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Assumptions report: Projections for small scale embedded energy technologies

Report to AEMO

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1 Introduction

This report was commissioned by AEMO who require projections of small-scale embedded technologies which include solar photovoltaic systems (solar PV), battery storage and electric and fuel cell vehicles. The projections data includes installations, capacity and the operational profiles of batteries and electric vehicles. The projections are for the purpose of assisting AEMO in producing electricity consumption and maximum/minimum demand forecasts for AEMOs 2019 electricity forecasting insights and related documents.

The projections are provided for five scenarios: Neutral Slow change, Fast change, High DER and Low DER which were developed with AEMO based on their initial descriptions and an extended set of scenario drivers specific to distributed energy resources developed further in this report. The scenario data assumptions included input from AEMO on drivers such as customer growth, gross state product and electricity prices. CSIRO also developed other scenario data assumptions drawn from a range of other relevant drivers, depending on the technology.

The projections are required at a state level from 2018-19 to 2050-51. For Western Australia and Northern Territory, only the South West Interconnected System (SWIS) and Darwin-Katherine Interconnected System (DKIS) are included. Some projections were also supplied to AEMO at the postcode level. However, this report mostly focusses discussion on state level results.

The solar PV projections are separated by size and market segment as follows: residential, commercial 10 to 100kW, commercial 100kW to 1MW, commercial 1MW to 10MW and commercial 10MW to 30MW. The first two segments are generally rooftop solar systems and are eligible to receive funding under the Small-scale Renewable energy Scheme (SRES). Battery storage projections are also provided under these two segments with two sizes for commercial systems.

The last three solar segments are referred to as Non-scheduled Generation (NSG) and may receive funding under the Large-scale Renewable Energy Target (LRET). In previous projections (Graham et al. 2018) a sixth segment which is standalone power systems (SAPS) or off-grid systems was included combining solar PV, battery storage and petroleum based generators. In this report we replace this category with vehicle to home electricity. This category provides the potential to provide all household electricity needs but without the need for the noise and local air emissions of a generator.

The market segments for electric vehicles include three engine configurations: Short range (<300km) and long range (>500km)[1] 100% electric (SREV and LREV) and plug in hybrid electric (PHEV). The vehicle types include passenger vehicles (large, medium and small), light commercial vehicles (large, medium and small), rigid trucks, articulated trucks and buses.

[1] The focus on the short and long range is for the purposes of capturing different vehicle price points and infrastructure constraints with respect to range. Whilst not modelled explicitly, we recognise mid-range electric vehicles may also fill a market niche. For the purposes of this report mid-range adoption can be understood as a subset of long range.

The report describes the projection methodology, scenario drivers and data assumptions. The appendices also describe additional data assumptions and maps of sub-state results.

2 Methodology

2.1 Adoption projections method overview

CSIRO applies a common projection methodology for electric vehicles, storage and all solar panels below 100kW. We regard these technology markets as “consumer” markets in the sense that investment decisions are driven by a combination of financial and non-financial drivers so that adoption will broadly follow the consumer technology adoption curve. For large solar systems we take the view that such decisions should be regarded as more pure financial investment decisions and therefore a mostly financially driven projection method.

2.1.1 Adoption in “consumer” technology markets

The consumer technology adoption curve is whole of market scale property that we can exploit for the purposes of projecting adoption, particularly in markets for new products. The theory posits that technology adoption will be initially 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).

In the last 50 years, a wide range of market analysts seeking to use the concept 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. Payback periods are a relatively straightforward to calculate and compared to price also capture the opportunity cost of staying with the existing technology substitute. A more difficult task is to identity the set of non-price demographic or other factors that are necessary to capture other reasons which might motivate a population to slow or speed up their rate of adoption. CSIRO has previously studied the important non-price factors and validated how the approach of combining payback periods and non-price factors can provide good locational predictive power for rooftop solar and electric vehicles (Higgins et al 2014; Higgins et al 2012).

In Figure 2-1 we highlight the general projection approach including some examples of the types of demographic or other factors that could be considered for inclusion. We also indicate an important interim step which is to calibrate the adoption curve at appropriate spatial scales (due to differing demographic characteristics and electricity prices) and across different customer segments (due to differences between customers electricity load profiles, travel needs, fleet purchasing behaviour and vehicle utilisation).

Once the adoption curve is calibrated for all the relevant factors we can evolve the rate of adoption over time by altering the inputs according to the scenario assumptions. 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 roof space or educational attainment in a region will result in different adoption curve shapes (particularly the height at saturation). Data on existing market shares determines the starting point on the adoption curve.

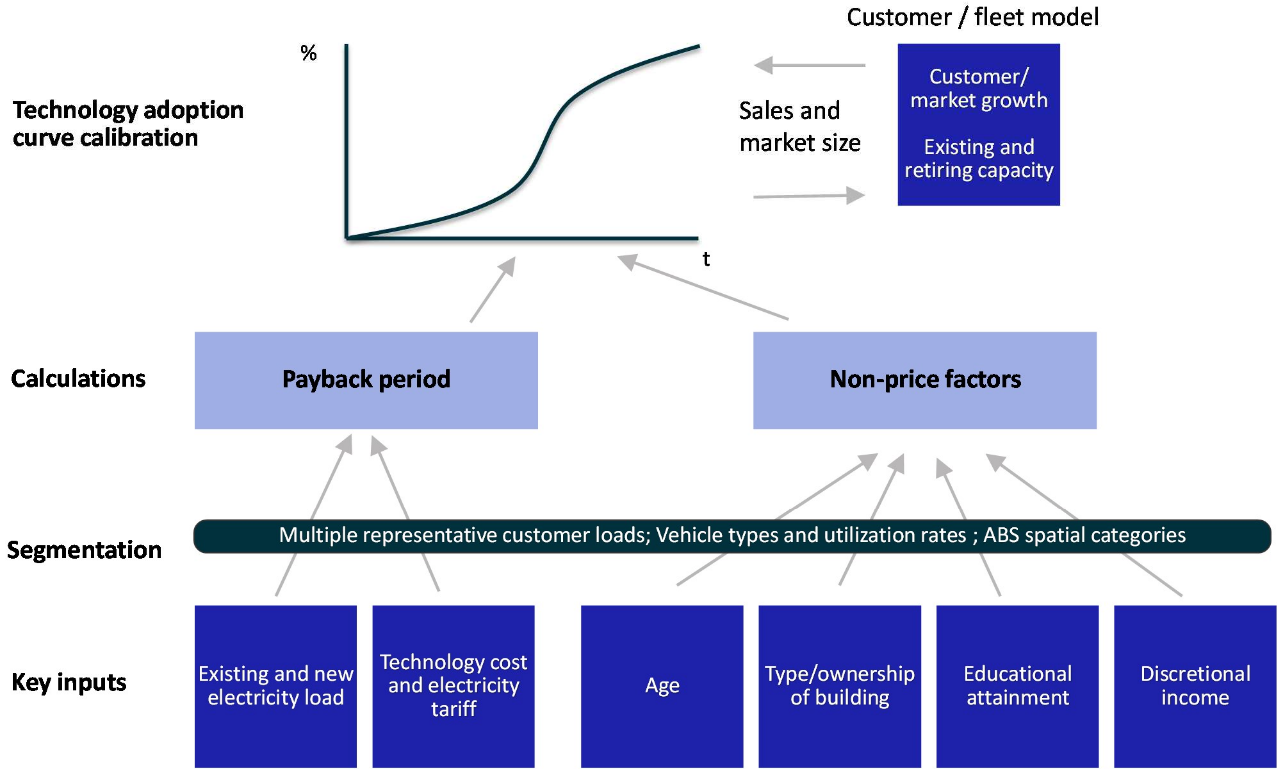

Figure 2-1: Projection methodology overview

The methodology also takes account of the total size of market available and this can differ between scenarios. For example, the total vehicle fleet requirement is relevant for electric vehicles, while the number of customer connections is relevant for rooftop solar and battery storage. The size of these markets are influenced by population growth, economic growth and transport mode trends and we discuss the latter further in the scenario assumptions section. While we may set a maximum market share for the adoption curve based on various non-financial constraints, maximum market share it is only reached if the payback period falls.

