Australia's National Science Agency

Electric vehicle projections 2022

Commissioned for AEMO's draft 2023 Input, Assumptions and Scenarios Report

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Acknowledgments

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Executive summary

This report updates CSIRO's projections of electric vehicle uptake and their daily charging patterns. It has been commissioned as an input to AEMO's various planning and forecasting tasks. This update is occurring around 18 months since CSIRO produced its previous electric vehicle projections in May 2021. The key changes are:

1. Stronger uptake before 2030
2. The assumed demand at peak for household charging has decreased
3. Charging is higher on weekends
4. Time of use charging behaviour has been updated
5. Public or fast charging behaviour has also been updated

Since the 2021 projections the most significant market development has been a proliferation of stronger state and commonwealth electric vehicle policies – in particular, 2030 targets of around 50% sales and state subsidies of $3000-$3500 and Commonwealth subsidies of $8000-$12000 in the form of fringe benefit tax exemptions for electric vehicles. The new policies began with a New South Wales announcement in June of 2021. Generally stronger climate policy settings are also reflected in revised AEMO scenarios that incorporate the revised nationally determined commitment of Australia to a 43% reduction in emissions by 2030.

It is also significant that electric vehicles have increased their rate of growth in sales in Australia while the global vehicle market has been otherwise contracting in the past few years. It has been possible to get clearer insight into electric vehicle sales in Australia with improved data from the Electric Vehicle Council (EVC) and Federal Chamber of Automotive Industries (FCAI). This data set already shows those states with subsidies experience the strongest growth.

As a result of the timing of the previous report, the new policies, improved data and scenarios with stronger climate policy settings, electric uptake projections in the short term have substantially increased in the period to 2030. We do allow for the possibility of both exceeding and falling short of the state electric vehicle sales targets. However, even those scenarios which fall short of the new state targets are higher than their nearest scenario in the2021 projections, reflecting that uptake has increased across the range before 2030.

In contrast, the projected number of electric vehicles by 2050 and their associated consumption levels are projected to be similar to the 2021 projections. We continue to provide a range of timings for the almost complete replacement of internal combustion vehicles between 2045 and 2065. While governments will play a role in this outcome through sales bans such as that announced in other countries and locally in the Australian Capital Territory by 2035, it is also expected that the global vehicle manufacturing, maintenance, and refuelling industries will not indefinitely maintain support for internal combustion vehicles. This eventual withdrawal of commercial services for internal combustion vehicles is a potential source of accelerated retirement of the internal combustion vehicle fleet (and conversely accelerated sales of electric vehicles).

Previous data on the charging behaviour of electric vehicles was based on Australian trials from more than five years ago and adapted overseas data. However, the past 18 months has resulted in the publication of electric vehicle trial data by Origin Energy, Energex and Ergon networks, University of Queensland and the Electric Vehicle Council. The new data has resulted in four new charging insights:

Utilising this new data, the major new insight for the convenience profile was that the charge at peak is not as strong as assumed in the 2021 data. This reflects our new understanding of household charger selection as revealed by the trials. Some trials have found that most users are relying on a standard power point which can deliver a charge of 2.3 to 3.6kW. Dedicated household chargers need to be purchased and require an electrician to install. They can deliver more charge and the previous profile was based on the assumption that most dedicated household chargers would be around 7kW. Public chargers can be even larger (up to several hundreds of kWs) but these are included as a separate item from onsite household chargers.

A second charging insight is that the 2021 projections had been expecting charging quantities to be lower on weekends because travel is generally lower. However, the opposite has proven to be true in the trial data with more charging on weekends. This appears to reflect the car having more opportunity to be charged while less in use.

The third insight is that we have more access to profiles which are responding to a time of use (TOU) signal. These were less of a focus in older trials. The new data indicates TOU profiles are more W-shaped with only brief periods of limited charging. The 2021 projections had previously designed two TOU profiles (day and night) to have longer flatter periods of limited charging.

AEMO was also able to access new data on public fast charging and provide it to CSIRO. Compared to the 2021 data which was based on traffic intensity and had two distinct peaks at morning and evening, the new data shows that public faster charging has a single drawn out peak in the middle of the day covering day light hours.

1 Introduction

Each year, AEMO requires updated projections of electric vehicle adoption and operation of electric vehicle chargers for input into various planning and forecasting tasks. CSIRO has been commissioned to provide electric vehicles projections for four scenarios: *Progressive Change*, *Exploring Alternatives, Step Change* and *Hydrogen Export*. These are described further in the body of this report.

The report focusses on battery electric vehicles, plug-in hybrid electric vehicles and fuel cell electric vehicles (BEVs, PHEVs and FCEVs). Due to differences in costs, Short and long duration BEVs are considered separately in the modelling methodology but are not separately discussed in the projections. Only electric vehicles in the on-road sector are considered. Electrification of vehicles in off-road sectors such as mining are not included. On-road vehicles include light vehicles (cars and motorcycles) owned by households or businesses as well as trucks and buses.

In calculating on-road vehicle electrification we consider the size of the road sector versus other transport modes. We also provide assumptions about the potential extent of electrification of non-road transport sectors. We calculate the electricity needed to produce the hydrogen for FCEVs but do not highlight this in the results which focus on the electricity needs of BEVs and PHEVs.

The report is set out in five sections. Section 2 provides a description of the applied projection methodology. Section 3 describes the scenarios and their broad settings. Section 4 outlines the scenario assumptions in detail and the projections are presented in Section 5.

2 Methodology

AEMO requires two different types of data projections: the number of electric vehicles and their electricity consumption. The technology types we include are:

- Battery electric vehicle (BEV) with short- and long- range variations
- Plug-in hybrid electric vehicle (PHEV)
- Fuel cell electric vehicle (FCEV)

Internal combustion vehicles are also part of the method since they represent most of the existing stock of vehicles but are not a focus of the projection results. Vehicle types included are:

- Motorcycles
- Passenger vehicles with small, medium and large sizes
- Light commercial vehicles with small, medium and large sizes
- Trucks of which there are two types: rigid and articulated
- Buses

The number of each vehicle and technology type is an essential input to calculating electricity consumption from road transport. The number of vehicles is calculated via methodologies described further below. The calculation of electricity consumption is carried out in two ways (Figure 2 1). Two methods are required because data is needed on both the total annual consumption but also shape of electricity consumption on a daily half-hourly basis. The half hourly data can be summed up to a year as a crosscheck on the annual data.

Annual consumptions is calculated by multiplying the number of vehicles by the kilometres each vehicle travels per year and its electricity consumption per vehicle per kilometre. Half hourly electricity load is calculated by multiplying the number of vehicles by the half hourly charging profiles weighted by the percentage of each profile that applies to that vehicle. Each half hourly profile is in kilowatts and the charge at any point in time is based upon various charging behaviour types and the daily distance travelled (which relates back to the annual vehicle kilometres but with come consideration of weekday/weekend and monthly variability). To aggregate the half hourly consumption to an annual consumption amount, each half hour in the year is summed up (and divided by two to convert kilowatts to kilowatt hours).

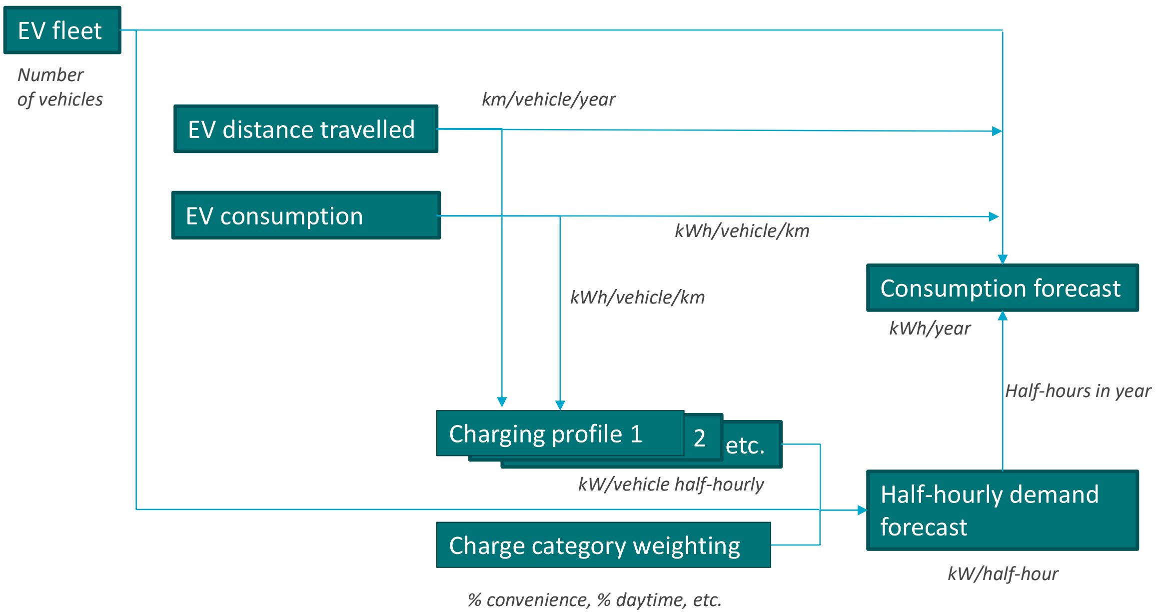

Figure 2-1 Illustration of the two ways in which electric vehicle consumption is calculated (jointly developed with AEMO).

2.1 Adoption projections method overview

The projections for the number of vehicles is provided for periods of months, years and decades. Consequently, the projection approach needs to be robust over both shorter- and longer-term projection periods. The longer-term adoption projections are based on fundamental models of relevant drivers that includes human behaviour, market behaviour as well as physical drivers and constraints. While these models are sound, long term adoption models can overlook short term variations due to imperfect information, unexpected shifts in key drivers and delays in observing the current state of the market[1]. To improve the short-term performance of the adoption models, the approach should ideally include a specific shorter-term projection approach to account for short term variations in the EV market.

Short term projection approaches tend to be based on extrapolation of recent activity without considering the fundamental drivers. These include regression analysis and other types of trend analysis. While trend analysis generally performs best in the short term, extrapolating a simple trend indefinitely leads to poor projection results as fundamental drivers or constraints on the activity will assert themselves over time, shifting the activity away from past trends.

Based on these observations about the performance of short- and long-term projection approaches, and our requirement to deliver both long- and short-term projections, this report applies a combination of a short-term trend model and several long-term models. The Consumer Technology Adoption Model and Market Retirement Models determine the share of sales. The Market Retirement model is required for scenarios where internal combustion vehicles are mostly eliminated. This is the case in three of the four scenarios in this report. The Transport Demand Model determines the total number of vehicles of any type that will be needed over the projection

[1] For example, in this report we have only been able to observe electric vehicle sales up to June 2022

period. Figure 2-2 provides an overview of the models and the projection timeline over which they are applied. The retirement model is deployed from around 60% sales but with some leeway to account for plausible global supply chain shifts. The following sections describe each of the models in more detail.

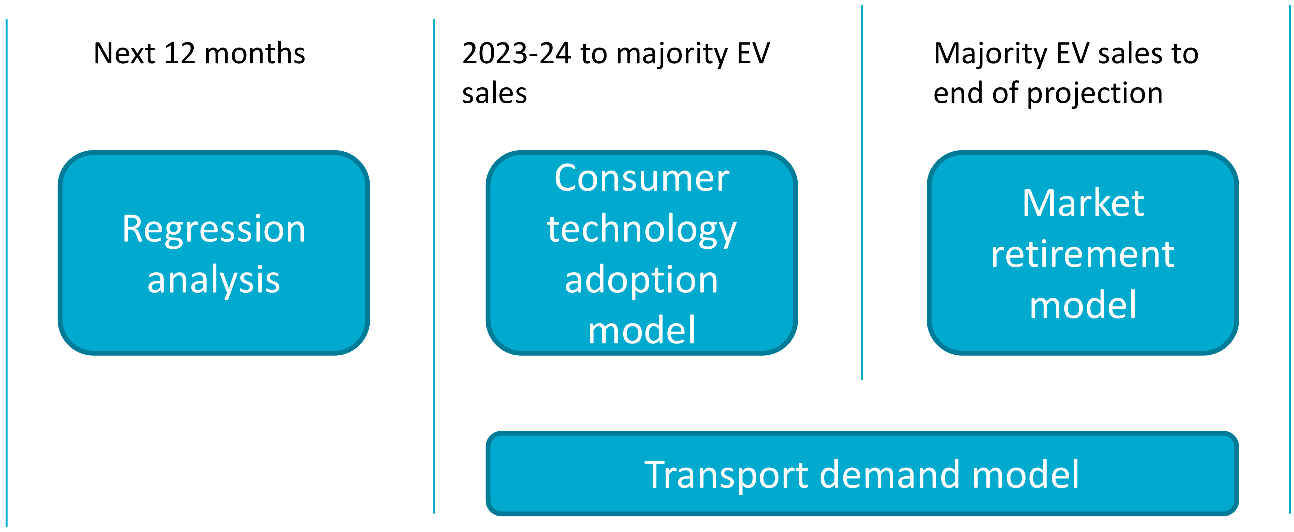

Figure 2-2 Models and the projection timeline over which they are applied

2.1.1 Trend model (regression analysis)

For the period to June 2022-23, trend analysis is applied to produce projections based on historical data. Only the most recent three to four[2] years are included in the trend calculation to provide more emphasise on recent outcomes At the national level, the historical data to end of 2021 aligns with data published by the Electric Vehicle Council (2022). An additional 6 months of data was available from FCAI (2022) so that the year 2021-22 is the last historical financial year. A variety of other sources are used to determine where those vehicles are currently located at the state and postcode level (FCAI, 2022, NSW government road and maritime services, 2022).

The EV trend is estimated as a linear regression. A separate regression is run for plug-in hybrid and battery electric vehicles (PHEVs and BEVs). Figure 2-3 shows the projections from the trend analysis. An exception to applying the trend is that we ensure the short term projection is reasonably consistent with subsidies available in each state. We assume that all subsidies are taken up such that this places a floor on the annual sales achieved.

The trend model also applies some variation between scenarios[3] in the short-term to capture uncertainty during this period. The *Exploring Alternatives* scenario assumes the underlying trend remains unchanged while the 2022-23 trend for Progressive Change is adjusted downwards by 10% and the trend for the remainder of the scenarios is adjusted upwards to a maximum of 20%. This captures the potential for stronger non-linear growth trends in the short term. The ranges are based on the author's judgement of the degree of upside and downside uncertainty in the trend.

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[2] A judgement is made in each state about how many years are to be included depending on how different recent behaviour are from the past.

[3] Not shown here. The variation is added as part of the results shown in Section 5. Figure 2-3 is the underlying trend only which is assigned to the Exploring Alternatives scenario.

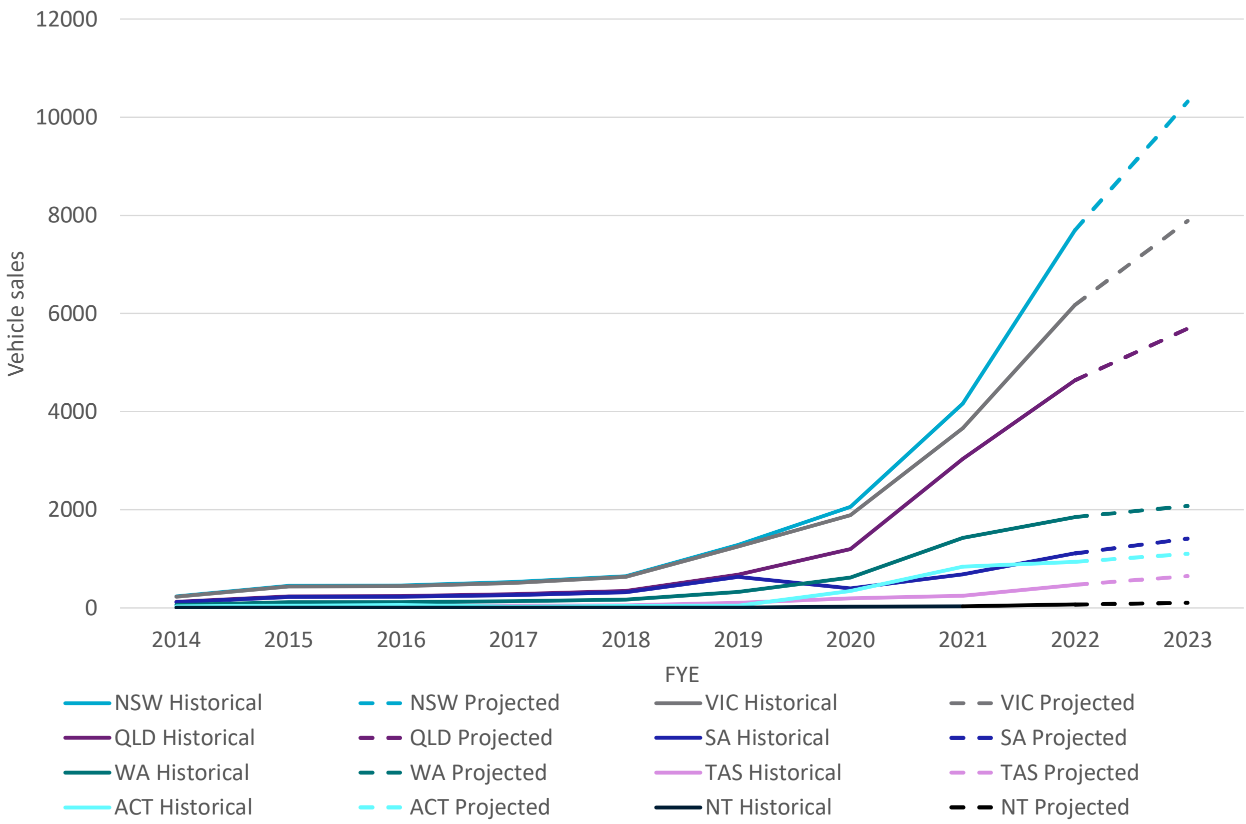

Figure 2-3 Historical and projected electric vehicle annual sales by state to 2032, *Exploring Alternatives* scenario

2.1.2 Consumer technology adoption model

The consumer technology adoption curve is a whole of market scale property that is exploited for the purposes of projecting adoption, particularly in markets for new products. The theory posits that technology adoption will be led by an early adopter group who, despite high payback periods, are driven to invest by other motivations such as values, autonomy and enthusiasm for new technologies. As time passes, fast followers or the early majority take over and this is the most rapid period of adoption. In the latter stages the late majority or late followers may still be holding back due to constraints they may not be able to overcome, nor wish to overcome even if the product is attractively priced. These early concepts were developed by authors such as Rogers (1962) and Bass (1969).

Over the last 50 years, a wide range of applications seeking to use this as a projection tool have experimented with a combination of price and non-price drivers to calibrate the shape of the adoption curve for any given context. Price can be included directly or as a payback period or return on investment. The adoption curve is developed by applying a payback period and a maximum market share assumption. Data on these two inputs are required to calibrate the shape of the logistic curve function.

Payback periods are relatively straightforward to calculate and when compared to price also captures the opportunity cost of staying with the technology substitute. The formula for the payback period, expressed in years, is expressed as follows:

$$PaybackPeriod_{v,m,s,t} = \frac{Capitalcost_{v,m,s,t} - CapitalCostICE_{m,t}}{AnnualOperatingCostICE_{r,m,t} - AnnualOperatingCost_{r,v,m,s,t}}$$

Where:

$$AnnualOperatingCost_{r,v,m,s,t} = AnnualFuelCost_{v,m,s,t} + AnnualMaintenanceCost_{v,m} + AnnualRegistrationCost_{r,v,m} + AnnualInsuranceCost_{r,v,m,s,t}$$

$$AnnualOperatingCostICE_{r,m,t} = AnnualFuelCostICE_{m,t} + AnnualMaintenanceCostICE_{m} + AnnualRegistrationCostICE_{r,m} + AnnualInsuranceCostICE_{r,m,t}$$

r is the region

v is the four electric vehicle technology types: battery electric (short and long range), plug-in hybrid, fuel cell,

m is the ten road modes or vehicle types: motorcycles, passenger (3 sizes) , light commercial vehicle (3 sizes), rigid truck, articulated truck, bus,

s is the four scenarios,

t is the financial year (to 2051-52).

The *CapitalCost* for internal combustion vehicles (ICE) varies by mode and time. The *CapitalCost* for electric vehicles also varies by the vehicle type and scenario and is net of any subsidies.

The *AnnualFuelCost* for ICE vehicles is calculated as the petroleum price multiplied by average new vehicle fuel efficiency and kilometres travelled per year. The assumptions for these factors change by mode and over time[4]. The *AnnualFuelCost* for electric vehicles is the same formula but varies by vehicle type and scenario to recognise the use of different fuels (electricity and hydrogen) and changes in electricity prices between scenarios.

A more difficult task than calculating the payback period is to identify the set of non-price demographic or other factors that are required to capture other drivers for the maximum market share assumption. CSIRO previously investigated the important non-price factors and validated the approach of combining payback periods and non-price factors that provides good locational predictive power for rooftop solar and electric vehicles (Higgins et al 2014; Higgins et al 2012).

In Figure 2-4 the general projection approach is highlighted that includes examples of demographics and other factors that are considered for inclusion. An important interim step is also included, which is to calibrate the adoption curve at appropriate spatial scales (due to differing demographic characteristics and electricity prices) and across different customer segments (differences between customers' travel needs, fleet purchasing behaviour and vehicle utilisation).

[4] The report assumptions mostly address electric vehicles rather than ICEs. ICE fleet fuel efficiency has grown around 0% to 1% per annum in the last few decades depending on the vehicle mode and is expected to continue to do so. Oil prices are assumed to return to more normal levels after the current high price period has passed. Kilometres per year recover from low levels during the pandemic but not completely.

Once the adoption curve is calibrated for all the relevant factors, the rate of adoption is evolved over time by altering the inputs according to the outlined scenario assumptions[5]. For example, differences in technology costs and prices between scenarios will alter the payback period and lead to a different position on the adoption curve. Non-price scenario assumptions such as available charging infrastructure or highest educational attainment in a region will result in different adoption curve shapes (particularly the height at saturation or maximum market share). Data on existing market shares determines the starting point on the adoption curve.

