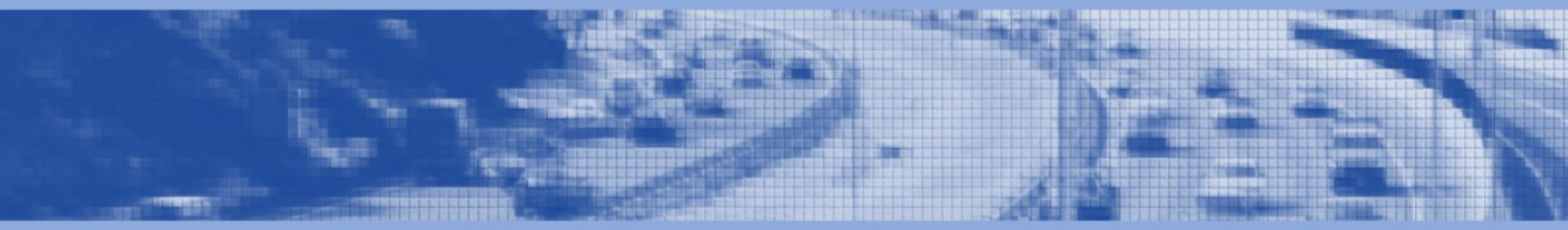

Do battery electric cars significantly increase average fleet mass? Unlikely.

Transport Emission Energy Research

Transport Emission Energy Research

Transport Energy/Emission Research Pty Ltd (TER)

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Table of Contents

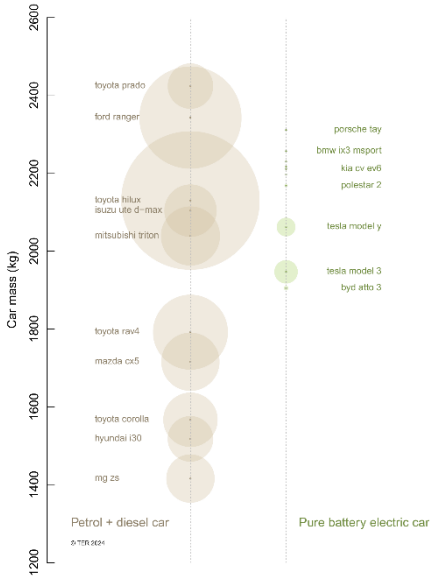
Executive summary

Statements have been circulating on the internet and in the (social) media that battery electric cars will cause a large increase in the average mass of the on-road fleet, and used as an argument against battery electric (BE) cars. The stated reason is generally that electric car batteries are heavy, thereby increasing overall vehicle mass. This is relevant since a larger vehicle mass will reduce energy efficiency, increase emissions, reduce traffic safety and impact on parking spaces and potentially roads.

The problem is that these statements often oversimplify a complex reality and tell only part of the story, which can be misleading. For instance, the fact that fossil-fuelled (petrol, diesel, LPG) internal combustion engine (ICE) cars have also consistently increased their mass over time (car obesity) is often ignored. Similarly, these statements pretend to know how complex consumer behaviour will respond to future availability of battery electric cars and their fast changing and improving specifications. This report has identified four points of contention:

- There are different ways to define and compare vehicle mass – In practice, different methods are used to compare the mass of battery electric and combustion engine cars, the choice of which is arbitrary and will affect the results. This includes the actual definition of vehicle mass. The comparison may neither be adequate nor accurate.
- It is not only the battery that matters – The commonly used argument is that batteries are heavy and, as a consequence, electric cars are heavier than fossil-fuelled cars. This simplifies the discussion because the actual additional battery mass depends on a range of factors such as battery chemistry, battery size and energy storage capacity (drive range). Moreover, other parts of the electric car are smaller and lighter, which can reduce mass up to 50%.
- Car obesity has significantly and consistently increased ICE car mass – it is critical and fair to include increased car obesity for fossil-fuelled combustion engine cars in the comparison with battery electric cars, otherwise it only tells half the story.
- It is challenging to accurately predict the future mass impacts of electric cars – An assumption is often that future vehicle purchasing behaviour does not change when switching to battery electric cars. This seems unlikely and oversimplifies the comparison. For instance, market availability, purchase price and performance characteristics will largely guide purchase decisions, all of which are currently highly dynamic, and undergoing significant and rapid change.

