Australia's National
Science Agency

Electric vehicle projections 2023: update to the 2022 projections report

Commissioned for AEMO's draft 2024 Forecasting Assumptions Update

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Contents

Figures

Tables

Acknowledgments

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Executive summary

This report updates projections for electric vehicle uptake and charging profiles and was commissioned by AEMO as part of their regular updates to modelling and planning inputs and assumptions. Previous CSIRO reports on this topic provided a full explanation of the methodology and all assumptions. However, owing to time constraints this report is written as an update to the previous 2022 projections report. It uses the same methodology as the previous report but does not repeat the methodology description. The assumptions section of this report is also briefer, describing only those assumptions that have changed since 2022. Readers may need to refer to the 2022 projections report for methodology and assumptions information that was not included here.

Australia's electric vehicle sales share has experienced strong growth reaching 8.4% in 2022-23 compared to around 4% in the previous year. To address climate policy goals, the scenarios included in the report assume that electric vehicles will eventually dominate road transport in Australia, albeit over a multi-decade timeframe. Strong sales growth in the short term adds to the plausibility of the projections. Another development supporting stronger uptake has been consideration by the commonwealth government of the introduction of a fuel efficiency standard for cars. Fuel efficiency standards can be a very significant tool for driving greater supply of electric vehicles to Australia. The policy had not been introduced nor the targets set at the time of writing. However, the methodology includes a targeting of sales in 2030 which can be adjusted over time as the policy process matures.

For the post 2030 to 2050s period, the modelling considers how the road vehicle supply chain will change in a period where electric vehicles are the majority of vehicles sold. Vehicle manufacturers may not be able to guarantee supply of spare parts for discontinued models of internal combustion vehicles. Falling demand for liquid fuel may reduce the number of service stations supplying liquid fuel and/or increase the price of fuel. In these circumstances it is proposed that internal combustion vehicles might experience accelerated scrapping rates relative to the present, as some consumers find it too inconvenient to maintain internal combustion vehicles for their normal operational life. This development could result in a faster fleet transition than current fleet scrapping rates would allow for.

The report relies on the charging profiles developed for the 2022 projections report but addresses feedback received. Some main areas of feedback received from were that some stakeholders find it difficult to relate to after-diversity or population level profiles, the names of each profile are misleading, and they would like a clearer link to the type of charger being used. This report has been more explicit about how charger types are changing over time and how that might interact with the balance of different types of charging behaviour. This report has also changed and extended the names of the profiles for clarity.

The report places greater focus on reporting how the profiles look when combined over time and whether these aggregated profiles produce a reasonable trend in the shape of statewide electric vehicle charging over time.

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 three scenarios: *Progressive Change*, *Step Change* and *Green Energy Exports*. 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 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.

For brevity this report is presented as an update to the 2022 projections report. The projection methodology has not changed and so is not repeated in this report but may be found in the 2022 report (Graham, 2022). This update report is set out in four sections. Section 2 describes the scenarios and any ways in which the scenario settings have changed since 2022. Section 3 includes any changes in the scenario and data assumptions but otherwise does not report assumptions that remain the same as the 2022 projections report. The resulting updated 2023 projections are presented in Section 4 and compared to the 2022 projections.

2 Scenario definitions

The three scenarios defined in this section are *Progressive Change*, *Step Change* and *Green Energy Exports*[1]. The AEMO scenario definitions are described in narrative form and then by their key drivers in Table 2-1.Further detail is available in AEMO (2023). To implement the electric vehicles projections, CSIRO has developed an additional set of extended scenario definitions based on more detailed road transport sector drivers than are covered in the broader scenario design process.

The following scenario narratives and table are from the *2023 Inputs Assumptions and Scenarios Report: Final Report* (AEMO, 2023).

Progressive Change

A scenario that assumes ongoing challenges in global economic conditions that limits broader actions that could increase the current pace of change of Australia’s transition to net zero. The scale of action therefore focuses on achieving current domestic and global policy objectives. Under this scenario the pace of decarbonisation across the economy may be inconsistent with limiting temperature rise to below 2°C by 2100 even if current energy sector objectives are met. Consistently, under this scenario, less ambitious actions are taken in other sectors of the economy, there are assumed to be significant supply chain constraints, and/or more measured global action.

This scenario captures a slower global recovery from the COVID-19 pandemic and ongoing disruptions affecting international energy markets and associated supply chains. Challenging economic conditions and business pressures increase the relative risk of industrial load closures, and slow the pace of investment to extend beyond current commitments regarding decarbonisation, further limiting the economic advantages that may exist with a near zero emissions intensive energy system.

In this scenario, lower disposable incomes and slower and lesser cost reductions are incorporated in the uptake of CER, including a lower pace of growth affecting transportation electrification. For example, ongoing consumer investment in improving building and appliance energy efficiency is more muted, and broader electrification (including by consumers in preferring and being willing to invest in alternative heating appliances to traditional fossil fuelled alternatives) is also slowed in the short to medium term.

Global progress towards net zero ambitions is in line with currently announced policies and ambitions, and while Australia likewise delivers on its commitment to a 43% reduction of emissions by 2030, and net zero by 2050, this is unlikely to be consistent with the pace and breadth of change expected to limit temperature rise to 2°C by 2100.

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[1] *Green Energy Exports* was previously called *Hydrogen Export* in the 2022 projections. A fourth scenario included in the 2022 projections called *Exploring Alternatives* is no longer included in the scenario set.

Step Change

A scenario with strong industry and consumer energy investments to decarbonise, and actions to lower emissions across Australia's economy above current levels. In this scenario the NEM provides a strong and economy-enabling contribution to that purpose through a fast-paced transformation.

This scenario includes growing momentum to embrace a Step Change from the status quo, increasing the pace of the transition in the energy sector to support an economy-wide transition to net zero. Domestic and international action increases to achieve the minimum objectives of not only Australia's current commitments to the Paris Agreement, but the longer term goal of contributing to the limiting of global temperature rise to well below 2°C compared to pre-industrial levels. Economy-wide decarbonisation investments increase at pace above current levels, with faster and deeper cuts to emissions across the economy aligned to beating the objective to limit temperature rise to well below 2°C. With a relatively fast pace of transformation affecting the NEM, it may be compatible with even greater limitation of temperature rise to 1.5°C, if even more rapid and widespread complementary action was taken by other sectors of Australia's economy.

In this scenario, moderate growth in the global and domestic economy underlies the appetite to address climate change and provides a supporting environment for the development and uptake of relevant technologies.

Under the *Step Change* scenario, rapid transformation of the energy sector is enabled at utility scale by assumed continued cost reductions for renewable energy investments, and strong consumer appetite and willingness to invest to contribute directly through high uptake of CER, and electrified transport. Successful coordination of CER is assumed to be facilitated as consumers shift to this new innovative use of behind-the-meter assets, with an assumption of growing savings through energy efficiency measures.

It is also assumed that consumers and industry consolidate their energy supplies, with high growth in electrification and changing solutions for consumers in improved building design, smart appliances, and digitalisation that help consumers manage energy use.

Under this scenario the scale of hydrogen production in the NEM is limited, with significantly less availability than the *Green Energy Exports* scenario.

Green Energy Exports

A scenario with very rapid and widespread transformation of the economy making a very significant contribution from the electricity sector aimed at achieving a temperature rise limited to 1.5°C. Consumer investments are very high, and global demand for green energy contributes to a new and very strong green energy export economy.

This scenario represents a world with very rapid action towards decarbonisation, technology cost improvements, and robust domestic and international economic outcomes. Technology cost reductions improve Australia's capacity to expand "green commodity" exports, including hydrogen and other energy-intensive products such as green steel, supporting stronger domestic economic outcomes relative to other scenarios. The availability of low-cost and low emissions energy, support domestic energy consumers as well as international customers, supplementing declining exports of traditional emissions-intensive resources from global decarbonisation efforts.

Table 2-1 AEMO scenario definitions (current at time of modelling)

	Progressive Change	Step Change	Green Energy Exports
National decarbonisation target	At least 43% emissions reduction by 2030. Net zero by 2050	At least 43% emissions reduction by 2030. Net zero by 2050	At least 43% emissions reduction by 2030. Net zero by 2050
Global economic growth and policy coordination	Slower economic growth, lesser coordination	Moderate economic growth, stronger coordination	High economic growth, stronger coordination
Australian economic and demographic drivers	Lower	Moderate	Higher (partly driven by green energy)
CER uptake (batteries, PV and EVs)	Lower	High	Higher
Consumer engagement such as VPP and DSP uptake	Lower	High (VPP) and Moderate (DSP)	Higher
Energy efficiency	Lower	Moderate	Higher
Hydrogen use	Low production for domestic use, with no export hydrogen.	Medium-Low production for domestic use, with minimal export hydrogen.	Faster cost reduction. High production for domestic and export use
Hydrogen blending in gas distribution network	Up to 10%	Up to 10%	Up to 10%
Biomethane/ synthetic methane	Allowed, but no specific targets to introduce it	Allowed, but no specific targets to introduce it	Allowed, but no specific targets to introduce it
Supply chain barriers	More challenging	Moderate	Less challenging
Global/domestic temperature settings and outcomes	Applies RCP 4.5 where relevant (~ 2.6°C)	Applies RCP 2.6 where relevant (~ 1.8°C)	Applies Representative Concentration Pathway (RCP) 1.9 where relevant (~ 1.5°C)
IEA 2021 World Energy Outlook scenario	Stated Policies Scenario (STEPS)	Sustainable Development Scenario (SDS)	Net Zero Emissions (NZE)

While well beyond current levels, this scenario has rapid investment in decarbonisation investments. For consistency, there is a high degree of electrification and energy efficiency investments across many sectors, and consumers further increase their investment in consumer energy resources (including electrified vehicles), and energy efficient homes. The transport sector, in particular, rapidly embraces electric and hydrogen-fuelled options to decarbonise both light and heavy vehicle fleets.

The energy transition in Australia is in step with actions globally, which are assumed to be occurring at a commensurate level. A mixture of electrified and molecular energy options enables consumers of all types (residential, commercial and industrial) to decarbonise efficiently at a greater level than is currently occurring.

2.1.1 Extended scenario definitions

The AEMO scenario definitions have been extended in Table 2-2 by adding additional detailed assumptions on the economic, infrastructure and business model drivers for road transport. 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 Section 3.

Table 2-2 Extended scenario definitions

Driver	Progressive Change	Step Change	Green Energy Exports
Timing of cost[1] parity of short-range electric vehicles with ICE	2035	2030	2027
Cost of fuel cell vehicles	High	Medium	Low
Growth in apartment share of dwellings	Low	Medium	High
Decline in home ownership	Low	Medium	High
Extent of access to variety of charging options	Low	Medium	High
Feasibility of ride sharing services	Low	Medium	High
Affordable public charging availability	Low	High	High
Vehicle to home or grid (passenger vehicles)	Yes from 2030	Yes from 2030	Yes from 2028
ICE vehicle availability[2]	New vehicles unavailable beyond 2050	New vehicles unavailable beyond 2040	New vehicles unavailable beyond 2035
ICE commercial services collapse / no longer viable to operate[2]	2060	2050	2045

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. 2. Special purpose vehicles exempted. Commercial services include fuel supply, parts supply and mechanical repairs.

There are many financial and non-financial drivers of electric vehicle adoption incorporate in the modelling methodology and these also include the emergence of alternative business models that could assist in overcoming current barriers. The approach for including the full range of drivers in the scenario assumptions and modelling has not changed. Section 3.2 of the 2022 projections report has this information.

2.1.2 Changes in government policy

The government policies included in the modelling are the same as the 2022 projections report except for adjustments to take account of policy changes that have occurred since late 2022. The major changes in government policy since the 2022 projections report are the potential introduction of an Australia-wide new-vehicle emission standard, and an increase in the Queensland electric vehicle subsidies from $3000 to $6000 and a high court case that disallowed state road user charges.

Electricity vehicle subsidies

The Queensland subsidy is means tested at annual income of $180,000. For incomes over that amount a $3000 subsidy remains available. The scheme is available until funding of $45 million is exhausted. This allows for between 7,500 to 15,000 electric vehicles to be subsidised, depending on the income level of those who take up the subsidy. Recent historical state sales are within the range indicated by the subsidy. Victoria’s subsidy program was concluded a year earlier than originally planned in June 2023.

Road user charges

The introduction of a road user charge that applied to electric vehicles in Victoria was successfully challenged in the high court which has ruled against the policy. In the 2022 projections report it was assumed that all states would follow the path of Victoria and introduce road user charges with most states aiming for 2027 as the year of introduction.

Road user charges had been designed to capture a similar amount of taxation revenue as would have been collected by fuel excise had the vehicle been using a liquid fuel. A complication, however, in this seemingly straight forward change in collection of taxes is that fuel excise is collected by the Commonwealth government and is not a state tax. There are a few possibilities going forward for how this high court ruling will impact electric vehicles taxation and who might collect it. One is that the states abandon collecting taxes from electric vehicles but the Commonwealth steps in and introduces a road user charge or other mechanism to collect revenue in cooperation with the states. A second is that the states find another way to collect the equivalent amount of revenue from another state mechanism, such as registration fees, without Commonwealth assistance. The third is that both levels of government do not implement a new tax on electric vehicles.

