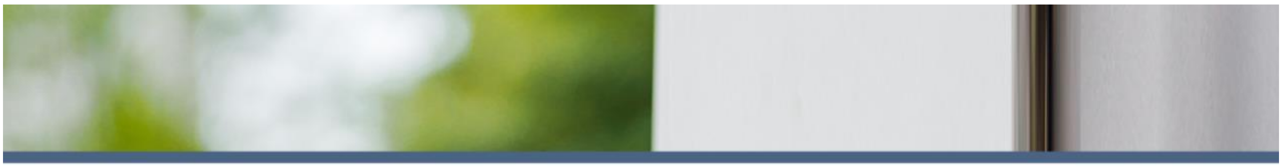

BACKGROUND AND METHODOLOGY REPORT

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www.greenelectriccar.guide
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CONTENTS

Key messages

1. All cars have environmental impacts, so we should use alternatives as much as possible.
2. Electric cars have fewer environmental impacts over their lifetimes than fossil fuel equivalents, but some are "greener" than others, no matter how they are driven or charged.
3. Many factors influence the environmental impacts of electric cars, especially the battery size and type, the energy used to mine and process the minerals used in the battery and electric motor; the energy efficiency of the car when driven; its longevity; and how EV batteries can be reused or recycled.
4. The Green Electric Car Guide has been created to make it easier to choose between more or less green electric cars for sale in Australia in 2023 by comparing them on a range of environmental criteria. Alternately, buyers can simply look at two publicly available stats—weight and energy efficiency or consumption—to inform their choice. The lower both of these are, the better.
5. When you buy a car, you are also investing for years to come in a car maker. The Guide also scores carmakers on their public commitment to electrifying and decarbonising private transport in Australia. *All* legacy carmakers are effectively undermining the transition by continuing to support the development and sale of their fossil fuel cars.
6. Greenwash is a problem. While we came across few examples of blatant misleading or deceptive conduct, there is extensive evidence of "look over here" syndrome. That is, some legacy carmakers appear to believe that they are doing the planet a favour just by producing a small number of cars with an electric rather than fossil fuel powertrain, while simultaneously continuing to not only sell but develop new ICE cars that are carbon time-bombs.
7. Individual action—private car purchases—can make a difference, but this should not be a substitute for strong government regulation of the car industry to require strong emissions standards and steep decarbonisation targets.

"There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all (*very high confidence*)."

IPCC, March 2023[1]

INTRODUCTION

So you've decided to buy an electric car. But which one? If you are driven by the desire to reduce the carbon emissions and other environmental impacts from your driving, this guide should help.

All private cars have environmental impacts. They use non-renewable resources to manufacture; need fossil fuel or renewable energy infrastructure to power; mostly have a limited lifespan; and some of their materials (such as plastics) are difficult to reuse or recycle. The associated infrastructure (especially roads and car parks) takes up a lot of space and has its own impacts (eg, reducing vegetation and contributing to the urban heat island effect). And while a fraction of the toxic cocktail of air pollutants caused by fossil burners, they all produce microplastics and airborne particulates from tyres as they wear.

From an environmental perspective, the best ways to get around are on public transport, a bicycle or your own two legs. However, if you do need a car, electric vehicles (EVs) are a no-brainer compared to internal combustion engine (ICE) vehicles powered by petrol, diesel or fossil gas. There have now been numerous studies which have conclusively demonstrated that over their lifecycle, EVs are responsible for substantially lower carbon emissions than their ICE equivalents in almost all scenarios. And they avoid most of the localised air pollution caused by the burning of fossil fuels, which, according to a recent study by University of Melbourne researchers, causes about 11,000 extra deaths and 66,000 active asthma cases per year in Australia alone via traffic pollution.[2]

Lead the Charge

"The transition to electric vehicles (EVs) is now inevitable – and that's a good thing. But as we say goodbye to fossil-fuelled cars, we also need to transform their dirty supply chains. We need to ensure the new generation of electric vehicles aren't manufactured in a way that harms people and the planet, but instead benefits us all."

https://leadthecharge.org

Some EVs are better (or less worse) for the planet than others, though. If you want to get the most "zap for your bucks" in your choice of EV, that's where we come in. Brought to you by a cofounder[3] of the Green Electricity Guide, Total Environment Centre's (TEC's) Green Electric Car Guide (GECG) scores and ranks the base model[4] of every EV model currently for sale new in Australia for under $100,000.

We do this by covering not only the car's likely carbon emissions in manufacture, use and disposal, but also a range of other environmental impacts. Wherever we can, we use public data. Where this information is not publicly available, we use either proxies (wherein one publicly available metric is regarded as being a good indication of another that is not available) or the informed views of a range of experts in this field.

This is a guide only, and has its limitations. For instance, a large part of any EV's overall environmental impact will depend on how far and hard it is driven, and whether it is charged using renewable energy or fossil fuels. These factors are beyond the scope of the guide. What we can tell you, though, is how efficient a car is likely to be in terms of its energy consumption per kilometre. Because it uses less electricity to charge, a more energy efficient car will have a lower environmental impact than a less efficient car that is driven and charged the same way.

Environmental impacts are likely to be only one of a number of considerations potential buyers have in mind. For instance, if you live in the country, you may need a car with a bigger battery, even though this may be less desirable from an environmental perspective. Likewise, if you have a big family, you may need a bigger car. So we are not asking you to go out and buy the cars at the top of the rankings. But equally, we would urge you to buy the car that has the lowest environmental impacts among the models which would meet your everyday needs.

This is the first edition of the GECG. Whether it morphs into a living resource which is updated with every new model arriving on our shores depend on your response and ongoing funding. Please tell us what you think of it, whether it is useful, and what changes you think we should introduce to make it even better. Just email gecg@tec.org.au.

Our promise—and a disclaimer

TEC guarantees that this guide is, and always will be:

- *Independent*: We receive no financial or other inducement or reward to create and maintain the guide from any source in the transport or fossil fuel sectors, and have no conflicts of interest in relation to this project.
- *Comprehensive*: the guide is the most thorough analysis available in the Australian context of the environmental impacts of private car purchase, use and disposal.
- *Transparent*: We are committed to full public disclosure of our methodology and results.

Nevertheless, TEC does not have the capacity to do original field research—eg, to test and verify environmental claims made by carmakers about their supply chains, manufacturing processes and progress on meeting sustainability targets. We rely on publicly available data, wherever possible from independent sources. And we promise to promptly rectify any mistakes users alert us to.

Meanwhile, many thanks to the following experts for their feedback on drafts of this guide:

Dr Rob Passey, UNSW

Professor John Storey, UNSW

A/Prof Peter Pudney, University of South Australia

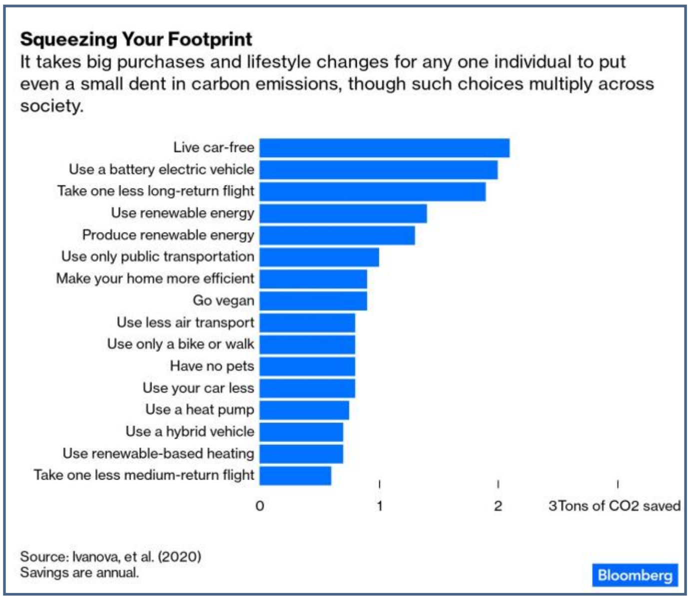
Professor Glenn Platt, University of Sydney

Naturally, any mistakes and all opinions are the responsibility of Dr Mark Byrne, Energy and Transport Analyst, TEC, and TEC itself.

DECARBONISING TRANSPORT

No matter where or how we live, we are all in the midst of a climate emergency which is already having catastrophic outcomes around the world.

Like the rest of the economy, we need to urgently decarbonise the transport sector. As this chart from Bloomberg shows, next after not having a car at all, using an EV is possibly the best thing we can do to reduce our personal carbon footprint.[5]



"Net zero by 2050" is the most commonly quoted aspiration, but it is a political rather than a science-based target, and is not nearly enough to avoid a global atmospheric temperature rise of at least two degrees by 2050.