As an alternative approach, this TER study compared the differences in vehicle mass – defined as mass in running order, adjusted for average vehicle occupancy - between the Top 10 most sold battery electric and diesel or petrol combustion engine cars in the Australian market in 2022, as shown in the Figure on the right.[1]



[1] Section 3 (page 6) shows a larger version of this chart.

The sales data show that current sales of battery electric cars cluster more at the heavy vehicle end, but that the most popular BE cars are relatively light. The sales of fossil-fuelled cars have a larger spread in mass, but in contrast to battery electric cars, most of them are relatively heavy SUVs or Utes. When ranked by popularity and compared, battery electric cars can be almost 300 kg (12%) lighter to almost 800 kg (55%) heavier than the corresponding ICE passenger car. As a consequence, the difference in the sales-weighted Top 10 fleet average mass between BE and ICE cars is just 68 kg, or only 3%. This small difference is insignificant in terms of energy and emission impacts, particularly in the light of the superior energy efficiency of battery electric vehicles.

It is, of course, clear that the current sales profile may not be representative of a future sales profile, since it may currently be largely defined by a certain type of customer (e.g. high-income early adopter) and may not be representative of mainstream consumers in coming years. Future purchasing behaviour is uncertain and challenging to predict and would critically depend on (new) policy measures, the actual vehicles offered for sale by vehicle manufacturers and possibly also cultural changes. Any shifts in purchasing behaviour have the potential to significantly impact on fleet average mass. They could continue the current trend towards larger and heavier vehicles or there could be a shift towards smaller and lighter vehicles (light-weighting).

But this is the point: the impacts of electrification of passenger vehicles on average mass are highly uncertain. In markets where car sales are dominated by heavy petrol and diesel combustion engine vehicles, such as Australian and New Zealand, the evidence suggests that a significant increase in average vehicle mass due to increased sales of electric cars is unlikely. In fact, average mass could actually go down, for instance, when cheaper and lighter BE cars become available on the Australian market.

This report is not downplaying the importance of vehicle mass in the transport emissions debate. TER estimated that only an on-road passenger vehicle fleet that is dominated by small and light battery electric vehicles may get Australia close to achieving the net zero target in 2050. To meet the net zero target in 2050 and reduce emissions, it is thus important to arrest and reverse the ongoing trend of increasing car obesity, for both ICE and BE cars.

1. Introduction

Vehicle mass[2] is one of the most important variables that affect energy efficiency, fuel consumption and emissions, particularly in urban driving conditions with frequent stops, decelerations and accelerations.[1]

Statements have been circulating on the internet and in the (social) media that battery electric cars will cause a large increase in the average mass of the on-road fleet, and then used as an argument against battery electric cars.[2,3,4,5] The stated reason is generally that electric car batteries are heavy, thereby increasing overall vehicle mass. Battery mass is relevant because a heavier vehicle mass will reduce energy efficiency, increase emissions, reduce traffic safety for people and animals outside the vehicle (i.e. increase crash fatality risk) and impact potentially on parking spaces and roads.[2]

The problem is that these statements oversimplify a complex reality and tell only part of the story, which can be misleading. This TER report will therefore take a closer look at this topic. Section 2 will identify and unpack four points of contention in relation to the vehicle mass debate. Section 3 will present an alternative way of comparing battery electric (BE) and internal combustion engine (ICE) cars (petrol, diesel, LPG). Finally, Section 4 will briefly discuss the importance of reducing vehicle mass in the emission reduction debate.

2. Points of contention

2.1 There are different ways to define and compare vehicle mass

There are different definitions of vehicle mass, for instance tare mass, kerb mass, mass in running order and gross vehicle mass [6], and the definition used in a technology comparison is not always clear but matters to the results.

Moreover, comparing battery electric (BE) and fossil-fuelled (diesel, petrol, LPG, CNG) internal combustion engine (ICE) cars is not as straight-forward as it sounds, because electric cars do not fit well into conventional ICE car classification schemes.[7]

One approach is to look at current and past vehicle sales. Often the comparison is made between battery electric cars and similar or similarly sized internal combustion engine cars.[2,3,4] Similarly, BE cars can be allocated to specific ICE market segments, for instance using power output, and then compute the difference in average mass.[8] Or BE cars can be compared only to an equivalent non-electric ICEV version (e.g. VW Golf vs. VW e-Golf or Hyundai Kona).[5,7] Another variation is to simply compare the (average) mass of a large range of BE and ICE cars currently on sale, but without considering the relevant impact of sales volumes.[9] Sales volumes are important, affect the results and cannot be left out. Section 3 will show an alternative way of comparing mass using sales volume data as well.