Given there is an existing taxation regime associated with road use and a clear need for road funding[2], this report has ruled out the idea that governments will give up on recouping the revenue that is expected to be lost to fuel excise as the road sector transitions away from internal combustion vehicles. Consequently, the projections assume an equivalent level of taxation is recovered from electric vehicle owners by 2027, even though the implementation details are unknown at this stage.

Fuel efficiency standards

An Australian wide new-vehicle[3] fuel efficiency standard[4] could have a significant impact on electric vehicle sales but at the time of creating this report was not legislated and nor is it a fully detailed policy. The impact of the policy depends crucially on the trajectory of fuel efficiency standards that are required to be met over time. Given our new internal combustion vehicles are around 30% behind their equivalent overseas fuel efficiencies, a weak standard could in theory be met purely by purchasing more fuel-efficient internal combustion vehicles and have limited impact on electric vehicle sales in the early years of the scheme. On the other hand, a very strong standard could quickly reduce the viability of internal combustion vehicles as an option for new vehicle sales.

Perhaps the most likely outcome is that we will align our standards with comparable developed countries such as the United States or United Kingdom. The trajectory of the United Kingdon leads to only zero emission vehicles being able to meet the standard in 2035 (i.e., the requirement by 2035 is for new vehicles to have only zero emissions). Standards in the United States are slightly higher but follow a similar trajectory. The Australian government consultation paper explores a range of options including linear and non-linear trajectories with no specified zero emission end date (DITRDCA, 2023).

Prior to any real or notional end date for internal combustion vehicle sales, a typical design feature for emission standards is to allow vehicle suppliers to meet the standards through averaging and offsetting their new vehicle sales. That is, they can sell vehicles that exceed the standard, the more vehicles themselves or others sell that are below the standard, particularly electric vehicles which have zero emissions.

To provide an example, the passenger vehicle standard in other countries by 2030 is around 50g/km. Let us assume that Australia planned to catch up to that standard by 2030. Let us also assume that the practical limit for a passenger internal combustion vehicle that meets most consumer expectations of current vehicle purchases is around 100g/km. The implication of the standard would then be that new vehicle suppliers need to sell around 50% internal combustion vehicles and 50% zero emission vehicles to meet the standard.

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[2] Even though is no technical mechanism for applying road taxation only to road funding, the community accepts there is, at least, a strongly implied link.

[3] Light vehicles only, not trucks and buses.

[4] These are implemented as fuel efficiency standards but are targeting an emission outcome. When fuel is consumed in a vehicle it is nearly 100% combusted and as such the amount of emissions released into the atmosphere is in a direct proportion to fuel use. Zero greenhouse gas emission fuels such as electricity and hydrogen are considered to have no emissions or fuel consumption for the purposes of the standards. European Union legislation also allows for synthetic fuels made from hydrogen and captured CO_2 to be deemed as a zero emission fuel. Standards already exist in Australia for emission of non-greenhouse gases such as nitrogen oxides and particulates.

Through thinking about how combining electric vehicles with internal combustion vehicles could result in a particular average outcome, it might be possible, albeit with a lot of practical uncertainty, to target an electric vehicles sales share using a fuel efficiency standards policy. The practical uncertainty comes from not knowing exactly what customers will prefer and how efficient internal combustion vehicles can be without sacrificing their amenity or cost to the point where consumers switch to an electric vehicle.

In summary,

- there is currently no confirmed Australian fuel efficiency standard trajectory, but we can expect one to be developed soon and it could align with other developed countries,
- some existing developed country fuel efficiency standard trajectories imply mostly electric vehicle sales from 2035 or later,
- emission standards can also imply electric vehicle sales rates, but with significant uncertainty, making emission standards a tool which could contribute to meeting national electric vehicle sales targets.

2030 sales targets

Before being elected the present government produced modelling by Reputex Energy (2021) which found that the commonwealth government's measures resulted in raising the EV sales share from 29 per cent to 89 per cent in 2030[5]. However, this modelling outcome has not been adopted as a government target. New South Wales, Victoria and Queensland all have 50% sales targets by 2030 and there are a mix of states with 2035 as a common target year to reach 100 electric vehicle sales.

In the 2022 projections report, the main method under which we give meaning to the state and commonwealth sales targets, subsidies and other broad policies was to take an alternative view by scenario on how successful or unsuccessful the broad package of electric vehicles policies will be in reaching 2030 electric vehicle sales targets. The introduction of a national emissions standard strengthens the likelihood of meeting stronger sales targets, but even once the detail of the emission standards trajectory is known, it still maintains some uncertainty on exactly what sales rate will be reached since the target can be met by the average of a wide combination of internal combustion vehicles and electric vehicles and will depend not only on the strategy of suppliers but on consumer preferences.

It is concluded therefore that the approach established in the 2022 projections for representing government policy outcomes remains relevant and in fact is likely to remain relevant even after the proposed fuel efficiency standard trajectory is announced and legislated. Information that could tighten the range of uncertainty would be if the policy background included a plan to adjust the fuel efficiency standards trajectory over time to reach a specific sales target and if it also included a zero fuel efficiency date. However, it is not clear at this stage what the basis of trajectory setting will be and how far into the future the standard will be set.

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[5] An emission standards policy was not included in the policy measures underpinning that modelling.

The government policy scenario assumptions are outlined in Table 2-3 and apply to all regions. The range of assumptions allows for both under and overachievement of 2030 targets. The key reasons for underachievement are likely to be supply chain issue associated with electric vehicles numbers and models available as well as lower policy ambition recognising that Australia is coming from a higher point than other countries in terms of alignment with fuel efficiency standards in other countries. Overachievement could reflect stronger policy ambition, 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. Note that the fuel efficiency standard currently proposed by the US Environment Protection Agency would result in 60% electric vehicles sales share in 2030. As such, the higher outcome is consistent with Australia aligning to currently proposed US fuel efficiency standards.

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 2-3 Assumed electric vehicle sales by scenario resulting from commonwealth fuel efficiency standards policies

	Progressive Change	Step Change	Green Energy Exports
2030 outcome[6]	35% new vehicle sales	50% new vehicle sales	60% new vehicle sales

These national targets will not be realised evenly in all states because of the differences in preferences and driving conditions. Regions with longer driving ranges will have greater concerns about the range capability and adequacy of charging infrastructure for electric vehicles and lag other states with shorter driving distances. Charging infrastructure will be more economic to deploy in more densely populated areas. To capture these issues, we adjust the national 2030 sales starts for each state by the amounts shown in Table 2-4.

Table 2-4 Assumed adjustment to national 2030 sales target to recognise state differences

State	Adjustment to target
New South Wales	0.1%
Victoria	0.6%
Queensland	-1.0%
South Australia	0.4%
Western Australia	-0.8%
Tasmania	0.1%
Northern Territory	-2.1%
Australian Capital Territory	5.3%

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

3 Data assumptions

This section outlines the data assumptions that have changed since the 2022 projections report. Any other assumptions not discussed here remain the same as in the 2022 projections. Vehicle cost projections remain broadly the same although the assumed timing of cost parity with internal combustion vehicles in each scenario has shifted slightly for some scenarios (see Table 2-2). The key focus of this section is standard updates to base year data and macroeconomic parameters. The base year data is indicating that some impacts on transport demand from the COVID-19 pandemic are likely permanent. There is also a significant update to developing assumptions over time regarding the mix of charging profiles to be applied to the electric vehicle stock.

3.1 Income and population growth

3.1.1 Gross state product

Gross state product (GSP) assumptions by scenario are presented in Table 3-1 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 change in the adoption readiness over time. However, in our projection methodology, it should be noted that movement along the adoption curve is largely driven by factors other than economic growth. As such, overall, economic growth assumptions have only a marginal impact (no more than 20%) on uptake projections.

Table 3-1 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	2.0	1.9	1.4	2.2	1.4	2.1
Step Change	2.1	2.3	2.2	1.7	2.4	1.7	2.2
Green Energy Exports	2.6	2.9	2.7	2.2	2.8	2.0	2.7

3.1.2 Population

Population growth assumptions by scenario are shown in Table 3-2 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 3-2 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	1.0	1.1	0.5	1.2	0.3	1.2
Step Change	0.9	1.3	1.3	0.7	1.4	0.4	1.4
Green Energy Exports	1.3	1.7	1.6	1.0	1.8	0.6	1.7

3.2 Separate dwellings and home ownership

Owing to rising land costs in large cities where most residential customers reside, there is a trend towards building of apartments or town houses, 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 3-1). 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 assumptions have been provided by AEMO and their economic consultant, BIS Oxford Economics. In the 2022 projections, these assumptions were based on CSIRO research. Using AEMO's consultant data provides for greater consistency of assumptions across various other inputs to AEMO's forecasting and planning work. AEMO's consultant does not provide home ownership projections. Home ownership projections remain the same as the 2022 projections with home ownership being lower the stronger the economic growth and climate policy ambition due to higher economic pressure on the housing stock.

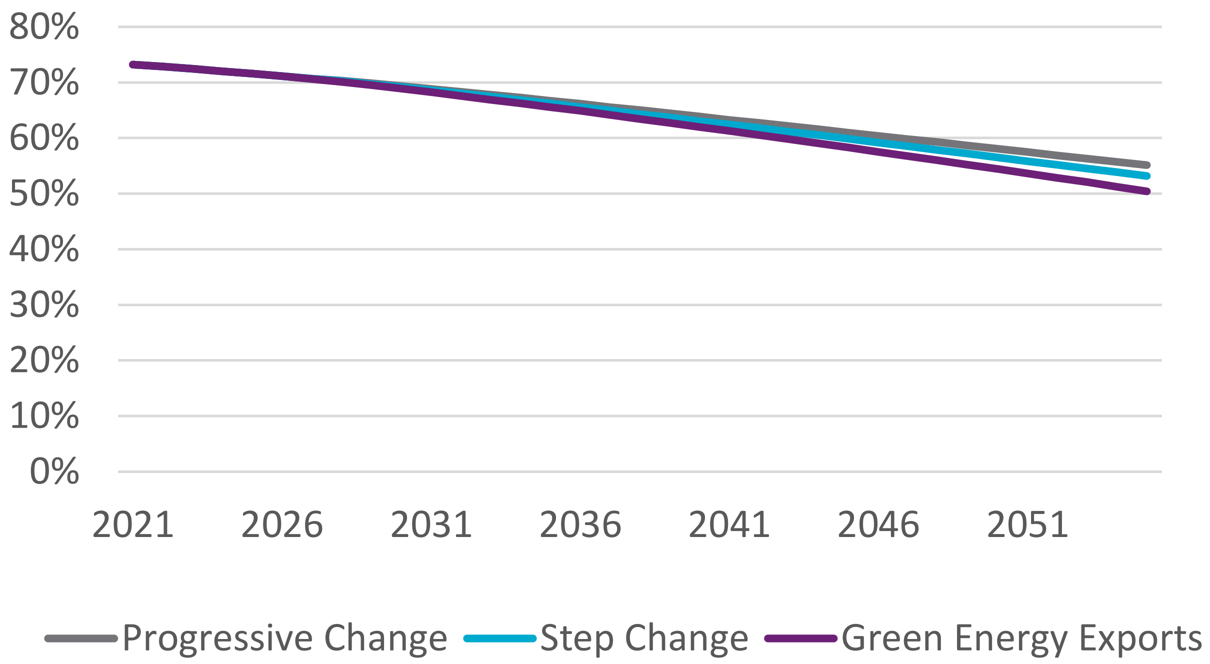

Figure 3-1 Assumed share of separate dwellings in total dwelling stock by scenario

3.3 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. In Table 3-3 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 new vehicle market share for each vehicle category via the formulas shown. The maximum new vehicle 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). After maximum market share is reached (typically around the 2030s) by design, the electric and fuel cell vehicle adoption rate is set to achieve 99% of the fleet for cars, buses and trucks by an assumed later date (e.g., between 2045 and 2060 as described in the scenarios summary table in Section 2). 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 but is also commercially driven. The collapse or commercial withdrawal in the services needed to continue to use internal combustion vehicles occurs because the scale of demand for internal combustion vehicles and their refuelling and spare parts supply chains becomes too small to maintain at a reasonable cost. During this period internal combustion vehicle scrapping accelerates to a faster than historical rate.

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.