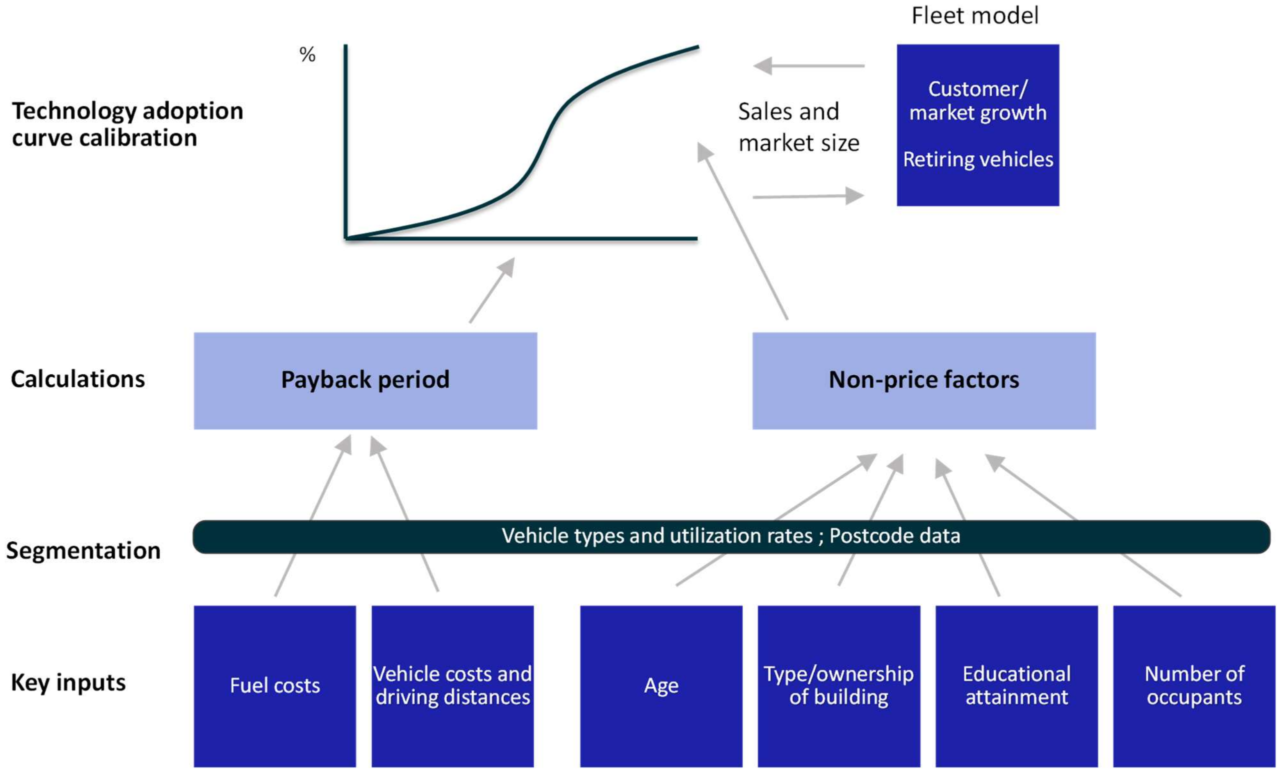

Figure 2-4 Adoption model methodology overview

The methodology also takes account of the total size of the available market, and this can differ between scenarios. The size of these markets is influenced by population growth, economic growth and transport mode trends and this is discussed further in the scenario assumptions section. While a maximum market share is set for the adoption curve based on various non-financial constraints, maximum market share is only reached if the payback period falls. That is, the logistic curve is calibrated between the maximum market share and the payback period. There is no hard relationship between time and maximum market share. Indirectly, the payback period falls over time and this changes the market share achieved over time. The applied maximum market share assumptions are outlined in the Data Assumptions section.

All calculations are carried out at the postcode level and are aggregated up to the state/territory, NEM or national levels for reporting purposes.

[5] Note that to "join" the short- and long-term projection models the trends projected to 2022-23 are seen as historical fact from the perspective of the long-term projection model and as such calibrate the adoption curve from that point.

2.1.3 Market retirement model

While the timing is uncertain, it is widely accepted that electric vehicle costs are likely to progress downwards to the point where they become economically attractive to a wide range of consumers, achieving a majority sales share (we define this typically around 60% but with some leeway to account for plausible global supply chain shifts). Our Market Retirement Model makes changes to the fleet based on the implications of this event for the required level of sales to meet both growth in road transport demand and ICE vehicle replacement (Figure 2-5).

If EVs reach this point, the transport supply industry may continue to supply both internal combustion engine (ICE) and EV vehicles services in parallel for a time. However, there will become a tipping point where vehicle manufacturers no longer develop new ICE vehicle models. The lack of new models makes further declines in the sales of ICEs inevitable. Following that, the support and servicing of internal combustion vehicles will begin to contract. Refuelling stations will eventually need to close due to low petroleum fuel sales volumes or reorient their business towards the needs of electric and fuel cell vehicles. Given the operating life of internal combustion vehicles we expect this process of a withdrawal of commercial services for ICE vehicles will take around a decade from when majority EV sales are achieved.

Under these circumstances, with ICE services being more difficult to access, consumers will naturally want to limit their exposure to ICE vehicles. At this point consumers only have three choices: sell the vehicle before the end of its natural life, scrap[6] it if they are unable to find a buyer or garage the vehicle (using it infrequently for special occasions).

The early removal of ICE vehicles from the fleet, while road transport demand is still growing, means that there will need to be a period of accelerated electric vehicle sales to make up the gap. We generally replace around 5% of vehicles in the fleet each year but that number if lower or higher depending on the region of Australia. The rate of replacement in the period of faster than normal fleet replacement is calculated by the model depending on the starting and end points of the electric vehicle fleet under the scenario. The period continues until the fleet reaches a new equilibrium where almost the entire fleet is electric, or hydrogen fuelled (allowing for a small number of special purposes ICE vehicles). A key input to the Market Retirement Model is the date at which we expect this near complete fleet change-over to occur. This is an input we outline in the assumptions section of the report.

[6] Around a quarter of Australia's steel is produced from scrap recycling. This is where most vehicles are sent when they are no longer road worthy. Some usable parts are extracted beforehand. The value of the vehicle depends on the current price of steel. In densely populated areas, Owners can expect to receive a small fee (no more than a few hundred dollars) down to a free takeaway service. Remotely located vehicles will have to pay for removal (and as a result may be left on vacant land). Given we are focussed on a mass scrapping event in these projections, our assumption is that there is no payment to owners but the vehicle is taken away for free.

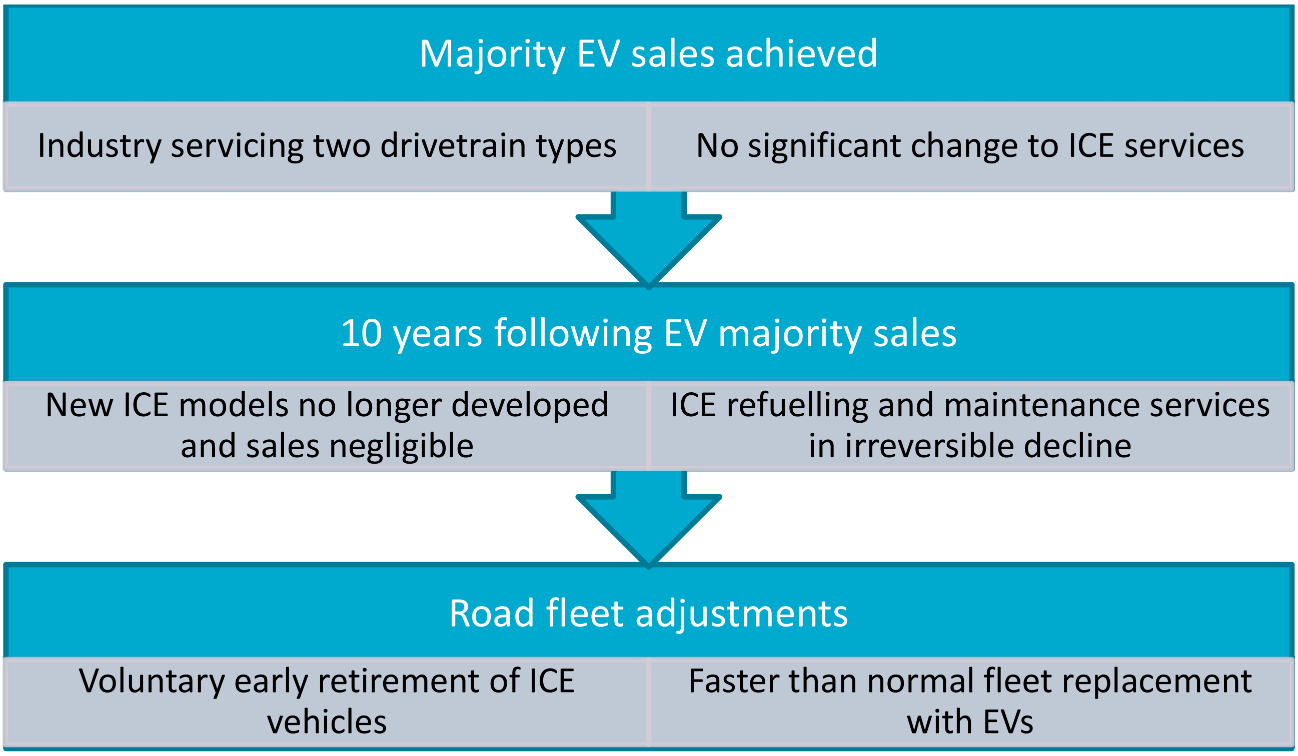

Figure 2-5 Implications of EV sales reaching a majority

2.1.4 Transport demand model

An overview of the process of projecting transport demand is shown in Figure 2-6. Growth in passenger (passenger kilometre) and freight (tonne kilometre) transport demand is driven by growth in population and GDP. GDP historically has been the stronger driver of both types of transport, but more recently population has been better at explaining growth in passenger transport. This is because most forms of transport are now affordable under current average household income. That is, the demand for passenger transport per person has reached a saturation point as cost of transport is not a significant barrier. New passenger transport demand is therefore driven by growth in population (immigration assumptions therefore become important).

Future mode share assumptions are developed based on an observation of historical trends and consideration of the future of cities in Australia that includes specific government programs to extend airports, rail and road infrastructure. For the non-road sectors, fuel consumption projections are based on multiplying projected demand by long term trends in fuel efficiency. In the past CSIRO would include some changes in transport mode[7] shares over time . For example, historically, aviation had been steadily capturing more of the passenger share market. However, the COVID-19 pandemic has interrupted and reversed some of these trends. Road and the active share of transport increased while aviation and rail decreased. The assumptions for the future of passenger mode shares are outlined later in the report. Freight transport mode shares were less

[7] In transport sector generally, the key transport modes are road, rail, aviation, shipping and active. The active transport mode includes walking and cycling. In the road sector we also talk about cars and trucks as sub-types of road transport modes.

impacted by COVID-19 and so their historical trends in mode share are allowed to continue with some differences in the rate of change by scenario(Section 4.8 shows the impact of these assumptions).

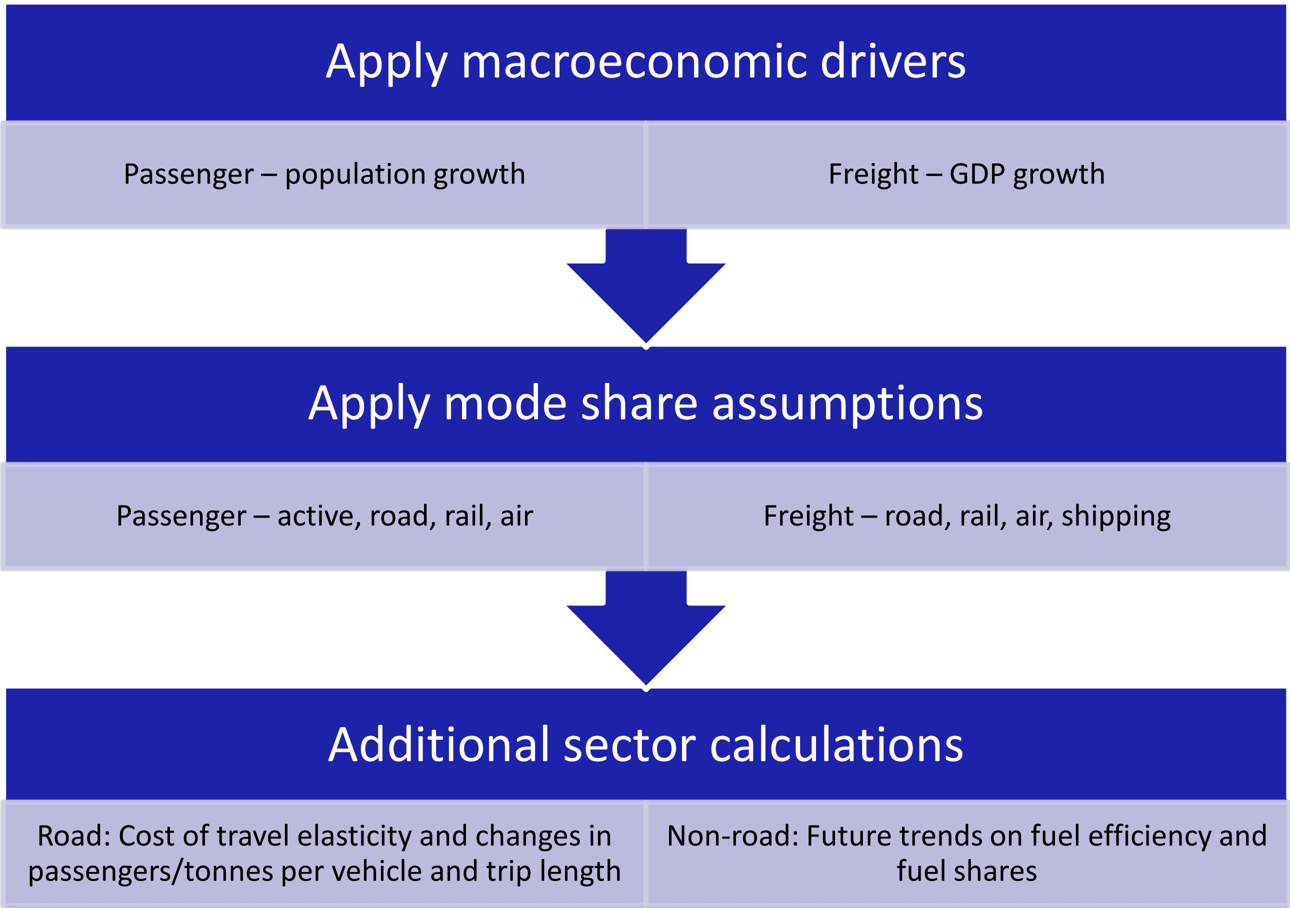

Figure 2-6 Overview of transport demand model

There are several more steps in projecting road sector transport demand. The first additional step is that the demand model takes cost of travel information from the adoption model and applies a price elasticity to demand of -0.2[8]. That is, if the cost of road transport (passenger or freight) is expected to fall by 10% this will lead to 2% increase in road transport demand. Conversely a 10% increase in cost of travel would lead to a 2% decrease in transport demand. Cost of travel is measured in dollars per kilometre and includes the whole cost of vehicle ownership and operation. The main driver of rising transport costs in the future is expected to be fuel prices. However, improved fuel efficiency and higher vehicle utilisation from vehicle electrification and autonomous vehicles[9] respectively could see costs fall.

The second additional step is to take account of changes in the vehicle load. For example, a decrease in passengers per vehicle implies more vehicle kilometres will be required to meet total demand for passenger kilometres. Similarly, an increase in tonnes per vehicle capacity would

[8] Transport demand elasticities have been studied for many decades. This site summarises available evidence: https://www.bitre.gov.au/databases/tedb

[9] Autonomous vehicles are assumed to all be electric because they are only widely available after electric vehicles become the dominant vehicle sold. Autonomous vehicle technology can apply to all vehicle types such as cars, buses and trucks. We discuss these in more detail in Section 4.8.1

mean fewer vehicles were required to meet freight tonne kilometre demand. Tonnes per vehicle are held constant over time for freight vehicles. Passengers per vehicle increases if the adoption model projects greater adoption of rideshare services.

The final step takes account of changes in trip length which is measured in aggregate by kilometres per vehicle. Kilometres per vehicle is varied to take account of changes due to the impact of COVID-19 and of autonomous vehicles and ride sharing. COVID-19 has reduced average kilometres per vehicle for passenger vehicles. We assume a partial recovery to above 2020 levels but 90% below 2019 levels on average for passenger vehicles varying by state and vehicle type. In some states trucks improved their utilisation during the pandemic and we allow these increased levels to be partially sustained.

The model projects the uptake of autonomous vehicles and ridesharing and their impact on transport demand. Ride sharing increases the number of passengers per vehicle which on face value reduces the amount of vehicle kilometres needed to meet passenger kilometre demand and this is taken account of in the previous step. However, the most convenient service[10] would pick up and drop off each passenger at their destination meaning that each passenger takes a longer trip than if they had used a non-ride sharing mode. These extra kilometres associated with ride sharing trips are considered in this step.

2.1.5 Commercial vehicles

It may be argued that commercial vehicle purchasers would be more weighted to making their decisions on financial grounds only. That is, commercial vehicle sales would rapidly accelerate towards electric vehicles as soon as the whole of life cost of owning an EV falls (which occurs sooner for commercial vehicles because of longer average driving distances than residential vehicles). However, it is assumed that infrastructure constraints including the split incentives or landlord-renter problem which can be captured using adoption curves are also relevant for businesses noting that many commercial vehicles park at residential premises. For business parked vehicles, if the business does not own the building, installing charging infrastructure may not be straight-forward. Hence, the applicability of non-financial factors to a business's needs is just as relevant as whether EVs will suit a household's needs and so there are no major differences applied in the methodology for commercial vehicles.

2.2 Demographic factors and weights

The projection methodology includes selecting a set of non-price factors, typically drawn from accessible demographic data to calibrate the consumer technology adoption curve in each postcode region. CSIRO assigns different weights to each factor to reflect their relative importance. The next section outlines the factors and weights chosen for electric vehicles.

[10] Note that the Australian version of UberPool currently does not directly pick up and drop off at your desired points. Rather it includes some walking to connect you with the route an existing vehicle is travelling and may include some walking after drop-off. However, some overseas version include point to point drop-off and pick-up. https://www.uber.com/en-AU/ride/uberpool/

2.2.1 Weights and factors for electric vehicles

Previous analysis by Higgins et al (2012) validated several demographic factors and weights for Victoria. A similar combination of factors and weights is applied across all states and outlined in Table 2-1. These weighting factors provide a guide for the adoption locations, particularly during the early adoption phase which Australia currently remains in. However, adoption is allowed to grow in all locations over time. It is likely that some of the factors included act as a proxy for other drivers not explicitly included (such as income).

The weights, defined in the range of 0 to 1 for each factor are used to calculate a score for each postcode to indicate relative propensity for electric vehicle uptake. After a general level of maximum national electric vehicle adoption is set, for example 50%, the postcode score is used to adjust the local level of adoption up or down by a maximum of plus or minus 25%. In this case the best scoring postcode achieves a maximum adoption of 75% and the worst scoring region 25%. The maximum national electric vehicle adoption assumptions are outlined in Section 4 Table 4-4.

Table 2-1 Weights and factors for electric vehicles

Factors	Weight ranges
Share of ages (in 10-year bands)	0-1 with the 35 to 54 age bands receiving highest scores
Share of number of household residents (1-6+)	0.3-1 increasing with smaller households
Share of educational attainment	0.25-1 for advanced diploma and above, 0 otherwise
Share of mode of transport to place of work	1 for car, 0 otherwise

2.3 Role of economic growth in projection method

Economic growth closely tracks changes in residential and business income and is a metric for the general health of the economy. This section provides an overview of how changes in economic growth impact the projections through the modelling approach we apply.

Income influences the electric vehicle adoption model only through the size of transport demand. Economic growth is not considered in the demographic score for calibration of the electric vehicle adoption curve. Passenger transport demand is a larger component of transport, and this is driven by population growth. However, demand for light commercial vehicle and truck transport is driven by economic growth. This means, while stronger demand for EV means more vehicle sales, it influences only a small proportion of total vehicle sales. A large proportion of sales is car replacement. making up about 80% of sales.

Changes in economic growth only impacts around 20% of the sales of a minority of vehicle types (freight vehicles only). As such, alternative economic growth assumptions only have a marginal direct impact on EV projections. Indirectly, if higher economic growth occurred due to higher population growth, that mechanism would broaden the impact of higher economic growth because the whole of transport demand is experiencing higher demand. In that case, the impact would still affect approximately 20% of sales increasing in line with increases in GDP and population.

3 Scenario definitions

The four scenarios are *Progressive Change*, *Exploring Alternatives*, *Step Change* and *Hydrogen Export*. The AEMO scenario definitions are described in narrative form and then by their key drivers in Table 3-1. To implement the electric vehicles projections, CSIRO has developed an additional set of extended scenario definitions based on consideration of additional economic, infrastructure and policy drivers. These are summarised and then each of the financial and non-financial drivers are described in more detail.

Progressive Change

In this scenario:

- COVID-19 recovery is slow, supressing growth, investment, and employment. Australia's population growth is relatively lower than other scenarios.
- Consumers continue to install distributed PV at high rates, continuing high recent uptake despite adverse economic conditions. Over time though the uptake moderates. In contrast, investment in household battery storage and EVs do not grow as fast.
- Consumers' choice for heating remains unchanged compared to today.
- Currently legislated or materially funded state-based renewable energy (VRE) policies are achieved. Future investment beyond current policies, is driven by commercial decision-making.
- Decarbonisation policy is less of a priority. Insufficient action is taken globally to achieve the objectives of the Paris Agreement.
- The energy transition across the economy is lower.

Exploring Alternatives

In this scenario:

- Uptake of DER reflect continued strong distributed investments. Beyond 2030, energy efficiency measures gradually increase in response to progressive tightening of emission targets.
- Moderate growth in light of COVID-19 recovery.
- Currently legislated or materially funded state-based VRE policies and targets are achieved.
- Early focus on technological R&D leads to commercialisation of new and emerging low emissions technologies over time. Decarbonisation accelerates after 2030, eventually reducing emissions economy-wide to net zero by 2050.
- The costs of new technologies continue to fall. The electricity sector decarbonises earlier than other sectors, enabling greater progressive electrification of fossil-fuel intensive loads.
- Electrification investments increase as 2050 approaches. A gradual transition increases the reliance on electrification of some of the more challenging processes.
- Global emissions reductions are insufficient to achieve the Paris Agreement's objectives.

Step Change

In this scenario:

- Moderate growth in the economy
- Increasingly energy literate consumers contribute to lower emissions. DER uptake is increasing the number of active consumers who better manage energy use.
- Strong climate action underpins rapid transformation of the energy sector. Temperature rises are approximately 2°C above pre-industrial levels. Government policy and corporate objectives are aligned to decarbonise.
- Currently legislated or materially funded state-based VRE policies and targets are achieved.
- Emissions-intensive generation sources are withdrawn earlier than presently announced.
- Some opportunity for domestic hydrogen as other sectors innovate to decarbonise, but is broadly limited, either technically or economically.
- No *Hydrogen Export* facilities are connected to the NEM.
- Electrification potential is high, particularly from the transport sector. EVs soon become the dominant form of road passenger transportation.
- Carbon sequestration supports a pathway towards net zero emissions more rapidly.