There are about 1.5 billion cars in the world. Of that number, only about two percent are EVs to date. Cars typically last between one and two decades before being scrapped.[6] About 80 million are manufactured each year, of which 10 million were EVs in 2022.[7] Much more needs to be done to decarbonise the transport sector.

In Australia, transport emissions are responsible for about one-fifth of the nation's total carbon pollution—nearly 100 million tonnes per year and rising again after a temporary Covid-related reduction in 2020 and 2021.[8] Unlike other OECD countries, which have managed to reduce carbon emissions from cars and "light duty vehicles" up to 33 percent since 2000, in Australia they have increased by 20 percent.[9]

This is partly because Australia still has no vehicle fuel efficiency standards. Only two percent of new car registrations in 2022 were full battery EVs (BEVs, not hybrids). While this figure is likely to accelerate in 2023 and beyond, that means that 98 percent of new cars on our roads are still "baking in" a decade or more of carbon and other pollution of the air we breathe, the land we walk on and the water we drink.

The increase in transport-related emissions in Australia is also due to the growing dominance of big, heavy SUVs and utes in the Australian market, bolstered by generous tax concessions and incentives to polluters.[10]

This trend is inconsistent with Australia's 2015 pledge—via the Paris Agreement—to try to limit global heating to 1.5 degrees. While transport emissions continue to rise, the electricity sector is gradually reducing emissions, mostly by investing in renewable energy generation. Some sectors of the economy (agriculture and manufacturing) are regarded as being difficult to decarbonise. Because of the "lag effect" from new car purchases, transport is another. The need is now urgent for governments, industry and citizens to do whatever they can to limit the impact of our choices on future generations and the biosphere.

CARMAKERS

When we buy a car, we are also investing in a carmaking company: one which may or may not have a genuine commitment to cleaning up their industry and contributing to high ESG (environmental, social, and governance) outcomes.[11] This applies even if we don't keep the car for its entire lifespan: every new ICE vehicle is a carbon time bomb that locks in emissions for an average of 15-20 years.[12]

In this respect, it is odd that carmakers have, particularly in Australia, largely had a free ride with respect to their responsibility for causing global heating. Climate scientists have been sounding the alarm since the 1980s. The *UN Framework Convention on Climate Change* dates from 1994. Yet the average fuel consumption of Australian passenger vehicles in 2020 was 11.1 litres per 100 km,[13] a figure that is almost unchanged since the ABS started collecting relevant data in 1963.[14] In that time millions of cars have travelled billions of kilometres on Australian roads, spewing a kilogram of carbon emissions (and other pollutants) into the atmosphere roughly every seven kilometres, or over 1.6 tonnes of CO2e per car every year.[15]

No carmaker can claim to have been ignorant about the contribution of their vehicles to climate change for at least 30 years. It is extraordinary that in that time we have seen them do so little towards voluntarily cleaning up this mess. The Toyota Prius has been on sale since 1997, and its hybrid technology has been widely adopted across the Toyota range and more recently by other carmakers, yet Toyota has resisted moves towards full electrification. Nissan, Renault and Mitsubishi introduced small full battery EVs around 2009-10, but these models have remained outliers in a market still overcrowded with fossil burners, including in these manufacturers' model ranges.

We have to ask where the electrification and decarbonisation of the transport sector would be today were it not for the global success of Tesla, which introduced the Roadster in 2008 and the Model S in 2012, and which now not only dominates the EV market but with the Model Y has the biggest selling car overall in Europe in 2023.

Meanwhile there is only one legacy automaker that is committed to going all-EV in the short term (2026) in Australia: Volvo. Other larger carmakers like Hyundai-Kia, Mercedes, BMW, Stellantis,[16] Volkswagen Group and the Chinese companies[17] SAIC and GWM are making EVs in relatively small numbers while continuing to develop and spruik new versions of their fossil burners, which constitute the overwhelming majority of their sales and profits.

In TEC's view, these companies are just as responsible for global heating (not to mention localised air pollution, which may be responsible for 11,000 additional deaths per year in Australia)[18] as the big coal, oil and gas miners.

This guide is one small step towards keeping carmakers accountable for their impacts on the global environment. In the longer term, we would like to see a certification scheme for EVs that recognises their progress towards what we regard as the ultimate goal that all carmakers should aspire to: making and selling only carbon neutral cars. To be consistent with the Paris Agreement, this would mean going way beyond meeting weak net zero emissions by 2050 targets by selling only carbon neutral cars by 2030.[19] That is admittedly a big ask, but it is what the climate crisis requires.

Even this goal is not enough, however, because it doesn't go beyond carbon emissions to account for impacts such as plastic pollution and biodiversity loss. Here is a more comprehensive "wish list" of things carmakers could realistically undertake to reduce their environmental impacts:

- Undertake and publish ISO 14067: Product Carbon Footprint for all EV models.[20]
- End ICE vehicle manufacturing by 2030 at the latest.
- Set targets for corporate carbon neutral operations of at least 50% by 2030 and 100% by 2045 or earlier.
- Support the introduction of national fuel efficiency standards in Australia.
- Power the entire vehicle supply chain, including the mining and processing of raw materials, manufacturing plants, vehicle transportation and end of life battery reuse and recycling with 100% renewable energy no later than 2030.
- Increase the use of recycled materials in manufacturing to at least 25% by weight by 2030.
- Reduce the environmental impacts of the manufacture and use of batteries, including by
    - Reducing or eliminating the use of rare earth materials and the use of minerals which are difficult or toxic to extract and process, and recycle those that are used.
    - Reducing battery weight.
    - Increasing battery energy density and safety.
- Reducing the amount of water required for the processing of raw materials and vehicle manufacturing.
- Reducing the environmental impacts of the use of tyres and paint.
- Reducing the use of virgin plastics derived from fossil fuels.
- Increasing the longevity of their EV models, including, but not only, by making battery replacement affordable and simple.[21]

We would also like to see the introduction of an independent national or global green car accreditation scheme like a "FairTrade on wheels", which would give potential buyers confidence about the environmental performance of particular models and manufacturers. It could conceivably also include human rights issues, which are not dealt with in this report.

A fairer car?

"With every [car] we make, we're getting closer to a fairer and more sustainable [car] industry. From responsible material sourcing to advocating for workers' welfare, we share all our results freely and set new standards for the entire industry…

It's no secret: we're out to change the world. Fair[car] puts people and the planet first. We care about human rights and worker well-being. We care about the climate and our planet's delicate ecosystem. We care about designing longer-lasting products that are easier to repair. We care about reducing waste and making the most of what we already have."

From the Fairphone website, substituting [car] for "phone" and "electronics" in the original.

EVs AND THE ENVIRONMENT

Most human activities use natural resources, including energy. To minimise negative impacts, the idea is to:

- Minimise the use of finite resources.
- Maximise the use of renewable resources.
- Use all resources as efficiently as possible (ie, maximise the output per unit of resource input, including by reuse and recycling).
- Prevent air, land and water pollution.
- Avoid the need for creating carbon offsets (because they seldom work as intended over the long term).

The economic model which best encapsulates these principles is the *circular economy:*

> …a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible… The three principles required for the transformation to a circular economy are: eliminating waste and pollution, circulating products and materials, and the regeneration of nature.[22]

The individual ownership of resource-intensive manufactured products with limited lifespans such as cars is not usually compatible with the principles of a circular economy. However, if we accept that private cars are likely to be around in various guises for many years to come, the challenge is to minimise the negative impacts of their manufacture, use and disposal; minimise their resource utilisation; and maximise their energy efficiency.