Table 3-3 Non-financial limitations on electric and fuel cell new vehicle sales share prior to ICE vehicle market collapse

		Progressive Change	Step Change	Green Energy Exports	Rationale/formula	Equivalent business constraint
Limiting factors (residential)						
Separate dwelling share of households	A	58%	57%	54%	Based on housing industry forecasts	Businesses located on standalone site
Share of home owners	B	62%	63%	64%	Based on historical trends	Business not renting their site
Share of landlords who enable (passively or actively) EV charging onsite	C	70%	90%	100%	Data not available. Assumed range of 60-100%	Same
Off-street parking/private charging availability	D	41%	44%	44%	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	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	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	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%	Based on laggards generally being no larger than a third of customers. Sustainable growth assumes ICEs suffer a collapse in manufacturing due to systematic loss of supporting infrastructure	Business owner's attitudes and specific vehicle needs
Share of people who prefer private vehicle ownership for all household cars	I	95%	85%	85%	General preference for private vehicle ownership	Business preference for private ownership
Share of people willing for their second or more cars to be replaced with ride share	J	10%	20%	25%	Assumed that only a laggard proportion would object to this arrangement	Same
Fuel stations with access to hydrogen supply chain	K	5%	20%	30%	Data not available due to uncertainty. Assume range of 5-30%.	Same

	Progressive Change	Step Change	Green Energy Exports	Rationale/formula	Equivalent business constraint
Maximum market share					
Short range electric vehicles	17%	23%	27%	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)	
Long range electric vehicles	82%	100%	100%	Key limitation is charging and customer who would prefer ICE. Formula=(1-H)*(D+E)	
Plug-in hybrid electric vehicles	82%	100%	100%	Same as long range	
Fuel cell vehicles (light)	5%	20%	30%	Formula=(1-H)*K	
Fuel cell large trucks	30%	70%	90%	Scenario setting	
Autonomous ride share vehicles	6%	13%	19%	Formula=J*F	

Table 3-4 Assumed shares of different electric vehicle chargers by vehicle type by 2050

Vehicle type	Charger type	Current (estimated)	Progressive Change	Step Change	Green Energy Exports
Passenger	Home - L1	68%	53%	41%	30%
	Home - L2	23%	23%	27%	30%
	Work - L2	5%	10%	15%	20%
	Public - L2	1%	4%	5%	6%
	Public - Fast	4%	10%	12%	14%
LCV	Home - L1	38%	19%	14%	10%
	Home - L2	13%	28%	22%	15%
	Work - L2	48%	50%	60%	70%
	Public - Fast	2%	3%	4%	5%
Truck/bus	Work - L2	29%	24%	19%	14%
	Work - Fast	69%	73%	77%	81%
	Public - Fast	2%	3%	4%	5%

Table 3-5 Assumed shares of different charging profiles by 2050

	Current	Progressive Change	Step Change	Green Energy Exports
Passenger - Unscheduled home charging, flat tariff	70%	56%	44%	33%
Passenger - TOU tariff with no day incentives other than use of home solar	23%	3%	3%	3%
Passenger - Vehicle to home/grid (dynamic system-controlled charging)	0%	15%	24%	33%
Passenger - Public L2 and fast charge	5%	14%	17%	20%
Passenger - TOU tariff including day charging incentives	3%	13%	13%	11%
LCV - Overnight due to day use of vehicle	80%	77%	72%	65%
LCV - Daytime oriented allowing for vehicles parked at workplace	18%	20%	24%	30%
LCV - public fast charge	2%	3%	4%	5%
Trucks & buses - Overnight due to day use of vehicle	88%	85%	78%	72%
Trucks & buses - Daytime oriented allowing for vehicles parked at workplace	10%	12%	18%	23%
Trucks & buses - public fast charge	2%	3%	4%	5%

3.4 Shares of electric vehicle charger types and charging behaviour

In the 2022 projections, charging profiles were allocated according to a formula which was linked to the vehicle market segmentation assumptions (Table 3-3). Feedback has indicated that stakeholders would prefer the charging behaviours are more directly related to the charger type. Charger types include Level 1 and Level 2 chargers which may be public or private and fast direct current chargers which are generally public. Truck and bus fleets may also use a version of fast charging given their much larger power needs. Level 1 chargers use a standard power point and existing wiring. A level 1 charger can recover average daily driving in 2 to 3 hours. However, a 500km range electric vehicle requiring a full charge after a longer trip would take 30 to 40 hours to recharge. Level 2 chargers require new wiring and deliver higher charge. They can recharge average daily travel in an hour and a full recharge in around 14 hours. Fast chargers require specialised distribution connections as well as new wiring but can recharge average daily travel in minutes and a full recharge in a few hours depending on the size.

3.4.1 Charger type

There is no public source of data which directly links charging profiles to charger type. The profile shape of the small number of publicly available charging profile studies can be inferred to relate to a particular tariff type since the presence of a time of use tariff tends to create an obvious reduction in charging at peak times. Publicly available charging profiles also contain an obvious daytime increase in charging regardless of the tariff type indicating that some owners are taking advantage of their lower cost home solar electricity production to charge their vehicles. These conclusions are based on observing the charging shape and reports of reasonable high solar ownership in some studies.

Most charging studies report something about the type of chargers used and the degree of home versus away charging in their sample of EV owners. From this information, an estimate of the current share of charger types by vehicles is presented in Table 3-4. Shares of charger type by scenario were then projected forward based on the following principles:

- Workplace and public charging will need to grow to accommodate housing which has limited off-street parking. More fast public charging will also be preferable for all households as more electric passenger vehicles are used for longer trips.
- Greater orchestration of electric vehicle charging will be required as EV's fleet share increases, and this activity will be more associated with Level 2 chargers (the required communication and other capability is more likely to come as an extra feature in Level 2 than in lower cost Level 1 devices). The stronger the climate policy, the faster the electric vehicle uptake and greater the resulting orchestration

This approach leads to a lower share of Level 1 chargers and a drift towards more high powered charging for all vehicle types over time, the faster the electric vehicle uptake in each scenario. The main reason why charging does not shift even more strongly to workplace and public charging is the limitations to funding the infrastructure. The appetite from EV owners for more convenient charging will be strong but ultimately the charging infrastructure needs to be funded. The product being supplied at work or public spaces can be accessed at home for a few dollars a day. This puts a limit on how many customers would be willing to pay a premium to owners of public or workplace chargers for their electric supply. A premium is likely to be necessary to cover the cost of installing workplace and public chargers, notwithstanding any subsidy programs that may be available in the short term[7].

3.4.2 Charging profile type

The next step is to relate these charger type shares to charging profiles. The current and projected charging profile shares are shown in Table 3-5. To create this data, the principles for relating charger type to charging profiles were:

- Level 1 charger ownership was assumed to be more associated with unscheduled charging profiles given a simple power point offers the least capability in terms of power available and control.
- Level 2 charging was assumed to be associated with TOU tariff charging and business vehicles are generally assumed to be facing TOU tariffs than passenger vehicle owners.
- The degree of TOU charging that included price structures designed to encourage day or solar aligned charging was limited by the vehicle type. Passenger vehicles were considered to be most amenable to taking up this incentive. Light commercial vehicles, buses and trucks were significantly less amenable due to their greater day time use of the vehicle.
- Public chargers are assigned the profile that have been collected from public chargers.

Vehicle to grid or home charging (vehicle to X) is assumed to require at least a Level 2 charger but is otherwise considered as an independent assumption.

Feedback on the 2022 projections indicated the charging profile names needed to be updated to better convey their meaning. provides a guide to how the new charging profile names related to the previous ones and the new abbreviations that are used.

Table 3-6 Guide to new charging profile naming conventions

Descriptive name	Previous abbreviation	New abbreviation
Unscheduled home charging, flat tariff	CONV	UNSCHED
TOU tariff with no day incentives other than use of home solar	NIGHT	TOU_HOME_SOLAR
Vehicle to home/grid (dynamic system-controlled charging)	V2G/V2H	V2G/V2H
Public L2 and fast charge	FHWY	PUBLIC
TOU tariff including day charging incentives	DAY	TOU_GRID_SOLAR

[7] Western Australia has a relevant subsidy scheme: https://www.wa.gov.au/organisation/energy-policy-wa/charge-workplace-ev-charging-grants

3.4.3 Vehicle to X

Once electric vehicles are established[8], 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. In this report we consider on board use.

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 cycle life still does not present a great limitation on use. 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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[8] AEMO's scenario design assumes this occurs 2028 to 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).

3.5 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. Before the COVID-19 pandemic a simple extrapolation of past trends would have been appropriate because that event the aviation transport mode has been steadily gaining market share in passenger transport demand for decades at the expense of road transport. However, the COVID-19 pandemic has disrupted this trend. Besides the share of transport modes shifting, passenger travel was forced down by the pandemic and has not fully recovered to its previous levels. Due to the greater prevalence of working from home and use of telepresence rather than meeting in person in business, some passenger travel is likely permanently lost to transport demand. In contrast, freight transport was not significantly impacted by the pandemic.

It is assumed that the increased share of the road mode share persists in *Green Energy Exports* as this would be consistent with a strong vehicle market and strong climate action since road transport is the most amenable to adoption of low emission technologies such as electric vehicles. The *Step Change* and *Progressive Change* scenarios are assumed to progressively revert back to the historical trend of a flat or declining road mode share.

Given the lack of impact of the pandemic on freight transport mode shares the historical trend in mode share, namely rail share increasing at the expense of other modes, is allowed to continue but at different rates, with the strong usage of road modes again associated with stronger climate policy ambition. Freight transport itself is highly sensitive to growth in Gross Domestic Product (GDP) and so all transport modes grow faster when economic growth is stronger which, in the AEMO scenarios, tends to be aligned with stronger climate action. *Green Energy Exports* has stronger population and economic growth and so this strengthens passenger and freight transport demand. *Step Change,* and *Progressive Change* are assumed to have to progressively lower population and economic growth.

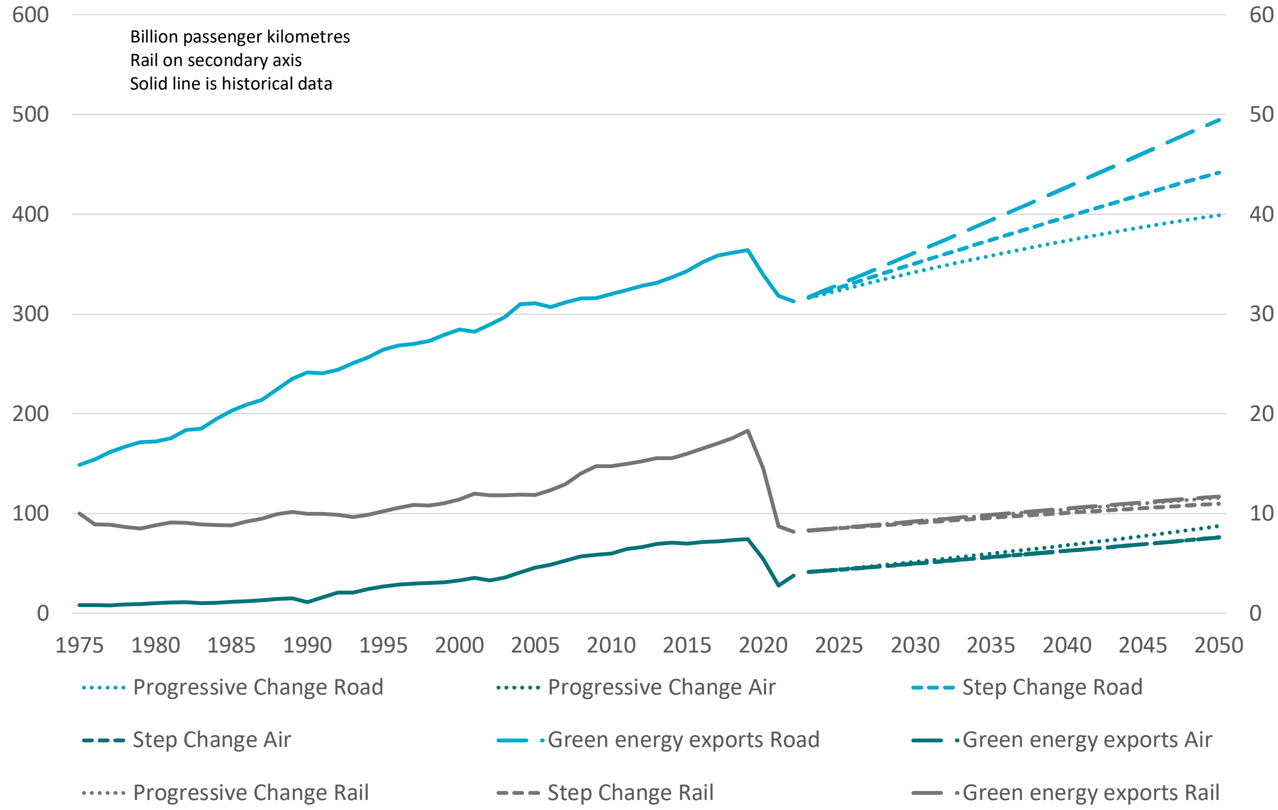

Figure 3-2 Historical and projected passenger transport demand

The results of these passenger and freight transport demand projections are shown in Figure 3-2 and Figure 3-3. The reduction in passenger transport demand during the COVID-19 pandemic is strongly evident in the 2020 data. The data outlined in Figure 3-2 and Figure 3-3 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 also imposes a price elasticity response by tracking future road transport costs.