Hydrogen Export

In this scenario:

- Faster decarbonisation to tackle climate change, with net zero emissions before 2050.
- Australia establishes strong *Hydrogen Export* partnerships to meet international demand for clean energy, supporting NEM-connected electrolysis powered by renewable energy.
- The energy transition in Australia is embraced by consumers, as they seek clean energy and energy efficient homes and vehicles

Table 3-1 AEMO scenario definitions (current at time of modelling)

Scenario	Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export
Decarbonisation target	43% emissions reduction by 2030. Net zero by 2050 (RCP 4.5)	At least 43% emissions reduction by 2030. Net zero by 2050 (RCP 2.6)	At least 43% emissions reduction by 2030. Net zero by 2050 (RCP 2.6)	At least 43% emissions reduction by 2030. Net zero no later than 2050 (RCP 1.9)
Global economic growth and policy coordination	Slower economic growth, lesser coordination	Moderate economic growth, moderate coordination	Moderate economic growth, stronger coordination	High economic growth, stronger coordination

Scenario	Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export
Australian economic and demographic drivers	Lower	Moderate	Moderate	Higher (partly driven by Hydrogen Export)
DER uptake (i.e., rooftop PV, batteries and EVs)	Lower	Moderate	Higher	Higher
Consumer engagement e.g., in uptake of VPP and DSP	Lower	Moderate	Higher	Higher
Hydrogen use	Allowed	Allowed	Allowed	Faster cost reduction. High production for domestic and export use
Biomethane/synthetic methane	Allowed	7.5% blending target for reticulated gas by 2030 and 10% by 2035	Allowed	Allowed
Other electrification	Moderate (but lower with lesser economic growth)	Moderate	Higher	Moderate
Social license	Limited social licence impacting the speed and scale of transformation	Moderate	Moderate	Moderate

3.1.1 Extended scenario definitions

The AEMO scenario definitions have been extended in Table 3-2 by adding additional detailed assumptions on the economic, infrastructure and business model drivers. The purpose is to fill out more detail about how the scenarios are implemented whilst remaining consistent with the higher level AEMO scenario definitions. The scenario definitions are in some cases described here in general terms such as “High” or “Low”. More specific scenario data assumptions are outlined further in the next section and in Section 4.

Table 3-2 Extended scenario definitions

Driver	Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export
Timing of cost[1] parity of short-range electric vehicles with ICE	2035	2030	2027	2025
Cost of fuel cell vehicles	High	Medium	Medium	Low
Growth in apartment share of dwellings	High	Medium	Medium	Low
Decline in home ownership	High	Medium	Medium	Low
Extent of access to variety of charging options	Low	Medium Increasing post 2030	High	High
Feasibility of ride sharing services	Low	Medium	High	High
Affordable public charging availability	Low	Medium Increasing post 2030	High	High
Vehicle to home or grid (passenger vehicles)	Yes from 2030	Yes from 2030	Yes from 2030	Yes from 2028

1. Upfront sales costs of vehicle, not whole of vehicle running cost. Short range is less than 300km. Long range electric vehicles do not reach upfront vehicle cost parity due to the additional cost of batteries of around $5000. However, they do reach cost parity on a whole of travel basis around 3 years after the dates for short range upfront vehicle cost parity.

3.2 Financial and non-financial scenario drivers

3.2.1 Direct economic drivers

For privately owned electric and fuel cell vehicles the economic drivers and the approach to including them in the scenarios is listed in Table 3-3.

Table 3-3 Economic drivers of electric and fuel cell electric vehicles (FCEV) and approach to including them in scenarios

Driver	Approach to including in scenarios
The whole cost of driving an electric or fuel cell vehicle including vehicle, retail electricity, the charging terminal (wherever it is installed), hydrogen fuel, insurance, registration and maintenance costs	Vehicle costs vary by scenario and are outlined in Section 4.1.1. Retail electricity prices are varied by scenario and outlined in Section 4.2.1. The remaining factors are held constant.
The whole cost of driving an internal combustion engine (ICE) vehicle as an alternative including vehicle, fuel, insurance, registration and maintenance costs	Not varied by scenario
Perceptions of future changes in petroleum-derived fuel costs including global oil price volatility and any fuel excise changes	Not varied by scenario
The structure of retail electricity prices relating to electric vehicle recharging	Varied by scenario and outlined in 4.7
The perceived vehicle resale value	Not varied by scenario

Future hydrogen fuel costs are hard to predict because there is a diversity of possible supply chains, each with their own unique cost structures. While natural gas-based hydrogen (steam methane reforming) is currently lowest cost, by the time fuel cell electric vehicles (FCEVs) are relevant, electrolysis hydrogen production and use of CCS in steam methane reforming are expected to be viable as low emission hydrogen sources.

For autonomous private and ride share vehicles the additional economic drivers compared to electric and fuel cell vehicles and the approach to including them in scenarios is shown in Table 3-4.

Table 3-4 Economic drivers of autonomous private and ride share vehicles and approach to including them in scenarios

Driver	Approach to including in scenarios
The cost of the autonomous driving capability	On-cost of autonomous features not varied by scenario, but underlying cost of electric vehicle varied by scenario as outlined in Section 4.1.1
The value of avoided driving time	Not varied by scenario but assumptions discussed in Section 0
The lower cost of travel from higher utilisation of the ride-share vehicle compared to privately owned vehicles (accounting for some increased trip lengths to join up the routes of multiple passengers)	Not varied by scenario
The avoided cost of wages to the transport company for removing drivers from autonomous trucks	Not varied by scenario but assumptions discussed in Section 0
Higher utilisation and fuel efficiency associated with autonomous trucks	Not varied by scenario

3.2.2 Infrastructure drivers

The are several infrastructure barriers to accessing electric vehicles and associated refuelling (Table 3-5). Electric, fuel cell and autonomous ride share vehicles all face the common constraint of a lack of variety of models in the initial phases of supply of those vehicles. While perhaps ride share vehicles can be more generically designed for people moving, purchasers of privately owned vehicles will prefer access to a wider variety of models to meet their needs for the how they use their car (including sport, sedan, SUV, people moving, compact, medium, large, utility, 4WD, towing).

Key infrastructure drivers for FCEVs are varied by scenario as maximum market share assumptions and outlined in Section 4.5. The drivers are:

- A mature hydrogen production and distribution supply chain for FCEVs. There are many possible production technologies and resources and many ways hydrogen can be distributed with scale being a strong determinant of the most efficient distribution pathway (e.g., , electrolysis on-site or trucks at low volumes, pipelines at high volumes).
- The greater availability of FCEVs for sale.

Table 3-5 Infrastructure drivers for electric and fuel cell vehicles and approach to including them in scenarios

Driver	Approach to including in scenarios
Convenient location for a power point or dedicated charging terminal in the home garage or a frequently used daytime parking area for passenger vehicles and at parking or loading areas for business vehicles such as light commercial vehicles, trucks and buses	Varied by scenario and expressed as maximum market share in Section 4.5
Whether the residence or business has ownership or other extended tenancy of the building or site and intention to stay at that location to get a long-term payoff from the upfront costs of installing the charger.	Varied by scenario and expressed as maximum market share in Section 4.5
Convenient access to highway recharging for owners without access to extended range capability (or other options, see below)	Varied by scenario and expressed as maximum market share in Section 4.5
Access to different engine configurations of electric vehicles (e.g., fully electric short range, fully electric long range and plug-in hybrid electric and internal combustion)	Varied by scenario and expressed as maximum market share in Section 4.5
Convenient access to other means of transport such as a second car in the household, ride sharing, train station, airport and hire vehicles for longer range journeys	Varied by scenario and expressed as maximum market share in Section 4.5
Whether hydrogen distribution and refuelling terminals have been deployed widely enough for convenient use of fuel cell vehicles	Varied by scenario and expressed as maximum market share in Section 4.5

Sufficient electricity distribution network capacity to meet coincident charging requirements of high electric vehicle share could also be an infrastructure constraint if not well planned for. However, networks are obligated to expand capacity or secure demand management services to meet load where needed and so any such constraints would only be temporary. If hydrogen supply is based on electrolysis this will also mean increased requirements for electricity infrastructure, but its location depends on whether the electrolysis is on site (e.g., at a service station) or centralised (where the production location might be an industrial precinct).

Given the constraints of commute times and cost of land in large cities, there is a slow trend towards apartments rather than separate dwellings in the capital and large cities where most Australians live. This is expected to result in a lower share of customers with access to their own roof or garage space impacting all types of embedded generation (these assumptions are defined later in the report). There has also been recent evidence of a fall in home ownership, especially amongst younger age groups. For electric vehicles these trends might also work towards lower adoption as denser cities tend to encourage greater uptake of non-passenger car transport options and ride sharing services (discussed further in the next section) which result in fewer vehicles sold. Home ownership and separate dwelling share are varied by scenario and outlined in Section 4.4

3.2.3 Disruptive business model drivers

New business models can disrupt economic and infrastructure constraints by changing the conditions under which a customer might consider adopting a technology. Table 3-6 explores some emerging and potential business models which could drive higher adoption. Demand management is an example where trials and rule changes which are the basis of emerging business models could become more established in the long run. The degree to which these potential business model developments in regard to charging infrastructure, ride sharing and vehicle to home or grid apply by scenario is expressed primarily through their ability to change the maximum market shares for electric, autonomous and fuel cell vehicles as outlined in Sections 4.5 and 4.8.1.

Table 3-6 Emerging or potential disruptive business models to support embedded technology adoption

Name	Description	Paradigm disrupted
Affordable and ubiquitous public charging	Ubiquitous public charging is provided cost effectively	Low cost access to electric vehicle charging will be primarily at the home or business owner’s premises
Autonomous ride-share vehicles[1]	Ride sharing services which utilise autonomous vehicles could result in business-led electric vehicle uptake achieving very high vehicle utilisation and lower whole of life transport costs per kilometre	Electric vehicles will be predominantly used for private purposes by the vehicle owner and the return on their investment will be governed by that user’s travel patterns.
Vehicle to home or grid	Electric vehicles are coupled with an in-garage inverter system to provide the role of a stationary battery when at home. This aligns well with grid needs and/or eliminates most household evening and night demand.	Using the battery capacity in your electric vehicle for home or system energy management requires a more complicated setup, low cost day charging options and reduces the amenity of vehicle operation for transport purposes

Collapse of internal combustion engine (ICE) business model	Sales of ICE vehicles fall to a low level such that ICE oriented businesses (petroleum fuel supply, vehicle maintenance) lose economies of scale and are commercially withdrawn	ICE vehicles services will always be available such that those that prefer ICE vehicle will not have to adopt electric or fuel cell vehicles

1 While increasing the kilometres travelled via electric vehicles, this may potentially reduce the number of electric vehicles overall since this business model involves fewer cars but with each car delivering more kilometres per vehicle.

In regard to the potential collapse of the internal combustion engine business model, this potential outcome has been specifically built into the projection modelling framework discussed in Section 2. The specific assumptions for each scenario are as shown in Table 3-7.

Table 3-7 Scenario assumptions regarding the collapse of ICE commercial services

	Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export
ICE vehicle availability[1]	New vehicles unavailable beyond 2065	New vehicles unavailable beyond 2045	New vehicles unavailable beyond 2040	New vehicles unavailable beyond 2035
ICE commercial services collapse / no longer viable to operate[1]	NA	2055	2050	2045

1 Special purpose vehicles exempted. NA Not applicable because the event is too far out from the projection period to be relevant. However, a similar collapse would be expected at some time in the future.

3.2.4 Commonwealth policy drivers

There are a variety of commonwealth policy drivers which impact solar, battery and electric vehicle adoption. These are rationalised for each scenario and described in further detail below.

Emissions Reduction Fund[11] and Climate Solutions Fund

The ERF consists of several methods for emission reduction under which projects may be eligible to claim emission reduction and bid for Australian Carbon Credit Units (ACCUs). The ACCU price has been volatile since the end of 2022 peaking at over \$60/t in early 2022 but is currently round \$30/tCO_2e. The higher price reflects stronger demand from business rather than the result of government auctions for purchase.

The relevant method in this case is the *Carbon Credits (Carbon Farming Initiative – Land and Sea Transport) Methodology Determination 2015*. It is possible for businesses to develop projects under the ERF where each project may receive funding for deployment of electric vehicles.

[11] The Emissions Reduction Fund (ERF) was extended by the Climate Solutions Fund announced in 2019

However, there have been no significant uptake of this scheme, as the incentive is not significant. ICE passenger vehicle emissions are around 4 tonnes per year. At an ACCU price of $30/tCO$_2$e, avoiding the use of a single ICE vehicle only delivers roughly $120 per year in benefits to be claimed.

Commonwealth climate policy

The incoming Commonwealth government of 2022 has recently increased its legislated 2030 emission reduction target to a 43% reduction by 2030. The announced transport elements of the climate and energy policy are:

- A National Electric Vehicle Strategy, including funding for Fringe Benefits Tax exemption for electric vehicles below the luxury car tax threshold for fuel efficient vehicles. The 5% vehicle import tax is also removed where it is still paid.
- Improved electric vehicle charging infrastructure by requiring Commonwealth funded road upgrades to incorporate charging infrastructure where appropriate
- All relevant properties which the Commonwealth owns, or leases, to be fitted with appropriate charging infrastructure
- A review of the National Construction Code to consider charging infrastructure or electrical connections for future infrastructure.
- A commitment of $14 million over four years to establish a real world emissions testing program.
- Implementation of an EV target for the Commonwealth fleet

The Fringe Benefits Tax exemption increase the amount of salary that would have remained after an employee has sacrificed part of their salary towards a novated vehicle lease. This presents as a subsidy but does not change the cost of the electric vehicle.

Modelling by Reputex Energy (2021) found that these measures resulted in raising the EV share from 29 per cent to 89 per cent of new car sales in 2030 with EVs making up 15 per cent of all vehicles on Australian roads by 2030. The projections in this report do not apply these modelling outcomes, but they provide a guide to the government's intent.

Commonwealth fuel excise policy

Petroleum based fuel excise is indexed to inflation but there is currently no Commonwealth fuel excise on electricity or hydrogen used in transport. Some states have begun considering or introducing kilometre based electric vehicle charges. As such, CSIRO has included state-based road user charges into the modelling that is outlined in the next section.

3.2.5 State policy drivers

All state and territory government have developed electric vehicle strategies. These strategy documents contain the detail for how each region intends to enable adoption of electric vehicles. The main policy settings have been summarised in Table 3-8.

Table 3-8 Summary of state/territory electric vehicle strategies

	NSW	VIC	QLD	SA	TAS	WA	ACT	NT
Targets	50% sales by 2030 and 100% sales by 2035	50% light vehicle sales by 2030	50% sales by 2030 and 100% by 2036	100% sales by 2035	No	No	100% sales by 2035 implemented by disallowing registration of new ICE	No
Subsidies	$3,000 for first 25,000 EVs less than $68,750. Stamp duty exemption equivalent to a $1,350 subsidy for $45,000 vehicle. Reverse auction for EV fleet purchases	$3,000 for first 4,000 EVs below $68,740, with subsidies for further 16,000 to be determined $100 reduction in registration fee. Exemption from luxury car duty.	$3,000 for first 15,000 EVs, up to price of $58,000. Reduced stamp duty of $2 per $100 up to $100,000 and $4 per $100 thereafter (discounted from the normal $6 per $100)	$3000 for first 7,000 EVs less than $68,750. 3 year registration fee exemption for EVs purchased prior to 30 June 2025. $2000 subsidy on smart chargers, first 7500.	2 year exemption from stamp duty equivalent to $885 subsidy on $45,000 vehicle. Registration waived for EV rental or bus company purchases $2,000 subsidy for up to 7,000 home smart chargers	$3,500 for up to 10,000 EVs priced below $70,000.	Interest free loans of up to $15,000. Stamp duty exemptions equivalent to a $1350 subsidy for $45,000 vehicle 2 years free registration	No registration fee and stamp duty reduced by $1,500 for vehicle below $50,000 for 2022 to 2027
Government fleet targets	50% EV procurement passenger fleet by 2026. Fleet all electric by 2030	All bus purchases to be EVs by 2025. Remainder of fleet to commence greater EV purchases by 2023	No	Moderate intent to electrify passenger and bus fleets	100% electric fleet by 2030	25% of light to medium passenger fleet by 2025-26	100% EV by 2040 including buses. 140 passenger EVs at present with 90 buses ordered	200 or around 7% by 2030
Funding for public charging networks	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Road user charge	By July 2027 or when EVs are 30% of new car sales (whichever is earlier). 2.5c/km for BEVs and 2c/km for PHEVs	2.5c/km for EVs and 2c/km for PHEVs from 2021. This value will be indexed to inflation.	No	By July 2027 or when EVs are 30% of new car sales (whichever is earlier). 2.5c/km for BEVs and 2c/km for PHEVs	Under consideration	By July 2027 at 2.5c/km for EVs and 2c/km for PHEVs. It will rise with inflation over time.	No	Under consideration

The impact and availability of charging infrastructure is dealt with under our maximum market share assumptions in Sections 4.5 which vary by scenario. State road user charges and plans to transform their own government fleets are directly implemented and not varied by scenario. However, the scope of the subsidies for light vehicles at both the state and commonwealth level is quite limited and difficult to implement for that reason. State policies are for a small number of vehicles relative to total state annual vehicle sales. The commonwealth subsidy only applies to salary packaged vehicles. The main method under which we give meaning to these state and commonwealth subsidies is to take an alternative view by scenario on how successful the package of policy will be in reaching 2030 electric vehicle sales targets (which are 50% in the three largest states).

The assumptions are outlined in Table 3-9 and apply to all regions except for Northern Territory and Tasmania. Western Australia has no target but is assumed to be aligned with the targets of the three largest state because of similarly in other electric vehicle policy areas. The key reasons for underachievement are likely to be supply chain issue associated with electric vehicles numbers and models available as well as the limited range of impact of the subsidies. Overachievement could reflect stronger than expected global electric vehicle manufacturing ramp up, lower electric vehicle costs in the relevant scenario and additional policies not currently announced either by state or the commonwealth.

The total fleet sales share will not perfectly align to these targets because they are applied to light vehicles. Each state also has some degree of support for heavy electric vehicles through transition of their government fleets (e.g., buses).

Table 3-9 Assumed level of achievement of state electric vehicle sales targets

	Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export
Degree to which state targets met in 2030[12]	Underachieved by 30 percentage points	Underachieved by 15 percentage points	Met	Overachieved by 15 percentage points

[12] We assume the target is met during 2030 but may not align exactly with June

4 Data assumptions

This section outlines the key data assumptions applied to implement the scenarios. Some additional data assumptions which are used in all scenarios are described in Appendix A.

4.1 Technology costs

4.1.1 Electric and fuel cell vehicles

Exploring Alternatives has a moderate electric vehicle uptake and so we start with this scenario in assigning likely changes in technology costs. *Exploring Alternatives* scenario short-range electric vehicle (SREV) costs are assumed to reach upfront cost of vehicle parity with internal combustion engine light vehicles in 2030 and remain at that level thereafter (Table 4-1). Heavy SREVs are assumed to reach up front cost parity in 2040 due to their delayed development relative to light vehicles and higher duty requirements (both load and distance). Up front cost parity may be reached earlier in other countries where vehicle emissions standards are expected to increase the cost of internal combustion vehicles over time. The modelling considers SREV adoption across five vehicle classes: light, medium and large cars, rigid trucks, and buses. Long-range electric vehicles (LREVs) also include larger articulated trucks which perform the bulk of long-distance road freight. LREVs do not reach up front vehicle cost parity because their extra range adds around $5,000 in battery costs to light vehicles (and proportionally more to heavy vehicles). However, from a total cost of driving perspective (i.e., $/km), LREVs are cost competitive by 2030, paying back the additional upfront cost through fuel savings within 2-3 years.

The modelling does not consider applying a plug-in hybrid engine configuration to the small light vehicle class as these vehicles are already efficient so the additional cost would be difficult to payback with limited additional fuel savings.

The vehicle cost assumptions for the *Progressive Change, Step Change and Hydrogen Export* scenarios are framed relative to *Exploring Alternatives*. In the *Progressive Change* scenario, it is assumed that the cost reductions are delayed by 5 years to 2035. In the *Step Change* scenario, cost reductions are brought forward 3 years to 2027[13]. For *Hydrogen Export* which has stronger global climate change policy ambition cost reductions are brought forward by 5 years to 2025. This would also reflect a supply chain rebound whereby the current high prices for raw materials is met with strong investment in new capacity, supporting future cost reductions.

[13] This is two years later than in CSIRO's 2021 projections to acknowledge that there are more difficult supply chain constraints than previously expected.

Table 4-1 Exploring Alternatives scenario internal combustion and electric vehicle cost assumptions, 2022 $'000

	2025	2030	2035	2040	2045	2050
Internal combustion engine						
Light/small car - petrol	15	15	15	15	15	15
Medium car - petrol	25	25	25	25	25	25
Large/heavy car - petrol	41	41	41	41	41	41
Rigid trick - diesel	61	61	61	61	61	61
Articulated truck - diesel	300	300	300	300	300	300
Bus - diesel	180	180	180	180	180	180
Electric vehicle short range						
Light/small	21	15	15	15	15	15
Medium	36	25	25	25	25	25
Large/heavy	53	41	41	41	41	41
Rigid truck	92	80	70	61	61	61
Bus	246	223	200	180	180	180
Electric vehicle long range						
Light/small	28	20	20	20	20	20
Medium	42	30	30	30	30	30
Large/heavy	61	46	46	46	46	46
Rigid truck	125	109	95	83	82	81
Articulated truck	694	535	468	410	404	400
Bus	279	252	227	204	203	202
Plug-in hybrid electric vehicle						
Medium car - petrol	35	33	33	33	33	33
Large/heavy car- petrol	53	49	49	49	49	49
Rigid truck – diesel	122	81	81	81	81	81
Articulated truck - diesel	606	396	396	396	396	396
Fuel cell vehicle						
Light/small	35	32	27	24	22	22
Medium	41	37	33	30	29	28
Large/heavy	51	48	43	40	38	37
Rigid truck	96	84	77	71	70	68
Articulated truck	479	419	385	357	350	342
Bus	221	207	199	192	190	188

Given that fuel cell and electric vehicles have significantly fewer parts than internal combustion engines it could also have been reasonable to consider their costs reaching lower than parity with internal combustion vehicles by 2050. However, in the context of the adoption projection methodology applied here, when the upfront price of an electric vehicle equals the upfront price of an equivalent internal combustion vehicle, the payback period is already zero in the sense that there is no additional upfront cost to recover through fuel savings. After this point, adoption is largely driven by non-financial considerations. Also, it was considered that vehicle manufacturers might continue to offer other value-adding features to the vehicle if this point is reached rather than continue reducing vehicle prices (e.g., luxury, space, information technology and sport features).

4.1.2 Autonomous vehicle costs and value

Autonomous vehicles (AVs) could have benefits for all vehicle classes from cars through to buses and freight trucks. While there are various levels of autonomy that a car can be equipped with, in this report, when we refer to an AV (or an A-EV) we are referring to a highly autonomous vehicle (SAE level 4/5) which needs minimal or no human intervention and is not expected to be available until the late 2020s at the earliest. This capability is currently being tested as an add-on to an underlying vehicle (an ICE or EV) which includes both hardware (sensors and processors) and software (the vehicle operating system). AVs could be privately owned or could be made available under ride-sharing or car-sharing business models.

Published costs are mostly focussed on cars and CSIRO scales these up for other vehicle types by applying the same premium. BCG (2015) conducted expert and consumer interviews establishing that an autonomous vehicle (AV) would have a premium of around $15,000 and that customers would be willing to pay a premium of around $5000 to own a fully autonomous road passenger vehicle. This last point seems to align well with the concept of valuing people’s time saved in transport studies. If commuting via an autonomous vehicle gives back 1 hour of time for other activities per working day and if that time is valued that at around $20/hr (slightly more than average earnings), then its value over 235 working days (assuming 5 weeks leave) is $4700 per year.