All calculations are carried out at the Australian Bureau of Statistics Statistical Area Level 2 (SA2) as this matches most of the available demographic data. However, we convert the technology data back to postcodes or aggregate up to the state level as required.

2.1.2 Adoption of larger technology investments

For solar panel sales and capacity above 100kW, we employ a different approach. The difference in approach is justified on the basis that larger projects require special purpose financing and, as such, are less influenced by non-financial factors in terms of the decision to proceed with a project. In other words, financiers will be exclusively concerned with the project achieving its required return on investment when determining whether the project will receive financing. Commercial customer equity financing is of course possible but it is more common that businesses have a wide range of important demands on available equity, so this is only a very limited source of funding (as compared to being the main source of small scale solar investment).

The projected uptake of solar panels above 100kW is based on determining whether the return on investment for different size systems meets a required rate of return threshold. If they do, investment proceeds in that year and region. Electricity prices and any additional available renewable energy credits in each state or territory will therefore be one of the stronger drivers of adoption. Where investment is able to proceed we impose a build limit rate based on an assessment of past construction rates and typical land/building stock cycles. Figure 2-2, Figure 2-3 and Figure 2-4 show the historical total deployment in each of solar plants in the 0.1MW to 1MW, 1MW to 10MW and 10MW to 30MW ranges respectively (source from APVI (2019)). They indicate the trends in build rates across each state. Deployment activity is most frequent and more evenly spread across states in the smaller ranges, particularly 0.1MW to 1MW. 10MW to 30MW plant are less frequent and concentrated only in New South Wales, Western Australia and the Australian Capital Territory.