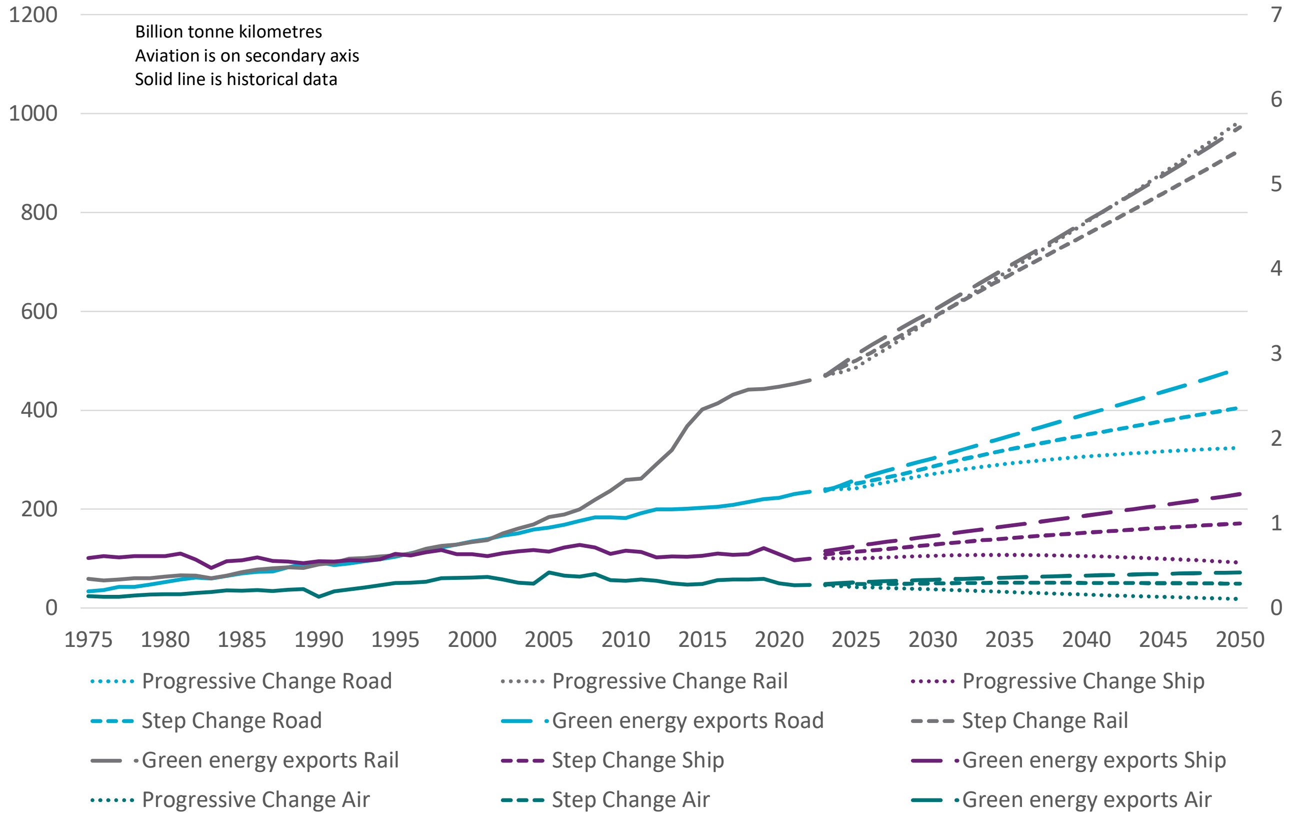

Figure 3-3 Historical and projected freight transport demand

3.5.1 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. All road vehicle types were traveling around 10% less per year on average than in 2022 compared to 2019. Western Australia, Northern Territory and the Australian Capital Territory had the least changes in vehicle utilisation.

This data indicates that working from home and greater use of telepresence in place of face to face meetings are likely to persist and as a result the modelling does not assume any recovery in average kilometres travelled per vehicle.

Taking the passenger and freight kilometres projection in Figure 3-2 and Figure 3-3 and assumed average freight load and passengers per vehicle (the average is 1.59 for cars before adjusting for some uptake of rideshare vehicles in decades ahead), the road vehicle kilometres travelled to meet passenger and freight tasks is calculated and presented in Figure 3-4. The demand for road vehicles is calculated by dividing through by vehicle utilisation and the result is shown in Figure 3-5.

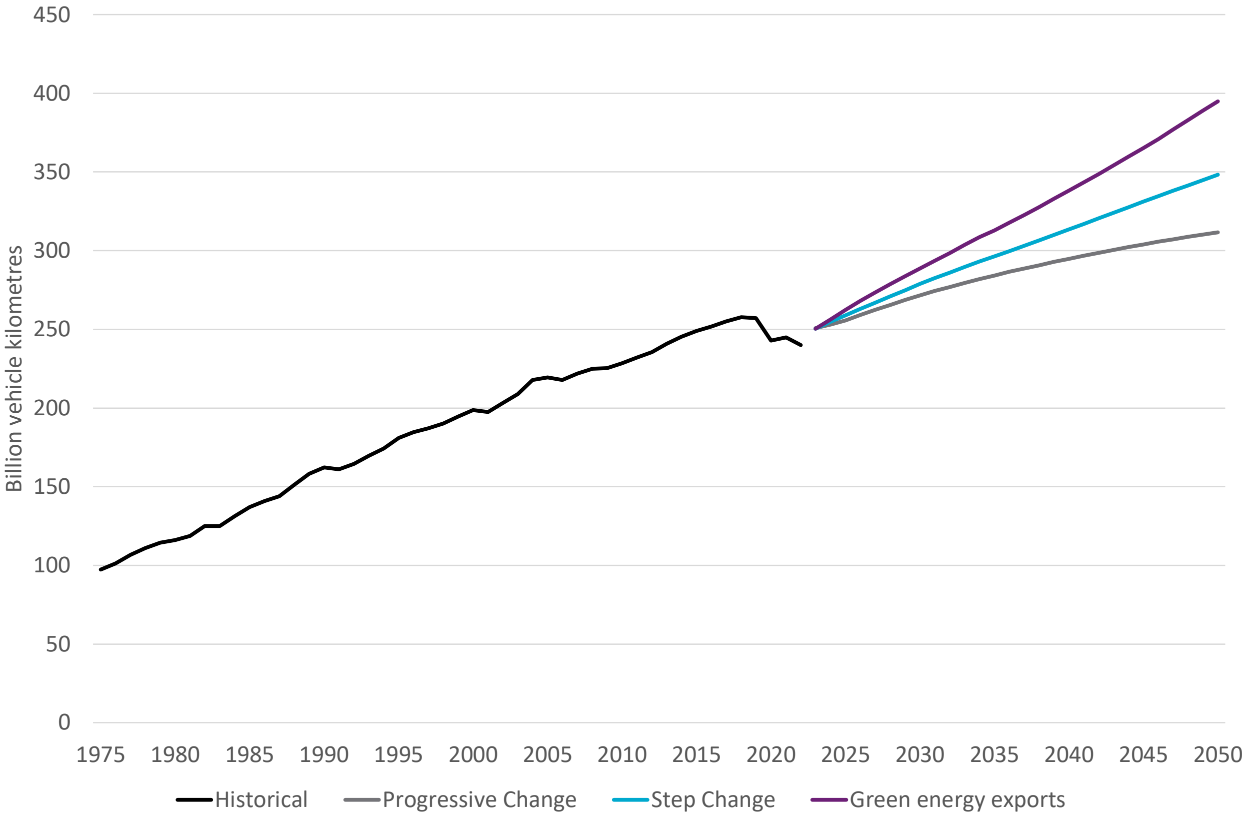

Figure 3-4 Historical and projected national road vehicle kilometres travelled, all road modes

The highest demand for road transport is in *Green Energy Exports* 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* has medium economic and population growth and subsequent road transport demand. All scenarios are assumed to have slightly stronger growth in the short term during the ongoing recovery in passenger travel demand from the COVID-19 pandemic. As discussed, this recovery is assumed to be incomplete with some passenger travel demand permanently lost. Together with a declining rate of growth in population owing to historical trends in birth rates, this tends to result in a slowing trend in growth over time, particularly in *Progressive Change*.

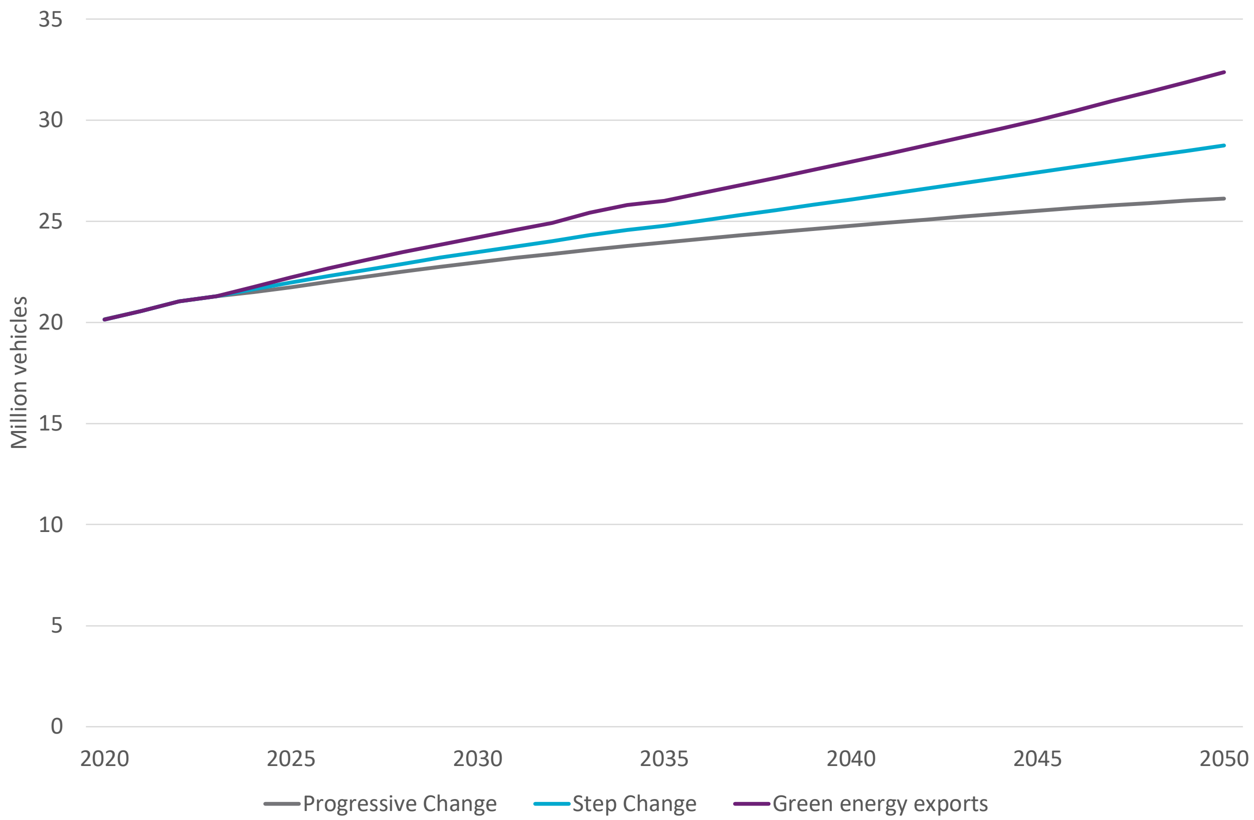

Figure 3-5 Projected national road vehicle fleet by scenario

3.6 Vehicle charging profiles

AEMO requires state level charging profiles which represent the aggregated charging profiles from all vehicles in the state divided by the number of vehicles. These are also called after-diversity profiles. After-diversity profiles are very different from individual charging profiles. The diverse behaviour of many individuals smooths and flattens out the kilowatts per vehicle charging profile compared to the behaviour of a single individual vehicle. Individual charging profiles are useful in circumstances where the behaviour being studied is at a less aggregated level such as charging demand at the street level. The profiles discussed here are not relevant for those lower scales.

In the 2022 projections a new state level unscheduled or ’convenience’ profile associated with a flat retail tariff structure was constructed based on after-diversity profiles available from the Energex and Ergon Energy Network (2022a, 2022b), Origin Energy (2021, 2022) and Philip et al. (2022) trials and combined with older 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 unscheduled profile.

The Origin trial provided a separate TOU tariff daily profile, and it showed 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). These sources were used to create new TOU tariff profiles.

AEMO has also provided CSIRO with new data on public charger profiles. The new data was based on actual public charging metering data. There was no new data for profiles for commercial or heavy vehicles, however we took the trends we were seeing in the passenger vehicle profiles and adjusted the other profiles to take account of these new information where we thought it would be applicable to commercial and heavy vehicles.