While the application of these principles can quickly get complex, there are a few "no brainer" questions you could ask yourself that will get you most of the way. These are listed below, roughly in order of their environmental importance:

1. *Size* matters. Is the car big and/or heavy? If so, it is likely to have a relatively substantial environmental impact over its lifecycle.
2. Is the *shape* more like a bird or a brick? The former will use less energy. There is a name for this: the drag co-efficient (Cd).[23] Every car has a number for this: the lower (closer to zero in theory, and in practice down to 0.2 for mass market cars) the better (the worst performers are up around 0.3). It might not seem like a big difference, but it can have a noticeable impact on energy consumption, especially at highway speeds.
3. Do I really need a big *battery*? There are two main issues here:
    - Size: the bigger it is, the more energy it takes to lug it around. The answer is probably "No" if you live in a city and only do a few long drives every year. The answer might be "Yes" if you live in a regional, rural or remote area without good access to public charging stations (although this situation is rapidly improving).
    - Chemistry: the two main chemistries[24] currently used in the cathodes[25] of lithium-ion EV batteries are nickel – manganese – cobalt (NMC) and lithium – iron – phosphate (LFP or LiFePo4). While slightly less efficient and therefore bigger and heavier, LiFePo batteries are more robust (less flammable),

handle being repeatedly charged to 100 per cent, and avoid the need to mine and process "risk" or "conflict" minerals like cobalt.[26]

4. Ditto *electric motors*. Again, there are two issues here:
   - Number: car makers often offer base models with a single motor and higher (more expensive) variants with two or even four motors—one to drive each wheel. More motors means more power, but they can also help with weight distribution, handling and off-road capability. But as well as adding to the upfront cost, more motors also means more weight to lug around, resulting in lower efficiency and range.
   - Type: there are two main electric motor types: asynchronous induction and synchronous permanent magnet motors. Both have their pros and cons, but from an environmental perspective the one standout difference is that most permanent magnet motors require the mining and processing of rare earth materials. This doesn't make them always a bad choice, but it is one of the reasons why some manufacturers are trying either to avoid using them, or to design them without rare earths.
5. *Tyres and wheels.* Do you really need big, fat 20 inch wheels? Manufacturers often offer 18 inch wheels as standard, and bigger wheels as an option. Bigger wheels might look more impressive and improve the car's grip and handling, but they are usually also fatter, increasing a car's energy consumption by increasing the airflow resistance. The composition of tyres also affects energy consumption. Go for ones which are likely to be long wearing (ie, have lower "rolling resistance")[27] and/or designed to handle the heavier weight of EVs. Tyres also produce microplastics and other toxins as they wear,[28] but that's common to ICE cars as well. The lighter a car is, the less tyre pollution it creates.
6. *Interiors*. There is a lot of hype (and scepticism) around vegan interiors. Putting aside the vexed issue of leather (which has animal rights as well as environmental dimensions), the most important environmental considerations are reducing the amount of plastic and increasing the use of natural and recycled fabrics and textures.
7. *Warranties and service schedules*. The longer and more inclusive the warranty for the high voltage (HV) battery and the rest of the car, and the lower the servicing requirements, the more likely it is that a manufacturer has confidence in its products. This is likely to translate into a longer lifespan for the car, which in turn translates into a lower environmental impact.
8. *Techno-bling*. New EVs are sometimes described as computers on wheels. That involves lots of semiconductors (computer chips), which are lightweight and reliable, but it also involves complex supply chains and the extraction and processing of precious metals and rare earth minerals. Much of this technology is related to safety. But some of it is superfluous: do you really need to be able to play computer games or sing *karaoke* on the road? How about a sunroof that drivers will barely notice, or a 0-100 km/h time that will get you into trouble with the cops more often than getting you out of it?

Much of the rest of the environmental impact of an EV depends on how you use it. That will depend mostly on whether or not you charge it from renewable energy or fossil fuels. Homegrown rooftop solar is best, because it's convenient, cheap and doesn't need big infrastructure investments to get to your car. If you don't have rooftop solar and can't recharge overnight, the options are either to install a home battery to store your rooftop solar for overnight EV charging, or to buy your grid energy from a retailer that guarantees it is 100 percent renewable.[29]

METHODOLOGY

This first iteration of the GECG scores cars according to three main criteria: lifecycle carbon emissions, sustainable technologies and carmakers.

1. Lifecycle carbon emissions

In view of the urgent need to decarbonise transport, which accounts for about 20 percent (and rising)[30] of Australia's contribution to global atmospheric heating, this is the most important criterion for scoring and ranking.

The current global standard for this process is a lifecycle analysis (LCA) using either of the relevant international standards.[31] (ISO 14067: Product Carbon Footprint). It requires the assessment of carbon pollution during the manufacture, use and end-of-life phases of a car's lifespan (which Tesla claims is typically 17-20 years in the US). EVs produce between half and almost all of their lifecycle emissions during the manufacturing phase (depending primarily on the fuel source for recharging),[32] whereas ICE vehicles incur about two-thirds of their much higher total emissions "debt" during the use phase.

At present it appears that only Volvo and its offshoot Polestar have published the full results from applying the international standards to their EVs.[33] Even then, ISO 14067 is a methodology, not a baseline for performance. That is, just undertaking an LCA is no guarantee that the car will have a low greenhouse or other environmental impact. And naturally, unless an LCA has been undertaken by an independent organisation, there may be questions about its accuracy.[34]

Tesla has developed its own LCA methodology. We understand why it has done this—basically, because it wants to use the real-world data collected from its millions of cars to give a real-world assessment of use phase emissions. Still, this makes comparisons difficult—as does the absence of a corporate Impact Report including LCAs for 2022.[35]

For this Guide, we need a different method for assessing lifecycle carbon emissions that could be applied to carmakers other than Tesla, Volvo and Polestar. As stated above, EVs incur more of their lifecycle carbon emissions "debt" during the *manufacturing phase*[36] than ICE vehicles. Most of this difference is due to the energy intensive nature of battery manufacturing. The bigger the battery, the more it will weigh. Because makers do not separately, identify battery weights, we use the weight of a car as a proxy for its manufacturing emissions. (In other words, the heavier the EV, the higher the carbon emissions related to its manufacture are likely to be.)

Our proxy for the carbon emissions for the *use phase* of an EV's lifespan is its efficiency—that is, its energy consumption per kilometre of driving. As well as the distance driven, driving style and emissions intensity of the energy used to recharge, none of which we can measure in advance, this is a combination of size, weight, aerodynamics (the drag coefficient, Cd, and the car's frontal surface area), tyre type (rolling resistance), battery chemistry and the efficiency of the electric motor.

The *end-of-life phase*[37] is challenging. It is an immature and fast-evolving space with a number of complex dimensions (eg, disassembly, battery reuse or recycling and final disposal), and there are not yet enough reliable data to include anything on end-of-life impacts that would separate EV carmakers from each other. The most useful criterion might be whether or not carmakers have a battery reuse and/or recycling operation or plan in Australia. However, for most manufacturers there is plenty of time to get their act together before such an operation would be required at scale—especially noting some manufacturers' claims or plans to build battery packs that will outlive their cars.[38] In the meantime there are organisations such as the Battery Stewardship Council and companies such as Envirostream which are exploring potential solutions to the problem. In time, a properly regulated product stewardship scheme will be required inn Australia. We also note that the end-of-life phase represents a relatively small proportion of lifecycle emissions in any case.

For these reasons we are only allocating five points out of 100 to the end-of-life phase. These points recognise carmakers actively involved in battery recycling programs (in Australia or internationally) that can collect and repurpose, refurbish or recycle the bulk of batteries and their often high-value ingredients.

2. Sustainable technologies

Carbon emissions are not the only form of pollution caused by cars. This category includes a range of technological choices carmakers have made which can decrease or increase a car's environmental impacts:

- "Vehicle to X" (V2X) *bidirectional charging*, which creates the potential for greater battery utilisation—eg, during blackouts, as alternative to fossil fuel home generators. Vehicle to load (V2L) is the first step in this direction, followed by vehicle to home (V2H) and then vehicle to grid (V2G). V2X should lead to more efficient, battery utilisation: why buy a home batteries if you've already got one (on wheels) in your garage?[39]
- *Battery chemistry*: lithium ferrous phosphate (LiFePO4 or LFP) has advantages over nickel manganese cobalt (NMC) including greater resource availability, easier manufacturing, less toxic disposal, double the typical lifetime cycles & greater depth of discharge (DoD). However, they also store less energy by weight than LMC, so LFP battery packs are heavier.[40] Other chemistries (eg, sodium-ion) and designs (eg, solid state) may have lower environmental impacts but are not yet a feature of mass market EVs.
- *Battery size*: The average daily car use in Aust is ~40 km. Buying an EV with a large battery that is seldom needed is a waste of resources and energy; reduces energy efficiency (due to the extra weight that gets lugged around day-to-day); and keeps battery and EV prices high, slowing the mass take-up of EVs.
- *Other innovative technologies* which contribute to better environment outcomes, such as:
  - Designing the electric motor/s to avoid the need to use rare earth elements (as found in most permanent magnet motors).[41]
  - The use of natural fibres or recycled plastics in body panels and interior design.
  - The use of energy-efficient heat pumps to heat the battery and interior.[42]
  - The inclusion of onboard solar power.[43]
  - Fitting high distance, low rolling resistance and low toxicity tyres.
  - Reduced water usage in manufacturing.
  - The use of low toxicity paint or alternatives.
  - High aerodynamics (drag coefficient, Cd = <0.25)
  - Use of green steel and/or aluminium in manufacturing.