[2] Mass and weight may seem like the same thing, but in fact they describe different physical properties. **Mass** is the amount of matter in an object and expressed as kilograms, whereas **weight** is the force exerted on an object's matter by gravity and expressed as Newtons. In common usage, the mass of an object is often referred to as its weight. However, in this report the proper term will be used: vehicle mass.

Other scientific studies base conclusions on specific assumptions about the make up of the future electric car fleet and subsequent changes in vehicle mass. For instance, one study assumes that a new wave of large, heavy, high-powered EVs will come into production, noting as an example the all-electric 4.5 tonne "supertruck" the EV Hummer.[10]

The issue is that in all these cases the choice of method and allocation is arbitrary and the mass definition may be unclear, so the comparison may neither be adequate nor accurate.

The main underlying assumption is often that vehicle purchasing behaviour does not change when switching from ICE to BE cars. This seems unlikely, as will be discussed later. For instance, market availability, purchase price and performance characteristics (e.g. rated power, fuel/energy use) will largely guide purchase decisions. These aspects are currently highly dynamic, and undergoing significant and rapid change.

It is thus quite possible that ICE car owners would buy a BE car in a different vehicle class. This would then also lead to a different impact on fleet average vehicle mass.

2.2 It is not only the battery that matters

The argument used in the media is generally that batteries are heavy, and, as a consequence, electric cars are heavier than fossil-fuelled cars. This simplifies the discussion because the actual additional battery mass depends on a range of factors such as battery chemistry, battery size and energy storage capacity (drive range). Indeed, battery mass generally varies between 100 and 900 kg for cars.[11]

But that is not the whole story. Electric car motors are smaller and lighter than an internal combustion engine, and in particular lighter than relatively heavy diesel engines. Moreover, EVs replace traditional components with light-weight materials. High-strength steel, magnesium alloys, aluminium alloys, carbon fibre and polymer composites can allow the mass to be reduced up to 50%.[11]

The general conclusion from overseas studies is that BEVs are typically about 10-25% heavier (about 200-300 kg) than ICEVs, due mainly to the mass of the battery.[5,7,8] This, however, misses an important aspect that also applies to ICE cars: car obesity.

2.3 Car obesity has significantly and consistently increased ICE car mass

Car obesity refers to the sustained and increasing proportion of large and heavy passenger vehicles (SUVs, Utes) in on-road fleets around the world, including Australia. These vehicles generally have a detrimental effect on energy efficiency and greenhouse gas emissions and lead to substantial emission abatement loss. SUVs and Utes are larger and heavier than conventional passenger cars and the laws of physics dictate they need more energy and fuel per kilometre of driving, when compared with smaller and lighter vehicles.

TER estimated that on-road fleet-average CO_2 emissions rates (g/km) for Australian new ICE passenger vehicles have hardly improved since 2015, and may have actually increased by a few percent each year since 2015. A sustained increase in vehicle mass and a shift to the sale of more four-wheel-drive cars (in other words, SUVs and large Utes) were found to be the main factors contributing to this trend.[12,13]

It is thus critical and fair to include increased car obesity for ICE cars in the comparison with BE cars, otherwise it only tells half the story.

A previous TER study in 2020 found that both Australian diesel cars and SUVs are significantly heavier than their petrol counterparts, and that this mass difference is increasing, up to 500-600 kg (about 30-40%) in more recent years. In contrast, Australian BE cars were found to have similar mass to their petrol counter parts, although the fleet average results varied by year of manufacture. Australian diesel cars were on average about 25-30% heavier than Australian BE cars.[7]

2.4 It is challenging to accurately predict the future mass impacts of electric cars

A like-for-like method to simulate future BE car adoption seems – at first sight- reasonable. This approach assumes, for instance, that future customers who would have traditionally bought a small and energy efficient ICE car, would instead buy a similar small BE car. Similarly, a future customer who would normally purchase a large ICE sport utility vehicle (SUV), would instead buy a large BE SUV.