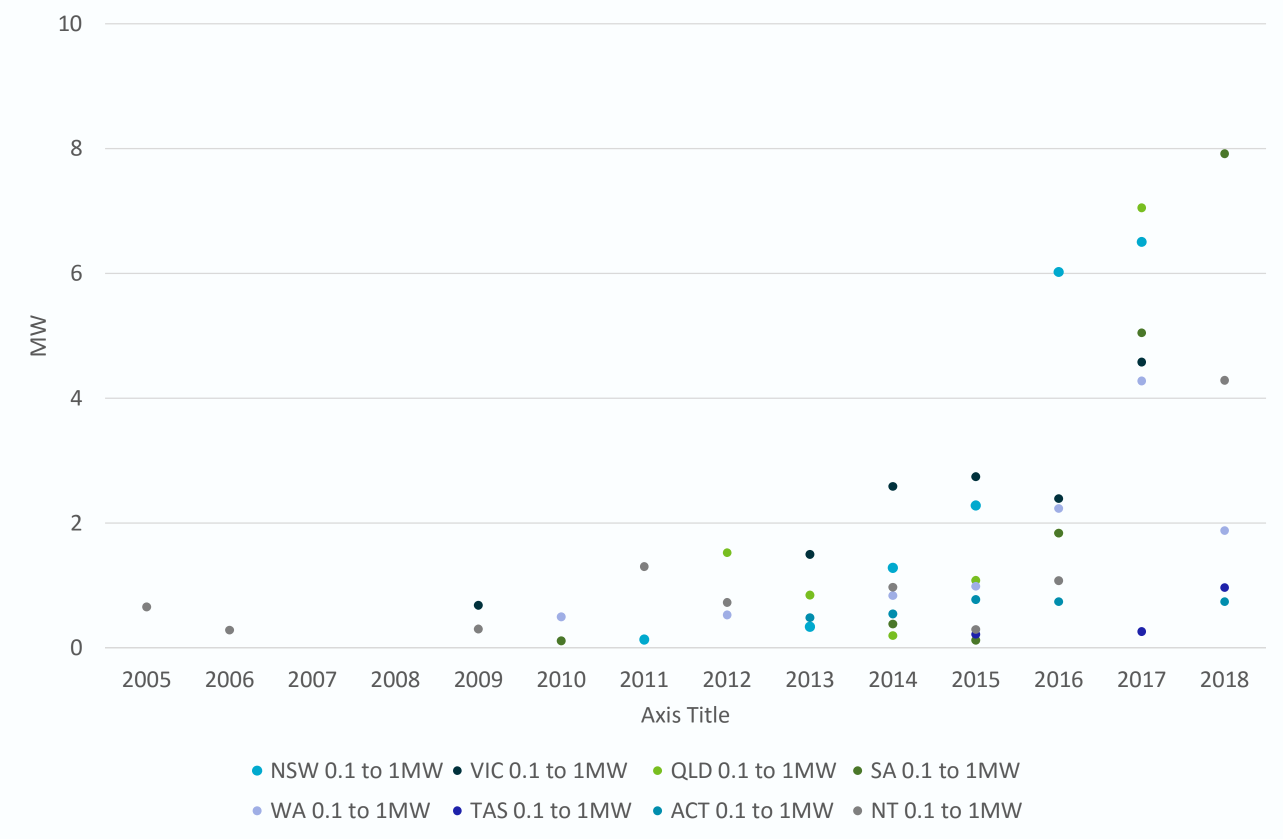

Figure 2-2: Historical deployment by state of solar systems of size 0.1 to 1 MW

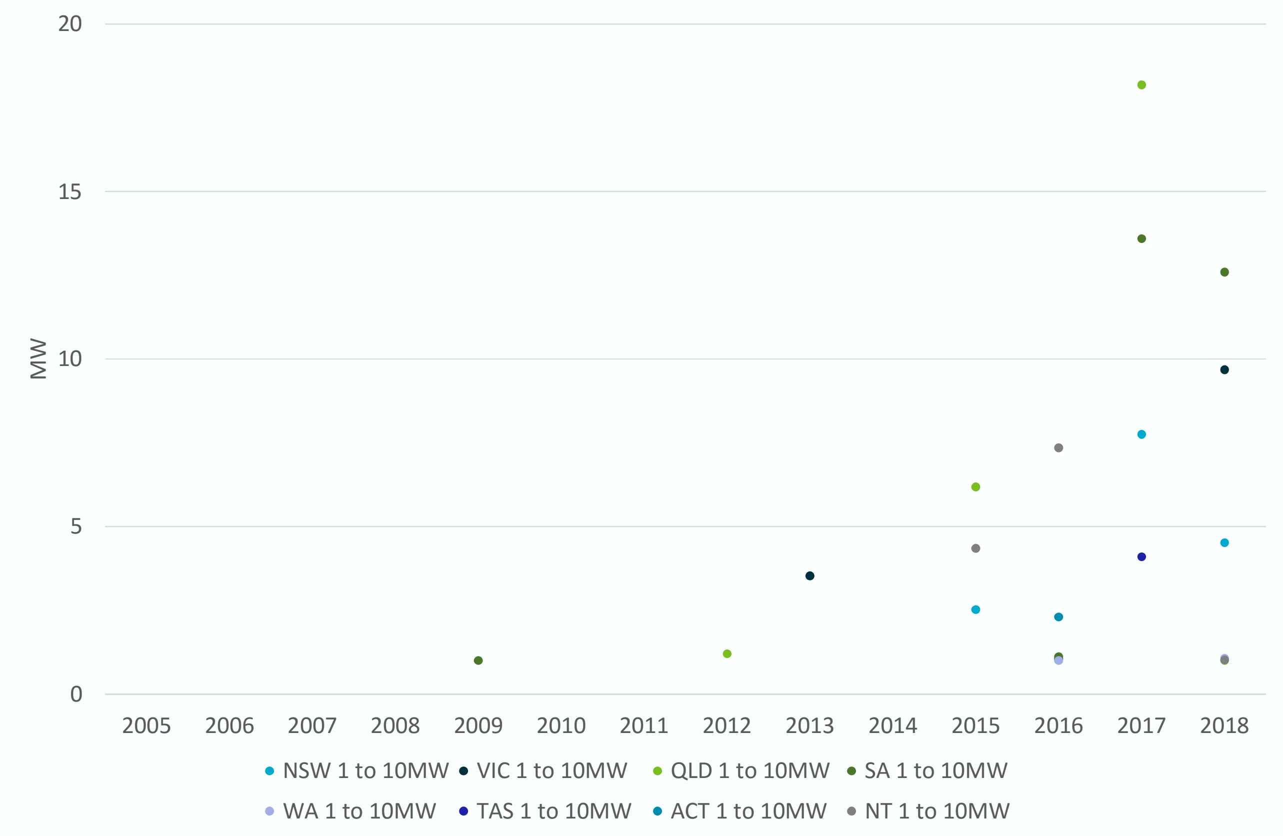

Figure 2-3: Historical deployment by state of solar systems of size 1 to 10 MW

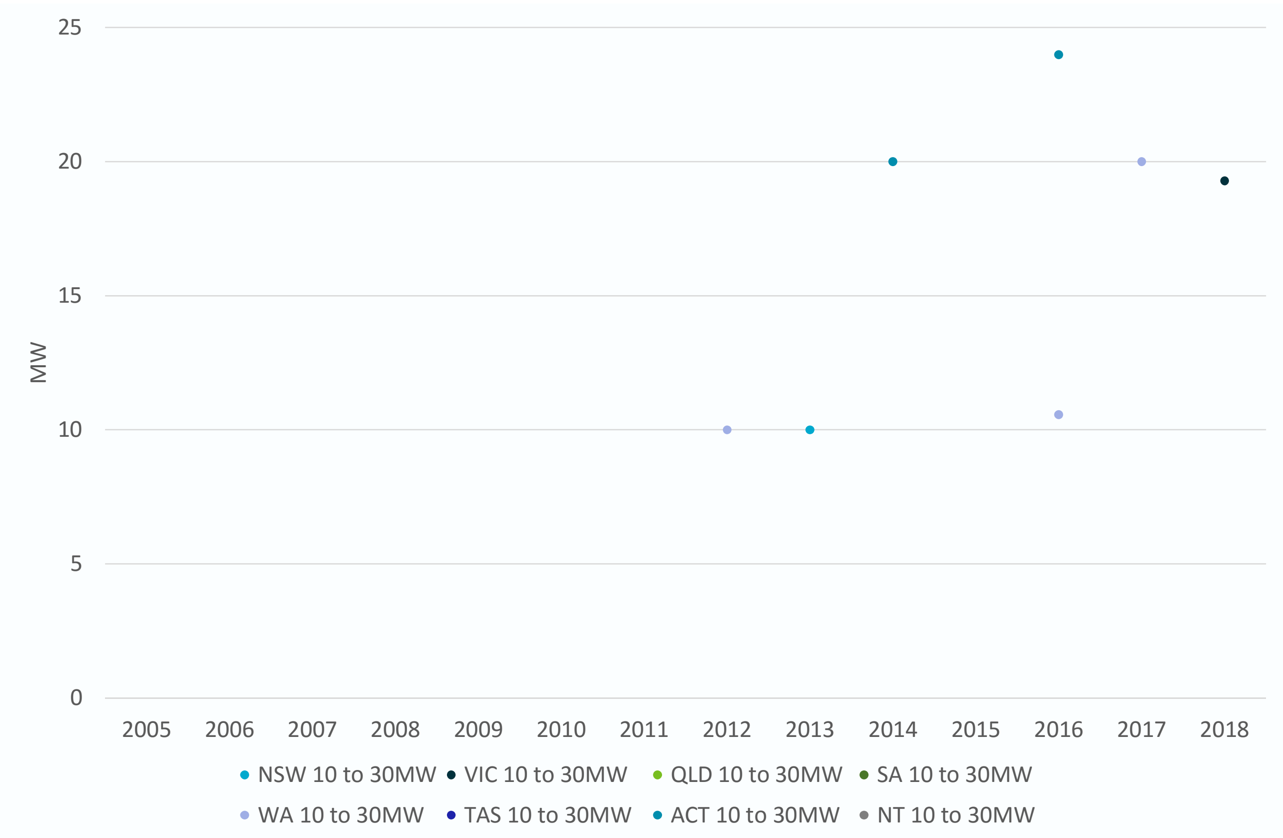

Figure 2-4: Historical deployment by state of solar systems of size 10 to 30 MW

2.1.3 Commercial vehicles

It could 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 they offer lower whole of life costs. However, we believe that infrastructure constraints including the landlord-renter problem are also relevant for businesses noting that many commercial vehicles parked at residential premises. For business parked vehicles if the business doesn't own the location installing a charger may not be straight forward. Also, the applicability of range to a business's needs is just as constraining as whether range suits a household's needs.

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. An optional second step is to assign different weights to each factor to reflect their relative importance. Here we outline the factors and weights chosen for the small-scale technologies categories

2.2.1 Weights and factors for rooftop solar and battery storage

Higgins et al (2014) validated prediction of historical sales for rooftop solar by combining a weighted combination of factors such as income, dwelling density and share of Greens voters. While these factors performed well the model was calibrated for 2010. Given the time that has passed and 2010 being very a much an early adopter phase of the market we tested a new set of factors. We have also emphasised using data that is readily available in SA2. The weights and factors applied were tested over 2017 sales data and are shown in Table 2-1.

Battery storage sales data is not available below the state or territory level. Consequently it is not possible to calculate a set of historically validated combination of weights and factors. In the absence of such data we assume the same weights apply to battery storage as rooftop solar.