KPMG (2018) uses a value of 20% for the AV cost premium which would be $3,000 to $8,200 for the standard passenger vehicle types used in our modelling. CSIRO interprets this costing approach as a focus on a larger vehicle and longer-term point of view (i.e., not a first of a kind vehicle). This matches the expectation that the autonomous vehicles would initially be targeted towards the larger less-budget conscious end of the market.

Based on these studies, CSIRO assumes AVs command a premium starting at $10,000 decreasing to $7,500 by 2030 and remaining at that level. Given how consumers value time, significant cost reductions beyond these assumptions may not be necessary to support growth in adoption. However, it is assumed that the vehicles will not be available for adoption until the late 2020s.

For freight vehicles, the major value from AVs are fuel consumption savings through platooning, resting drivers so they can complete longer trips without a break or, if technically feasible, completely removing the driver.

By removing the driver, the wages costs are avoided which are on average around $75,000 per annum while also increasing truck utilisation. Our assumption is that AV truck premiums will be significantly higher (proportionate to the ratio of truck to passenger car costs) owing to the greater complications of a larger vehicle under load in terms of reaction times for autonomous systems and the requirement of better sensing for AVs. However, if these vehicles can achieve full autonomy, the financial incentives are significant.

These assumptions set the economic foundations for AVs which is an important driver for adoption. The adoption of AVs, particularly those with ride share capability in the passenger segment, results in changes to the required size of vehicle fleet and sales which has secondary impacts on the adoption of all vehicles. These issues are discussed further in Section 4.8.1.

4.2 Electricity tariffs

4.2.1 Assumed trends in retail prices [place holder text until AEMO retail pricing received]

Retail electricity prices have increased in 2022-23 reflecting the impact of high international fossil fuel prices on generation costs. These higher generation costs are expected to ease in the next few years as international circumstances improve and increasing non-fossil fuel capacity is brought into the generation market. Thereafter retail prices are assumed to be more stable throughout the projection period and are not a strong driver of uptake trends or differences between scenarios. This is because electricity refuelling costs are a small proportion of total vehicle running costs (the vehicle is the main cost). Modest differences between a small component across scenarios therefore cannot drive major changes in vehicle adoption.

Some modest increases in generation and retail prices are assumed later in the projection period as higher electricity generation prices are required to support investment necessary for replacement of retiring generation capacity and to meet new demand growth. The non-generation components of the retail price are expected to be more stable.

Retail electricity prices in Western Australia and Northern Territory are set by government and are therefore less volatile. Commercial retail prices are assumed to follow residential retail price trends for all scenarios, although under different tariff structures.

4.2.2 Current electricity tariff status

Electricity tariff structures are important in determining the return on investment from customer adoption of EVs and, perhaps importantly for the electricity system, how they operate those technologies. The majority of residential and some small-scale business customers have what is called a ‘flat’ tariff structure which consists of a daily charge of $0.80 to $1.20 per day and a fee of approximately 20 to 30c for each kWh of electricity consumed regardless of the time of day or season of the year. Customers with rooftop solar will have an additional element which is the feed-in tariff rate for solar exports. Customers in some states have an additional discounted ‘controlled load’ rate which is typically connected to hot water systems.

Except where flat tariffs are available to smaller businesses, in general, business customers generally face one of two tariff structures: ‘time-of-use’ (TOU) or ‘demand’ tariffs. In addition to a daily charge, TOU tariffs specify different per-kWh rates for different times of day. Demand tariffs impose a capacity charge in $/kW per day in addition to kWh rates (with the kWh rates usually discounted relative to other tariff structures). Demand tariffs are more common for larger businesses. TOU and demand tariffs may also be combined. Both types of business tariff structures reflect the fact that, at a wholesale level, the time at which electricity is consumed and at what capacity does affect the cost of supply. These tariff structures are not perfectly aligned with daily wholesale market price fluctuations but are a far better approximation than a flat tariff. In that sense, TOU and demand tariffs are also described as being more 'cost reflective' or 'smart' tariffs.

A smaller but increasing proportion of residential customer also have TOU retail tariffs. Some more technically savvy customers have determined that TOU tariffs give them the best opportunity to manage their costs, particularly if they have a home battery system. In other cases, flat retail tariff customers have been moved to TOU retail tariffs when they connect to solar PV or make other significant changes to their connection.

There is also a class of tariffs called network tariffs. These are the tariffs that networks charge retailers. In most cases networks are increasingly charging retailers a TOU tariff for residential customers (Figure 4-1). Retailers are not obliged to pass this network tariff structure through in their retail tariffs and there are no publicly available statistics on TOU share of residential customer retail tariffs.

In some regions such as Western Australia and Northern Territory there is greater government involvement in setting tariffs. In such cases time of use tariffs are less common and these regions are assumed to move more slowly away from flat tariffs.

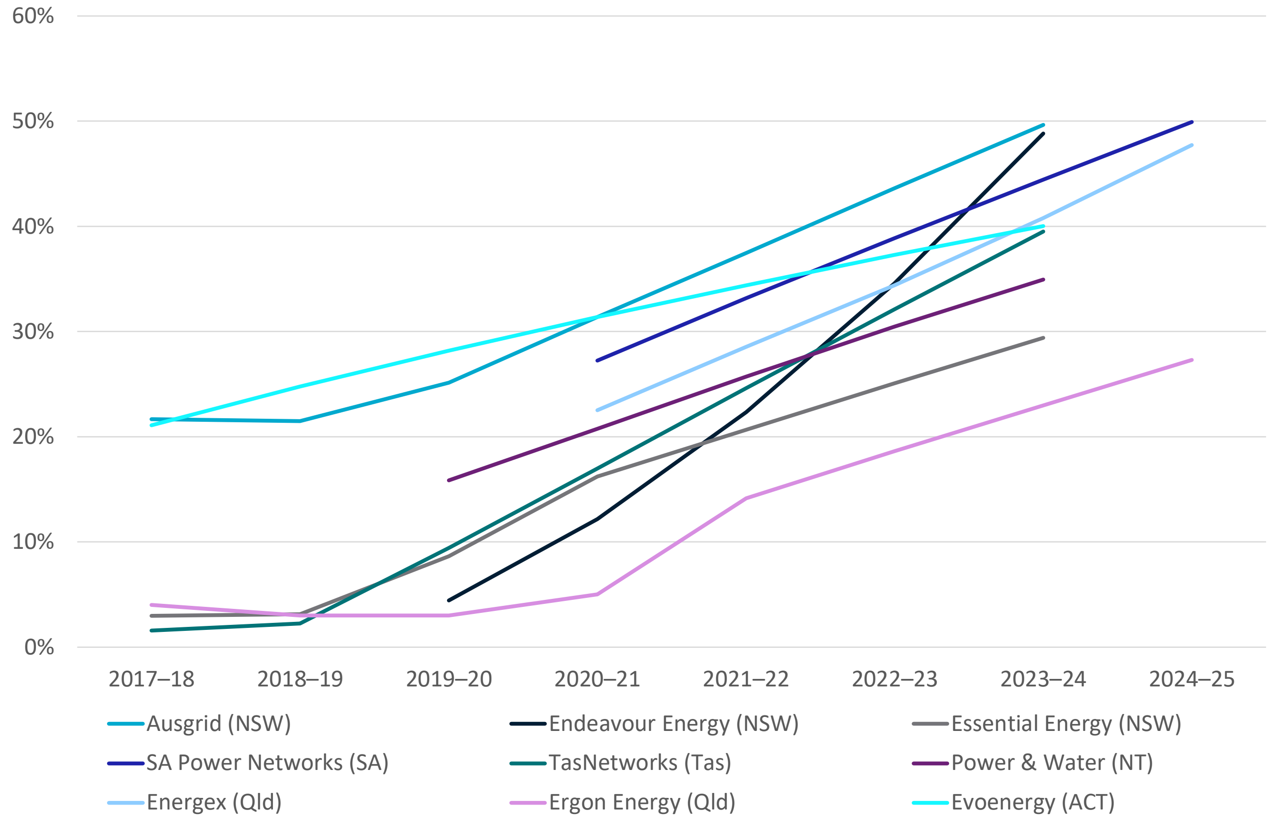

Figure 4-1 Projected assignment of cost-reflective tariffs for residential consumers by electricity distribution networks, AER (2021)

Some customers with home batteries have also participated in virtual power plant (VPP) trials. AEMO (2021) reported that around a quarter of all registered battery owners had participated in trials. Given the propensity for trail offers to be more generous than market offers its unclear how well this may translate out of trials. However, it is an indicator that battery ownership is a facilitator for customer adoption of more complex tariffs. This likely reflects that customers are less invested in how their batteries operate (of all home appliances, their daily operation does not impact directly on household amenity and comfort). This experience could be partially transferable to electric vehicles.

4.2.3 Future developments in EV owner incentives and management

Changes to customer connections and network charges to retailers are the main policy arrangements in place for changing the tariff structures that EV owners face. Historical research has shown that customers do not necessarily want more complicated tariffs[14] but there are clearly cases, such as in the recent VPP trials, where customers are willing to adopt new approaches. Retailers should have some success in offering cost savings for electric vehicles to charge at times that are lower cost for the system without impacting vehicle amenity given the large storage capacity of electric vehicles relative to daily driving needs.

Customers will indirectly participate in TOU pricing by using public charging infrastructure (daytime charging) which will be subject to a TOU tariff between the business and retailer. The assumptions for the share of vehicles adopting such charging practices are outlined in Section 4.5.

There are long term issues with relying too heavily on TOU tariffs as the main incentive and control mechanism. Once electric vehicles reach a greater critical mass, TOU tariffs will result in new peak charging behaviours during the transition from peak to off-peak pricing. Consequently, this report also considers more direct control measures. Direct control measures in the context of electric vehicles are called vehicle to home or vehicle to grid schemes and these have only recently begun to be trialled in Australia.

This report does not outline the operation of vehicles under direct control schemes – this is estimated by AEMO in their market modelling. CSIRO only estimates the number of vehicles participating in such schemes on a static basis. CSIRO includes vehicle to home and vehicle to grid from 2028 in *Hydrogen Export* and from 2030 in all other scenarios. the share of participation is assumed to be stronger in scenarios with faster electric vehicle uptake and stronger climate policy ambition. It is assumed those participating in such schemes can access lower cost charging similar to off-peak pricing in a TOU tariff. This will likely require widespread access to public charging infrastructure at daytime parking places.

4.3 Income and population growth

4.3.1 Gross state product

Gross state product (GSP) assumptions by scenario are presented in Table 4-2 and these are provided by AEMO and their economic consultant, BIS Oxford Economics. These assumptions have been applied to project commercial and freight vehicle numbers and are relevant for calibrating adoption functions where income is part of the adoption readiness score. However, in our projection methodology, movement along the adoption curve is largely driven by factors other

[14] Stenner et al (2015) provide further insights on customer's responses to alternative tariffs.

than economic growth. As such, economic growth assumptions have only a marginal impact (no more than 20%) on projections (for more discussion see Section 2.3).

Table 4-2 Average annual percentage growth in GSP to 2050 by state and scenario, source: AEMO and economic consultant

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australian Capital Territory
Progressive Change	1.8	2.1	2.0	1.4	2.1	1.3	2.0
Exploring Alternatives	2.1	2.4	2.3	1.7	2.3	1.7	2.2
Step Change	2.1	2.4	2.3	1.7	2.3	1.7	2.2
Hydrogen Export	2.7	3.0	2.8	2.1	2.7	1.9	2.6

4.3.2 Population

Population growth assumptions by scenario are shown in Table 4-3 and these are provided by AEMO and their economic consultant, BIS Oxford Economics. These assumptions have been applied for determining growth in passenger transport demand.

Table 4-3 Average annual percentage rate of growth in customers to 2050 by state and scenario, source: AEMO and economic consultant

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australian Capital Territory
Progressive Change	0.7	1.1	1.2	0.5	1.2	0.4	1.3
Exploring Alternatives	0.9	1.3	1.3	0.7	1.4	0.5	1.4
Step Change	0.9	1.3	1.3	0.7	1.4	0.5	1.4
Hydrogen Export	1.3	1.7	1.6	1.0	1.8	0.7	1.7

4.4 Separate dwellings and home ownership

4.4.1 Separate dwellings

Owing to rising land costs in large cities where most residential customers reside, there is a trend towards building of apartments that are stratas, compared to detached houses (also referred to as separate dwellings in housing statistics). As a result, it is expected that the share of separate dwellings will fall over time in all scenarios (Figure 4-2). This assumption does not preclude periods of volatility in the housing market where there may be over and undersupply of apartments relative to demand. The assumption for *Exploring Alternatives* and *Step Change* was built by extrapolating past trends resulting in separate dwellings occupying a share of 45% by 2050, around 18 percentage points lower than the 2021 ABS Census data. The *Progressive Change* and *Hydrogen Export* assumptions were developed around that central projection with *Hydrogen*

Export experiencing a less rapid shift to apartments which supports higher electric vehicle adoption.

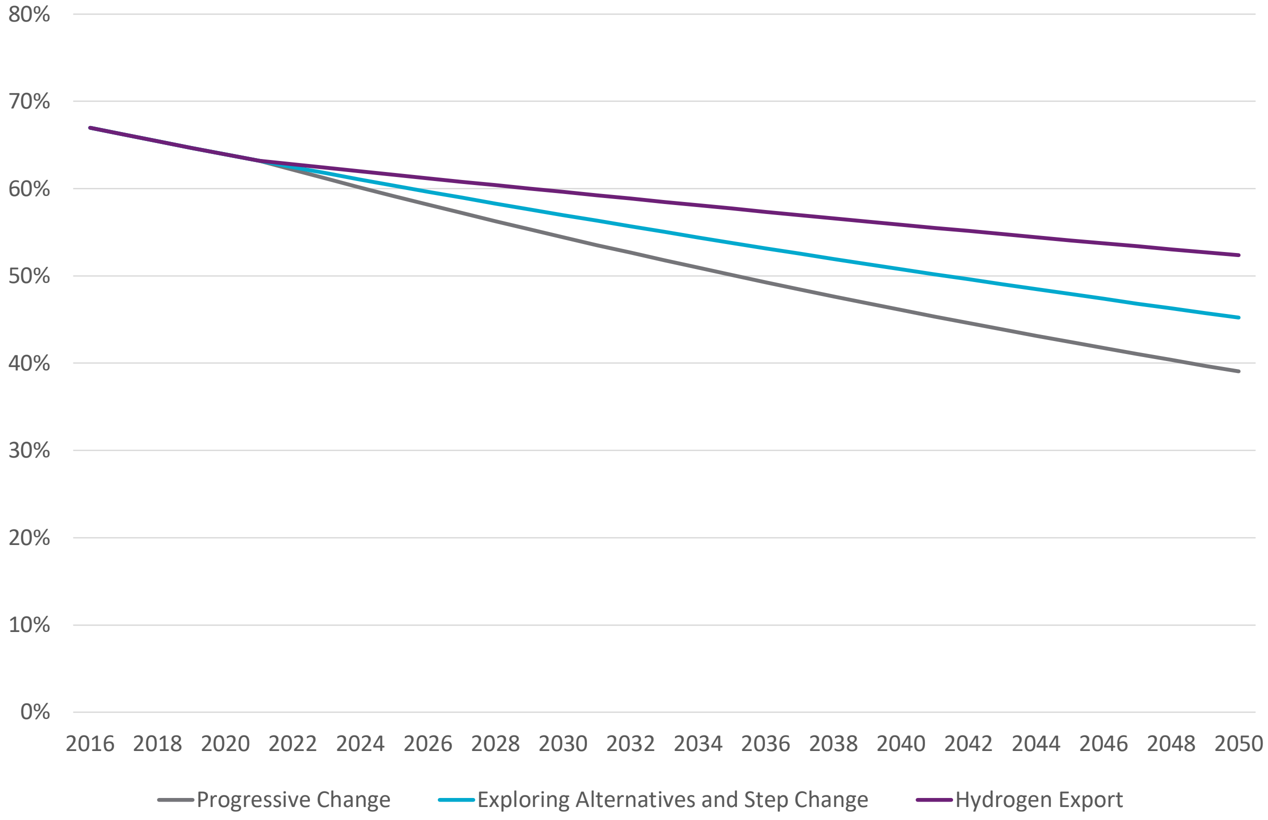

Figure 4-2 Assumed share of separate dwellings in total dwelling stock by scenario

4.4.2 Home ownership

While not a hard constraint, home ownership increases the ability of occupants to modify their house to include small-scale embedded technologies and EV chargers. Home ownership (which includes homes owned outright and mortgaged) increased rapidly post-World War II and was steady at around 70% for the last century. However, in the 15 years from 2001, home ownership declined to 65.4% in 2016 and increased slightly to 65.9% in the 2021 ABS Census (Figure 4-3). Ownership rates are uneven amongst age groups with stronger declines in ownership among young people (25 to 34).

Under the *Exploring Alternatives* and *Step Change* scenarios, the declining trend in home ownership is assumed to continue to wane to 2050 at a rate consistent with the last 10 years. For the *Progressive Change* scenario, a declining trend consistent with that of the last 20 years is assumed, leading to a slightly faster reduction in home ownership rates. For the *Hydrogen Export* scenario, consistent with higher solar and battery installation, a slower rate of decline in home ownership is assumed consistent with the last 25 years (Figure 4-3).

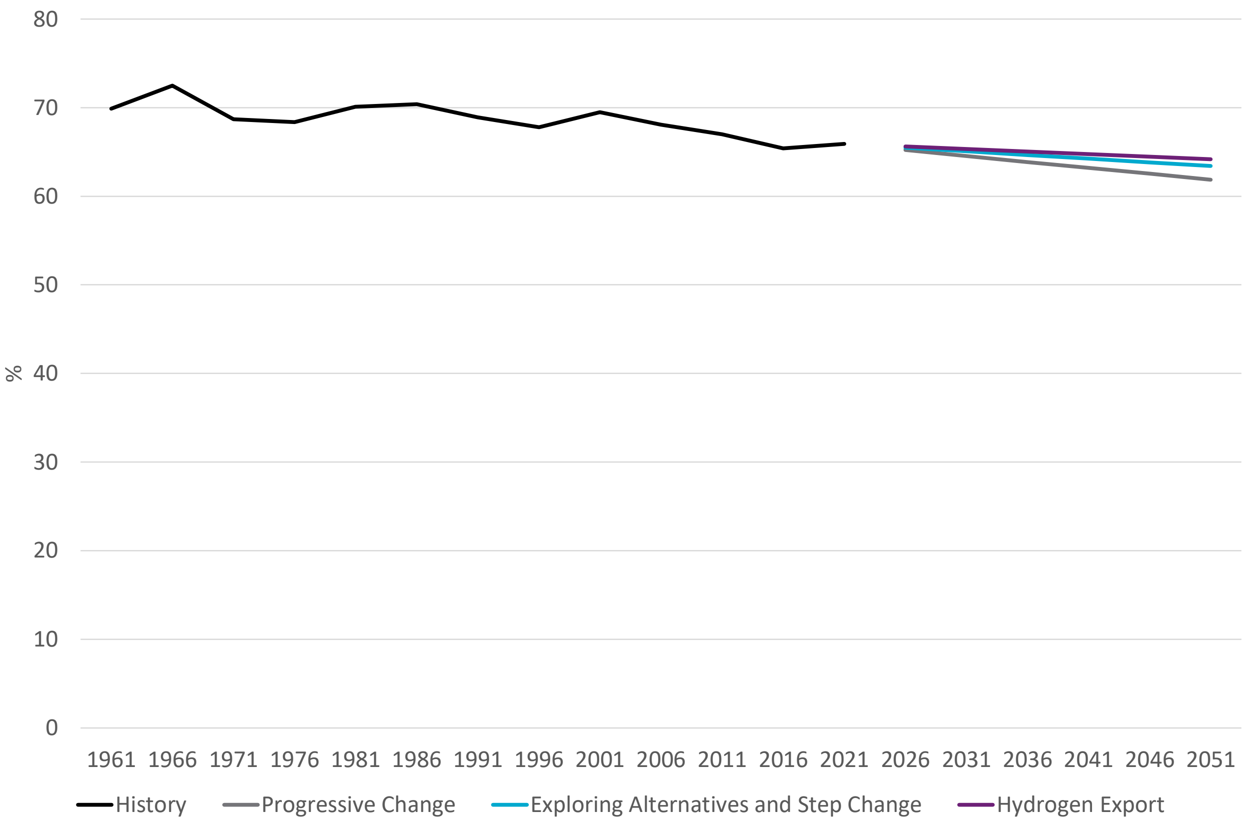

Figure 4-3 Historical (ABS Census) and projected share of homes owned outright or mortgaged

4.5 Vehicle market segmentation

It is useful to segment the market for electric and fuel cell vehicles to determine if any constraints should be applied to the maximum market share in the adoption projections. This also allows the assignment of different shares of electric vehicle charging profiles to different segments to understand the diversity of charge behaviour across the fleet.

In Table 4-4 below, assumptions for the non-financial factors that might limit the size of a vehicle in each market segment are outlined. These are generally based around limits faced by households because the relevant data for households is more readily available. It is assumed, however, that the limitations apply equally to businesses such that there is an equivalent concept (see rationale in the last column). Each row describes the share of households in each scenario to which the factor applies and the rationale for that assumption which may be a combination of data sources and scenario assumptions.

The table concludes by calculating the maximum market share for each vehicle category via the formulas shown. The maximum market shares are then applied to calibrate the consumer technology adoption curve. The calibration works in a way such that the maximum market share of sales is allowed if the payback period has fallen to a very low level (e.g., one year). At higher payback periods, sales are less than the maximum market share. An exception is *Exploring Alternatives, Step Change* and *Hydrogen Export* where, by design, the electric and fuel cell vehicle adoption rate is set to achieve 99% of the fleet for cars, buses and rigid (smaller) truck by 2055, 2050 and 2045. This 99% transformation of the vehicle fleet to zero emission vehicles is consistent with the scenario narrative of net zero greenhouse gas emissions in those scenarios. However, *Progressive Change* allows for the possibility that the road transport sector is unable to contribute a strong role in decarbonisation due to turnover of the internal combustion vehicle stock failing to sufficiently accelerate at the rate needed[15].

In most cases, the market shares across vehicle types adds up to greater than 100%. As such they should be interpreted as the maximum achievable share to be reached independent of competition between vehicles. When applied in the model, the after-competition share is lower. Note that autonomous ride share vehicles are assumed to be a subset of long-range electric vehicles since this is the most natural vehicle type for this service (i.e., lowest fuel cost for high kilometre per year activity). The market share limits are imposed on average. However, the modelling allows individual locations (modelled at the postcode level) to vary significantly from the average according to their demographic characteristics).

[15] In Exploring Alternatives, Step Change and Hydrogen Export the internal combustion fleet scrapping rate has to be accelerated above the historical scrapping rate in order to meet the timing indicated.