However, future purchasing behaviour is uncertain and challenging to predict. It will critically depend on (new) policy measures, the actual vehicle range offered for sale by vehicle manufacturers (costs, performance, …), marketing efforts by vehicle manufacturers and possibly also cultural changes.

Any shifts in purchasing behaviour have the potential to significantly impact on fleet average mass. They could continue the current trend towards larger and heavier vehicles or there could be a shift towards smaller and lighter vehicles (light-weighting).

But the key message is: we do not really know this in a rapidly changing environment.

3. An alternative comparison

Given the rapidly changing availability of BE cars and their improving specifications, an estimate of the future differences in mass between BE and ICE cars is speculative at best. What we can do is compare the most popular makes and models that are sold now.

TER recently developed a new bespoke tool that simulates the impacts of different design options for the New Vehicle Efficiency Standard (NVES tool).[14] It included the development of an associated input data file for vehicle model year (MY) 2022, using publicly available data and information. The MY 2022 input file was used to assess the differences in vehicle mass between the Top 10 BE and ICE cars sold in the Australian market in 2022.

In this comparison vehicle mass is defined as ‘mass in running order’ or MIRO, but adjusted for average vehicle occupancy. Mass in running order is defined as the mass of the vehicle, with its fuel tank filled to at least 90 per cent of its capacity, including the mass of one driver, fuel and liquids, fitted with the standard equipment in accordance with manufacturer specifications and, when they are fitted, the mass of the bodywork, the cabin, the coupling and the spare wheel(s) as well as the tools. The average occupancy in Australia is taken as 1.6 passengers per vehicle.[15]

The input file includes total sales numbers by make and model, as well as adjusted MIRO (kg). The comparison between the Top 10 most sold new BE and ICE cars in the Australian market in 2022 is shown in Figure 1 and in Table 1.

Figure 1 shows that current BE sales generally cluster more at the heavy vehicle end, with most passenger vehicles being SUVs, except for two cars (Polestar 2 and Porsche Taycan). However, the most popular BE cars (Tesla model 3 and model Y) – as shown with the size of the circles – are relatively light when compared with the other BE passenger vehicles. In comparison, the sales of ICE cars are more spread out in terms of vehicle mass. But in contrast to battery electric cars, most fossil-fuelled passenger vehicles sold are relatively heavy SUVs or Utes with only a few cars (Toyota Corolla and Hyundai i30).