Table 2-1: Weights and factors for residential rooftop solar and battery storage

Factor	Weight
Average income	0.25
Share of separate dwelling households	1
Share of owned or mortgaged households	0.25

The current public data is insufficient to locate commercial systems and slightly distorts our understanding of residential solar capacity per spatial region. The spatial data for solar systems below 100kW is not separated by type of owner, only total installations and kilowatts per postcode. Based on other sources, we know the relative share of residential and commercial systems at a state level. We therefore calculate residential and commercials systems as the state share of systems in that postcode.

2.2.2 Weights and factors for electric vehicles

Previous analysis by Higgins et al (2012) validated a number of demographic factors and weights for Victoria. We apply a similar combination of factors and weights as shown in Table 2-2. These weighting factors provide a guide for the adoption locations, particularly during the early adoption phase which we currently remain in. However, we allow adoption to considerably grow in all locations over time. It is likely that some of the factors included proxy other drivers not explicitly included (such as income).

Table 2-2: Weights and factors for electric vehicles

Factors	Weight ranges
Share of ages (in 10 year bands)	0-1 with middle-aged 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

3 Scenario definitions

The projections for small-scale embedded technologies are provided for the five scenarios as shown in Table 3-1: Neutral, Slow change, Fast change, High DER and Low DER. The AEMO scenario definitions provide useful direction about the differences between the scenarios. In this section we expand on these descriptions to provide greater clarity about what has been assumed in each scenario. We first outline the options for financial and non-financial drivers that are relevant to include in the scenario descriptions. We then combine these more detailed drivers and the original scenario definitions to create extended scenario definitions to support development of modelling assumptions for each scenario.

Table 3-1: AEMO scenario definitions

Demand Settings	Neutral	Slow change	Fast change	High DER	Low DER
Economic growth and population outlook	Neutral	Weak	Strong	Neutral	Neutral
Rooftop PV - up to 100 kilowatts (kW)	Neutral	Proportionally less household installations than the Neutral	Proportionally more household installations than the Neutral	Strong, relatively stronger than “Fast Change”, per capita	Weak, relatively weaker than “Slow Change” per capita
Non-scheduled PV - above 100 kW (up to 30 MW in NEM)	Neutral	Proportionally less commercial installations than the Neutral	Proportionally more commercial installations than the Neutral	Strong, relatively stronger than “Fast Change”, per capita	Weak, relatively weaker than “Slow Change” per capita
Electric vehicle uptake	Neutral	Weak	Strong, with EVs more rapidly reaching cost parity with ICE	Strong, with EVs more rapidly reaching cost parity with ICE	Weak, relatively weaker than “Slow Change” per capita
Electric Vehicle Charging Times	Central Estimate	Slower adoption of consumer energy management opportunities, leading to less controllable charging times	Greater adoption of consumer energy management opportunities, leading to more controllable charging times	Greater adoption of consumer energy management opportunities, leading to more controllable charging	Slower adoption of consumer energy management opportunities, leading to lesser controllable charging
Battery storage installed capacity	Neutral	Proportionally less household installations than the Neutral	Proportionally more household installations than the Neutral	Strong, relatively stronger than “Fast Change”, per capita	Weak, relatively weaker than “Slow Change” per capita
Battery storage aggregation by 2050	Central Estimate	Slower adoption of energy aggregator opportunities, leading to lesser aggregation	Faster adoption of energy aggregator opportunities, leading to more aggregation	Fast, relatively faster than “Fast Change” per capita	Slow, relatively slower than “Slow Change” per capita

Demand Settings	Neutral	Slow change	Fast change	High DER	Low DER
Emissions reduction trajectories	26% / 2005 – 2030 With achievement linked to large scale investment in renewables and earlier coal retirements – meaning **no** direct carbon pricing mechanism to signal action to consumers	26% 2005 – 2030 With achievement linked to large scale investment in renewables and earlier coal retirements – meaning **no** direct carbon pricing mechanism to signal action to consumers	45% 2005 – 2030 With achievement linked to large scale investment in renewables and earlier coal retirements – meaning **no** direct carbon pricing mechanism to signal action to consumers, as well as increased policies to support small-scale DER investments, increasing DER uptake	45% 2005 – 2030 With achievement linked to large scale investment in renewables and earlier coal retirements - meaning **no** direct carbon pricing mechanism to signal action to consumers, as well as greatest direct policies to support small-scale DER investments, increasing DER uptake	45% 2005 – 2030 With achievement linked to large scale investment in renewables and earlier coal retirements – meaning **no** direct carbon pricing mechanism to signal action to consumers
Battery cost trajectories (utility and behind the meter)	Neutral	Relatively weaker cost reductions than neutral	Relatively stronger cost reductions than neutral	Relatively stronger cost reductions than neutral	Relatively weaker cost reductions than neutral
Tariff arrangements	No significant change to existing / proposed tariff arrangements.	No significant change to existing / proposed tariff arrangements.	Significant change to existing / proposed tariff arrangements to foster and support a prosumer future, with customers embracing digital trends to take advantage of new tariff structures that lower consumer costs.	Significant change to existing / proposed tariff arrangements to foster and support a prosumer future, with customers embracing digital trends to take advantage of new tariff structures that lower consumer costs.	No significant change to existing / proposed tariff arrangements.

3.1 Financial and non-financial scenario drivers for consideration

3.1.1 Direct economic drivers

Rooftop solar and batteries

Whilst the general buoyancy of the economy is a factor in projecting adoption of small scale technologies, here we are concerned with the direct financial costs and returns. The key economic drivers which alter the outlook for rooftop solar and battery storage adoption scenarios are:

- any available subsidies or low interest loans (we discuss some government policies further below)
- installed cost of rooftop solar and battery storage systems and any additional components such as advanced metering,
- current and perceived future level of retail electricity prices,
- the structure of retail electricity tariffs or other incentives available to that residence or business,
- the level of feed in tariffs (FiTs) which are paid for exports of rooftop solar electricity,
- wholesale (generation) prices which may influence the future level of FiTs
- the shape of the customer's load curve

Alternative road vehicles

For privately owned electric and fuel cell vehicles the economic drivers are:

- 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
- the whole cost of driving an internal combustion vehicle as an alternative including vehicle, fuel, insurance, registration and maintenance costs
- perceptions of future changes in petroleum-derived fuel costs including global oil price volatility
- the structure of retail electricity prices relating to electric vehicle recharging
- the perceived vehicle resale value

Future hydrogen fuel costs are hard to predict because there is a diversity of possible supply chains, each with their own unique cost structures. Electricity derived hydrogen would probably offer the most flexibility for accessing a low carbon energy source and allowing hydrogen to be generated at either the end-user's location, at fuelling stations or at a dedicated centralised facilities.

For autonomous private and ride share vehicles the additional economic drivers compared to electric and fuel cell vehicles are:

- the cost of the autonomous driving capability
- the value of avoided driving time
- 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)
- the avoided cost of wages to the transport company for removing drivers from autonomous trucks
- Higher utilisation and fuel efficiency associated with autonomous trucks

3.1.2 Infrastructure drivers

Rooftop solar and batteries

One of the key reasons for the already significant adoption of rooftop solar has been its ease of integrating with existing building infrastructure. Battery storage has also been designed to be relatively easily incorporated into existing spaces. However, there are some infrastructure limitations which are relevant over the longer term.