Some main areas of feedback we received from these new profiles is that some stakeholders find it difficult to relate to after-diversity or population level profiles, the names of each profile are misleading, and they would like a clearer link to the type of charger being used. This report has been more explicit about how we think charger types are changing over time and how that might interact with the balance of different types of charging behaviour. This report has also changed and extended the names of the profiles for clarity.

In regard to the profiles themselves (which can be seen in the 2022 projections report and in Excel files published by AEMO), we have shifted the focus to reporting how the profiles look when combined over time. That is, this report focuses in whether the combination of the profiles and the assumed share of each profiles produces a reasonable trend in the shape of statewide electric vehicle charging over time. The aggregated national profiles for 2035 and 2050 respectively is shown in Figure 3-6 for cars and in Figure 3-7 for trucks and buses.

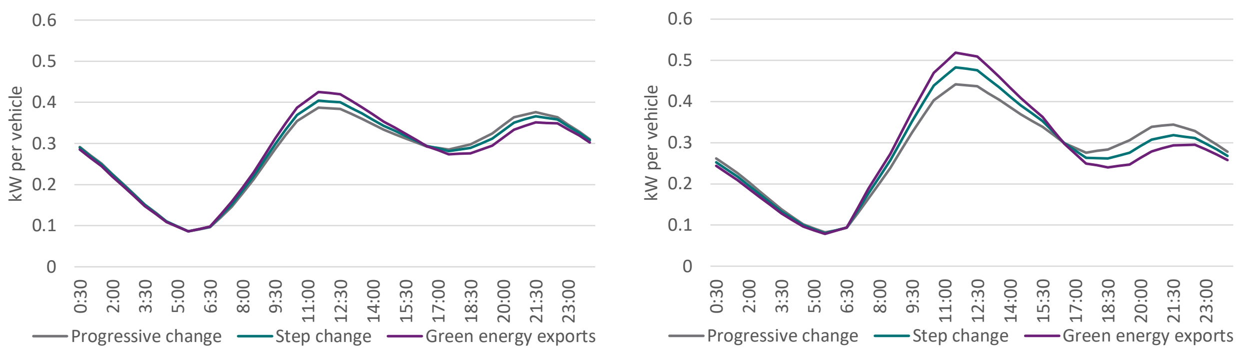

Figure 3-6 Aggregated electric vehicle charging profile for cars in 2035 (left) and 2050 (right)

By 2035, the car profile represents a combination of solar charging, and a partial avoidance of the evening peak period with more customers signed up to TOU tariffs but still many remaining on flat tariffs. By 2050, evening charging has fallen further, and more charging has moved into the middle of the day to match to solar supply. Overall, the 2050 profile is lower and flatter during the evening peak and more aligned to solar availability.

Trucks and buses perform heavy duty cycles in the sense that they carry heavy loads for long distances. While most cars will only use a small portion of their battery for daily travel, for cost and cargo space reasons, trucks and buses will likely be configured so that they consume close to their full battery capacity each day. This means that they need to do most of their charging at night and will need much more of the available night hours to get back up to full charge. These requirements mean that truck and bus charging is less likely to change over time. The modelling allows for a slight increase in day time charging for a minority of lower utilised or night duty vehicles that might have that option. The charge demand per vehicle is lower in *Step Change* and

Green Energy Exports because in those scenarios large trucks are assumed to have a greater reliance on hydrogen fuel cell engines. This reduces electric vehicle charging per total trucks and buses.

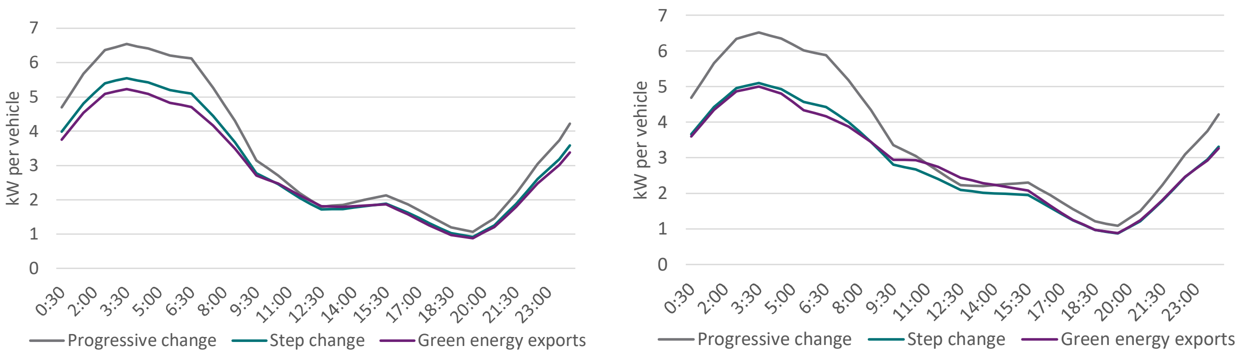

Figure 3-7 Aggregated electric vehicle charging profile for trucks and buses in 2035 (left) and 2050 (right)

CSIRO's projected statewide profiles are the first approximation using mostly existing TOU style tariffs to provide the incentive for orchestrating EV charging behaviour. In a secondary stage, AEMO makes further adjustment to charging behaviour that anticipates future changes in tariffs or other types of group coordination to address the changes in demand not anticipated by today's tariffs. For example, on a state-wide cloudy day, it may not be preferable for customers to concentrate their charging in the middle of the day (despite their TOU rates encouraging such activity). Changing the charging pattern on that day or asking customers to postpone charging until the next day would require additional coordination.

It is also important to note that the charging of vehicles participating in vehicle to grid is only approximated in the figures above but is modelled dynamically to suit the grid's needs (within set vehicle boundaries) when applied in AEMO modelling.

4 Projections results

The projections results are compared to CSIRO's 2022 projections (Graham, 2022). 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 2022 projections are referred to as CSIRO and their 2022 scenario names: *Progressive Change, Step Change* and *Hydrogen Export*[9]. The 2022 scenarios are presented as dashed lines on all figures in this section.

Most projections are presented to either 2055 or 2060. While 2055 is often a focus, 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.

4.1.1 One year trend projection (regression analysis)

For the period to June 2022-23, trend analysis is applied to produce a projection of the trend based on historical data. Only the most recent two to three[10] years are included in the trend calculation to provide more emphasises on recent outcomes. At the national level, the historical data to end of financial year 2023 aligns with data published by the Electric Vehicle Council (2023) and the June FCAI (2023) quarterly update so that the year 2022-23 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, 2023; 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). . The short term projections are checked to ensure that the sales trend met or exceeded the number of state electric vehicle subsidies available– this was true in all regions where they apply.

The trend projection is used directly but also modified for some scenarios to create a range. We need three different outcomes for the three scenarios and it is also important to take account of the potential for non-linear trends. In *Progressive Change* we assume sales are equal to the

[9] 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.

[10] 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.

projected linear trend. In *Step Change* sales are assumed to be 20% faster than the linear trend. The resulting annual sales level in *Step Change* is designed to be consistent with annualised value of the September quarter sales data for 2023-24 which was available at the time of writing. In *Green Energy Exports*, it is assumed that sales are 50% higher than the linear trend implying that sales in the remaining quarters are higher than the September quarter. The range applied across the scenarios assumes a stronger upside uncertainty in the short term. This will ideally correct for under prediction in the 2022 projections (Figure 4-1).

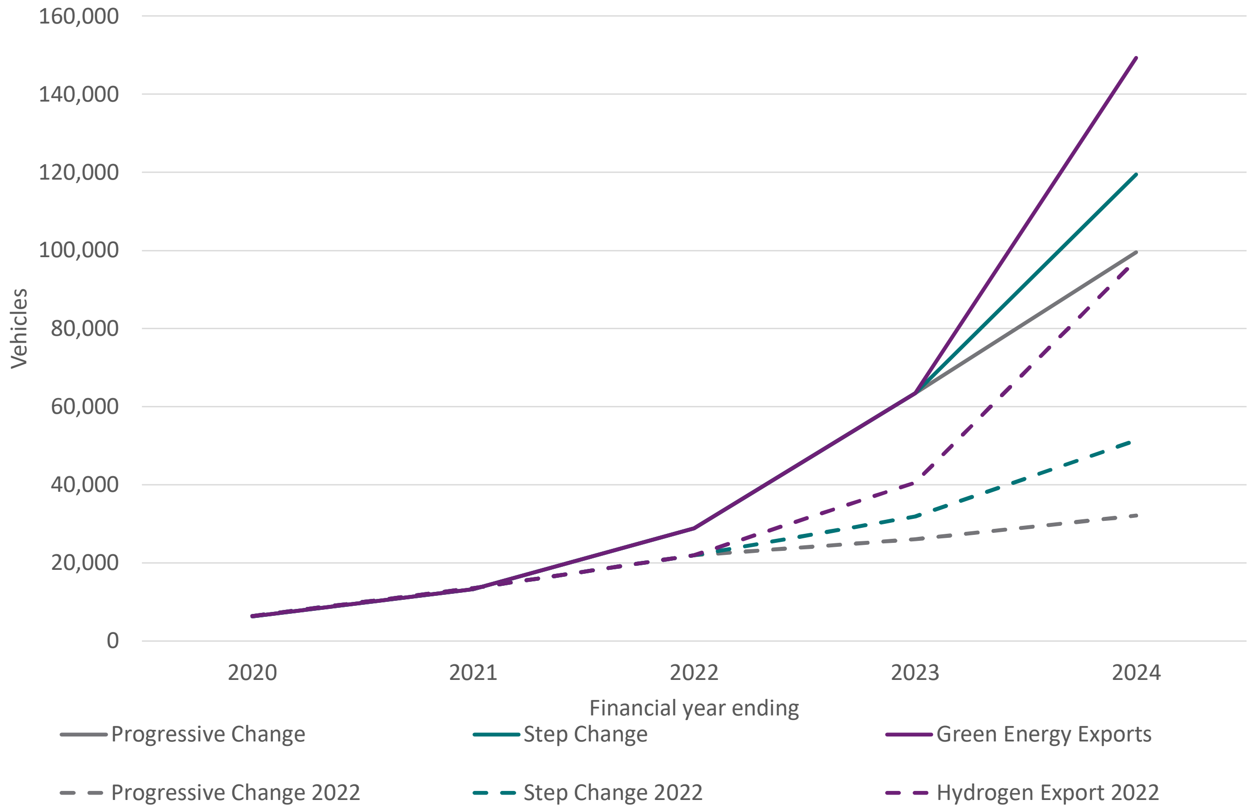

Figure 4-1 Historical and projected electric vehicle annual sales to 2023-24

4.2 Sales and fleet share

The projected sales and fleet share for electric vehicles is shown in Figure 4-2 and Figure 4-3. Historical shares to 2022-23 are included, then a one year ahead forecast as discussed above to 2023-24 and then a longer term adoption projection to 2060. The longer term adoption assumptions include meeting uncertain sales share policy goals in 2030 of 35%, 50% and 60% in *Progressive Change*, *Step Change* and *Green Energy Exports*, respectively. The sales curves pass through these points by scenario design. The scenarios are also designed to reach 99% sales share in 2050, 2040 and 2035. These anchor points for the scenarios have not changed for *Step Change* and *Green Energy Exports* (building on the 2022 *Hydrogen export* scenario) but have been brought forward for *Progressive Change*. This is because the lower sales rates for *Progressive Change* in the 2022 projections are no longer plausible given the strong historical sales in 2023 and the expected introduction of a fuel efficiency standard.

The *Progressive Change* scenario dips slightly between 2030 and 2035 because it has been assumed that short range electric vehicles are still more costly than internal combustion vehicles up to that point. This assumed intersection of costs between competing technologies occurs in 2030 and 2027 in the *Step Change* and *Green Energy Exports* scenarios.

Together, all of these factors define three stretched-out s-shaped adoption curves which are designed to capture a variety of developments which might be expected in emerging markets such as early adopter behaviour and the need to increase the number of models, charging stations and reduce vehicle costs to capture more mainstream consumers. A more drawn out curve captures potential reluctance from some groups to move to electric vehicles. However, this group will eventually find it increasingly difficult not to switch as commercial services for internal combustion vehicles are withdrawn due to a decreasing customer base.