Table 4-4 Non-financial limitations on electric and fuel cell vehicle uptake and the calculated maximum market share prior to ICE vehicle collapse

		Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export	Rationale/formula	Equivalent business constraint
Limiting factors (residential)							
Separate dwelling share of households	A	39%	45%	45%	52%	Based on housing industry forecasts	Businesses located on standalone site
Share of homeowners	B	62%	63%	63%	64%	Based on historical trends	Business not renting their site
Share of landlords who enable (passively or actively) EV charging onsite	C	60%	70%	90%	100%	Data not available. Assumed range of 60-100%	Same
Off-street parking/private charging availability	D	26%	32%	35%	42%	Assume 80% of separate dwellings have off-street parking. Formula=(0.8*A*B)+(0.8*A*(1-B)*C)	Same
Public or multi-occupant building charging availability	E	40%	50%	65%	80%	Availability here means at your work/regular daytime parking area, apartment carpark or in your street outside your house. Assumptions are based on this type of charging being the least financially viable.	Same
Share of houses that have two or more vehicles	F	58%	60%	65%	75%	Based on historical trends	Share of businesses with two or more fleet vehicles
Share of houses where second vehicle is available for longer range trips	G	67%	70%	75%	80%	Assumed range of 65-80%. There may be a range of reasons why second vehicle is not reliably available for longer trips	Operational availability of fleet vehicles
Share of people who would prefer ICE regardless of EV/FCEV costs or features	H	10%	0%	0%	0%	Based on laggards generally being no larger than a third of customers. Exploring Alternatives, Step Change and Hydrogen Export assume ICEs suffer a collapse in manufacturing due to systematic loss of supporting infrastructure	Business owner's attitudes and specific vehicle needs
Share of people willing for their second or more cars to be replaced with ride share	J	10%	15%	20%	25%	Assumed that only a laggard proportion would object to this arrangement	Same

		Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export	Rationale/formula	Equivalent business constraint
Fuel stations with access to hydrogen supply chain	K	5%	10%	20%	30%	Data not available due to uncertainty. Assume range of 5-30%.	Same
Maximum market share							
Short range electric vehicles		10%	15%	18%	26%	Limitations are limited range and charging. Due to range issue, assume SREVS only purchased by two or more car households and 10% of 1 car households. Formula=[(F*G*D)+(0.1*(1-F)*D)]*(1-H)	Large trucks 0%
Long range electric vehicles		60%	82%	100%	100%	Key limitation is charging and customer who would prefer ICE.	
Plug-in hybrid electric vehicles		60%	82%	100%	100%	Same as long range	
Fuel cell vehicles (light)		5%	10%	20%	30%	Formula=(1-H)*K	
Fuel cell large trucks		30%	50%	70%	90%	Scenario setting	
Autonomous ride share vehicles		6%	9%	13%	19%	Formula=J*F	

Table 4-5 Shares of different electric vehicle charging behaviours by 2050 based on limiting factor analysis

Limiting factor		Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export	Rationale/formula
Customers accessing tariffs that support prosumer behaviour and system integration	L	30%	40%	50%	60%	Scenario assumption
Residential vehicles						
Home charging convenience profile		58%	47%	35%	23%	Residual
Home charging night aligned (non-dynamic)		6%	8%	10%	12%	Formula=0.2*L
Vehicle to home/grid (dynamic system-controlled charging)		11%	16%	23%	34%	Formula=D*E
Public charging highway fast charge		10%	10%	10%	10%	90%+ of driving is within 30km of home
Public charging solar aligned (non-dynamic)		16%	19%	22%	21%	Formula=0.8*(L-vehicle home/grid share)
Commercial vehicles						
LCV - Convenience / night		72%	63%	54%	45%	Non-highway kilometres. Formula=(1-L)*0.95
LCV - Daytime adjusted for solar alignment		18%	27%	36%	45%	Non-highway kilometres. Formula=L*0.95
LCV highway fast charge		10%	10%	10%	10%	Assume similar pattern to residential driving
Trucks & buses convenience / night		72%	63%	54%	45%	Non-highway kilometres. Formula=(1-L)*0.95
Trucks & buses solar aligned		18%	27%	36%	45%	Non-highway kilometres. Formula=L*0.95
Trucks & buses highway fast charge		10%	10%	10%	10%	Assume similar pattern to residential driving

4.6 Vehicle to home or grid

Once electric vehicles are established[16], they will represent a large battery storage resource. For example, if long-range electric vehicles are popular, each vehicle will represent around 100kWh of battery storage – some nine times larger than the average 11kWh stationary batteries that are marketed for shifting rooftop solar for households. It is therefore natural to consider whether this battery storage resource could be used either after its life on board a vehicle or during that life.

The average vehicle in Australia travels around 11,000km per year. For a SREV of 200km range the battery size is around 40kWh, the average daily charge cycle will be 6.7kWh which is a depth of charge/discharge of around 17%. If a driver were to travel 3 times that distance each year the shelf life of the battery will run out before the cycle life. However, such a driver more than likely has a long-range electric vehicle (due to their higher average kilometres per day) where the daily depth of charge/discharge might be even lower.

Given the expected under-working of electric vehicle batteries it therefore makes sense to consider how to get more use out of the battery while it is on the vehicle. Household yearly average electricity demand is 6000kWh or 16.4kWh/day. As such, any full charged electric vehicle, short or long range, can cover the required power needs with room to spare for the daily commute. However, the most likely candidate for vehicle to home would be a long-range vehicle with around 100-120kWh battery storage. An LREV could deliver energy to a home and would on average only lose 100km or 20% or less of its 500+km range for the next day's drive.

Vehicle to home would best suit a household that has access to charging at their normal place of daytime parking (i.e., at work, home(solar) or in a carpark). Apart from getting better utilisation out of an existing resource (the battery storage capacity in the vehicle), the other financial incentive to this arrangement is the potential that the vehicle can charge up at lower cost. This follows the general expectation that in the long term, as solar generation capacity increases, the lowest priced period for electricity from the grid will be around midday. The economics would also work well for the charging infrastructure provider. Instead of simply providing electricity for each cars' daily driving needs (around $2/day) they can instead provide their car plus home needs ($6/day).

The process is achievable from a technical point of view with a more specialised connection to the home. Several manufacturers have made this capability available although only one model is currently available for sale in Australia (the Nissan Leaf).

The major difference with vehicle to grid is that it may push the boundaries further in terms of utilisation of the vehicle battery to meet system needs which may be greater than home needs. Presumably the business model in this case would need to reach agreement with the vehicle owner on how much of the battery capacity can be accessed so that the owner's transport needs are not compromised. Potential faster and deeper discharges could shorten the vehicle battery life. Nevertheless, the scale of electric vehicle battery capacity in the higher EV uptake scenarios (even accounting for low availability and only access half the battery) could be sufficient to avoid

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[16] AEMO's scenario design assumes this occurs post 2030

the need for major large-scale battery deployment. As such, some level of compensation will be available to vehicle owners.

Our assumption is that commercial vehicles will not participate in either vehicle to grid or vehicle to business (home). The rationale is that higher duty vehicles will have less excess capacity that owners would be willing to make available to the grid. Commercial vehicles may still support the system through non-dynamic pricing (tariffs).

4.7 Shares of electric vehicle charging behaviour

Besides setting the technology adoption saturation levels, the maximum market shares identified in Table 4-4 are also applied, together with other assumptions, to determine what shares of different electric vehicle charging profiles should be applied by 2050 (Table 4-5). The key additional assumption is to assign the percentage of customers that are participating in tariffs or other incentives for prosumer and electricity system supporting behaviour (which is a scenario assumption).

For residential vehicles a small amount of public fast charging is assumed consistent with the observation from many trip studies that around 90% of driving is within local areas (see BITRE 2015). Aligned with this observation, charging experience in countries that are further down the path of electric vehicle adoption than Australia indicates a 10% public charging share. The amount of home charging is calculated from the amount of off-street parking (calculated in Table 4-4). Charging at home is split between convenience and solar aligned charging based on the tariff and other incentives assumptions. The formula allows for another fraction of customers to participate in vehicle to grid or vehicle to home activities and charge during the day at their daytime place of parking. This represents the subset of people who have both off-street parking and access to public charging in that scenario.

Some commercial charging profiles are aligned to the nighttime but could be incentivised to be aligned with solar generation should that become the new off-peak period to support electricity system efficiency (see Section 5.3 for charging profiles). Current tariffs faced by the commercial sector also incentivise avoiding peak periods. It is assumed that signing up to new tariffs or incentives could shift that part of charging which is not aligned with solar generation times into that time.

4.8 Transport demand

The future number of electric vehicles is partly determined by demand for transport and the number of road vehicles required to meet that demand. To develop our road vehicle demand projections, the process commences by projecting demand for passenger transport (passenger kilometres or pkm) and freight transport (tonne kilometres or tkm) across all transport modes. Passenger transport demand is a function of population, while freight demand is a function of economic growth. Next, assumptions are made about the share of transport delivered by each mode. In any normal year a simple extrapolation of past trends would be appropriate. For example, the aviation transport mode has been steadily gaining market share in passenger transport demand for decades. However, the COVID-19 pandemic has disrupted these trends and is likely to have some degree of ongoing impacts. It is assumed that the current road mode share persists in *Hydrogen Export* as this would be consistent with a strong vehicle market and strong climate action. The *Step Change*, *Exploring Alternatives*, and *Progressive Change* scenarios are assumed to progressively revert back to the historical trend of declining road mode share.

Freight transport mode shares were less impacted by COVID-19 and so historical trends in mode share are allowed to continue but at different rates, with the strong usage of road modes again associated with stronger climate policy ambition.

Aside from stronger road mode shares, *Hydrogen Export* also has stronger population and economic growth which also strengthens passenger and freight transport demand. *Step Change, Exploring Alternatives* and *Progressive Change* are assumed to have to progressively lower population and economic growth.

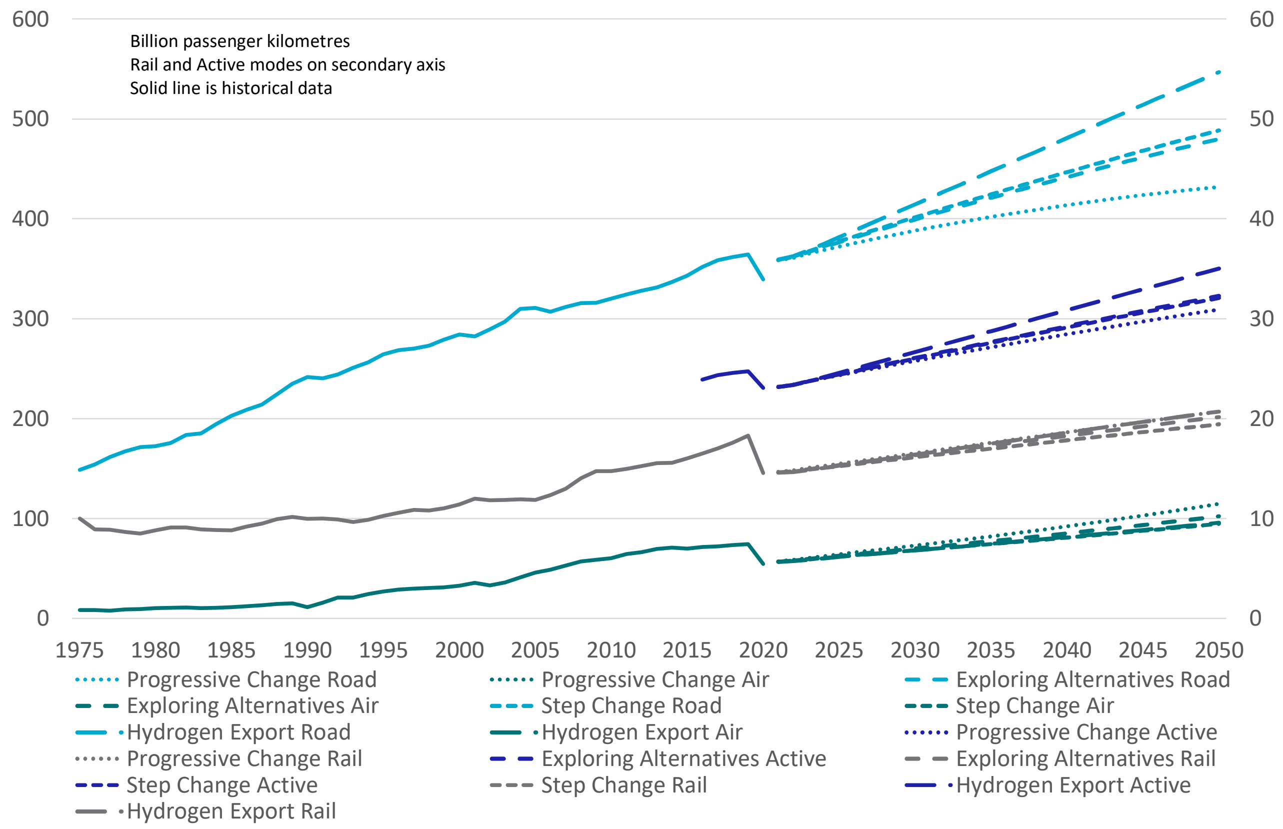


Figure 4-4 Historical and projected passenger transport demand

The results of these passenger and freight transport demand projections are shown in Figure 4-4 and Figure 4-5. The reduction in passenger transport demand during the COVID-19 pandemic is strongly evident in the 2020 data. The data outlined in Figure 4-4 and Figure 4-5 are national, but the projections are developed for each state and account for different levels of disruption from COVID-19 by state.

To calculate road transport demand in vehicle kilometres the modelling approach imposes a price elasticity response by tracking future road transport costs (based on an initial estimate of the vehicle mix). Views about autonomous vehicle adoption and the general level of vehicle utilisation are discussed below.

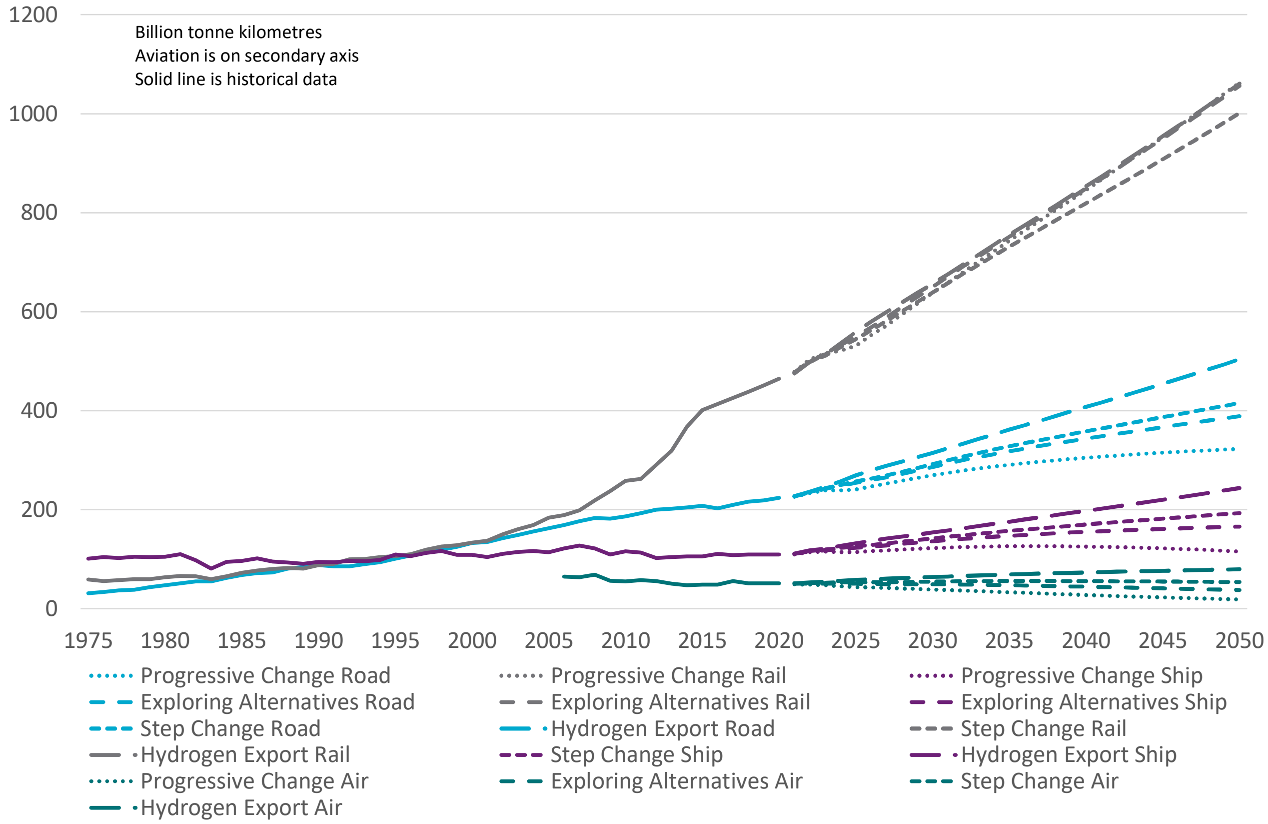


Figure 4-5 Historical and projected freight transport demand

4.8.1 Autonomous vehicles

As part of vehicle demand modelling, the uptake of automated vehicles in both the light and heavy vehicle markets for private use and as ride share vehicles are projected. The main delay in adopting these technologies is achieving complete safety and technological feasibility. Otherwise, the benefits of time and wages saved from driving appear to be well above the theoretical vehicle cost on a whole-of-life basis. The projections assume different market sizes over time across the scenarios based around the general uncertainty to this new way of delivering road transport services.

Figure 4-6 shows the projected share of passenger and freight autonomous vehicles by scenario by 2050. Ride-share are disaggregated from privately owned autonomous vehicles and are a smaller segment. The total across all passenger vehicle types ranges from less than 1% to almost 4% across all scenarios by 2050. For trucks and buses where the avoided wages benefit is a strong driver the maximum adoption rate is more than double passenger vehicles at over 8%.

Rideshare vehicles are of interest because they could reduce the total number of electric vehicles required on the road and is likely to impact the total energy consumed under each vehicle charge profile. While autonomous rideshare vehicle shares are relatively small, each rideshare vehicle displaces other vehicles depending on how successful they are in concentrating passengers into the rideshare vehicle. It is assumed the displacement is initially small but increases such that each rideshare vehicle displaces 2 non-rideshare vehicles by 2050 as the business model matures.

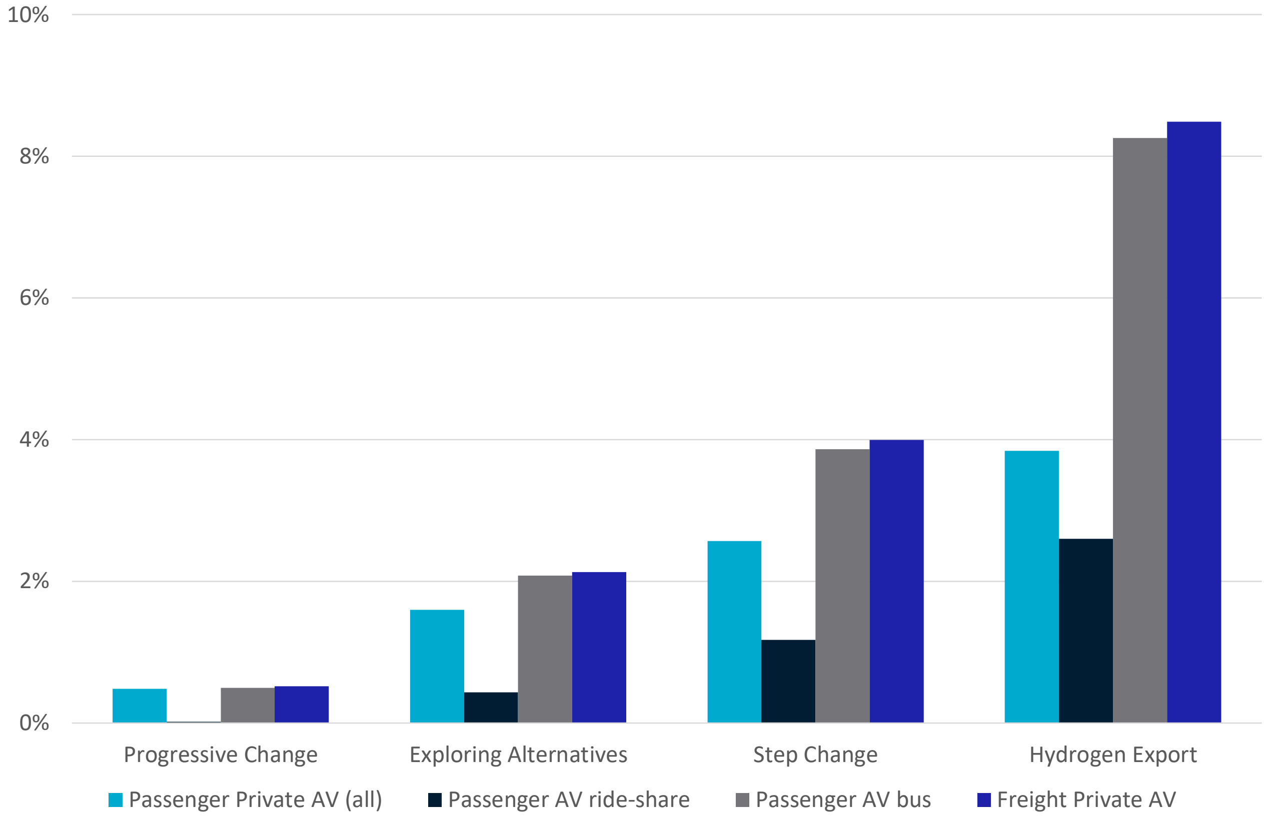


Figure 4-6 Share of autonomous vehicles in the passenger and freight road fleets by scenario in 2050

4.8.2 Vehicle utilisation and numbers

To convert road passenger transport demand to vehicle numbers requires assumptions to be made about average kilometres travelled per vehicle. All passenger vehicle types (motorcycles, passenger cars and buses) in all states experienced a significant reduction due to COVID-19. Buses suffered the strongest impact owing to the difficulty of social distancing for passengers within such a vehicle. Light commercial vehicles and trucks generally faired proportionally better with only modest reductions or increases in some states. Western Australia, Northern Territory and the Australian Capital Territory had the least changes in vehicle utilisation.

The extent to which the COVID-19 pandemic will lead to sustained changes in vehicle utilisation is uncertain. The experience has demonstrated to employers and employees that working from home can be productively applied to some jobs. This has raised expectations that the option to work from home may be available to employees well beyond the period in which such arrangements are implemented purely for public health compliance reasons. The longer pandemic conditions persist, such arrangements will be normalised. Therefore, it is not unreasonable to expect a partial continuation of these arrangements. It is also considered that the incidence of using video conferencing for work and other activities could increase as a greenhouse gas abatement strategy, particularly in scenarios with a net zero emissions target.

Taking the passenger and freight kilometres projection in Figure 4-4 and Figure 4-5 and assumed average freight load and passengers per vehicle (the average is 1.57 for cars before adjusting for uptake of rideshare vehicles), the road vehicle kilometres travelled to meet passenger and freight tasks is calculated and presented in Figure 4-7. The demand for road vehicles is calculated by dividing through by vehicle utilisation and the result is shown in Figure 4-8.