The key infrastructure drivers for rooftop solar and battery systems are:

- The quantity of residential or commercial roof space or vacant adjacent land, of varying orientation, ideally free of shading relative to the customer's energy needs (rooftop solar)
- Garage or indoor space, ideally air conditioned, shaded and ventilated (battery storage)
- The quantity of buildings with appropriate roof and indoor space that are owned or mortgaged by the tenant, with an intention to stay at that location (and who therefore would be able to enjoy the benefits of any longer term payback from solar or integrated solar and storage systems)
- Distribution network constraints imposed on small-scale systems as a result of hosting capacity constraints (e.g. several distribution networks have set rules that new rooftop system sizes may be no larger than 5kW per phase)
- Distribution network constraints relating to connection of solar photovoltaic projects in the 1MW to 30MW range
- The degree to which the NEM and WEM management of security and reliability begins to place limits on the amount of large and small scale variable renewables that can be accepted during peak supply periods (e.g. to maintain a minimum amount of dispatchable or FACS serving plant)
- The degree to which solar can be integrated into building structures (flat plate is widely applicable but alternative materials, such as organic solar, could extend the amount of usable roof space)

Alternative road vehicles

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 (sport, sedan, SUV, people moving, compact, medium, large, utility, 4WD, towing).

In addition, key infrastructure drivers for electric vehicles are:

- Convenient location for a 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

- 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 longer term payoff from the upfront costs of installing the charger.
- Convenient access to highway recharging for owners without access to extended range capability (or other options, see below)
- Access to different engine configurations of electric vehicles (e.g. fully electric short range, fully electric long range, plug-in hybrid electric and internal combustion)
- 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

Key infrastructure drivers for fuel cell vehicle are:

- A mature hydrogen production and distribution supply chain for vehicles. 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. trucks at low volumes, pipelines at high volumes).
- The greater availability of fuel cell vehicles for sale.

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 electricity infrastructure but its location depends on whether the electrolysis is on site (e.g. at a service station) or centralised (where the location might be a prospective renewable energy zone or fossil fuel resource).

Given the constraints of commute times and cost of land in large cities, we are generally observing a 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 (we define these assumptions 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.

3.1.3 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 3-2 explores some emerging and potential business models which could drive higher adoption of small-scale embedded technologies.

Table 3-2: Emerging or potential disruptive business models to support embedded technology adoption

Name (technology)	Description	Constraint reduced
Building as retailor **(rooftop solar)**	Apartment or shopping centre building body corporate as retailer	Rooftop solar is more suitable for deployment in dwellings which have a separate roof
Peer to peer **(rooftop solar)**	Peer to peer selling as an alternative to selling to a retailer	Owners may generate more from solar if they could trade directly with a related entity (e.g. landlords and renters, corporation with multiple buildings, families and neighbours) without a retailer distorting price reconciliation
Solar exports become a network customer obligation **(rooftop solar)**	Networks are incentivised through regulatory changes to purchase voltage management services	Network hosting capacity imposes restrictions on rooftop solar uptake through size of connection constraints and financial impact of curtailment (through inverter tripping, even after accounting for improved inverter standards)
Zero upfront solar **(rooftop solar)**	No money down or zero interest loans for rooftop solar	While costs have fallen, rooftop solar still represents a moderately expensive upfront cost for households and businesses with limited cash flow or debt appetite.
Virtual power plant **(battery storage)**	Retailers, networks or an independent market operator reward demand management through direct payments, alternative tariff structures or direct ownership and operation of battery to reduce costs elsewhere in the system	Given the predominance of volume based tariffs, the main value for customers of battery storage is in reducing rooftop solar exports. The appetite for demand management participation could be more directly targeted than current incentives.
Going off-grid **(Integrated rooftop solar with storage and petroleum fuel generator)**	Standalone power system is delivered at lower cost than new distribution level connections greater than 1km from existing grid	Except for remote area power systems, it is cost effective to connect all other customers to the grid
Going off-grid and green **(Integrated rooftop solar with storage and non-petroleum fuel solution)**	Energy service companies sell suburban off-grid solar and battery systems plus a non-petroleum back-up system yet to be identified but suitable for suburban areas	Except for remote area power systems, it is cost effective to connect all other customers to the grid
Solar/battery new housing packages **(Integrated rooftop solar with storage)**	New housing developments include integrated solar and batteries on new housing as both a branding tool and to reduce distribution network connection costs	Integrated solar and battery systems represent a discretionary and high upfront cost for new home owners under high mortgages
Affordable public charging	Ubiquitous public charging is able to	Low cost access to electric vehicle charging

Name (technology)	Description	Constraint reduced
(electric vehicles)	be provided cost effectively	will be primarily at the home or business owner's premises
Charging into the solar period **(electric vehicles and rooftop solar)**	Businesses offer day time parking with low cost controlled charging and provide voltage control services to network in high solar uptake areas	Electric vehicle charging will be primarily at home and overnight, poorly matched with solar which receives low FiTs and is frequently shut off by inverter due to voltage variation in high solar uptake areas
Vehicle battery second life **(electric vehicles and battery storage)**	Electric vehicle batteries are sold as low cost home batteries as a second life application	Battery storage represents a high upfront cost and discretionary investment.
Autonomous ride share vehicles **(electric 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 **(electric vehicles)**	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 public charging.	Battery storage represents a high upfront cost and discretionary investment. Using the battery capacity in your electric vehicle for home energy management would be complicated to setup and may void equipment warranties which were designed for isolated operation
Hydrogen economy **(fuel cell vehicles)**	Australia becomes a major hydrogen exporter and this supports some economies of scale in domestic supply of hydrogen for fuel cell vehicles	Fuel cell vehicle distribution infrastructure is not established and will involve a high upfront cost for a business investor.
Collapse of ICE business model	Sales of ICE vehicles fall to a level such that ICE oriented businesses (petroleum fuel supply, vehicle maintenance) lose economies of scale	"Laggards" who would otherwise never choose an electric or fuel cell vehicle have reduced choices because services have shifted to service new majority

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.

3.1.4 Commonwealth policy drivers

Small-scale Renewable Energy Scheme and Large-scale Renewable Energy Target

Rooftop solar currently receives a subsidy under the Small-scale Renewable Energy Scheme whereby rooftop solar is credited with creating small scale technology certificates (STCs) which Renewable Energy Target (RET) liable entities have a legal obligation to buy. Rooftop solar purchases generally surrender their rights to these certificates in return for a lower upfront cost.

The amount of STCs accredited is calculated, using a formula that recognises location/climate, the renewable electricity generation that will occur over the life of the installation. The amount of STCs accredited to rooftop solar installation will decline over time to reflect the fact that the Renewable Energy Target policy closes in 2030 and therefore renewable electricity generated beyond that time is of no value in the scheme.

STCs can be sold to the Clean Energy Regulator (CER) through the STC Clearing House for $40 each. However, the CER makes no guarantees about how quickly a sale will occur. Consequently most STCs are sold at a small discount directly to liable entities on the STC open market.

The Large-scale Renewable Energy Target (LRET) is a requirement on retailers to purchase large-scale generation certificates (LGCs). This represents a subsidy for large scale renewable generation but is relevant for any solar system above 100kW as they are not eligible for STCs. In this report we are interested in any solar system up to 30MW, hence the price of LGCs is a relevant driver for adoption. The requirements for the LRET are largely met within existing and under construction plant as the target currently plateaus in 2020 and remains at that level until 2030. As a consequence the LGC price is expected to be approaching zero in the next few years.