- 800 volt architecture (the benefits of which include less use of minerals such as copper in cabling).
- Non-metal body panels (to reduce weight).
- Factories powered by 100% renewable energy and/or carbon neutral.

3. Carmakers

While some manufacturers have been enthusiastically championing the cause of electric cars, others have either been quiet or have actively tried to undermine the speed of the transition. These stances influence government and public perceptions, so are necessary to identify and call out:

- *All-EV target*: A manufacturer's commitment to introduce a target year for having an all-EV fleet.
- *Decarbonisation target*: A manufacturer's commitment to introduce a target for ending the production of fossil fuel (including hybrid) cars.[44]
- *Fuel efficiency standards:* A manufacturer's support for the introduction of mandatory fuel efficiency standards in Australia, which should accelerate the uptake of EVs
- *Life cycle analysis:* Whether a carmaker has undertaken and published an LCA to enable independent assessments to be made concerning its commitment to reducing a car's carbon footprint in manufacturing,[45] use and end-of-life; and to allow cars to be compared in this respect.
- *Supply chain:* Much of the environmental impact of EVs occur upstream of the manufacturing process—eg, in the mining and processing of battery materials. We are therefore awarding points for evidence of carmakers' transparency around environmental impacts upstream of manufacturing; commitments to improving supply chain inputs; and success in implementing these commitments.[46]
- *Greenwashing and bad faith* (aka FUD—fear, uncertainty and doubt):[47]*S*ome manufacturers have made unsubstantiated claims about their cars' environmental impacts.[48] Conversely, some have appeared to use their media profile and political influence to undermine the transition to full EVs.[49]

Left right out

There are also a number of other potential scoring criteria which, for various reasons, have not been included in this first iteration of the guide:

- *Lifecycle analysis* (LCA): Publishing an LCA carried out according to an accepted international standard for measuring lifecycle carbon emissions (ISO 14040 or14067 or a credible equivalent) would be a simple, easily comparable gold standard for comparing the main environmental impact of EVs. However, as discussed above, only Volvo and Polestar have published these in full to date. Tesla has its own methodology. BMW/Mini publishes the results only in comparison to their EVs' ICE equivalents. Kia claims to have done one, but there appears to be nothing in the public domain about it. None of the all-Chinese carmakers in the guide (BYD, GWM and MG/SAIC) has an LCA on or linked to its Australia website. And so on. We therefore decided it was too difficult (ie, premature) to score all the EVs on this basis, so have used car weight and energy efficiency as proxies for now.
- *Affordability:* You can design, build and use the greenest car imaginable, but if almost nobody can afford to buy it, it won't make much of a difference. We therefore considered making affordability one of the scoring criteria, but eventually decided against this because price, while critical to the EV transition, is not a direct environmental impact.
- *Offsets:* One easy way to achieve net zero or net carbon neutral targets is to buy carbon offsets for emissions reduction which are deemed too difficult to achieve internally. However, national and global carbon offsets markets have so many problematic aspects (in design, monitoring, guaranteed longevity, additionality, etc.), we decided not to go there.

Scoring and weighting

After choosing the scoring criteria, we need to weight their relative importance. For this first iteration we have weighted 50 per cent of the total score for the lifecycle assessment proxies (#1 above): 25 points for embodied emissions in manufacturing (including battery module supply); 20 points for energy efficiency as a proxy for the use phase; and 5 points for battery recycling programs, as a proxy for end-of-life reuse or recycling. This allocation of points broadly reflects the relative emissions for each lifecycle phase for an EV charged with the current EU28 fuel mix.[50] As electricity grids gradually decarbonise, the contribution of the use cycle should decrease—but then, so too should emissions in the manufacture phase, as battery manufacture and materials production and refining become less emissions intensive.

Conversely, there are two 2.5 point penalties for evidence of greenwashing and/or bad faith (aka FUD: fear, uncertainty and doubt) on the part of carmakers.[51] A carmaker is debited for greenwashing if it makes public but unsubstantiated claims about the environmental benefits of its EVs. This includes highlighting "green" features (eg, "vegan" interiors) which are relatively trivial in the context of a car's overall environmental impacts if the larger impacts have not also been addressed.[52]

A company is debited for FUD where it deliberately and consistently undermines the electrification and decarbonisation of transport by either directly criticising EVs and related technology (such as chemical batteries) without foundation, or "muddies the waters" by promoting technologies (eg, hydrogen fuel cells, biofuels and hydrogen fuel cells) which it should be aware are not, on the evidence currently available, viable alternatives to ICE light vehicles or to current-generation EVs in the next few years.

This weighting has been influenced by feedback from industry experts and early users of the guide during its drafting. If we are able to attract funding to update and enhance the guide, the scoring criteria and ratings will also evolve. In future versions we would also like readers to be able to change our default scoring system to match their particular environmental preferences.

Below is a summary of how we have scored and ranked the cars. More detail is available in the scoring spreadsheet. The Aptera is shown as an example of a car that is among the EVs with a relatively low environmental impact, but is not shown in the final rankings because it is not currently available in the Australian market.

Aptera Launch Edition

Summary of scoring methodology

	Criterion	Explanation and metric	Score (/100)	Benchmark (Aptera) data	Benchmark (Aptera) points
1. LIFECYCLE CARBON EMISSIONS (up to 50 points)	**Embodied carbon in manufacturing**	In the absence of a comprehensive LCA, these metrics are reasonable proxies. Vehicle weight as proxy for manufacturing phase	**25**	820 kg	25
	Energy efficiency	Real world Wh/km as proxy for use phase	**20**	~60 Wh/km	20
	End-of-life initiatives	Battery repair, refurbishment, reuse and/or recycling program as proxy for end-of-life phase	**5**	?	0
2. SUSTAINABLE TECHNOLOGIES (up to 25 points)	**V2X (vehicle to load/home/grid)**	Creates potential for greater battery utilisation. Car has V2L(2.5) and/or V2X (5)	**5**	V2L	2.5
	Battery chemistry	LFP is more sustainable than NMC; other technologies (eg, solid state, sodium-ion) better still but not yet available	**5**	NMC	0
	Battery size	Lower kWh = more efficient use of resources, given average daily distances driven	**5**	42 kWh	5
	Other innovative technologies	Other innovations which help to lower environmental impacts include: - high aerodynamics (drag coefficient, Cd = <0.25) - use of green steel and/or aluminium in manufacturing - non-metal body panels (to reduce weight) - heat pump included or optional on base model (to increase battery efficiency) - > 10% use of recycled plastics - use of plant-based and/or recycled fabrics in cabin - factory powered by 100% renewable energy	**2.5 each up to 10**	Low drag cooling system. Composite body panels. Onboard solar. Supply chain transparency.	10
3. CARMAKERS 'POLICY POSITIONS (up to 25 points)	**All EV date**	Indicative of transport sector decarbonisation leadership. Public commitment to end production of ICE cars by year.	**5**	All EV company	5
	Decarbonisation date	Corporate carbon neutral or net zero target date. Indicative of transport sector decarbonisation leadership.	**5**	?	0
	Fuel efficiency standards	Indicative of transport sector decarbonisation leadership. Public support for introduction of strong and mandatory fuel efficiency standards in Australia.	**5**	NA	0
	Life cycle analysis	The most comprehensive way to compare the environmental impacts of EVs with ICEVs and between EVs.	**5**	?	0
	Supply chain	Evidence of supply chain transparency, responsible sourcing and renewable energy generation - eg, by using blockchain to trace compliance	**5**	?	5
	Greenwashing and bad faith (aka FUD)*	GW: Evidence that manufacturer has misled the public regarding the environmental impacts of their (or other companies') vehicles BF/FUD: Evidence that manufacturer has undermined the transition to full EVs	**−5**	No	0
TOTAL SCORE			**100**		87.5

* FUD = fear, uncertainty and doubt

RESULTS

Note: due to the inevitable subjectivity involved in weighting the various criteria, readers are advised to regard cars which are only separated by a point or two as effectively receiving a similar result.