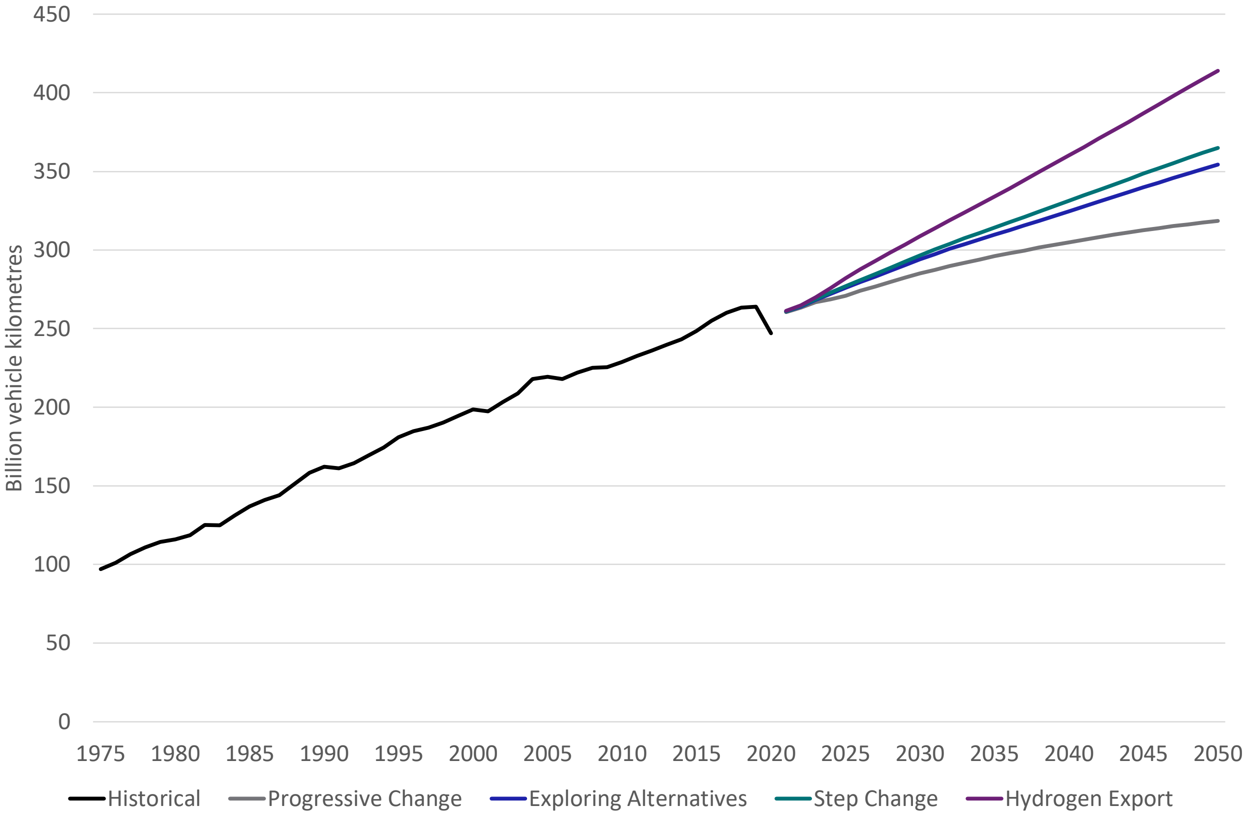


Figure 4-7 Historical and projected national road vehicle kilometres travelled, all road modes

The highest demand for travel is in *Hydrogen Export* reflecting stronger economic and population growth and slightly stronger road share of passenger transport. *Progressive Change* has the lowest economic growth and population and most significant decline in road mode share of passenger transport. *Step Change* and *Exploring Alternatives* have medium economic and population growth, with *Step Change* slightly stronger of the two scenarios.

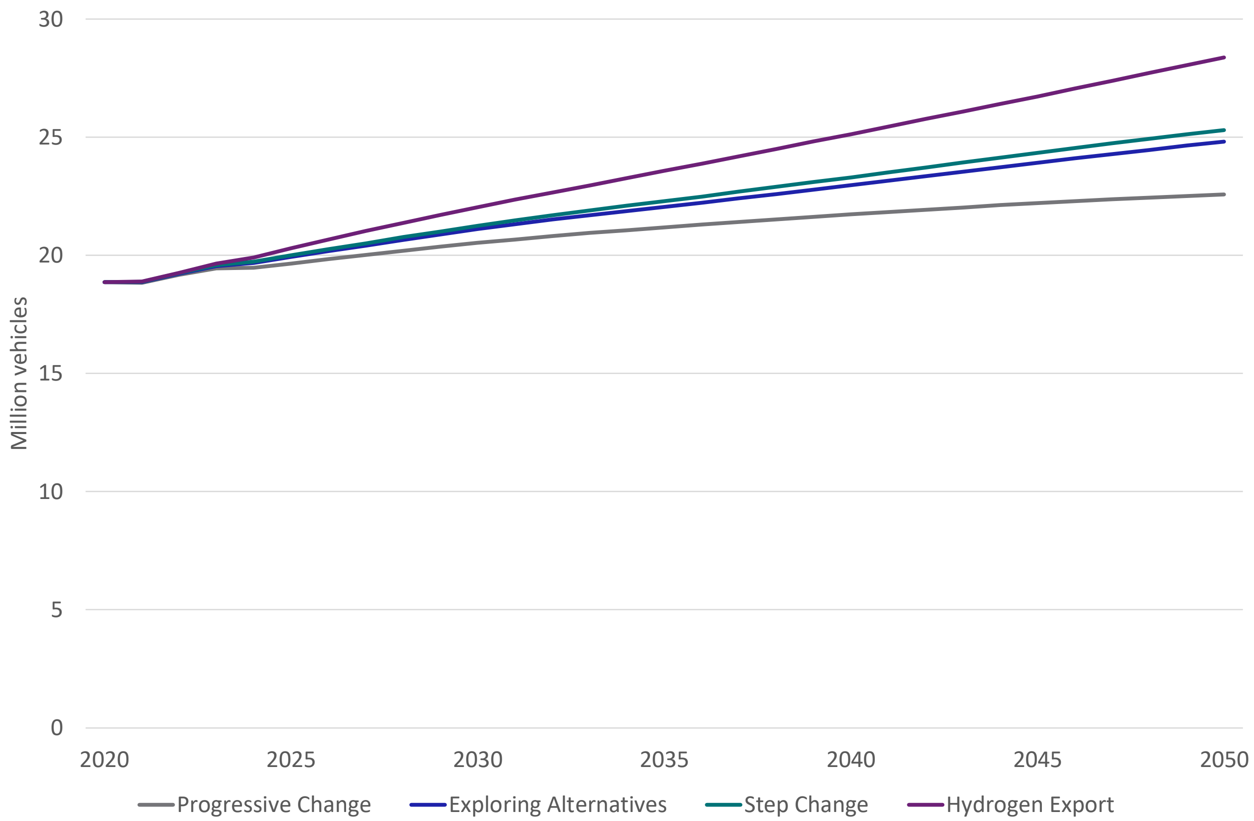


Figure 4-8 Projected national road vehicle fleet by scenario

4.9 Non-road transport electrification

The largest consumer of electricity in non-road transport is the passenger rail sector (around 3.3TWh nationally). This can be in the form of heavy rail or light rail (such as Melbourne's Tram system). These services are delivered by state governments and as such the degree of investment in expanding this mode is subject to competing demands on state budgets. There are also limitations on competing land uses for new rail corridors (tunnels are a partial means around this issue where geology is suitable). Passenger loads in existing corridors can be increased through modification of rolling stock (e.g., more standing space, or double level). Freight rail could be partially electrified. The main limitation is the cost of providing electricity supply along freight rail routes, some of which are remotely located. There is also the sunk cost of existing diesel rail engines which could be converted to other low emission fuels such as biodiesel. Hydrogen trains are also on option where no electricity infrastructure already exists. These constraints mean that electrification is expected to be low until technological advancements improve.

Up until recently aviation was not considered for electrification due to range limitations of batteries. However, the improvements in batteries, the success of electric-based drone technology in non-passenger applications and proliferation of transport-on-demand business models in cities, have made electrification of aviation more plausible. Delivery models being considered are diverse and include hybrids (single electric engine added to aircraft with other conventional propulsion), pure electric with modified air frame, vertical aero propeller / helicopter designs, hydrogen fuel aircraft designs and electric on-ground taxiing power. However, it is unclear if any of these designs would ever replace more than a few percent of long-haul high passenger load aviation. It is more likely that electrification or hybrid engines will be adopted in shorter route low passenger load aviation.

The consideration of electrification of shipping is less common. This is because ships can use some of the lowest cost liquid fuels available at present, their diesel engines are more easily adaptable to alternatives such as very low sulphur fuel oils, LNG, biofuel, natural gas and hydrogen. The weight of batteries and range limitation of electricity remains an unsolved issue. Consequently, electrification of marine transport is not included in the projections.

The projections for passenger rail electricity consumption are based on the projected rail passenger demand in Figure 4-4 multiplied by the extrapolated trend in rail energy requirements per passenger kilometre. For rail freight and aviation electrification, CSIRO calculates their overall energy demand and convert a share of demand over to electricity according to assumptions that are presented in Table 4-6. These are a subjective assessment of technology readiness and overcoming limits to adoption based on the scenario narratives.

Table 4-6 Rail freight and aviation electrification assumptions

Scenario	Electrification commencement date		Maximum share by 2050
	Rail freight	Aviation	
Progressive Change	2048	2047	3%
Exploring Alternatives	2037	2032	7%
Step Change	2035	2030	10%
Hydrogen Export	2030	2027	20%

4.10 Vehicle charging profiles

The publication of reports describing the outcome of electric vehicle charging trials in Australia have given CSIRO the opportunity to significantly revise its charging profiles[17]. Apart from providing average daily charging information, they have also highlighted the differences in types of chargers that customers are using. For example, the Origin Energy trial found that prior to joining the trial, 70% of participants were using a standard power socket (with only 4% being 15 amp). This observation is significant because it suggests the peak demand from such vehicle owners will be around 2.4kW. After diversity that could drop to around 0.4kW[18]. The CSIRO 2021 convenience profile peaked at almost 1.2kW. This was based on the observation that most chargers sold in Australia are around 7.2kW capacity. However, this new data which indicates dedicated chargers are less common suggests a lower peak is appropriate. To construct a new convenience profile the

[17] CSIRO gave consideration to the concern that trial data would represent early adopters who may not be a good guide to mainstream behaviour (once adoption reaches the mainstream). However, the trial data revealed that electric vehicle owners recruited into the trials were not particularly sophisticated in their charging behaviour, the majority relying on standard power points. Also, the trial participants use of home charging versus public charging appeared to be aligned to ratios seen in countries which have reached mainstream adoption.

[18] Based on seeing an after-diversity peak of 0.6kW in a trial where all customers had 3.5kW chargers

new baseline profiles available from the Energex and Ergon Energy Network (2022a, 2022b), Origin Energy (2021, 2022) and Philip et al. (2022) trials have been combined with the data from a UK trial (Roberts, 2016) . We would have preferred to only use the Australia trials. However, it is evident that in the baseline data of Australian trials, some customer either have TOU tariffs or have voluntarily set their vehicles to charge after 9pm, in the case of Origin trial, after 8pm in the Philip et al. (2022) trial or after midnight in the Queensland trial. We capture these behaviours in separate charging profiles and so do not wish to include them in the convenience profile.

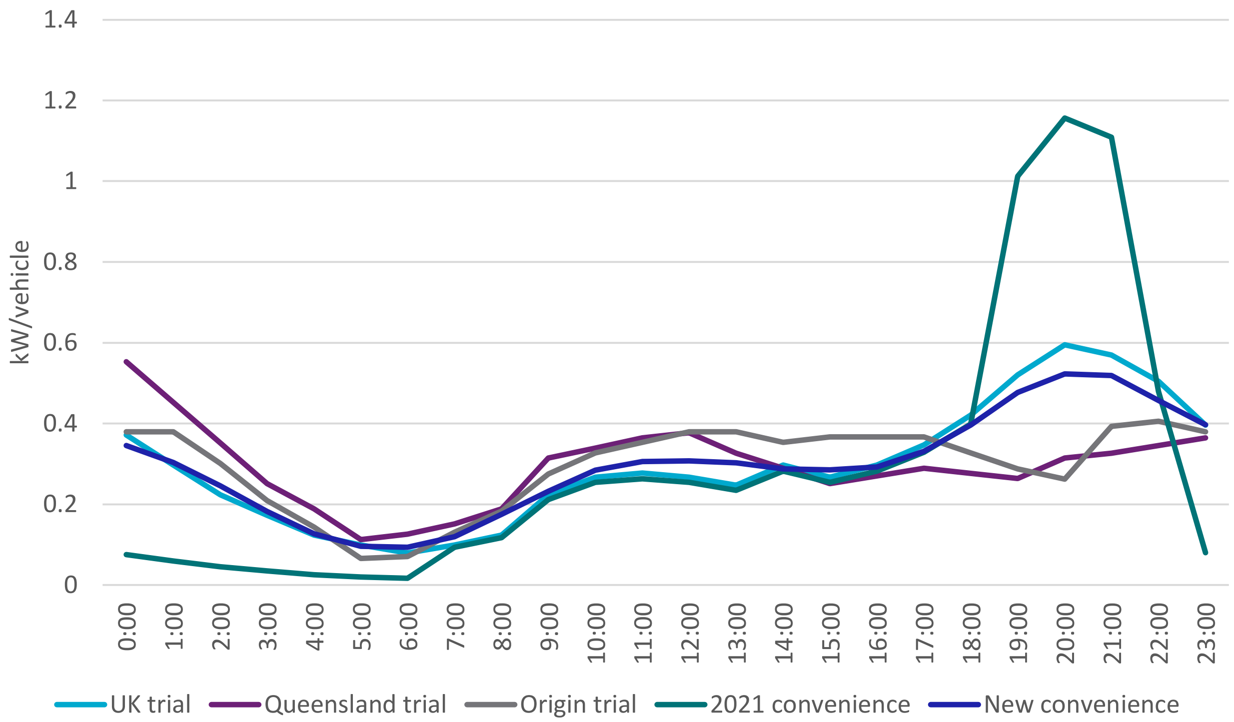


Figure 4-9 Alternative convenience charging profiles normalised to 7kWh/day

The Origin trial provides a separate TOU tariff daily profile, and it shows that there is a very low, but not zero, rate of charging during peak times. When the off-peak period begins, charging is not even. There is an immediate peak and then tapering off. This is also evident in the Queensland data (from midnight) and in Philip et al. (2022). CSIRO's 2021 nighttime profile had a flat shape in off peak times and so based on this new data it is adjusted to be peakier.

AEMO has also provided CSIRO with new data on public or fast chargers. Previously the fast charge profile was based on traffic movements as the best available proxy while public charging data was scarce. It showed mostly daytime demand with two peaks. However, the new data is based on actual public charging metering data. The new data shows a single flatter peak during the day. These new profiles for passenger vehicles are shown in Figure 4-10. The passenger vehicle data has also been used to make some adjustments to the profiles for heavy vehicles which should reflect TOU incentives but with a longer charge time and less flexibility to avoid overnight charging. Rigid truck charging profiles are shown in Figure 4-11.

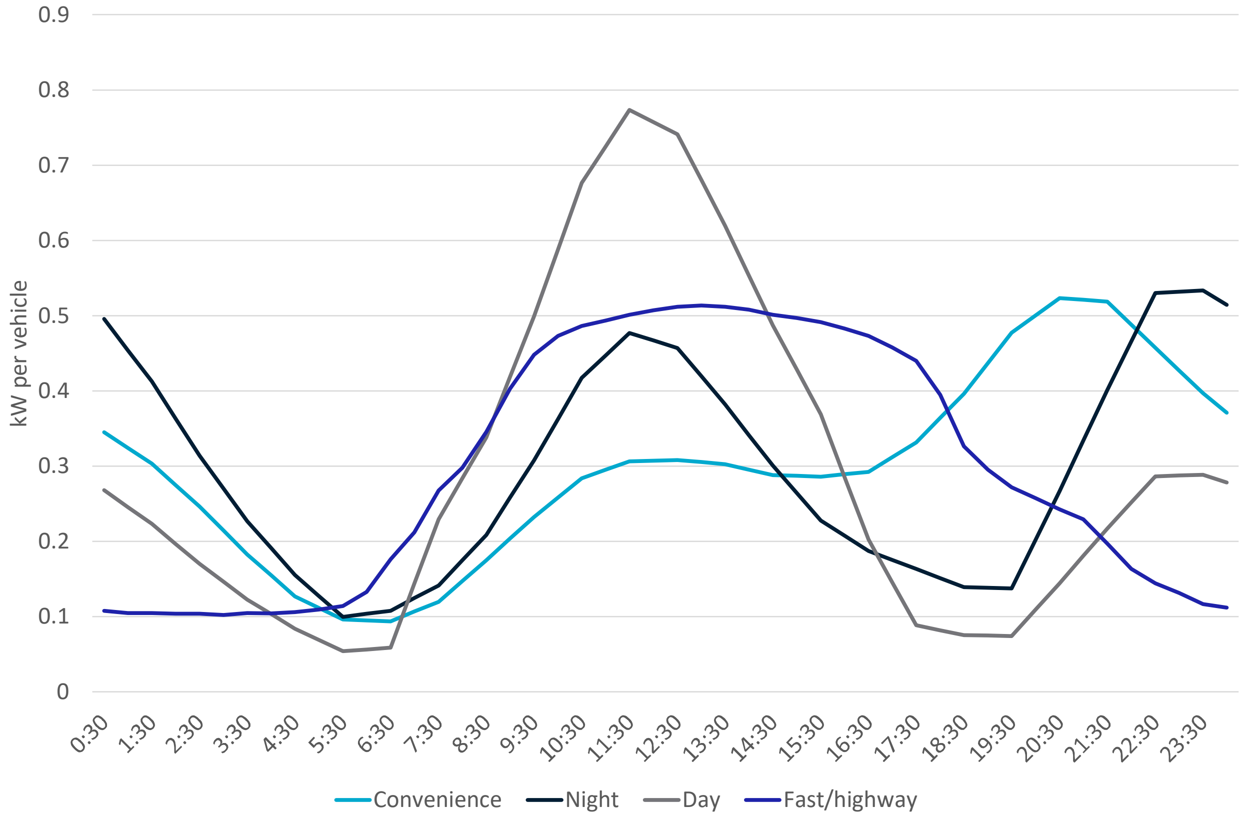


Figure 4-10 Charging profiles for medium sized passenger vehicles

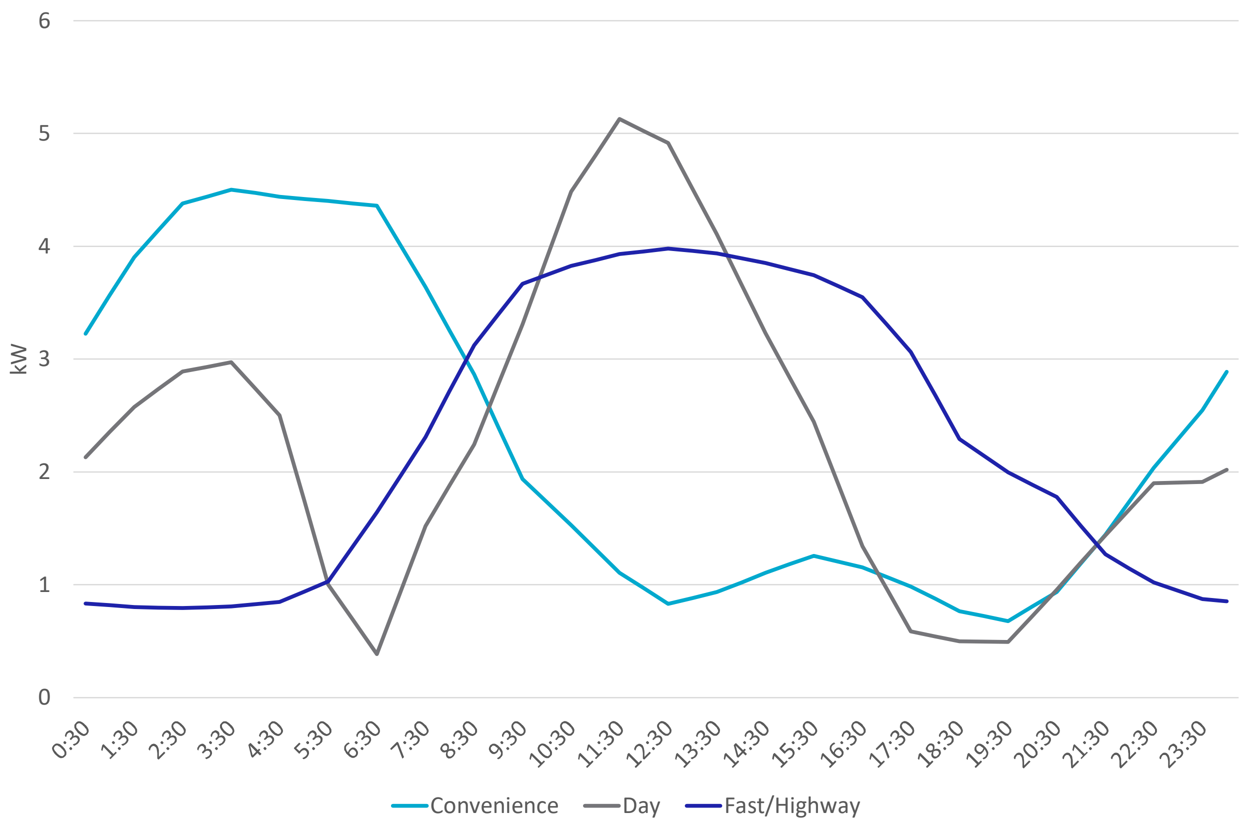


Figure 4-11 Charging profiles for rigid trucks

5 Projections results

The projections results are compared to CSIRO's 2021 projections (Graham and Havas, 2021). This comparison point is the most valid because it represents those changes that arise from changes in model inputs. Electric vehicle projections published by AEMO as part of its forecasting and planning assumptions will not perfectly align with CSIRO projections due to adjustments that take place post-modelling to take account of new developments such as policy changes or new historical data.

The 2021 projections are referred to as CSIRO and their 2021 scenario names: *Slow Growth Step Change* and *Export Superpower*[19]. The 2021 scenarios are presented as dashed lines on all figures in this section.

Most projections are presented to either 2050 or 2055. While 2050 is often a focus given Australia's net zero emissions target, it is useful to present another 5 years in some cases due to highlight changes in the vehicle market beyond that point.

Unless otherwise stated, electric vehicle projections include battery, plug-in hybrid and fuel cell electric vehicles. All of these vehicles use a common electric drivetrain but with alternative ways of delivering electricity to that drivetrain.