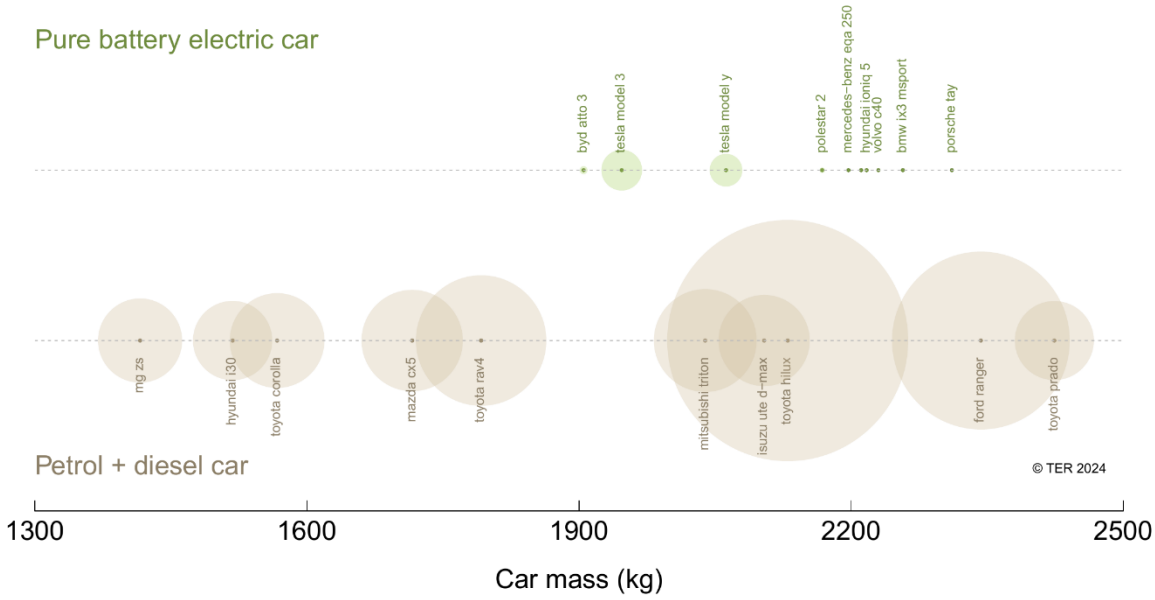


Figure 1 – Mass of the Top 10 most popular new battery electric (top) and fossil-fuelled internal combustion engine (bottom) passenger cars sold in the Australian market in 2022. The size of the circles represent relative sales volumes. The largest circle for ICE cars is the Toyota Hilux with 64,391 units sold. The largest circle for pure BE cars is the Tesla Model 3 with 10,877 units sold.

Table 1 shows the sales volumes that were used to create Figure 1 and also shows the mass difference between BE and ICE cars of similar rank. If the sold vehicles are ranked by popularity, the comparison suggests that BE passenger cars can be almost 300 kg (12%) lighter to almost 800 kg (55%) heavier than the corresponding ICE passenger car.

Table 1 – Comparison of the Top 10 annual sales (2022) and mass difference between battery electric (BE) and fossil-fuelled internal combustion engine (ICE) cars, ranked by popularity.

Top 10 ranking	Make/model		Annual sales 2022		Mass (kg)
	BE	ICE	BE	ICE	Difference
1	Tesla Model 3	Toyota Hilux	10,877	64,391	-183
2	Tesla Model Y	Ford Ranger	8,717	47,479	-281
3	BYD Atto 3	Toyota RAV4	2,113	34,845	113
4	Polestar 2	Mitsubishi Triton	1,480	27,436	129
5	Hyundai Ioniq 5	Mazda CX5	756	27,062	501
6	BMW ix3 Msport	Toyota Corolla	593	25,284	690
7	Kia CV EV6	Isuzu Ute D-max	564	24,336	107
8	Mercedes-Benz Eqa 250	MG ZS	547	22,466	781
9	Volvo C40	Hyundai i30	491	21,166	712
10	Porsche Taycan	Toyota Prado	428	21,102	-113
			26,566	315,567	68

This shows that BE cars do not necessarily have to be heavier than ICE cars in all cases. ICE cars can be heavier.

Of specific interest is the sales-weighted fleet-average mass (Top 10), which is included at the bottom of Table 1. The overall mass difference between electric and ICE cars is just 68 kg or 3%. This small difference is caused by the dominating sales of heavy fossil-fuelled SUVs and Utes, as was shown in Figure 1. In terms of emission impacts, this small overall difference in mass between new Australian BE and ICE cars is insignificant, particularly in the light of the superior energy efficiency of battery electric vehicles.

As mentioned before, it is, of course, clear that the current sales profile may not be representative of a future sales profile. Current sales may, for instance, be largely defined by a certain type of customer (e.g. high-income early adopter) and may not be representative of mainstream consumers in coming years.

But this is the point: the impacts of electrification of passenger vehicles on average mass are highly uncertain. In markets where car sales are dominated by heavy combustion engine vehicles, such as Australian and New Zealand, the evidence suggests that a significant increase in average vehicle mass due to increased sales of electric cars is unlikely. In fact, average mass could actually go down, for instance, when cheaper and lighter BE cars become available on the Australian market.

4. The importance of vehicle mass in greenhouse gas emission reduction

This report is not downplaying the importance of vehicle mass in the transport emissions debate.

A TER study in 2023 estimated that Australia will fall short of the net zero target, with a reduction of total greenhouse gas emissions from Australian transport in 2050 of only 35% to 45%, depending on the dominant hydrogen production pathway.[16]

This means that significantly more intensified and far reaching policies need to be developed and implemented if net zero is to be achieved in 2050. It was concluded that a combination of electrification and light-weighting of road transport appears to be the most effective and robust way forward. The simulation suggests that an on-road passenger vehicle fleet in 2050 that is dominated by small and light battery electric vehicles may get Australia close to achieving the net zero target.

To meet the net zero target in 2050 and reduce emissions, it is important to arrest and reverse the ongoing trend of increasing car obesity, for both ICE and BE cars.[16]

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