au/en/research/technology-space/energy/energy-in-the-circular-economy/battery-recycling
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43 Clean Energy Finance Corporation (2023). CEFC and Virescent Ventures back WA battery recycling start up Renewable Metals (5 October 2023). Retrieved from: https://www.cefc.com.au/media/media-release/cefc-and-virescent-ventures-back-wa-battery-recycling-start-up-renewable-metals/

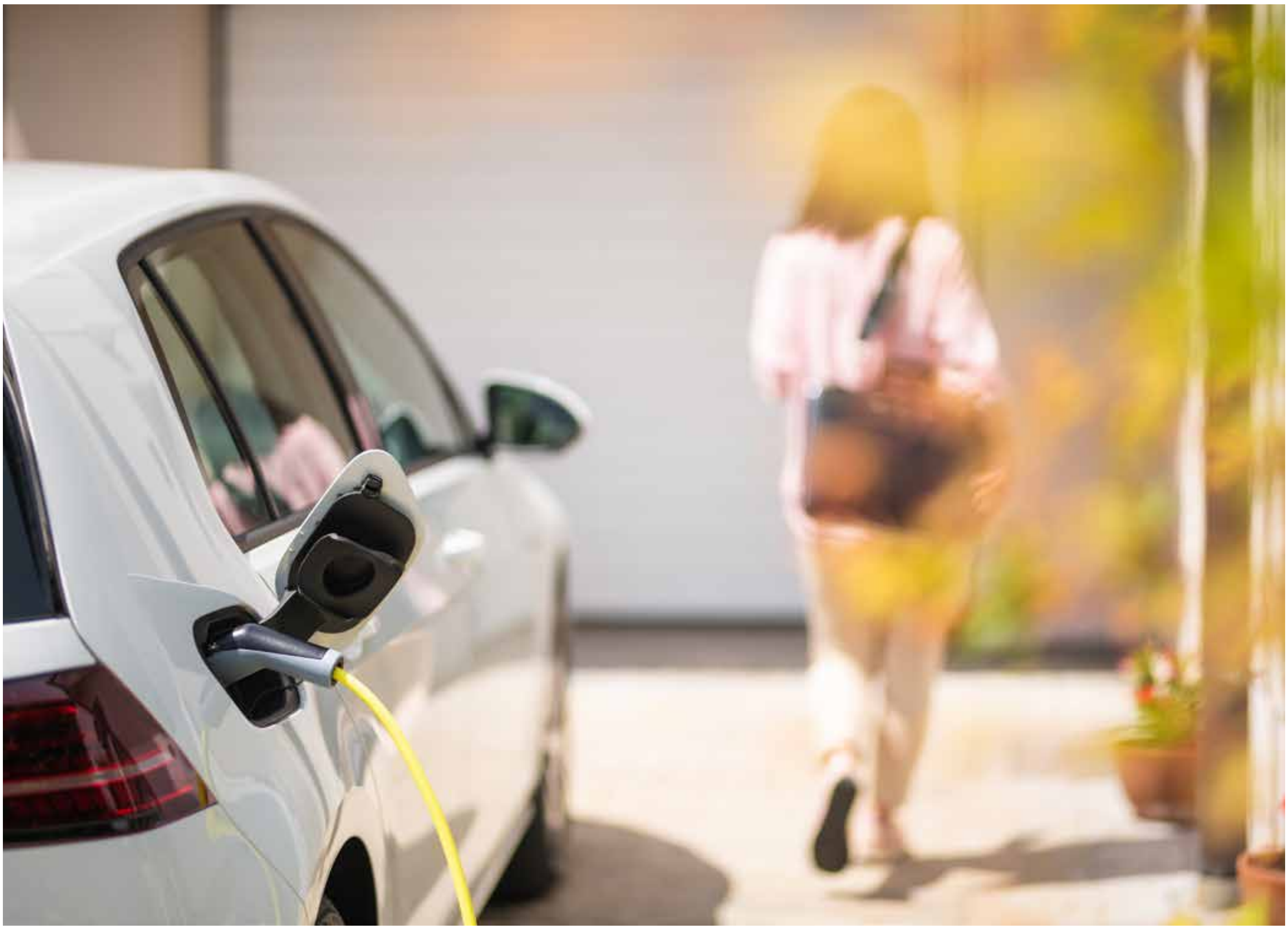
What can be done?

RAC's **Vision** is for a safe, sustainable and connected future for Western Australians.

Decarbonisation and environmental harm minimisation of the road transport sector cannot be achieved through vehicle electrification alone, and will require the implementation of a suite of technology, policy and behaviour change measures to reduce life-cycle emissions[44]. However looking beyond carbon, the manufacture and operation of vehicles contributes to numerous pollutants, such as particulate matter and oxides of nitrogen. Air quality monitoring, covering a broad range of pollutants, is important to provide richer local data that aids decision making and increases community understanding of the health and environmental impact of emissions.

Access to information is imperative to ensure we consider and reduce the entire range of adverse impacts a vehicle has across its life-cycle. Some opportunities include reducing emissions from the vehicle parts (e.g. batteries) through policies that require sustainable sourcing of materials, regulating the energy and emissions intensity of production, promotion of a circular economy, and setting high collection and recycling targets[45].

We have been a long-standing **advocate** for reducing vehicle emissions, and ensuring that the mobility choices we make today do not impact negatively on the lifestyle and choices of future generations. It is important that industry, government and the community all play a part to reduce the impact of our road transport system.



44 Climate Council of Australia (2022). Submission to the National Electric Vehicle Strategy Consultation. Retrieved from: https://www.climatecouncil.org.au/wp-content/uploads/2022/11/CCA-NEV-Submission.pdf
45 The International Council on Clean Transportation (2021). A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars: white paper. Retrieved from: https://theicct.org/wp-content/uploads/2021/07/Global-Vehicle-LCA-White-Paper-A4-revised-v2.pdf

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