Summary of scores (out of 100)

Tesla Model 3 Rear Wheel Drive	73
Tesla Model Y Rear Wheel Drive	68
Volvo EX30 Plus Pure Electric	67.5
Polestar 2 Standard Range Single Motor	62
Volvo XC40 Recharge Pure Electric	55
Volvo C40 Recharge Pure Electric	55
Hyundai Ioniq 6 Dynamiq	54
Fiat 500e La Prima	50.5
Nissan Leaf	48.5
Mini Electric	48.5
CUPRA Born	48
Kia Niro S	48
Mercedes-Benz EQA 250	46
Peugeot e-2008 GT	45.5
GWM Ora Standard Range	45
BYD Dolphin Dynamic	43
BYD ATTO 3 Standard	41
MG4 Excite 51	40.5
Kia EV6 Air	39
BMW iX1 xDrive30	39
Hyundai Ioniq 5 Dynamiq	36.5
MG ZS EV Excite	35.5

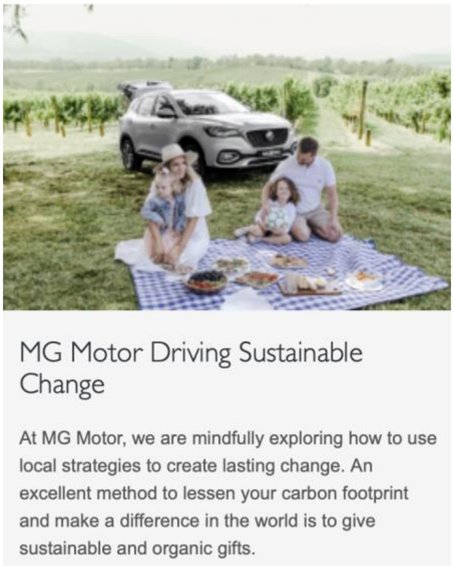
While there are significant differences in the scores attained on a range of environmental criteria by the 22 cars and their makers studied, even the lowest scoring EVs in this guide are still likely to significantly out-perform their nearest ICE equivalents—even when charged only from relatively dirty (ie, majority fossil fuel generation) grid power. (We can be sure about this because Volvo, BMW and Mini have published LCA results which directly compare the EV and ICE versions of the same car.)

On the other hand, even the highest ranked cars are a long way short of being carbon neutral, so every maker still has a lot of work to do to produce cars which do not have a net detrimental impact on our biosphere.

It is unsurprising but fortunate, from an environmental perspective, that the two cars at the top of the ranking table are also the top two sellers in Australia in 2023. While the Tesla Model 3 and Model Y are by no means new models, they lead the field environmentally as well because of their excellent energy efficiency and their mainstreaming of innovative technologies like heat pumps and LFP batteries, all backed up by Tesla's strong commitment to improving battery chemistry, streamlining the manufacturing process. Tesla also appears to be ambitious and genuine in its commitment to decarbonising the energy sector and encouraging a circular economy globally.

That said, even Tesla could do better. Its life cycle analyses are difficult to compare with other car makers (even though its critiques of theoretical or lab test methodologies have some validity). And its cars are still too big and expensive for most private buyers, even if the whole of life cost (total cost of ownership) is comparable with ICE equivalents at worst, or even net positive for its EVs.

What is perhaps more surprising is the fact that Volvo and its offshoot Polestar are nipping at Tesla's heels on our scoring metrics. Volvo is the legacy carmaker which (being relatively small and therefore nimble) has most fully embraced its responsibility to transition as fast as possible to EVs—including committing to an all-EV range in Australia, by 2026, four years ahead of the company as a whole. On the other hand, even the forthcoming EX30 small SUV, which is based on a dedicated EV platform and is significantly cheaper than Volvo's current EVs, will have an upfront cost which will still put it beyond the reach of most Australian drivers.



Then there is the curious case of Volvo's all-EV offshoot Polestar. If the Polestar 2 began life as a Tesla model 3 competitor on price as well as quality and performance, it has since crept upmarket in price, making it more unaffordable for most Australian drivers.The Polestar 2 is hamstrung somewhat by its ICE underpinnings, which impact on its energy efficiency. This downside is balanced in the scoring by the leading role in the company more broadly has taken in playing its environmental aspirations—especially in its "moonshot" goal to create a "climate neutral" production car by 2030.[53] And kudos for decreasing embodied carbon emissions by 1.2 tonnes in the 2024 Polestar 2.[54] However, its next announced EV, the Polestar 3, will have a stonking 111 kWh battery and weigh nearly 2.6 tonnes[55]—specs that belie the company's commitment to building sustainable cars.

Below Tesla and Volvo/Polestar on our leaderboard sits a group of cars from legacy carmakers which are building some good cars, but which are struggling in some respects to adapt (eg, by building their EVs on old ICE platforms, or failing to create software systems which, to use the old Apple tagline, "just work"). All of these carmakers have multi-billion dollar investments in fossil fuelled cars. This appears to have led them to be ambivalent about EVs: they are happy to make and sell them as long as it does not impact on their profits from fossil fuel cars. This has to stop. These companies are the 21st-century equivalent of tobacco companies, well aware of the contribution of fossil fuel emissions from their cars to the climate emergency, but perfectly happy continuing to produce and peddle products to consumers which they know will accelerate the crisis.

It is unfortunate that the majority of cars towards the bottom of the table are Chinese brands. Being mostly small, light and affordable, if they sell well they will make a positive contribution to the EV transition. However, they are let down by their manufacturers' failures to take seriously (at least on English language websites) their duties to transition to all-EV model ranges, to decarbonise their supply chains and own operations, and to present their cars' environmental credentials and impacts in ways which can be easily compared with those of other manufacturers. That said, BYD appears to perform better than GWM and SAIC by only selling plug-in hybrids and full BEVs, and by committing to 100 per cent zero corporate emissions by 2040.

Some of these carmakers appear to believe that they are saving the planet simply by producing EVs alongside their ICEVs. They could begin by resisting the temptation to engage in fatuous greenwashing, such as BYD calling itself the "Official Sponsor of Mother Nature" or MG giving away a bottle of organic wine and a pack of organic Earl Grey tea in a tote bag in lieu of a credible sustainability strategy.

FAQS

Why do we need this guide?

While battery electric vehicles (BEVs) produce substantially lower carbon emissions over their lifespans than equivalent vehicles with internal combustion engines (ICE) under nearly all conditions, not all EVs are born equal. We are creating a resource to help potential buyers choose the electric car that best meets their needs while having the lowest environmental impacts over its lifespan. We think that giving buyers reliable information will help them to be more confident about their potential choices, thereby helping to drive the mass adoption of EVs in Australia.

Why TEC?

The Total Environment Centre has form in the business of comparing and ranking products that claim green credentials. We created Carbon Offset Watch in 2007, and the Green Electricity Guide (with Greenpeace) in 2014.

There are some other EV guides around already, but they all have limitations for potential Australian EV buyers (see table below). This is the only Australia-specific guide that will cover the best information publicly available not only on lifecycle carbon emissions[56] and related technological advances, but also public policy issues.

Publication or website	Creator	Data	What it ranks or measures	Main differences to GECG
Green Vehicle Guide	Australian Government	2022	Scores and ranks all cars sold in Australia according to their fuel economy or energy efficiency.	Focuses on cars, not manufacturers. Includes ICE and hybrid cars. Use phase (tailpipe/electricity grid emissions) only.
Race to Zero ranking	Climate Council	2022	Ranks 12 carmakers according to their public commitments to go 100% EV by target date	Doesn't rank particular models. Focuses on one particular aspect of carmakers' decarbonisation progress.
GreenerCars Ratings	American Council for an Energy-Efficient Economy	2023	Combines carbon emissions from vehicle manufacture and use with other air pollution.	US models. Includes ICE and hybrid cars. No focus on carmakers.
Carboncounter	MIT	2023	"Cars evaluated against climate targets."	US models. Includes ICE and hybrid cars.
Bloomberg Green Electric Car Ratings	Bloomberg	2023	Ranks EV models by measuring range ÷ curb weight + battery size.	US models. Excludes carmakers' performance and affordability in scoring criteria.
Auto Environmental Guide	Greenpeace East Asia	2022	"A comparative analysis of decarbonisation efforts by global automakers"	Focuses on carmakers, not models.

Publication or website	Creator	Data	What it ranks or measures	Main differences to GECG
Automaker supply chain leaderboard	Lead the Charge	2022	Carmakers' progress in creating equitable, sustainable and fossil free EV supply chains.	Focuses on carmakers, not models. Includes human rights issues in EV supply chains.
Global Automaker Rating	International Council for Clean Transportation	2022	" [R]ates how the world's largest auto manufacturers stack up in the transition to EVs…"	Focuses on carmakers, not models. Excludes some brands sold in Australia (eg, Volvo, Polestar).
www.fueleconomy.gov	US EPA	2023	Fuel economy (tailpipe emissions or energy efficiency).	More narrow focus. US specific. Includes ICE and hybrid cars.