5.1 Sales and fleet share

As discussed in the methodology, CSIRO has updated the historical sales and fleet to June 2022. CSIRO then applies a regression to project forward to June 2023 and imposes a divergence on that regression across the scenarios to account for short term uncertainty. The consumer technology adoption model then takes over the projection. Finally, in the last 15 to 20 years, when electric vehicle sales are in the majority, a vehicle retirement model is mostly determining the rate of sales by determining the rate at which internal combustion vehicles need to be replaced by electric vehicles in order for a target 99% replacement date to be met (which is a scenario assumption – see Table 3-7). The combination of these three projection approaches results in a typical side-on drawn-out S-shape for sales over time (Figure 5-1). The joining of the three projection approaches can lead to some less than smooth turning points in the projections. However, these represent distinct shifts in customer groups from early adopters, mainstream adoption and late adopters and the speed of transition between these groups indicating the degree of local and global commitment to climate policy goals.

Compared to the 2021 projections there are several key differences. In the period from 2020 to 2023, the updated historical data plus regression has resulted in a much higher sales rate than

[19] In the 2021 CSIRO report the scenarios had different names but AEMO stakeholders will be more familiar with the scenario names shown here because they were the final names used before the most recent development of the 2022 scenarios. To map the scenario names used in the CSIRO 2021 report to those used here, use these formulas: Slow Growth = Slow Growth, Step Change = Sustainable Growth, Export Superpower = Export Superpower.

previously expected. In some cases, sales share is 5 years ahead of expectations compared to the 2021 CSIRO Slow growth scenario. The explanation for this outcome appears to be that global electric vehicle manufacturing and sales is different to the conventional vehicle market. Electric vehicle manufactures have had to develop new supply chains and contracting arrangements which appear to be less impacted by pandemic related supply chain disruptions. Nevertheless, we do expect electric vehicles to allow for the possibility that supply chain disruptions could impact the sector in the future. On the demand side, they have a greater level of pre-orders which likely provided more certainty for manufacturers to continue production during a global downturn in vehicle sales[20]. Producing fewer models also likely provides some additional resiliency.

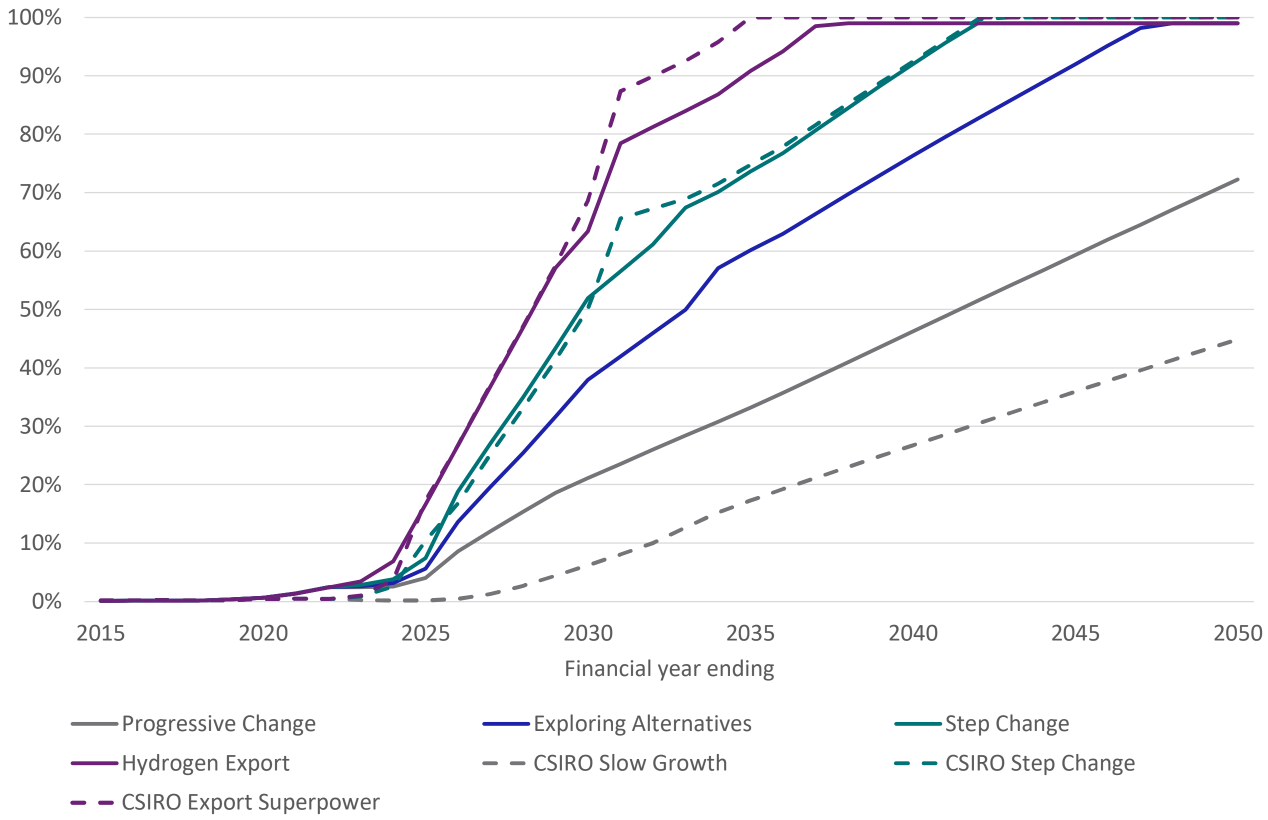


Figure 5-1 Projected electric vehicle sales share compared to 2021 scenarios (dashed lines)

In the period 2024 to 2030, the key driver is state and commonwealth electric vehicle policies and targets. For those states with targets, a common point of alignment is 50% electric vehicle sales by 2030. The CSIRO 2021 *Step Change* scenario previously met this target but it was driven by an assumed up-front cost parity for short range electric vehicles by 2025 with no subsidies available. In the updated *Step Change* we assume that cost parity point will be delayed to 2027 due to constrained global supply chain impacts. However, the commonwealth and the majority of states now provide subsidies which will help to offset this delay in reduced vehicle costs. The net effect of these changes is that *Step Change* arrives at a similar share of around 50% by 2030.

The *Hydrogen Export* scenario maintains that upfront cost parity will be achieved in 2025 (reflecting a stronger global commitment to limiting climate change to 1.5^{o}C) and this also aligns

[20] Global Car Sales To Fall, Spooked By Russian Invasion, China's Shutdown (forbes.com)

with the assumption that the scenario over-achieves the state targets by around 15 percentage points in 2030. *Exploring Alternatives* assumes upfront cost parity is achieved 3 years later than *Step Change* aligned with the assumption of a 15 percentage points under-achievement of the state targets in 2030. In *Progressive Change* upfront cost parity is further delayed to 2035 and has a 30 percentage point underachievement.

Beyond 2030 as some scenarios begin to achieve high electric vehicle sales rates, our third projection modelling approach is imposing the level of sales needed to replace 99% of internal combustion vehicles which is expected to be a necessary step as maintenance of repair, parts and refuelling services at reasonable cost for internal combustion vehicle owners is expected to become more difficult over time. The proposed dates for near complete replacement have not changed significantly for the scenarios, and hence we see a lot of commonality with the 2021 CSIRO projections through this period. *Hydrogen Export* and *Exploring Alternatives* reach 99% sales closer to 2035 and 2045 respectively to be better aligned with their respective scenario assumptions whereas these dates were less strictly adhered to in the 2021 projections. *Progressive Change* represents a scenario where replacement of internal combustion vehicles is under a longer timeline (2065), resulting in a more linear sales growth. This outcome would reflect both reluctance from a minority of consumers to take up electric vehicles and an internal combustion vehicle retirement rate which is consistent with historical rates (rather than the accelerated scrapping required in the other three scenarios)[21].

The concept of internal combustion vehicle replacement has been modified to mean 99% rather than 100% in the 2021 CSIRO projections. This allows for a small set number of specialised or historical internal combustion vehicles to remain in the stock.

[21] These could be locally driven phenomenon or may be part of a global consumer movement. If there is a significant group within Australia that continues to purchase internal combustion vehicles, they will need global manufacturers willing to continue to produce those vehicles. This outcome more plausible if Australia is not the only region with internal combustion vehicle demand.

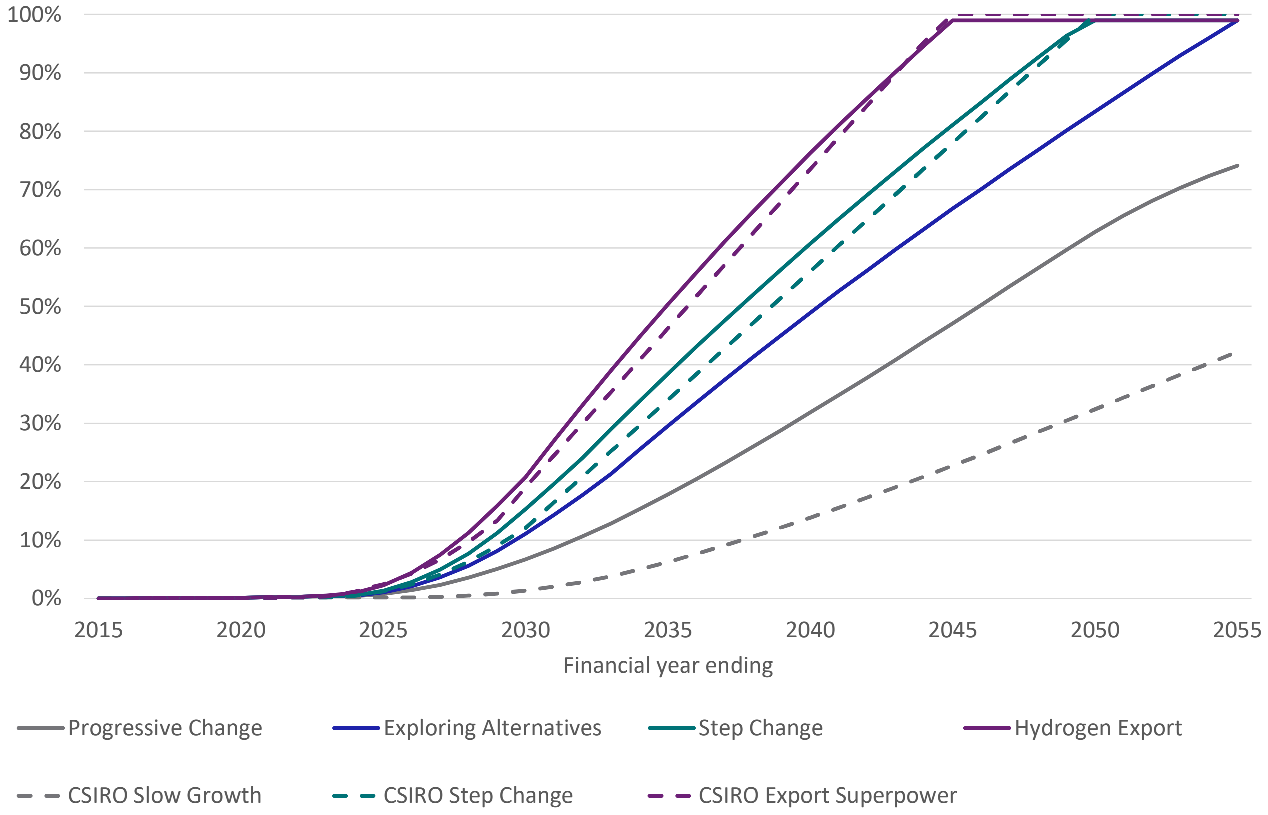


Figure 5-2 Projected electric vehicle fleet share compared to 2021 scenarios (dashed lines)

Higher electric vehicle sales shares eventually lead to higher shares of electric vehicles in the fleet, up to an assumed maximum of 99% (Figure 5-2). By design, *Hydrogen Export* reaches maximum share in 2045 reflecting stronger climate change policy ambition. *Step Change*, *Exploring Alternatives* and *Progressive Change* reach this point in 2050, 2055 and 2065 (not shown) respectively. Compared to 2021, the timing of these end-points for internal combustion vehicle replacement have not substantially changed. However, along the journey to reaching the end point, higher electric vehicle fleet shares are achieved. This reflects the improved historical and short term projections for sales particularly for scenarios that had previously expected no significant increase in sales until 2025.

5.2 Number of vehicles and consumption

The projected number of electric vehicles in the NEM and WEM are shown in Figure 5-3 and Figure 5-4 respectively. Both the current and 2021 projections feature a prominent reduction in vehicle growth in 2045 for *Hydrogen Export* and in 2050 for *Step Change* which coincides with those scenarios achieving 99% replacement of internal combustion vehicles. Prior to achieving that goal, electric vehicle sales needed to grow at faster than the historical sales rate to keep up with accelerated retirement of internal combustion vehicles. The normal scrapping rate for the fleet is 5% to 6% per annum or around 20 years for replacement. However, in *Hydrogen Export* and *Step Change*, the scenario assumptions which recognise a likely withdrawal of commercial services for internal combustion vehicles force a faster scrapping rate to occur. After fleet replacement has been achieved, there is no longer any need for the same rate of increase in electric vehicle numbers. The growth rate post replacement is closer to population growth (approximately 1%) which is the main driver for passenger vehicles numbers[22].

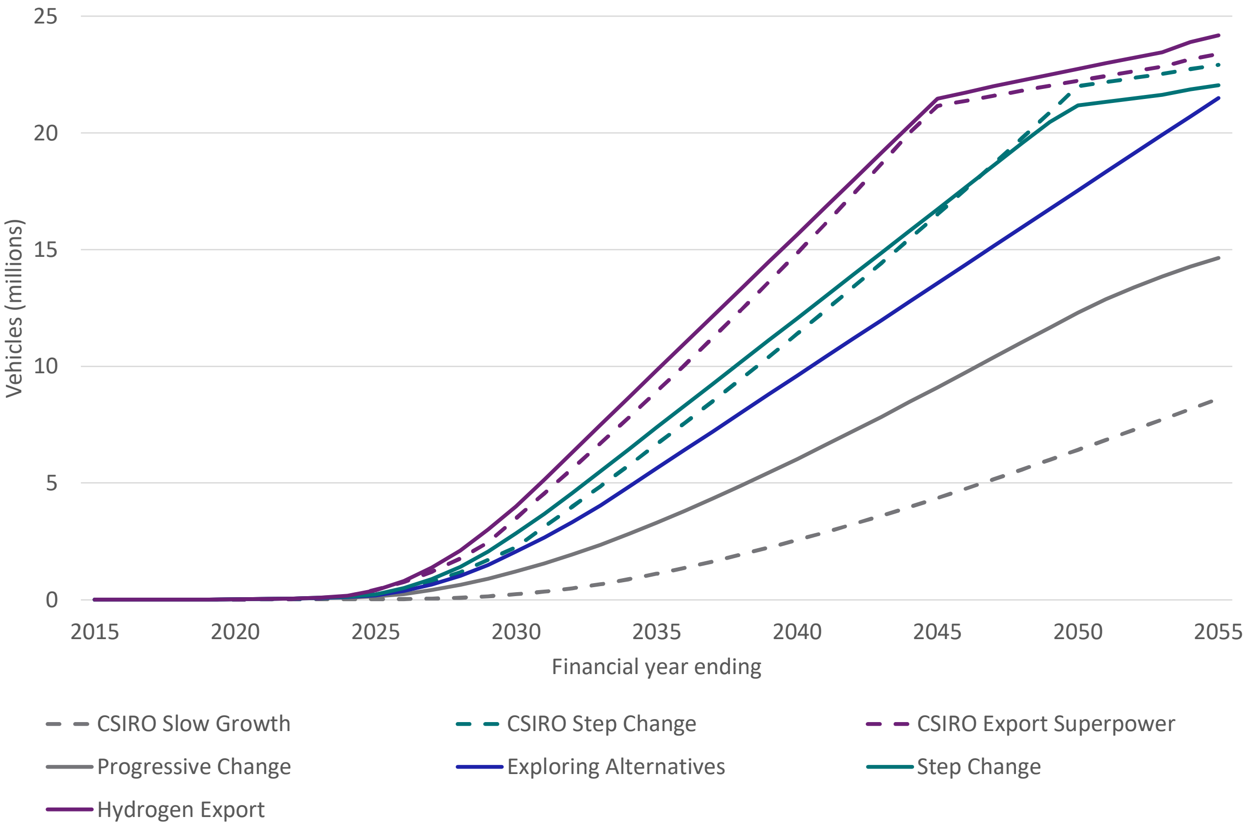


Figure 5-3 Projected number of electric vehicles in the NEM compared to 2021 scenarios (dashed lines)

In the 2021 projections, to 2030, the WEM was responding entirely to payback periods and vehicle prices in particular. In the updated projections, the WEM receives the same treatment as the larger eastern states whereby each scenario has a specific assumption about the extent to which it aligns with a target of 50% sales by 2030. The outcome of this new approach is that WEM projections are generally higher. This is appropriate given the availability of stronger policy support for electric vehicles in Western Australian since the 2021 projections. *Hydrogen Export*

[22] GDP is the key driver for commercial and freight vehicles, but these are a minority of the fleet. Consequently, population growth is more reflective of fleet growth rates.

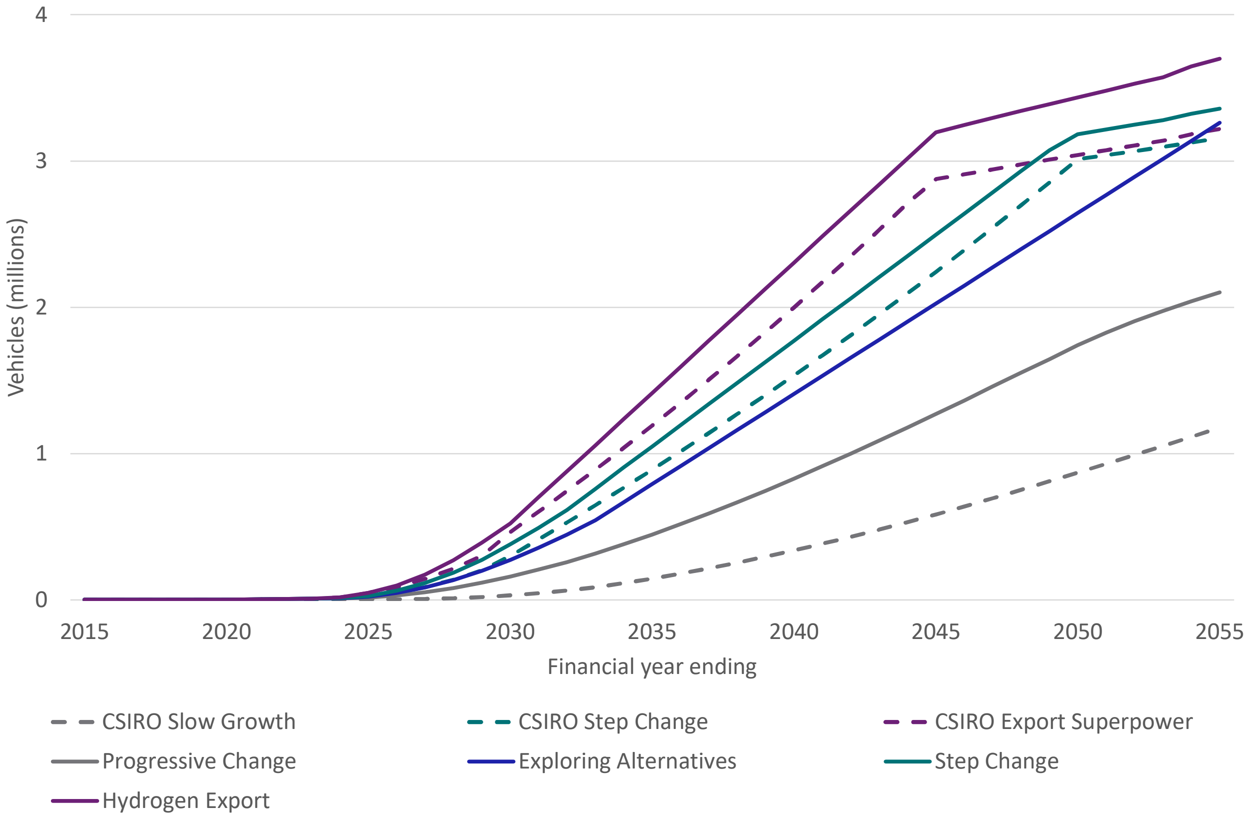


Figure 5-4 Projected number of electric vehicles in the WEM compared to 2021 scenarios (dashed lines)

Figure 5-5 and Figure 5-6 show the projected number of electric vehicles by vehicle type in 2050 in the NEM and WEM. SREV and LREV refer to short range and long range electric vehicles. Due to the shorter range of electric vehicles they cost less (due to fewer batteries) but as a result will appeal to a smaller market share. We set the market share for SREVs as part of the modelling assumptions. LREVs have a greater possible market share due to their longer range but cost more and still face challenges in respect to access to charging. Fuel cell electric vehicles (FCEVs) use stored hydrogen and a fuel cell as the onboard source of electricity rather than batteries. They have proven to be higher cost than electric vehicles and they require the development of major new refuelling infrastructure.

Given the disadvantages of FCEVs in cost and refuelling, they are not projected to achieve a significant share of the light duty vehicle market. However, they are expected to achieve reasonable uptake up to majority uptake in heavy duty applications, particularly the articulated truck fleet that is responsible for the majority of road freight. The high load and daily utilisation of articulated trucks means that it will be difficult to keep them charged to perform their duties. Battery trucks will need to spend significantly more time refuelling than they presently do unless some form of fast battery swap is undertaken. Fuel cell truck refuelling has more in common with current diesel refuelling practices. Also, the higher utilisation of trucks make it easier for fuel savings to pay for more expensive technology which fuel cell trucks would likely represent.