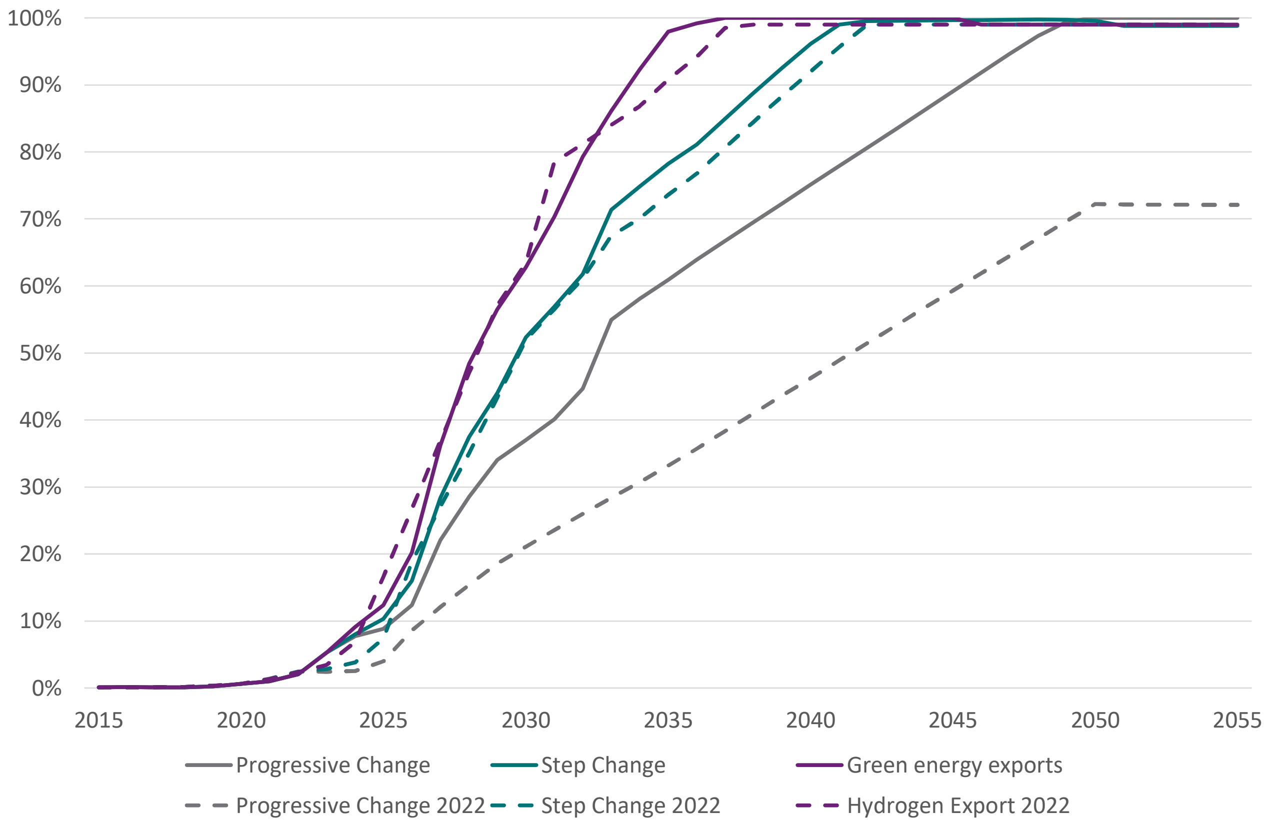

Figure 4-2 Projected electric vehicle sales share by scenario

The change in the fleet share is not as rapid because it takes time for the stock of vehicles to change given sales only represent slightly lower than 5% of the vehicle stock. At natural road vehicle retirement rates, it should take more than twenty years at a 100% electric vehicle sales rate for electric vehicles to replace all internal combustion vehicles. In this modelling, we assume internal combustion vehicles must remain at least 1% of the vehicle stock for special purposes including vintage car ownership. To get to 99% electric vehicle share only takes around ten years after reaching 100% electric vehicle sales. This is because we have assumed that internal combustion vehicles are scrapped at an accelerated rate during this period.

Accelerated scraping is expected to occur as a natural consequence of the major shift in the road vehicle supply chain. When vehicle manufacturers reach a point where they are only selling electric vehicles, it is unlikely that they will continue to supply spare parts for all existing internal combustion vehicles for the next 20 years. At 100% sales in each scenario the fleet is also generally around half or more converted to electric vehicles. This means that fuel suppliers are only experiencing around half or less the amount of sales for internal combustion vehicles. As a result, fuel suppliers may have to withdraw services or increase the cost of fuel making it more difficult to own an internal combustion vehicle, even if it is in sound mechanical condition. Sales were previously low enough in *Progressive Change* to avoid this outcome. However, with the potential introduction of a fuel efficiency standard it is less likely that the EV sales share will plateau.

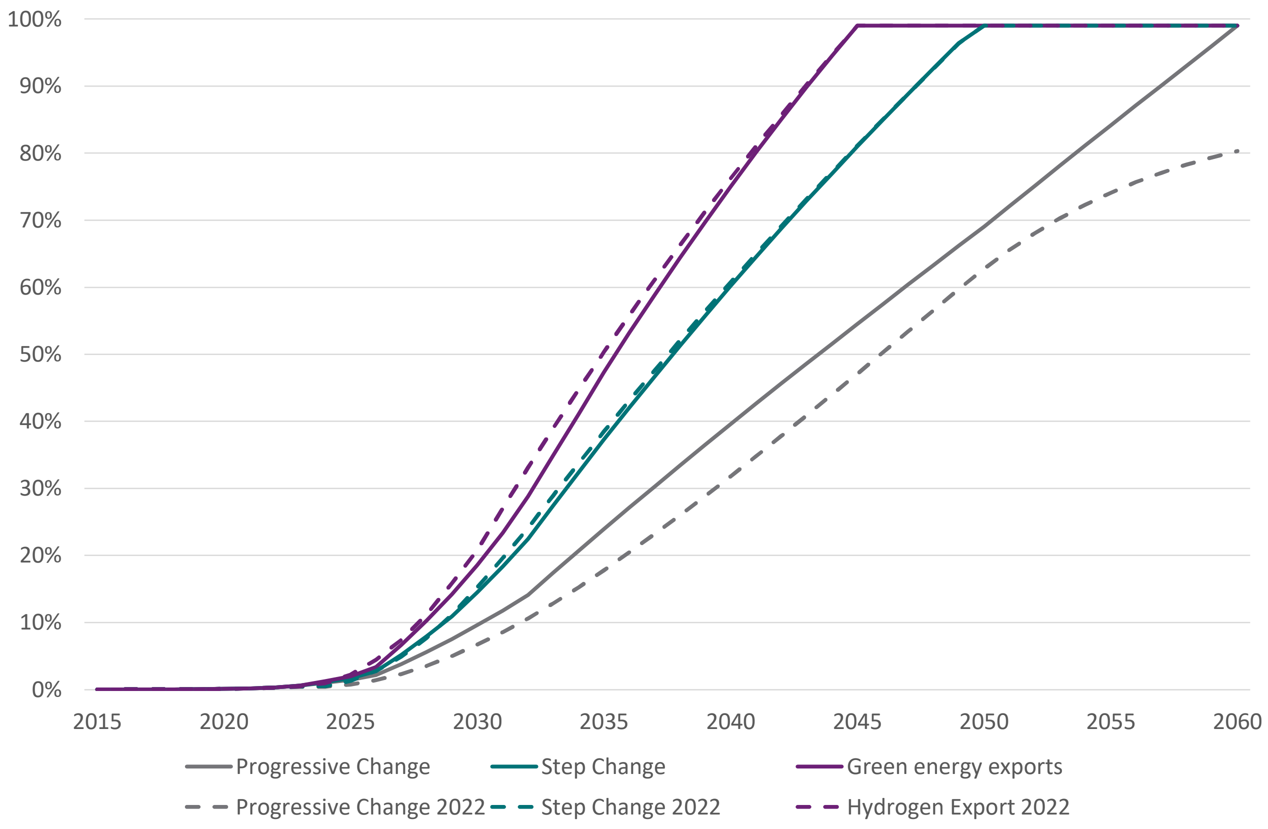

Figure 4-3 Projected electric vehicle fleet share

4.3 Number of vehicles and consumption

Given the projected fleet share, the resulting number of electric vehicles is the multiple of this fleet share and the expected number of vehicles of all types. The steps taken to project road transport demand and the subsequent number of vehicles needed to meet that demand were discussed in Section 3.5. A key change in that projection is that each vehicle will be driven fewer kilometres per year than assumed in the 2022 projections reflecting permanent changes in the number of people working from home and in business travel. As a result, while projected transport demand has decreased slightly from the 2022 projections, there are more vehicles expected to be owned, with each individually contributing a lower share of demand[11]. The

[11] If vehicle kilometres per year= number of vehicles times kilometres travelled per year. For vehicles kilometres to remain the same when kilometres travelled per year has fallen then vehicles must increase.

difference is greater for *Progressive Change* because that scenario has also been assigned stronger electric vehicle fleet share than in the 2022 projections (Figure 4-3).

As a result of this reduction in average kilometres travelled per vehicle, the updated projections for vehicles numbers in the NEM (Figure 4-4) and SWIS (Figure 4-5) have increased. The other key feature of the projections is the ‘knee’ in the trajectories of *Step Change* and *Green Energy Exports*. These turning points in their trajectory are a direct result of the discussion above about accelerated scrapping. The accelerated scrapping of internal combustion vehicles in the 10 years to 2045 for *Green Energy Exports* and the ten years to 2050 for *Step Change* results in faster than normal increase in electric vehicle numbers. However, after 2045 and 2050, the rate of scrapping can return to normal and the rate of growth in electric vehicle numbers slows to a more natural rate of increase. Little is known about the expected scrapping rate of a fully electric vehicle fleet – they might have longer lives, reflecting fewer parts, or shorter lives reflecting faster failure of key components in the electric drive train. Given this is an unknown at this stage they are assigned the same scrapping rates as internal combustion vehicles in Australia.