We don't pretend that this guide is the last word. We hope to be able to update it regularly—to add more cars, but also to improve the methodology based on feedback from users. In the meantime we will be consulting with a wide range of experts and other stakeholders[57] to ensure that our methodology is robust, comprehensive and transparent.

What about cars costing over $100,000?

There are already plenty of EV models costing over $100,000, but they sell in relatively small numbers, so they are not where the real action is needed to drive the mass electrification and decarbonisation of transport.[58] Also, they are mostly big and heavy, and contain luxury fittings and features that use precious resources for private benefit. They might be better than their ICE equivalents, but relative to investing in cheaper small cars and public transport they represent a poor use of resources. (Naturally, the same criticism could be made of big and heavy EVs costing less than $100,000.)[59]

Why only base models?

The first iteration of the guide will focus on the base version of each model, because these usually have smaller environmental footprints than luxury, dual motor "performance" or long-range versions, thanks to the latter's typically larger batteries, multiple motors, bigger wheels and increased weight. If you are interested in higher-spec variants, you could assume they would receive a slightly lower score (typically 5-10 points).

Why only new cars?

To limit the damage caused by climate change, we need to decarbonise the transport sector urgently. Alongside efforts to reduce the need for individual car ownership and use, this means electrifying cars and other light vehicles, while heavy trucks, buses and train, planes and ships may require a mix of electrification with battery storage and alternative fuels (eg, hydrogen and biofuels).

The average car is on Australian roads for somewhere between one and two decades,[60] so anyone who buys an ICE car now is effectively locking in more carbon emissions for all that time. Every new car choice is effectively a decision to help or hinder the fight against climate change.

That said, if you can't afford a new one, there are some used EVs that represent not just good value for money, but also wise environmental choices. Think small cars with small batteries and high efficiencies (the amount of energy drawn from the battery per kilometre of driving). But buying *any* used EV represents a step in the right direction, especially relative to its nearest ICE equivalents.

If you buy a used EV that has been imported, you are still effectively displacing another ICE car, so that's a good thing too. The Good Car Company is a useful place to start.

Isn't it better for the environment to keep my old ICE box going as long as possible, rather than feeding the demand for new cars?

Only if it is relatively frugal, well maintained and used as little as possible. Otherwise, the answer is probably no. To understand why, please watch this video.

Doesn't the environmental impact of an EV depend mostly on mostly on how it is driven and charged?

The carbon emissions created over the lifecycle of an ICE vehicle come mostly through the use of fossil fuels. Compared with ICE cars, and depending on how they are charged, EVs incur more of their environmental impacts in the manufacturing phase, especially because batteries are resource- and energy-intensive. We don't know where you live, how much driving you do, and your access to renewable energy to recharge. But we can point you to the most efficient EVs, so you will be ahead regardless of these other variables.

Are EVs always a better environmental choice than ICE cars over their lifecycle?

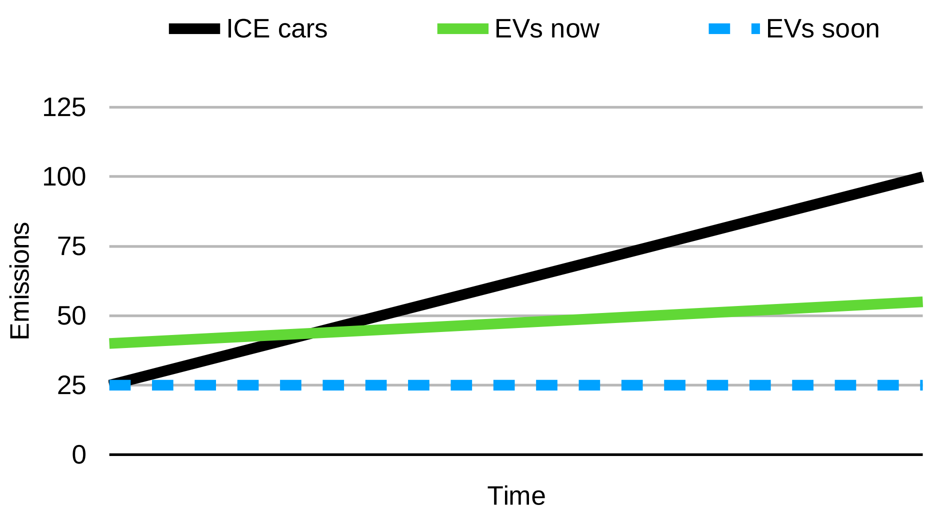
This guide is not intended to compare EVs and ICEVs, but since you asked, the answer is… in almost all cases, yes.[61] There have now been numerous reputable studies comparing the lifecycle carbon emissions from ICE versus electric cars.[62] Comparing otherwise similar cars, EVs come out ahead, even when they are recharged from a grid supplied mostly by coal and gas power stations. For instance, according to the International Council on Clean Transportation,

> …emissions over the lifetime of average medium-size BEVs registered today are already lower than comparable gasoline cars by 66%–69% in Europe, 60%–68% in the United States, 37%–45% in China, and 19%–34% in India. Additionally, as the electricity mix continues to decarbonize, the life-cycle emissions gap between BEVs and gasoline vehicles increases substantially when considering medium-size cars projected to be registered in 2030.[63]

The result is that, as the IPCC puts it, "Electric vehicles powered by low-GHG [greenhouse gas] emissions electricity have large potential to reduce land-based transport GHG emissions, on a life cycle basis (*high confidence*)."[64]

However, the higher up-front carbon cost of EVs (caused mostly by battery manufacturing) means that there is a "carbon debt" built into a new EV that needs to be repaid over time, until ICE vehicles overtake them via the carbon emissions from the ongoing consumption of petrol or diesel. Studies have shown the "break-even" point to be anything from two to five years, depending on various circumstances. Given that the average lifespan of a car in Australia is15 to 20 years,[65] in the long run EVs are a much better option—especially as renewable energy becomes the dominant form of power generation (and therefore of charging EVs) in Australia by 2030 and improvements in battery technology, make them lighter and more energy dense (see Figure 1 below).

Figure 1: Relative carbon emissions over time[66]



What about hybrids?

The accelerating climate crisis demands that we don't take half-measures that will entrench more carbon pollution for decades to come. So this guide is a hybrid-free zone.

So-called "mild hybrids" were a great idea two decades ago. Now they're just lipstick on a pig. And don't buy the hype about so-called "self-charging" hybrids. They're not. They store a bit of the copious amounts of energy that cars with petrol engines waste (mostly as heat). But those engines still burn a fossil fuel: no petrol in, no electric power out.[67]

Plug-in hybrids (PHEVs) were a great idea a decade ago. But now, it's like asking your doctor whether cutting your two pack a day smoking habit down to one pack will do the trick. PHEVs might look like a reasonable stopgap solution for driving long distances and in remote areas. But this is becoming less relevant every year, thanks to the combination of more places to fast and slow charge, and longer EV ranges. Meanwhile, you're getting the worst of both worlds. You've got a polluting vehicle with a couple of thousand moving parts that requires regular and maybe expensive maintenance, plus the dead weight of a battery. It's like carrying around an extra passenger who only pays their way for the first 50 or so kilometres per charge. Also, thanks to state governments, sooner or later you will likely pay both fuel excise and an EV road tax.[68] They aren't eligible for most government incentives. According to a recent study, their real-world fuel consumption may be far higher than advertised.[69] Lastly, by buying a plug-in ICE car today, you're locking in a car's lifetime of fossil fuel emissions. That's the last thing we need in a climate crisis.

Will the guide be kept up-to-date?

That's where you come in. The GECG is a one-off report that was created on the smell of a AAA battery. We would like to turn it into an interactive website that gets updated whenever a new model is available for sale in Australia. For that we need money. It could come from a government grant, philanthropic funding or crowd sourcing—as long as it does not jeopardise our independence and objectivity.

None of these cars gets anywhere close to a 100% score. Why?

Even the best EVs available today in Australia are far from perfect, so we need to leave room for improvement. But they are getting better all the time, thanks to technological innovations and the gradual replacement of fossil fuels by renewables to generate the electricity used to build and power them. We also hope that this guide will influence carmakers to do better. Meanwhile, we have used the forthcoming US-made Aptera[70] Launch Edition as our benchmark. This radical three wheeler features a very low drag coefficient and enough on-board solar generation capacity to theoretically power itself for everyday trips if parked for long enough in the sun. It is due to go into production later in 2023, and scores 87.5 out of 100 points.[71]

Won't a "green" EV cost more?