Potential changes to Commonwealth renewable energy and climate policy

Given Australia's nationally determined commitment at the Paris UNFCCC meeting, up until the last year, there had been a growing expectations that some sort of emission credit and targeting policy, with a degree of bi-partisan support would be implemented to clarify to how the electricity sector would contribute to achieving the national greenhouse gas emissions goal. The dissolution of bi-partisan support for this approach makes it more likely that governments will either take no action[2] or use more direct actions such as auctions and lower interest finance of renewable and storage capacity. If implemented these would represent a new source of subsidy to take over from LGCs and the LRET.

Low emission road vehicles policy

Australia is one of the few developed countries without vehicle greenhouse gas emission standards. As a consequence, vehicles sold in Australia are generally 20% less efficient than the same model sold in the UK (CCA 2014). The Commonwealth government has had a process since 2015 for considering a greenhouse gas emission intensity standard for road vehicles. An initial impact study concluded that introduction of a standard would have a positive net benefit on the basis that any increase in vehicles costs to meet the standard is offset by savings in fuel costs over time. The process moved on to designing how such a scheme would work in detail but appears to have stalled. With the changes in approach to achieving the Paris emission targets[3], further process may be halted altogether.

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[2] In its 2018 emission projections process the government pointed out that it might be possible to meet emission reduction targets by crediting excess cumulative emissions reductions achieved in the 2020 period to the 2030 period. In early 2019, it was also announced that funding for the Emission Reduction Fund which sources around 80% of emission credits from the land sector, would be increased. Together, these new approaches imply that little additional abatement would be required from the energy or transport sector

[3] See previous footnote

Should there be a change in government and a higher emission target transport would undoubtedly need to contribute to whole of economy abatement. Therefore we should also expect the possibility of a revitalised process to implement vehicle emission standards sometime in the future. Low emission vehicles such as electric vehicles are expected to be adopted with or without emission standards but they could accelerate their adoption.

3.1.5 State policy drivers

Policies supporting rooftop, larger scale solar and batteries

While subject to potential changes in policy with each election period it seems likely that the three larger eastern states, New South Wales, Queensland and Victoria will all have policies that work in addition to the Commonwealth RET. Two existing policies are the Victorian Renewable Energy Target (VRET) and Queensland Renewable Energy Target. Under current auction arrangements VRET is only open to renewable generators above 10MW which is relevant for some small-scale solar but not rooftop solar. However the current government is providing a subsidy of half the cost of solar (up to a value of $2,225) to 24,000 homes in 2018-19 and announced plans to expand the scheme to zero upfront cost beyond July 2019 for 650,000 homes (with means testing).

The Queensland government accepted a recommendation to not include an incentives under the QRET for rooftop solar in addition to the Commonwealth Small-scale Renewable Energy Scheme. New NSW government policy will also be available to support rooftop solar and batteries.

There are a number of state subsidy schemes directly targeting batteries. The South Australia government has a policy of providing subsidies to 40,000 homes to install batteries. The subsidy will be scaled with the size of the battery and capped at $6000. It is being delivered in collaboration with the CEFC. A set of minimum technical requirements for battery systems has been developed to ensure the batteries are capable of being recruited into a virtual power plant (VPP) schemes. The Victorian government's Solar Homes policy does not include batteries but they have provided funding to provide 650 homes with batteries to trial a VPP style micro-grid.

Low emission vehicles

Victoria provides a $100 discount on registration fees for electric vehicles available each year. This represents an ongoing subsidy of electric vehicles relative to other vehicle types. Other states offer similar policies including stamp duty discounts. The Australian Capital Territory's policy offers the greatest financial incentive. Average environmental performance vehicles at or below $45,000 are normally subject to a 3% stamp duty. A 5% stamp duty is applicable for each dollar above $45,000. Electric vehicles registered for the first time are exempt from this stamp duty. This application of different stamp duty rates to new vehicles is an approach unique to the Australian Capital Territory. It amounts to an upfront subsidy of $1350 on a $45,000 electric vehicle or $2110 on a $60,000 electric vehicle.

Feed-in tariffs

Feed-in tariffs (FiTs) were historically provided by most state governments to support rooftop solar adoption but have largely been replaced by voluntary retailer set feed-in tariffs for new solar customers. These legacy FiTs are in most cases still being received by those customers who took them up when they were available.

The current FiTs set by retailers recognises some combination of the value of the exported solar electricity to the retailer and the value to the retailer of retaining a rooftop solar customer. Retailer set FITs vary mostly in the range of 7-15 c/kWh across most states. While not calculated directly via this formula, this FiT level is close to the average generation price over a year. While there is retail competition in Northern Territory it is worth noting that FiTs are substantially higher in this region at around 25c/kWh to 30c/kWh reflecting higher costs of generation.

The exceptions, where state government policy or state owned retailers set the feed-in tariff (and are therefore potentially subject to political influence) are as follows:

- **Queensland:** Recognising lower competition, regional Queensland FiTs are set by the state government and were 9.369c/kWh from July 2018.
- **Western Australia:** Only applicable to residential, non-profit and educational premises the Renewable Energy Buyback Scheme pays a FiT of 7.135c/kWh in the South Western Interconnected system (SWIS).
- **Victoria:** the current minimum feed-in tariff of 9.9c/kWh is set by the government. It applies to retailers with more than 5000 customers and generation from any renewable energy less than 100kW. The rate will increase to 12c/kWh from July 2019. A time varying feed-in rate is also available from July 2019 with prices between 9.9 and 14.6c/kWh during off-peak and peak respectively and the day time feed-in tariff reduced from 12c/kWh to 11.6c/kWh.
- **Tasmania:** Aurora energy sets the feed-in tariff for residential and commercial customers at 8.541c/kWh from July 2018.

While not binding on retailors, the New South Wales Independent Pricing and Regulatory Tribunal has set a feed-in tariff benchmark price range of 6.9-8.4 c/kWh for 2018-19 and also indicates how the value of solar changes at different times of the day[4].

3.1.6 Interaction between state and Commonwealth policies

Given the divergent policies between the major political parties at the Commonwealth level, the electricity sector could face circumstances where state and Commonwealth policies either complement or double up on each other. In the latter circumstances, there may be a period realignment through the COAG processes to resolve the issues. The net effect of these alternative futures that could emerge from the combination of changes in policies at different levels of government in the energy policy space is that support for embedded technologies is never likely to go away completely in the next decade but in a subset of futures energy policy could become more standardised should state and Commonwealth policies converge.

[4] https://www.ipart.nsw.gov.au/Home/Industries/Energy/Reviews/Electricity/Solar-feed-in-tariffs-201819

3.1.7 Regulations and standards

Under the current electricity laws the Australian Energy Market Commission (AEMC) can make changes to regulations which are consistent with the goals set out in those laws. There is a general recognition that the electricity market rules were written at a time that did not envisage such a large and competitive role for distributed energy resources. The current customer obligations placed on networks are focussed on reliability of supply and power quality. They say nothing directly about ensuring that customers with rooftop solar can export their excess generation although this does intersect with power quality requirements. If too many rooftop system try to export generation relative to local demand, then voltage rises. Inverters are set to trip off solar exports once voltage exceeds the set point. This harms the returns to customers from owning rooftop solar.