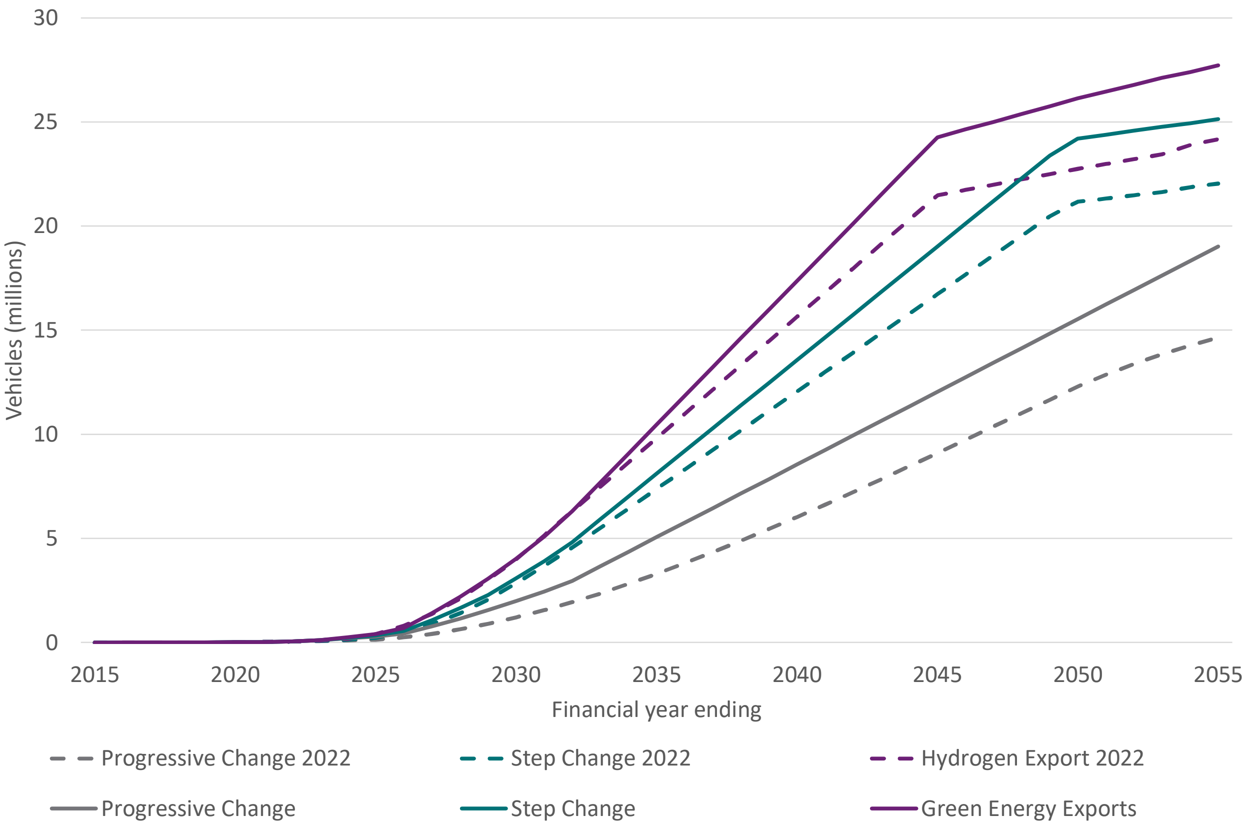

Figure 4-4 Projected number of electric vehicles in the NEM

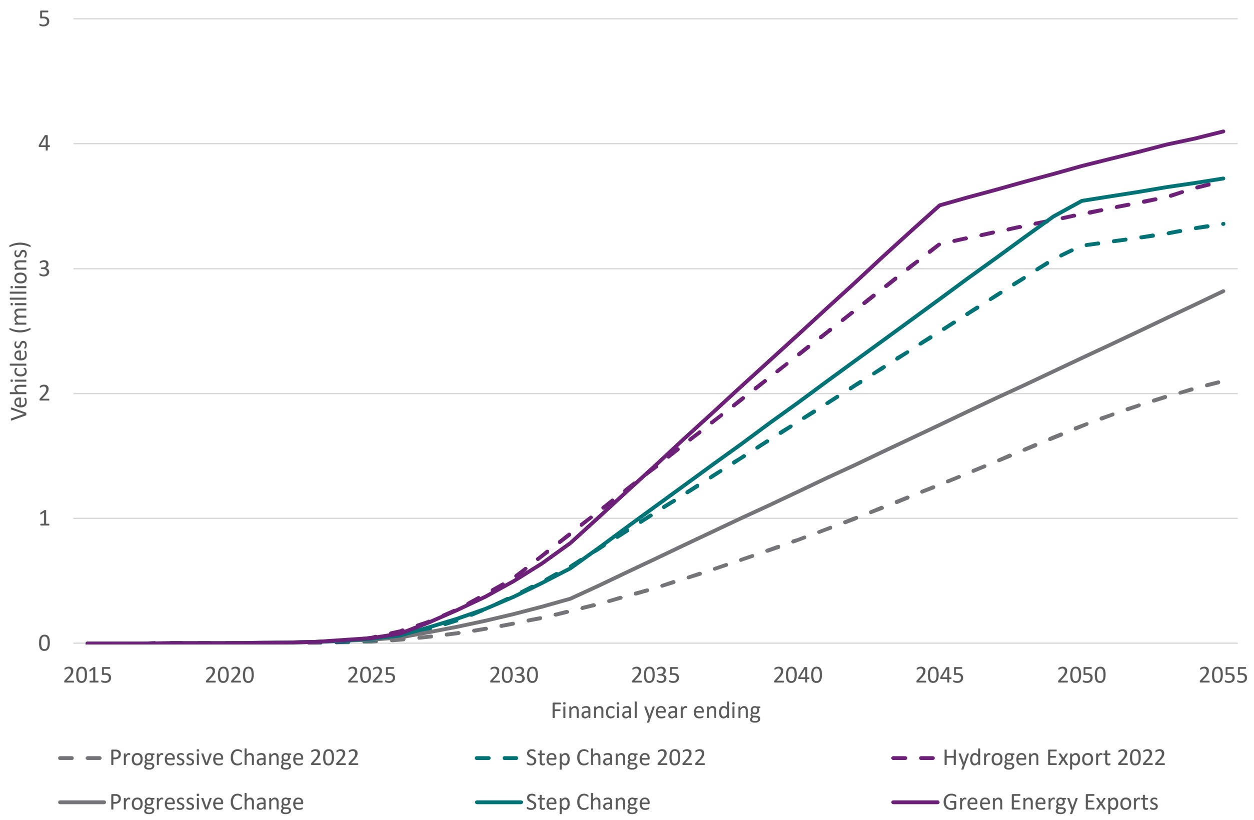

Figure 4-5 Projected number of electric vehicles in the SWIS

The consumption of electricity associated with electric vehicles is the multiple of the fuel efficiency of electric vehicles and the total electric kilometres travelled. While each vehicle is travelling fewer kilometres the projected total road kilometres is only slightly lower than in the 2022 projections (owing to slightly lower macroeconomic assumptions discussed in Section 3.1). The resulting projection of electricity consumption by electric vehicles is shown in Figure 4-6 for the NEM and in Figure 4-7 for the SWIS.

Both electricity consumption projections include the 2045 and 2050 turning points reflecting a direct flow on from the projected number of electric vehicles. The electricity consumption associated with production of hydrogen for use in fuel cell vehicles is not included in the results presented here, but is provided to AEMO separately as input to their calculations of electricity demand from the hydrogen industry.

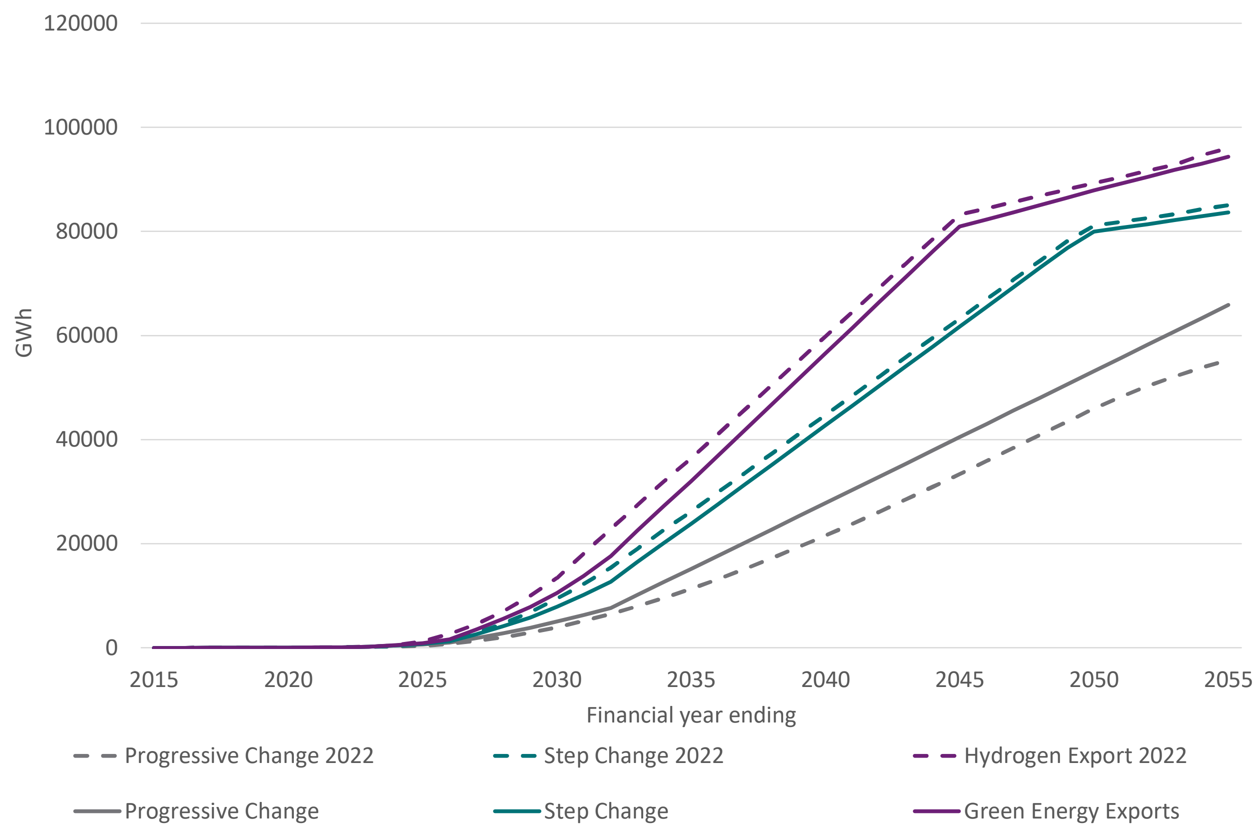

Figure 4-6 Projected electricity consumption from electric vehicles in the NEM

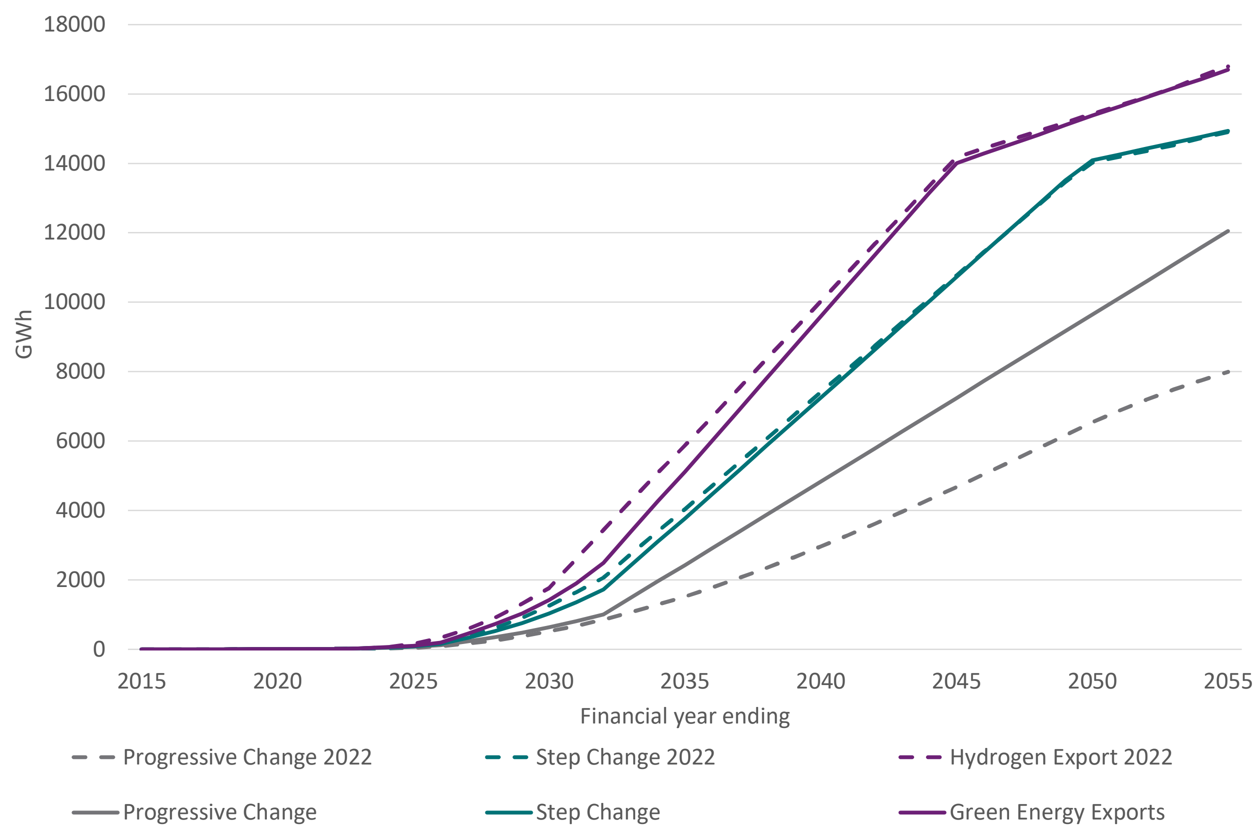

Figure 4-7 Projected electricity consumption from electric vehicles in the SWIS

4.4 Electric vehicle types

The results presented relate to all electric vehicle types – battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and hydrogen fuel cell vehicles (FCVs). The modelling also considers short and long range BEVs separately (SREVs and LREVs). To give a sense of the mix of alternative electric vehicles Figure 4-8 and Figure 4-9 show the projected mix of electric vehicles in the NEM and SWIS by scenario in 2050.

PHEVs are a significant absence from the technology mix in 2050. This reflects the historical trend away from PHEVs that has now been established for 9 years (Figure 4-10). PHEVs are an economical solution to the range issue while batteries remain high cost. However, the early adopter market has taken up BEVs in an increasing share over time. It is possible that a more mainstream market will appreciate PHEVs more. However, if battery costs decrease further the economic advantage will narrow over time and could switch to becoming a burden (i.e., maintaining two on board energy sources may eventually cost more than adding more batteries to achieve the same range). For that reason, the projections do not support a significant market share for PHEVs in the long term.

Electric vehicles dominate over fuel cell vehicles in the car market due to their demonstrated ability to bring their product to market. However, FCVs dominate the large truck segment in *Green Energy Exports* and *Step Change* given the hydrogen industries in those scenarios and the ability of FCVs to provide a simpler solution to the range issue for this heavy duty application. There is also modest market penetration in cars, buses and smaller trucks. The adoption of FCVs in *Progressive Change* is lower reflecting assumed higher costs and a less developed national hydrogen industry with lower capability to support development of the significant refuelling infrastructure needed for FCVs.