In the short-term, possibly, because the greener the car, the more it should internalise the costs that otherwise would be borne by society at large, such as climate change, air pollution and plastic waste. However, the more consumers vote with their wallets and support green EVs, thanks to economies of scale, the less the price difference is likely to be. EVs in general cost a fraction to maintain compared with ICE cars, and the guide's top performing EVs don't necessarily cost more to maintain than those at the bottom. Already, most EVs are cheaper from a total cost of ownership perspective than ICE equivalents. Even in Australia in mid 2023, there are now some EVs which are sticker or drive-away price comparable with ICE equivalents. The evidence to date is that EVs hold their value well in the used car market. And lithium-ion batteries are generally lasting longer than anticipated a decade ago.

How do we know the EV carmakers' claims are for real?

It's all about transparency and feedback. Initiatives such as this one aim to hold a spotlight to carmakers' environmental claims. As the saying goes, sunlight is the best disinfectant.

We also rely heavily on the years of dogged research and analysis of other climate and environmental groups, both in Australia and internationally. Hopefully we have given credit to them wherever it is due.

What about human rights issues?

Two main issues have been raised in relation to the manufacture of EVs. One concerns the use of child labour in the "artisanal" or small-scale mining of cobalt in the DRC (Congo). The other relates to the use of Uighur people as forced labour in the making of EVs in Xinjiang province in north-west China.

TEC strongly supports the ethical development of the EV industry globally. However, this guide focuses specifically on the environmental impacts of EVs. We have no human rights expertise, so leave these issues to other groups to pursue with our full support.

In relation to cobalt and other critical and rare earth minerals, *Responsible Minerals Sourcing for Renewable Energy*, while dated, is a good place to start. In relation to Uighur labour and EV, we suggest starting with Driving Force: Automotive Supply Chains and Forced Labor in the Uyghur Region. One excellent resource which tackles both environmental and human rights issues is Lead the Charge's Automotive Supply Chain Leaderboard Briefing.

In relation to cobalt specifically, it is used with nickel and manganese in the cathodes of lithium-ion batteries to increase their energy density, thereby increasing the car's range. A typical NMC battery has a cathode containing 10-20% cobalt. However, for engineering as well as environmental, human rights, safety, financial and supply chain security reasons many EV makers are seeking to reduce or eliminate the amount of cobalt in their batteries.

Or, as Polestar explains it, "Cobalt is a hard metal used to extend battery life in [EV] lithium-ion battery pack. Major risks associated with mining cobalt include forced labour and child labour, corruption, weak rule of law, high-intensity conflicts, and pollution from hazardous materials".

There are environmental concerns–especially in relation to the contamination of land and water resources–with the mining, processing and transport of a whole range of critical and rare earth minerals needed for the transition from fossil fuels to renewables across the whole economy. We hope to have the opportunity to address some of these concerns–and solutions to them–in more detail in later iterations of this guide.

ENDNOTES

[1] IPCC, AR6 Synthesis Report: Climate Change 2023, Summary for Policymakers, 25.

[2] See https://www.abc.net.au/news/2023-02-24/air-pollution-modelling-university-of-melbourne-traffic/102015778. Older studies generally show lower estimates: see, eg, Bureau of Transport and Regional Economics, Health impacts of transport emissions in Australia: Economic costs, 2005.

[3] With Greenpeace.

[4] Long range and high performance variants almost invariably score lower than base models because they include bigger, more powerful or multiple electric motors and bigger batteries. As an example, the Tesla Model Y Performance would have received a score of 57.5, in contrast to the base model's 67.5. the lower scores were for the Performance model's higher weight and lower efficiency. It narrowly avoided even lower score due to its larger battery and higher price. A similar pattern would likely be found in relation to other makes and models.

The only aspect in which higher spec models are environmentally preferable is when they use a heat pump to warm the HV battery in cold weather (and for interior heating). This typically results in an increase in the vehicle's range, because the battery is able to operate more efficiently. So where heat pumps are offered as standard or as a stand-alone option on base models, the vehicle may be more efficient (and thus score higher). But usually heat pumps are part of a package that includes more electric motors and bigger batteries, reducing their efficiency and thus their score. Tesla appears to be the only manufacturer which includes heat pumps as standard in the base models of its cars available in Australia.

[5] Chart from Bloomberg's + Green newsletter, 22 July 2023.

[6] This figure is from the US, but Australia is likely to be similar.

[7] The 2023 edition of the IEA's annual Global Electric Vehicle Outlook shows that more than 10 million electric cars were sold worldwide in 2022 and that sales are expected to grow by another 35% in 2023 to reach 14 million.

[8] See see https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-gas-inventory-quarterly-update-sept-2022.

[9] See https://www.theguardian.com/australia-news/2023/mar/28/rise-of-fuel-guzzling-suvs-costing-australians-13bn-extra-at-the-pump-per-year-report-finds?CMP=share_btn_link.

[10] See, eg, https://www.theguardian.com/australia-news/2023/mar/28/rise-of-fuel-guzzling-suvs-costing-australians-13bn-extra-at-the-pump-per-year-report-finds?CMP=share_btn_link and https://australiainstitute.org.au/wp-content/uploads/2023/03/P1371-In-reverse-The-wrong-way-to-fuel-savings-7.4.pdf.

[11] See Greenpeace's Auto Environmental Guide 2022 and Lead the Charge.

[12] Data on car lifespans is difficult to obtain, especially when it is often confused with the average age of vehicles on the road.

[13] https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/latest-release#key-statistics

[14] https://www.ptua.org.au/myths/efficient/

[15] According to the National Transport Commission, in 2021 the "Average emissions intensity for passenger cars and light SUVs was 146.5 g/km." That equates to approximately 1 kg CO2e every 7 km. According to the ABS, the average distance travelled per year by passenger cars was 11,100 km in 2021.

[16] The conglomerate comprising Fiat, Chrysler, Peugeot and Citroen.

[17] BYD is not in this list because it is a special case. It now manufactures only hybrids and battery EVs, but it does not appear to have set a target date for going all-EV.

[18] https://www.unimelb.edu.au/newsroom/news/2023/february/vehicle-emissions-may-cause-over-11,000-deaths-a-year,-research-shows

[19] At present, Polestar is the only carmaker that has publicly announced such a goal and appears to be genuinely working towards it.

[20] Noting that ISO 14067 is a methodology, not a benchmark.

[21] We would welcome feedback on what other features would increase longevity, and whether or it would be useful to set a goal – e.g. 15 or 20 years.

[22] See https://en.wikipedia.org/wiki/Circular_economy.

[23] Noting that Cd figures alone can be misleading. As one Australian reviewer of this report noted in relation to the difference aerodynamic efficiency between the Tesla Model 3 and Y, "The Model 3 is lighter and has less air to push out of the way. So it needs less energy than the Model Y to achieve the same thing. Sure, the 3 and Y share the same aerodynamic drag coefficient of 0.23, but there's a taller, wider body in the Y. So even though its shape is slippery it's having to shift more air. Between them it means the 3 will travel further between charges."

While Cd figures are readily available, one reviewer of this guide commented that "…Cd on its own can be misleading; what really matters is Cd x A, where A is the frontal area of the vehicle. Manufacturers like to advertise their Cd, but keep quiet about the frontal area. The real problem here is the trend away from hatchbacks and sedans to so-called SUVs. An SUV will usually have terrible drag, no matter how the manufacturer tries to spin it."

[24] A third battery chemistry used in some EVs is nickel-cobalt-aluminium (NCA), but it does not appear to be found in any of the new cars currently sold in Australia. Emerging chemistries include sodium-ion and M3P.

[25] All current BEV anodes are graphite. However, silicon-based anodes are coming: see here.

[26] Cobalt mining has become a lightning rod for opponents of EVs, despite its use in the manufacture of mobile phones, computers, and internal combustion engines. Also, some EV manufacturers are using NMC batteries with low cobalt concentrations. There appears to be a strong industrywide push to reduce or eliminate cobalt from EV batteries.

[27] Europe has mandatory tyre labelling that includes rolling resistance. Finding tyres with A-rated rolling resistance in Australia is difficult. Also, low rolling resistance tyres may also have reduced road grip.

[28] See, eg, this article on particulates from EV and ICE brake and tyre wear.