Improved inverter standards are partially improving the voltage issues associated with high rooftop solar exports onto the local distribution network. Inverters required to be installed at present are able to provide reactive power which limits the impact of exports voltage. However if rooftop solar penetration is very high (the exact limit depends on the type of feeder), even new inverters will not be able to prevent inverter trip off. Also, reactive power uses 20% of the available real power and so still represents an impact on rooftop solar customer returns from lack of distribution network capacity.

The current rules also tend to be silent on regulation of off-grid systems. That is, although it is becoming clear that customers at the end of long distribution lines could be more reliability and cost effectively served by off-grid systems, customers lose their protections from the electricity laws if they take themselves off grid. Also, if there is no change to align incentives about who is able to install, operate and retail off grid systems and who is able to reap the cost savings then the adoption rate will be stalled[5]. Current progress is based on trials such as at Western Power[6]. If stand alone power systems become widespread they result in reduced grid demand but would only represent less than 1% of state consumption in most cases.

Potential changes in regulations to incorporate these new realities associated with distributed energy resources will likely have some impact on the attractiveness (positive or negative) of their adoption. In some cases the rule change process is already in train but is not yet sufficiently mature to infer market impacts.

3.2 Extended scenario definitions

The AEMO scenario definitions have been extended as shown in Table 3-3 by adding additional detail on the economic, infrastructure and business model drivers discussed above with a view to aligning those factors with the original intent of the AEMO scenario definitions. We have not

[5] High cost to serve customers who could be more cost effectively supplied by off grid systems are not presented with those costs as network costs are socialised across an entire network area and may also be subject to subsidies. Network owners see the costs but are discouraged from owning generation assets or retailing electricity in most states.

[6] https://westernpower.com.au/energy-solutions/projects-and-trials/stand-alone-power-systems-trial/

included variations in all drivers in each scenario and some potential changes to policy or business models have been excluded. In that respect, the following assumptions will hold for all scenarios:

- **Cost of long range electric vehicles (LREVs):** Set to be proportionally higher based on additional cost of batteries to achieve 600km range compared to SREV cost assumptions by scenario
- **Feed-in tariffs**: Converges towards (declining) midday wholesale price in all regions
- **Network limits on residential rooftop solar size:** 5kW
- **Business models to overcome upfront costs:** available
- **Off-grid options:** available
- **Solar exports as a network customer obligation:** Not a new rule
- **Vehicle battery second life:** Available from 2040
- **Organic solar:** No significant uptake[7]

The scenario definitions are in some cases described here in general terms such as "high" or "Low". Specific scenario data assumptions are outlined in the next section.

Table 3-3: Extended scenario definitions

Driver:		Neutral	Slow change	Fast change	High DER	Low DER
Economic						
	Economic growth and population	Neutral	Weak	Strong	Neutral	Neutral
	Cost of solar photovoltaics and battery storage	As per GenCost 2018 report	As per GenCost 2018 report +20%	As per GenCost 2018 report	As per GenCost 2018 report	As per GenCost 2018 report +20%
	Timing of cost parity of short range electric vehicles (<300km range) with ICE	2030	2035	2025	2025	2035
	Cost of fuel cell vehicles	Medium	High	Low	High	Low
	Electricity prices	t.b.a.	t.b.a.	t.b.a.	t.b.a.	t.b.a.
	Customers accessing tariffs that support prosumer behaviour and system integration	10% by 2030, 20% by 2050	15% by 2030, 15% thereafter	50% by 2030, 70% by 2050	60% by 2030, 75% by 2050	7.5% by 2030, 10% thereafter
	LGCs or other subsidies (e.g. to meet state renewable targets)	$40/MWh falling to near zero by 2021	$40/MWh falling to near zero by 2021	$40/MWh increasing to $50/MWh by 2030, declining thereafter	$40/MWh increasing to $50/MWh by 2030, declining thereafte0	$40/MWh falling to near zero by 2021

[7] This assumption should not be read to imply that the prospects for this technology are poor. Rather there is not enough data available at this stage to make any meaningful assumptions about its prospects

Infrastructure					
Growth in apartment share of dwellings	Medium	Low	High	High	Low
Decline in home ownership	Medium	High	Low	Low	High
Extent of access to variety of charging options	Medium	Low	High	High	Low
Business model					
Tariff and DER incentive arrangements	No significant change	No significant change	Significant change.	Significant change	No significant change
System architecture changes support greater incentives to DER participation	Medium	Low	High	High	Low
Feasibility of vehicle to home storage	Low	Low	Medium	High	Low
Feasibility of ride sharing services	Medium	Low	High	High	Low
Feasibility of participation of apartment dwellers and renters in DER	Low	Low	High	High	Low
Affordable public charging availability	Medium	Low	High	High	Low
Vehicle to home	No	No	No	Yes from 2040	No
Hydrogen export industry supports hydrogen fuel supply	No	No	Yes	No	No

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 Solar photovoltaic panels and installation

The costs of installed rooftop or small scale solar installations for each scenario is shown in Figure 4-1 and is sourced from the 4 degrees[8] scenario in the GenCost 2018 report by Graham at al. (2018) which is the most recent public Australian technology costs projections report available. The Neutral scenario is assigned this cost assumption. The Slow change and Low DER scenarios are assumed to have 20% higher costs by 2030 converging back towards a common level by 2050. Conversely, the Fast Change and High DER scenarios are assumed to have 20% lower costs but also converge by 2050.

Note that 2019 costs shown imply that a 3kW system ought to be advertised for approximately $5100. However, we more commonly see systems advertised in the range of $3600 installed reflecting that the value of small scale certificates, which are around $450-550/kW depending on the location have been subtracted from the price with the intent that owners will give up their rights to claim them to the installer in return for a discount on the upfront cost. Another feature of the market is that larger system have economies of scale such that costs for a 5kW system maybe discounted by $100-200/kW.

It is also evident that locations that are further from capital cities pay a remoteness premium for installations and we have factored this in as a one third premium. A full survey of regional market prices was not in scope.

[8] The difference between the 4 degrees and 2 degrees scenarios is not large and 4 degrees is the most consistent with current nationally determined commitments by countries.