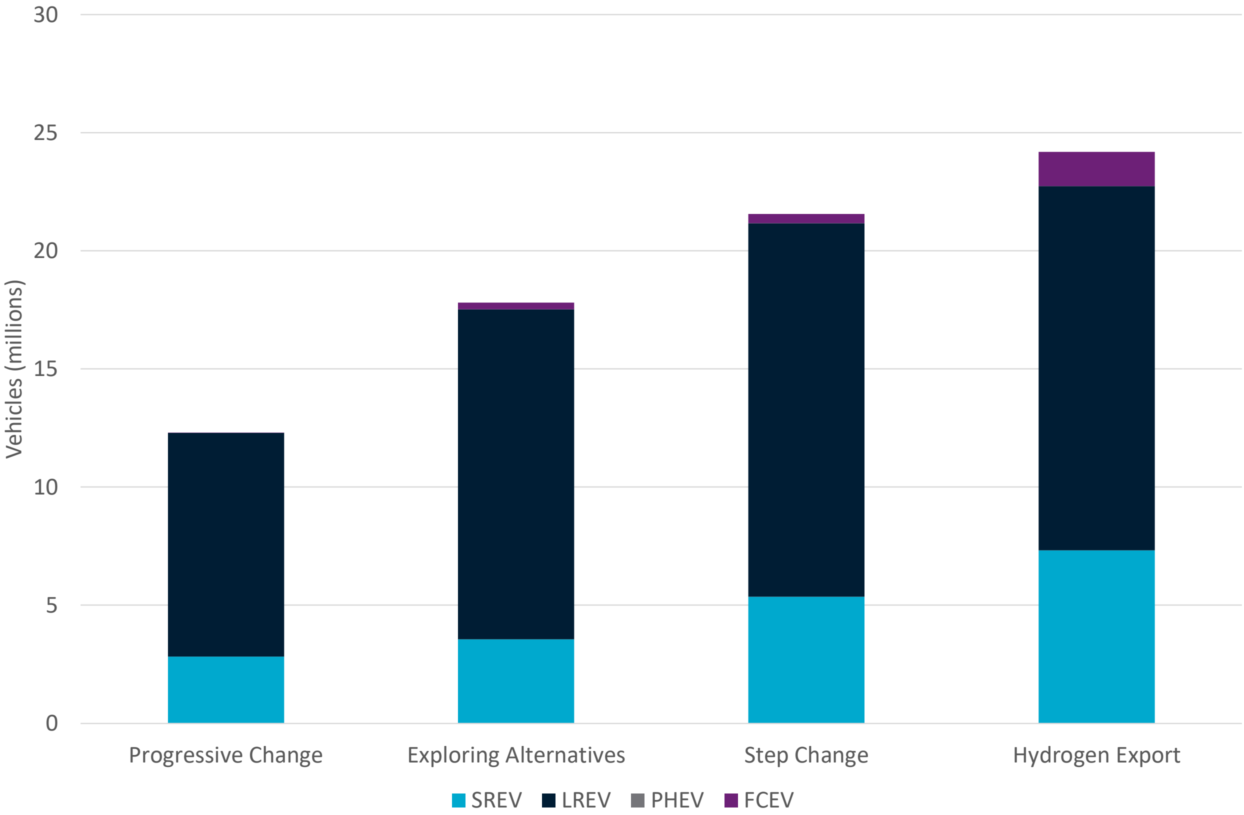


Figure 5-5 Projected number of electric vehicle types in the NEM in 2050

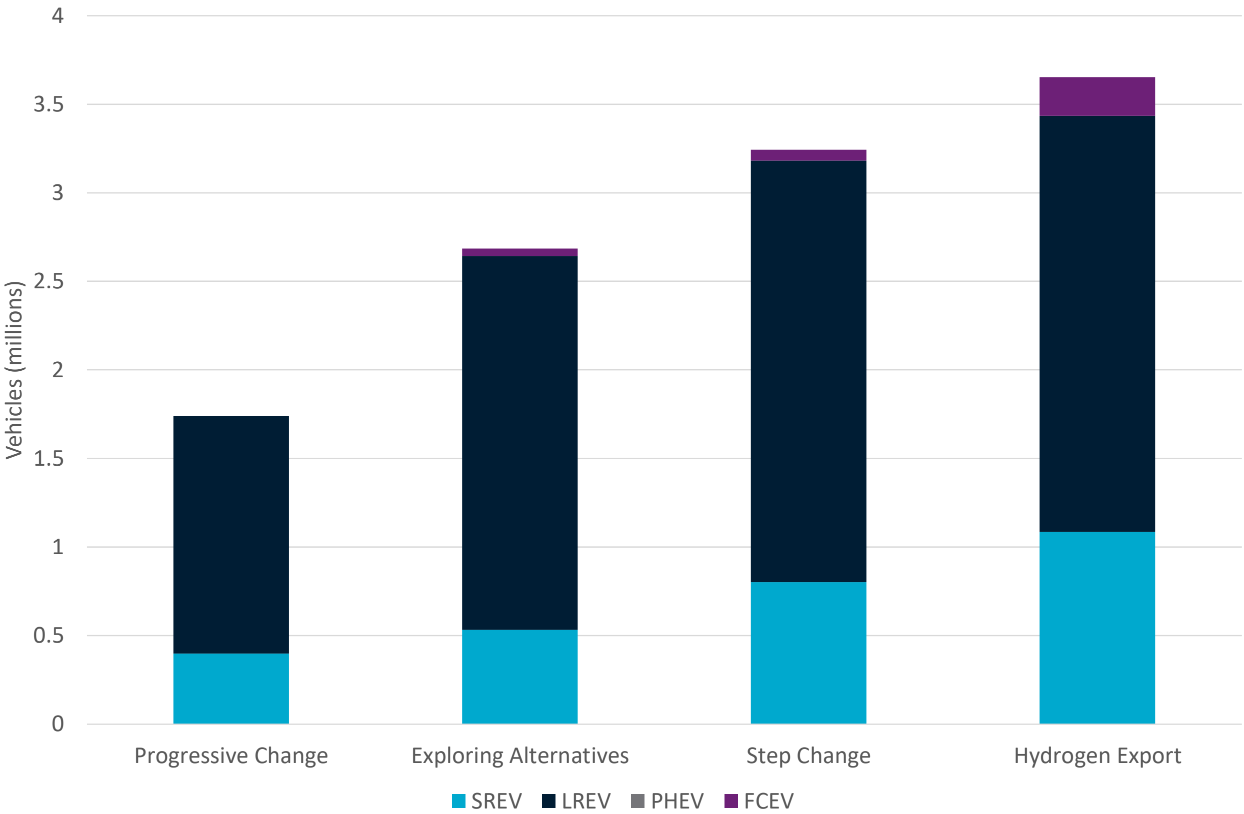


Figure 5-6 Projected number of electric vehicle types in the WEM in 2050

In the *Hydrogen Export* scenario, we allow for a less constrained environment for fuel cell vehicles with earlier cost reductions and higher prevalence of hydrogen refuelling infrastructure. This allows FCEVs to achieve a modest 5% share of the light vehicle market. These trends play out in the same way in the NEM and WEM. Any differences would only reflect slight differences in the share of heavy and light duty vehicles.

The projected electricity consumption for the NEM and WEM are shown in Figure 5-7 and Figure 5-8. These figures only include electricity consumption from charging of battery or plug-in electric vehicles for transport purposes. Any charging to supply home energy needs or grid storage services is not included. We also exclude the electricity that might be required to produce hydrogen for fuel cell electric vehicles. These additional sources of electric vehicle related electricity consumption are captured elsewhere in AEMO's modelling framework.

Consumption directly reflects differences in the number of electric vehicles and so the trends largely follow those present in the vehicle number projections. However, there are a few exceptions. The presence of any fuel cell vehicles reduces electricity consumption since their use of energy is excluded here. As a result, by 2050, the electricity consumption of *Exploring Alternatives* is closer to that of *Step Change* and *Hydrogen Export* than might have otherwise been expected. Also, compared to the 2021 projections, CSIRO's modelling includes a greater share of large size passenger vehicles, which consume more electricity, reflecting an update to the historical fleet characteristics.

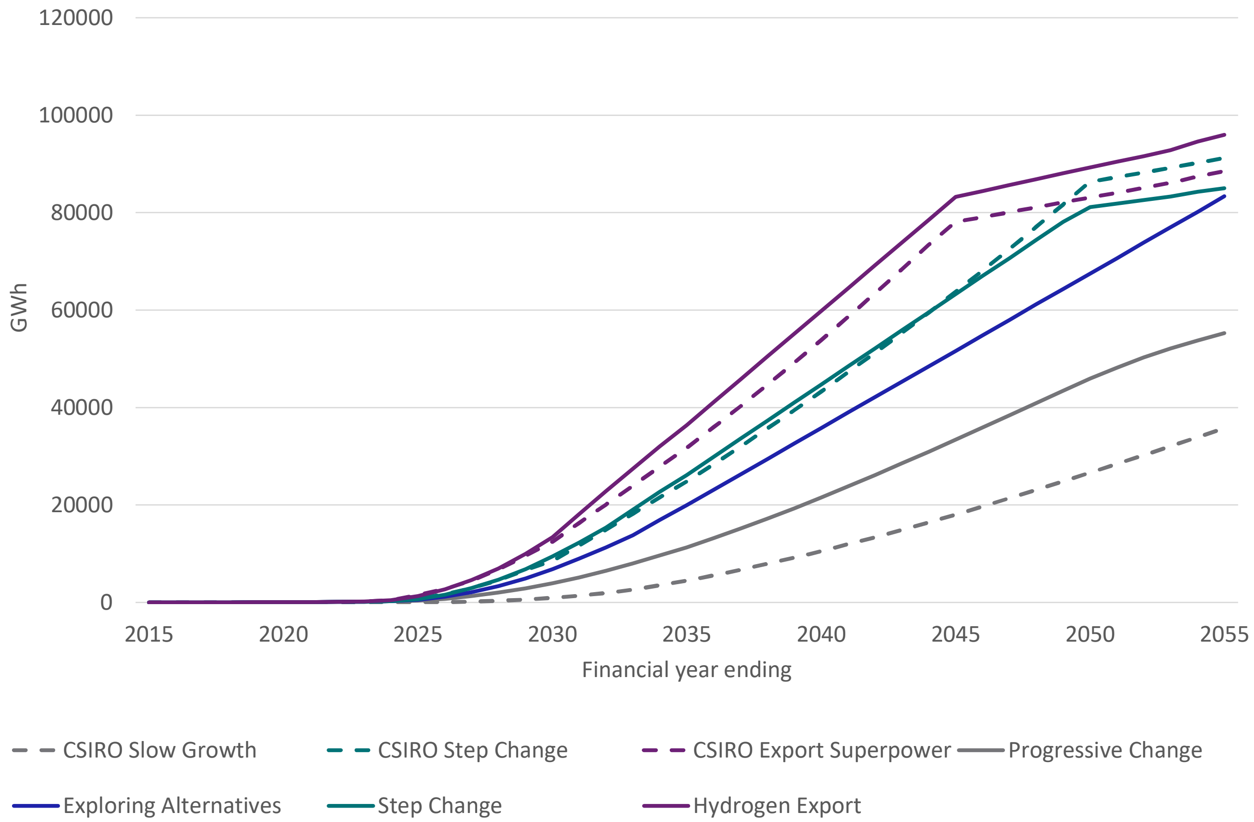


Figure 5-7 Projected electricity consumption in the NEM compared to 2021 scenarios (dashed lines)

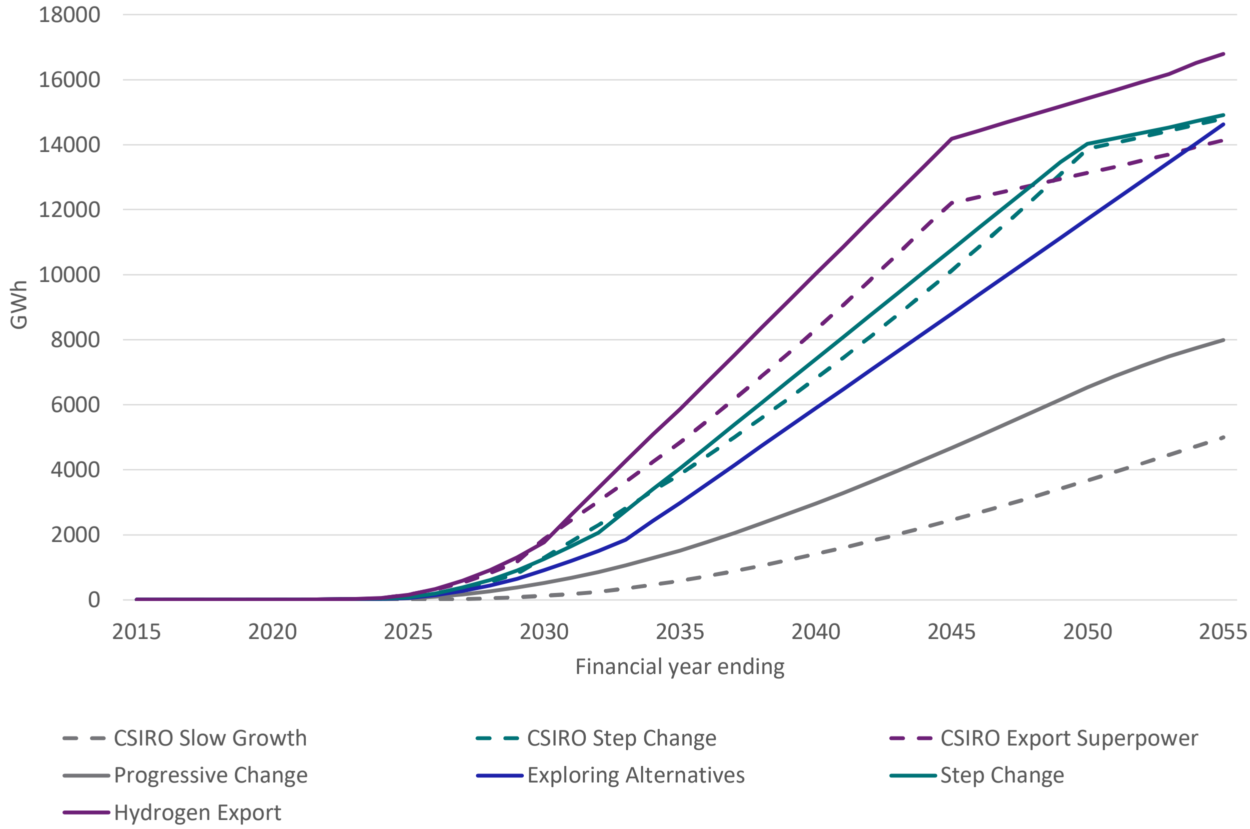
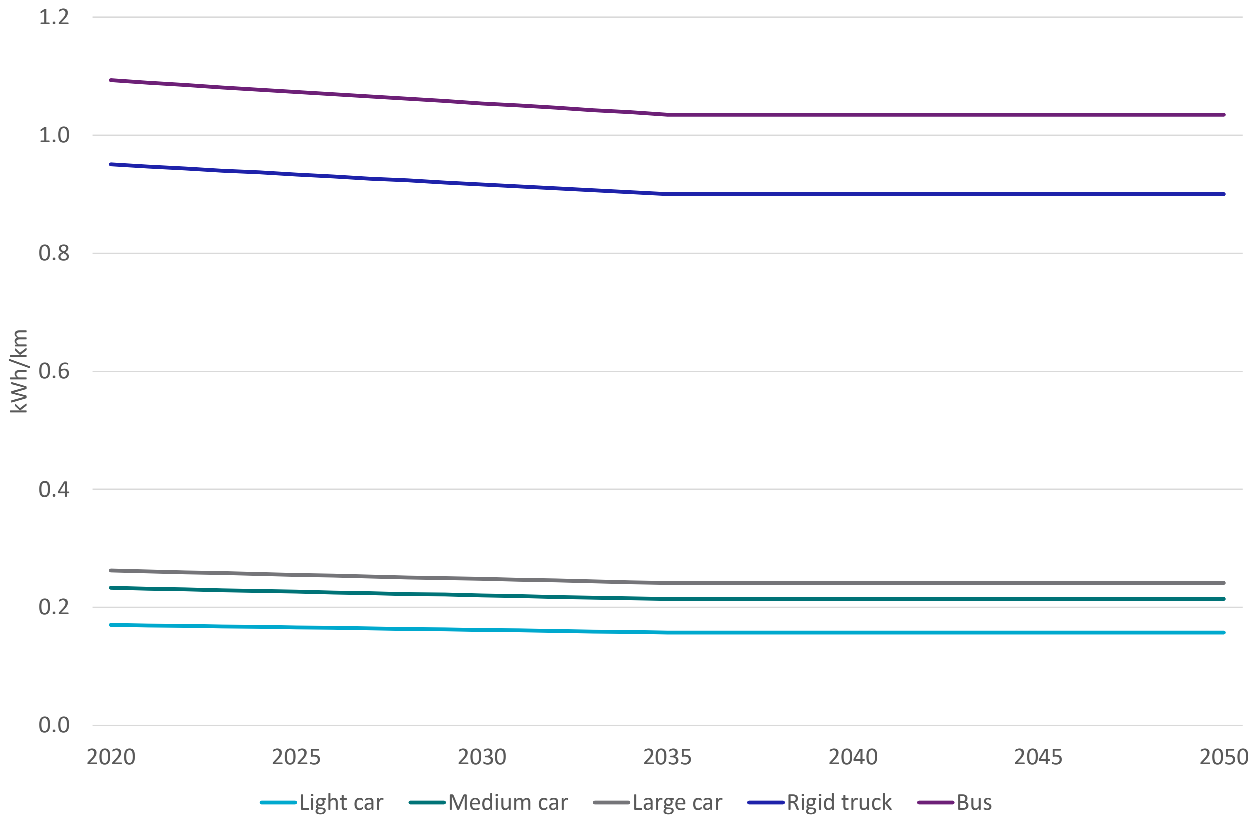


Figure 5-8 Projected electricity consumption in the WEM compared to 2021 scenarios (dashed lines)

Appendix A Additional data assumptions

A.1 Technology performance data

Figure A.1 shows the assumed vehicle fuel efficiency per kilometre by mode for electric vehicles.



Apx Figure A.1 Electric vehicle fuel efficiency by road mode

Rated fuel efficiency is not currently a good guide to on-road fuel efficiency performance. Based on our observations of the difference in internal combustion vehicle rated efficiency and on-road fuel consumption we scale up reported electric vehicle efficiencies[23]. The key determinant of differences in fuel efficiency between vehicles is vehicle weight with the lightest vehicles having the lowest electricity consumption per kilometre. The batteries which store the electricity adds to the total weight of each EV and CSIRO assumes further improvements in battery energy density over time. This leads to a steady improvement in fuel efficiency up to around 2035 and plateaus thereafter. Historically, internal combustion engine fuel efficiencies have plateaued unless there is significant fuel price pressure. That is, further engine efficiency improvements were traded off for better acceleration, better comfort, safety and space. CSIRO assumes electric vehicles will follow this similar trend.

[23] Not to the same extent because electric vehicles should perform better in traffic because they do not have to idle when stopped.

Appendix B Projection data tables

B.1 Sales and fleet share projection data

As part of its normal assumptions reporting, AEMO publishes data on the number and electricity consumption of electric vehicles. However, the most common enquiry to CSIRO for data from previous electric vehicle projection reports is in relation to the vehicle sales and fleet share projections which are not published elsewhere. We therefore provide these data tables. The shares relate to all electric vehicles including fuel cell electric vehicles at the national level. The residual of the sum subtracted from 1 therefore represents the share of internal combustion vehicles.

Apx Table B.1 Projected electric vehicle sales share

	Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export
2015	0.001	0.001	0.001	0.001
2016	0.001	0.001	0.001	0.001
2017	0.001	0.001	0.001	0.001
2018	0.002	0.002	0.002	0.002
2019	0.004	0.004	0.004	0.004
2020	0.006	0.006	0.006	0.006
2021	0.014	0.014	0.013	0.013
2022	0.025	0.024	0.024	0.024
2023	0.024	0.026	0.028	0.035
2024	0.026	0.032	0.038	0.068
2025	0.040	0.056	0.074	0.166
2026	0.086	0.137	0.188	0.268
2027	0.121	0.197	0.271	0.369
2028	0.154	0.254	0.350	0.470
2029	0.186	0.316	0.434	0.571
2030	0.211	0.380	0.519	0.634
2031	0.236	0.420	0.565	0.785
2032	0.260	0.460	0.611	0.812
2033	0.284	0.500	0.675	0.840
2034	0.308	0.571	0.701	0.869
2035	0.332	0.602	0.736	0.908
2036	0.357	0.629	0.767	0.942
2037	0.383	0.664	0.807	0.985
2038	0.410	0.697	0.845	0.990
2039	0.436	0.730	0.883	0.990
2040	0.462	0.763	0.920	0.990
2041	0.489	0.795	0.956	0.990
2042	0.515	0.827	0.990	0.990
2043	0.541	0.858	0.990	0.990
2044	0.567	0.889	0.990	0.990
2045	0.593	0.920	0.990	0.990
2046	0.619	0.951	0.990	0.990
2047	0.645	0.982	0.990	0.990
2048	0.671	0.990	0.990	0.990
2049	0.697	0.990	0.990	0.990
2050	0.722	0.990	0.990	0.990

Apx Table B.2 Projected electric vehicle fleet share

	Progressive Change	Exploring Alternatives	Step Change	Hydrogen Export
2015	0.000	0.000	0.000	0.000
2016	0.000	0.000	0.000	0.000
2017	0.000	0.000	0.000	0.000
2018	0.000	0.000	0.000	0.000
2019	0.001	0.001	0.001	0.001
2020	0.001	0.001	0.001	0.001
2021	0.002	0.002	0.002	0.002
2022	0.003	0.003	0.003	0.003
2023	0.004	0.004	0.004	0.005
2024	0.004	0.004	0.005	0.009
2025	0.008	0.010	0.013	0.022
2026	0.014	0.021	0.028	0.044
2027	0.023	0.036	0.049	0.074
2028	0.035	0.056	0.077	0.112
2029	0.050	0.081	0.111	0.158
2030	0.067	0.111	0.153	0.208
2031	0.086	0.143	0.196	0.270
2032	0.106	0.177	0.241	0.331
2033	0.128	0.213	0.290	0.390
2034	0.153	0.255	0.338	0.448
2035	0.178	0.295	0.385	0.504
2036	0.205	0.336	0.431	0.558
2037	0.232	0.375	0.476	0.611
2038	0.260	0.414	0.521	0.663
2039	0.289	0.452	0.565	0.713
2040	0.318	0.489	0.608	0.762
2041	0.348	0.526	0.650	0.810
2042	0.378	0.562	0.691	0.857
2043	0.409	0.598	0.732	0.902
2044	0.440	0.633	0.772	0.946
2045	0.471	0.667	0.811	0.990
2046	0.503	0.701	0.850	0.990
2047	0.534	0.735	0.888	0.990
2048	0.566	0.768	0.926	0.990
2049	0.597	0.801	0.964	0.990
2050	0.628	0.833	0.990	0.990
2051	0.656	0.866	0.990	0.990
2052	0.681	0.898	0.990	0.990
2053	0.703	0.930	0.990	0.990
2054	0.723	0.960	0.990	0.990
2055	0.741	0.990	0.990	0.990

Shortened forms

Abbreviation	Meaning
ABS	Australian Bureau of Statistics
ACCU	Australian Carbon Credit Unit
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AV	Autonomous Vehicle
COVID-19	Coronavirus Disease of 2019
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DER	Distributed energy resources
EE	Energy Efficiency
ERF	Emissions Reduction Fund
EV	Electric Vehicle
FCAI	Federal Chamber of Automotive Industries
FCAS	Frequency Control Ancillary Services
FCEV	Fuel Cell Electric Vehicle
GDP	Gross Domestic Product
GSP	Gross State Product
hrs	Hours
ICE	Internal Combustion Engine
IPART	Independent Pricing and Regulatory Tribunal
km	Kilometre
kW	Kilowatt

kWh	Kilowatt hour
LCV	Light Commercial Vehicle
LREV	Long-range electric vehicle
MW	Megawatt
MWh	Megawatt hour
NEM	National Electricity Market
NSG	Non-Scheduled Generation
PHEV	Plug-in hybrid electric vehicle
pkm	Passenger kilometres
SA2	Statistical Area Level 2
SGSC	Smart Grid Smart Cities
SREV	Short-range electric vehicle
SWIS	South-West Interconnected System
tkm	Tonne kilometres
TOU	Time-of-use
TWh	Terawatt hour
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WEM	Western Electricity Market

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