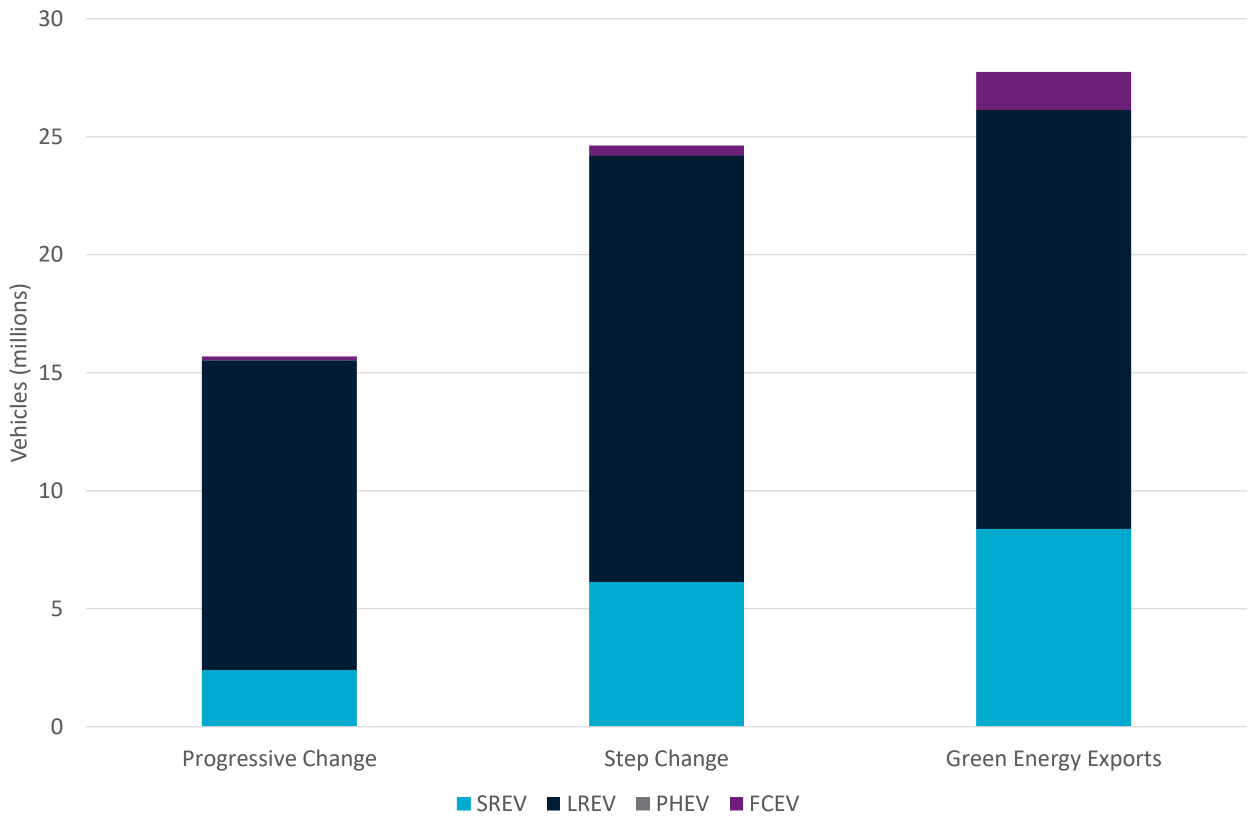

Figure 4-8 Projected mix of electric vehicle types in the NEM by scenario in 2050

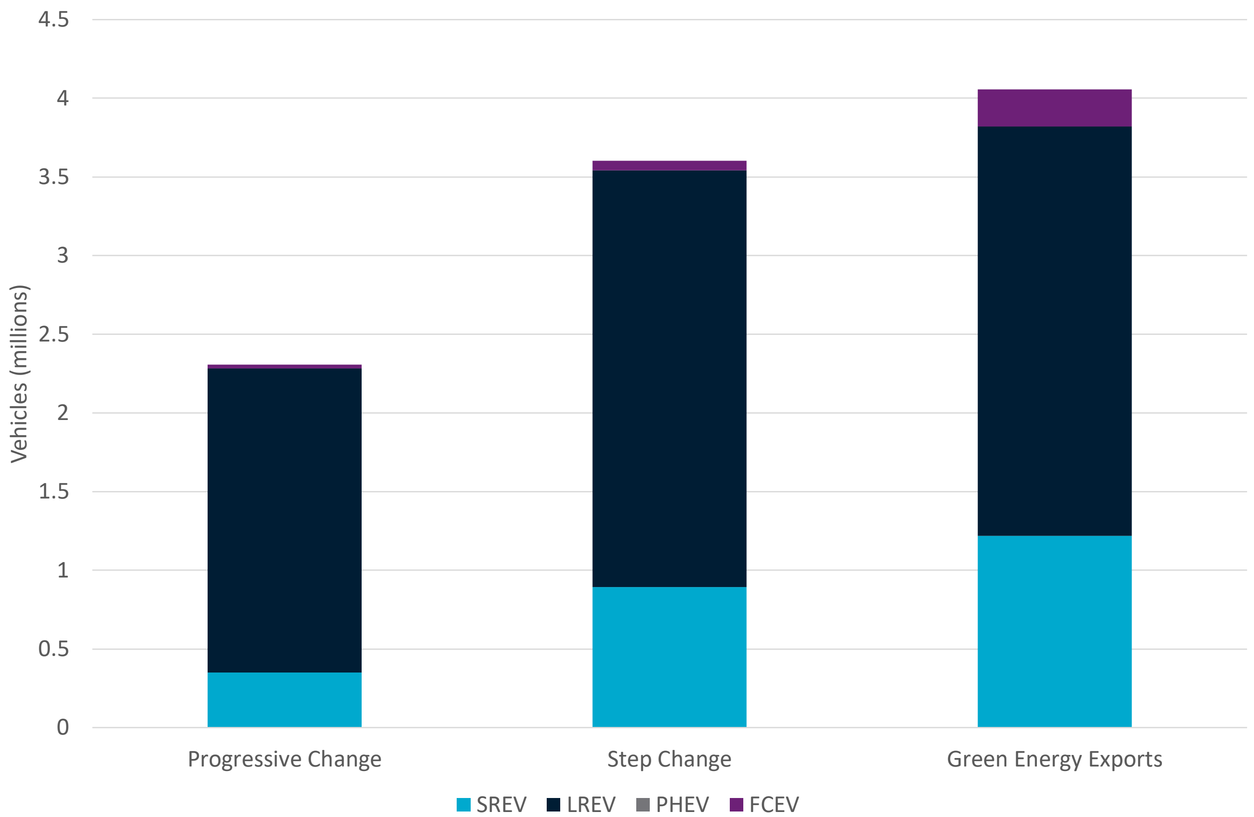

Figure 4-9 Projected mix of electric vehicle types in the SWIS by scenario in 2050

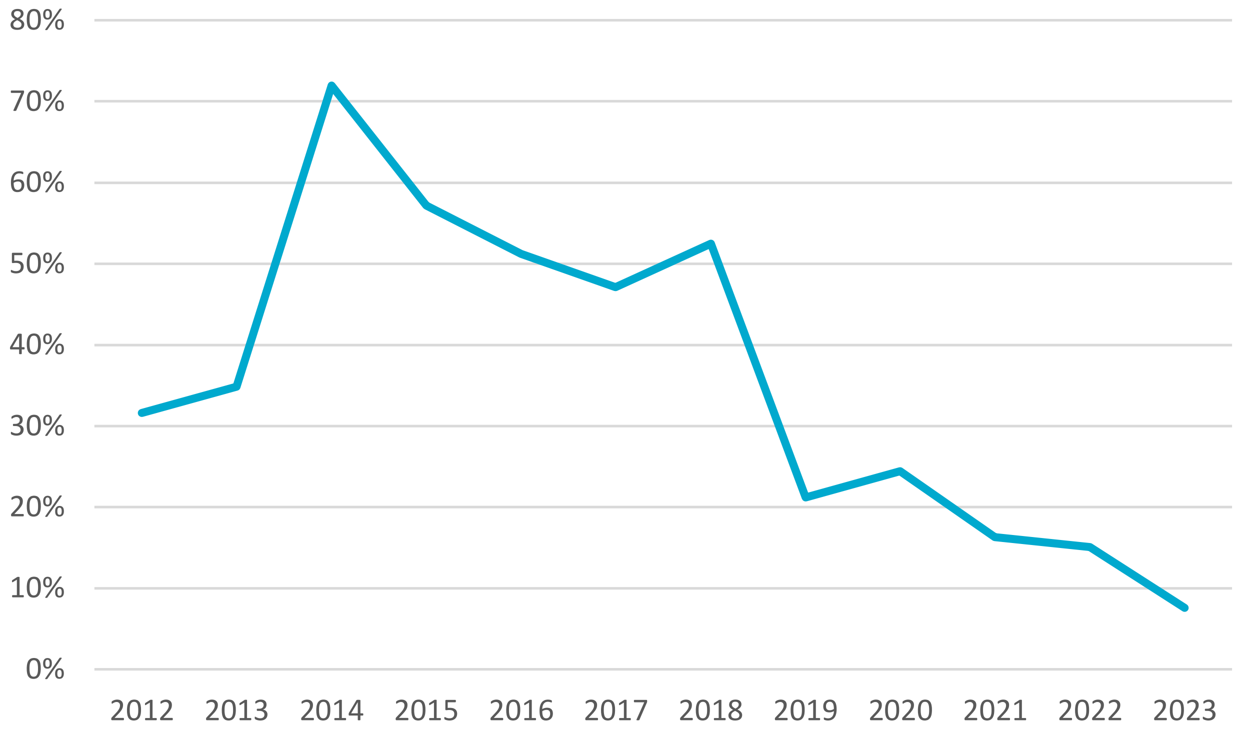

Figure 4-10 Historical share of plug in hybrid electric vehicles in total electric vehicles sales

Appendix A Projection data tables

A.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, vehicle sales and fleet share projections 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 A.1 Projected electric vehicle sales share

	Progressive Change	Step Change	Green Energy Exports
2015	0.001	0.001	0.001
2016	0.002	0.002	0.002
2017	0.001	0.001	0.001
2018	0.001	0.001	0.001
2019	0.002	0.002	0.002
2020	0.006	0.006	0.006
2021	0.010	0.010	0.010
2022	0.021	0.021	0.021
2023	0.053	0.053	0.053
2024	0.077	0.080	0.092
2025	0.088	0.103	0.124
2026	0.124	0.160	0.202
2027	0.221	0.284	0.362
2028	0.286	0.375	0.484
2029	0.340	0.440	0.566
2030	0.370	0.523	0.628
2031	0.401	0.569	0.703
2032	0.447	0.618	0.793
2033	0.549	0.714	0.861
2034	0.581	0.748	0.923
2035	0.609	0.783	0.979
2036	0.639	0.811	0.992
2037	0.668	0.849	1.000
2038	0.695	0.888	1.000
2039	0.723	0.925	1.000
2040	0.751	0.962	1.000
2041	0.779	0.990	1.000
2042	0.806	0.995	1.000
2043	0.834	0.996	1.000
2044	0.862	0.996	1.000
2045	0.890	0.997	1.000
2046	0.918	0.997	0.990
2047	0.947	0.997	0.990
2048	0.974	0.997	0.990
2049	0.994	0.997	0.990
2050	1.000	0.996	0.990
2051	1.000	0.988	0.990
2052	1.000	0.988	0.990
2053	1.000	0.988	0.990
2054	1.000	0.988	0.990
2055	1.000	0.988	0.990

Apx Table A.2 Projected electric vehicle fleet share

	Progressive Change	Step Change	Green Energy Exports
2015	0.000	0.000	0.000
2016	0.000	0.000	0.000
2017	0.000	0.000	0.000
2018	0.000	0.000	0.000
2019	0.001	0.001	0.001
2020	0.001	0.001	0.001
2021	0.002	0.002	0.002
2022	0.003	0.003	0.003
2023	0.006	0.006	0.006
2024	0.010	0.011	0.013
2025	0.014	0.017	0.020
2026	0.022	0.028	0.034
2027	0.038	0.052	0.067
2028	0.056	0.079	0.103
2029	0.075	0.109	0.142
2030	0.096	0.145	0.185
2031	0.118	0.183	0.233
2032	0.141	0.224	0.288
2033	0.174	0.274	0.349
2034	0.207	0.324	0.411
2035	0.239	0.373	0.473
2036	0.271	0.420	0.532
2037	0.303	0.467	0.589
2038	0.334	0.513	0.644
2039	0.365	0.558	0.698
2040	0.396	0.602	0.750
2041	0.426	0.645	0.801
2042	0.456	0.687	0.850
2043	0.486	0.729	0.898
2044	0.516	0.770	0.945
2045	0.545	0.810	0.990
2046	0.575	0.849	0.990
2047	0.604	0.888	0.990
2048	0.633	0.926	0.990
2049	0.662	0.964	0.990
2050	0.691	0.990	0.990
2051	0.721	0.990	0.990
2052	0.751	0.990	0.990
2053	0.781	0.990	0.990
2054	0.811	0.990	0.990
2055	0.841	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
TOU_GRID_SOLAR	TOU tariff including day charging incentives
TOU_HOME_SOLAR	TOU tariff with no day incentives other than use of home solar
TWh	Terawatt hour
UNSCHED	Unscheduled home charging, flat tariff
V2G	Vehicle to grid
V2H	Vehicle to home
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WEM	Western Electricity Market

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