[29] If you charge your EV from your rooftop solar, note that unless you install extra to cover your EV load, you are reducing the amount of renewable energy available to the grid. If you buy grid electricity for overnight charging, it's best to buy from a retailer, which guarantees that all their sales to consumers come from renewable energy generators: see www.greenelectricityguide.org.au for more info.

[30] About 11 percent comes from cars: see https://www.climatecouncil.org.au/wp-content/uploads/2017/09/FactSheet-Transport.pdf.

[31] ISO 14040::2006, Environmental management — Life cycle assessment — Principles and framework; ISO 14044, Environmental management — Life cycle assessment — Requirements and guidelines; or ISO14067:2018, Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification.

[32] See, eg, the Volvo C40 Recharge LCA report, Figure 5.

[33] BMW and Mini have published only their LCA results as a comparison with the equivalent ICE models. [33] TEC does not currently have the resources to independently assess the veracity of carmakers' LCAs. For this first iteration, we are excepting the voracity of carmakers' LCA data and conclusions.

[34] Eg, see this critique of the Polestar 2 LCA: https://insideevs.com/news/458458/legacy-automakers-backed-study-against-evs-debunked/ Curiously, the critique works in favour of the Polestar (in that it reduces the carbon payback point from 78,000 km to 25,000 km) but against former parent company Volvo's XC40 ICE (due to the substantially higher carbon emissions per kilometre attributed to the XC40 ICE by Auke Hoekstra, EV researcher at TU Eindhoven).

[35] See Tesla's 2021 Impact Report, Environmental Impact. Tesla reports the outcomes of its Model 3/Y LCA in gCO2e/mile for various use cases in the US and Europe, which are not directly comparable to the tCO2e used in ISO 14067.

[36] The term *manufacturing phase* is something of a misnomer, since the building of a car in a factory mostly consists of assembling parts which have been manufactured elsewhere, and is a relatively low source of emissions. The majority of emissions in this phase are caused by the mining, processing and transport of raw materials.

[37] The term *end-of-life phase* is something of a misnomer. In a circular economy, there is no such thing as end of life, rather a combination of reuse and recycling. This is one more place where EVs perform significantly better than fossil burners, because the latter become an economic to repair at some point. By contrast, Tesla says it is aiming to produce “million mile” batteries.

[38] See, eg, Tesla’s 2021 Impact Report, 67.

[39] Naturally, there are caveats here—-eg, because a car that is not at home when the power from its battery is needed to supply power during the evening peak.

[40] As one reviewer of this guide explained, “The reason LiFePO4 batteries need to be heavier is not because they are less efficient, but because they store less energy for a given weight. This is called the specific energy, commonly but incorrectly also called the ‘energy density’.”

[41] On the other hand, “Motors without permanent magnets, such as induction motors, use electric current, often with copper wiring, to create a magnetic field and power the motor. These are cheaper, but less efficient and require a larger battery, reducing the driving range”: https://www.reuters.com/business/autos-transportation/automakers-cutting-back-rare-earth-magnets-2021-07-19/ Eliminating rare earths usually means using more copper. EVs with 2 motors often have a permanent magnet motor on the rear axle and an electric induction motor on the front axle. To further complicate matters, some manufacturers are introducing permanent magnet motors that do not contain any rare earths: see, eg, Tesla’s 2023 Investors’ Day presentation, from ~58 minutes in. That applies to Tesla’s next power train, so does not affect cars sold in Australia in 2023.

[42] Heat pumps are often a feature of the most expensive EV variants, but are relatively rare on base models.

[43] Noting that onboard solar can only make a relatively minor contribution. especially on big, heavy cars.

[44] Polestar has taken this one step further and is aiming to produce a fully carbon neutral car by 2030. We have not recognise this laudable goal in the scoring because so far it is a one off (ie, no other carmaker has a similar objective, although we hope that changes soon.

[45] This is shorthand for “cradle to gate” phase—ie, raw materials mining, processing and transport as well as the actual manufacturing factory emissions (which are relatively minor).

[46] Eg, by creating a responsible sourcing program based on the OECD Due Diligence Guidance for Responsible Mineral Supply Chains (see Tesla’s 2021 Impact Report, Supply Chain.

[47] FUD: fear, uncertainty, and doubt: see https://en.wikipedia.org/wiki/Fear,_uncertainty,_and_doubt.

[48] Eg, BYD’s prominent but ludicrous claim on its Australian website that it is the “Official sponsor of Mother Nature”.

[49] See, eg, https://thedriven.io/2023/03/06/toyota-could-face-50-million-greenwashing-fine-after-referral-to-consumer-watchdog/

[50] See, eg, Volvo Cars, Carbon footprint report: Battery electric XC40 Recharge and the XC40 ICE, no date, figure 5, 24.

[51] See, eg, https://m.facebook.com/theguardian/posts/the-fud-fear-uncertainty-and-doubt-around-electric-cars-is-significant-but-is-it/10157779267886323/?locale=ms_MY .

[52] For an introduction to greenwashing in Australia, see this 2023 report by the ACCC.

[53] https://www.polestar.com/au/sustainability/climate-neutrality/polestar-0-project/

[54] https://media.polestar.com/ca/en/media/pressreleases/665846/polestar-reduces-relative-co2-emissions-by-eight-percent-in-continued-efforts-to-decouple-business-g

[55] Source: EV Database.

[56] What we *don't* cover is the projected carbon impacts of how an EV is recharged and driven, because that depends on where you live and how you drive and recharge.These will vary from person to person. But we can arm you with information that can you help to reduce your impact for any given location and driving and recharging pattern by choosing the best car for your needs that has the lowest relative emissions and other environmental impacts.

[57] Including: the EV Council, AEVA, EVChoice, Climate Council, NRMA, CHOICE and the Good Car Co.

[58] Noting that new technologies are often trialled first in expensive cars before they make their way into more affordable models.

[59] See, eg, https://www.nytimes.com/interactive/2023/02/17/climate/electric-vehicle-emissions-truck-suv.html?

[60] This is a rough, anecdotal guesstimate based on other countries' data, given the Apparent absence of relevant local data. Note that a car's lifespan is quite different to the average age.

[61] If you were desperate to disprove this argument, you could compare, say, a Toyota Yaris hybrid with a Hummer EV and conclude that the former has lower life cycle emissions than the latter if it is charged from a very dirty grid. But this is not a realistic comparison, since nobody would actually buy one or other of these vehicles depending on their relative carbon emissions. Such extreme comparisons are the exception that proves the rule.

[62] See, eg, MIT Energy Initiative: Insights Into Future Mobility, November 2019; MIT Climate Portal, Are electric vehicles definitely better for the climate than gas-powered cars? ; International Council on Clean Transportation, Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions, 2018.

[63] https://afdc.energy.gov/vehicles/electric_emissions.html.

[64] IPCC, AR6 Synthesis Report: Climate Change 2023, Summary for Policymakers, 30.

[65] This figure is anecdotal and approximate because hard data on average car lifespans in Australia are hard to come by. Commentators often mistake average age for average lifespan.

[66] The y-axis starting point of the dotted green line assumes that the average manufacture-phase emissions of an EV's lifecycle will gradually drop due to the increasing use of recycled, smaller and lighter components and renewable energy. The trajectory of the green dotted line reflects the increasing use of renewable energy to charge EVs. The green line is likely to pan out in the early 2030s in high-EV countries, but later in recalcitrant fossil fuel-dominated countries.

[67] That said, Toyota's "Hybrid Synergy Drive" (HSD) system, as used in the Prius and other Toyota hybrids, does have its fans. One reviewer of ann early draft of this guide called HSD "the ultimate development of the ICE drivetrain before ICEs became obsolete".

[68] To date, only in Victoria, but planned to be introduced in NSW in 2027.

[69] See media reports on 3 such studies since 2019 here: https://www.theguardian.com/environment/2023/feb/08/major-plug-in-hybrid-cars-pollute-more-than-official-measures-suggest; https://www.theguardian.com/business/2020/feb/02/car-industry-could-see-price-war-on-hybrid-vehicles-in-2020-emissions-fines and https://www.theguardian.com/business/2021/mar/02/plug-in-hybrid-cars-burn-more-fuel-than-tests-record-says-which.

[70] https://aptera.us/

[71] The Aptera dos not comply with Australian Design Rules (it's too wide), so in its current form could not be sold in Australia. Nevertheless, it constitutes an excellent example of what is possible beyond the current crop of available models. For another, very different take on what a more sustainable EV might look like, check out the Citroen Oli (which unfortunately is only a concept car).