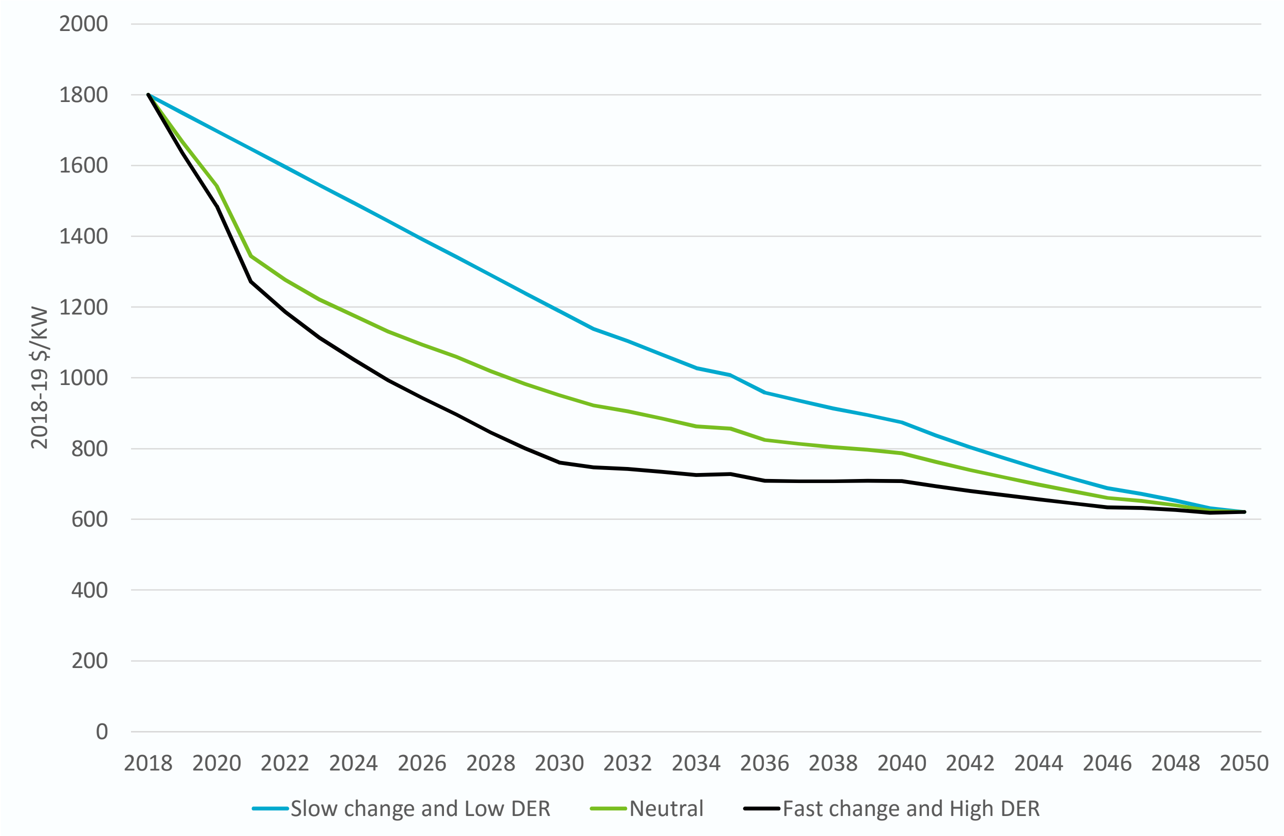

Figure 4-1: Assumed capital costs for rooftop and small-scale solar installations by scenario (excluding STCs or other subsidies)

4.1.2 Batteries and installation

The Neutral scenario battery and balance of plant costs are assumed to align with GenCost 2018 projections and are shown in Figure 4-2. GenCost 2018 projects a continued non-linear reduction in batteries and a close to linear reduction in balance of plant costs during the 2020s after which cost reductions slow. The Slow change and Low DER scenario battery and balance of plant costs are assumed to be 20% higher and Fast change and High DER scenario costs are 20% lower.

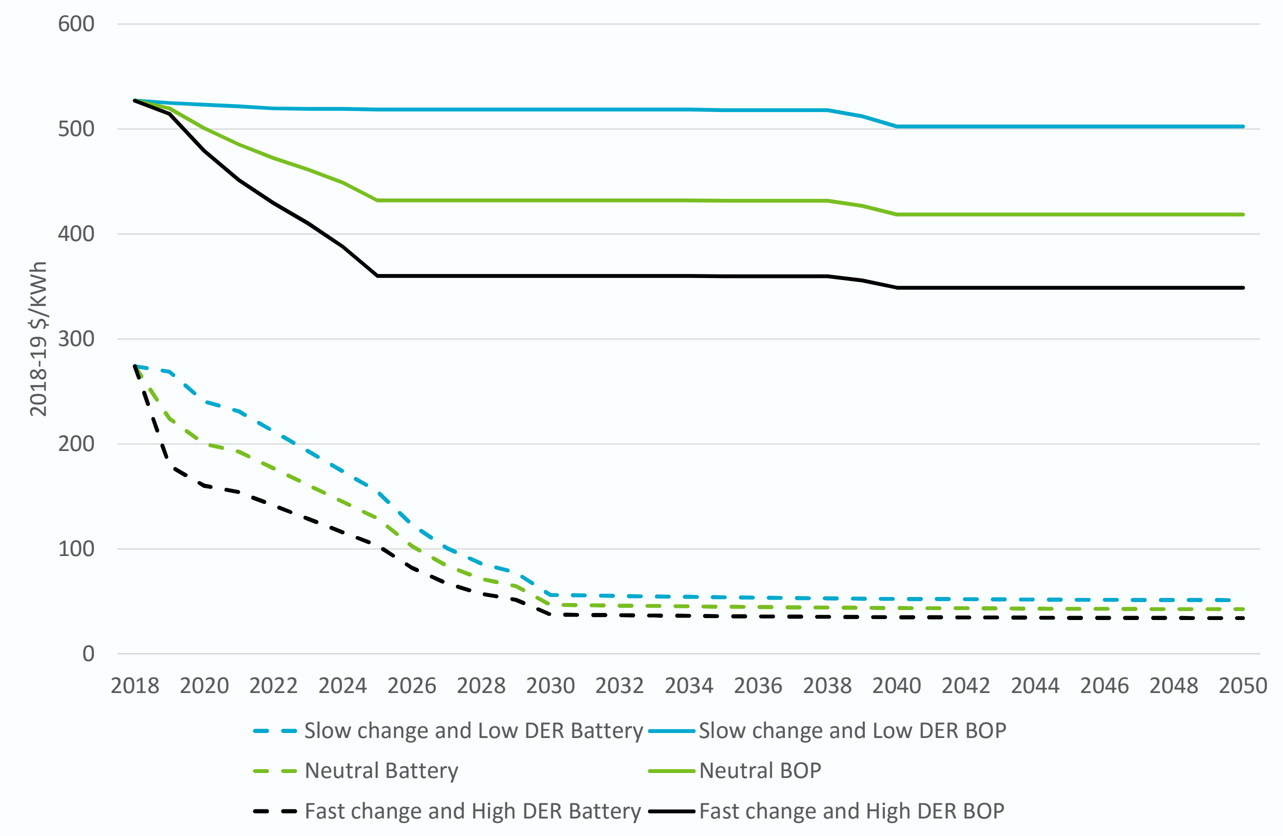

Figure 4-2: Assumed capital costs for battery storage installations by scenario

4.1.3 Electric and fuel cell vehicles

Neutral scenario short range electric vehicle (SREV) costs are assumed to reach upfront cost of vehicle parity with internal combustion engine light vehicles around 2030 and remain at that level thereafter (Table 4-1). Heavy SREVS are assumed to reach parity ten years later due to their delayed development relative to light vehicles and higher duty requirements (both load and distance). Parity may be reached earlier in other countries where vehicle emissions standards are expected to increase the cost of internal combustion vehicles over time[9].

We consider 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. The costs of LREVs do not reach vehicle cost parity because their extra range adds around $5000 in battery costs to light vehicles (and proportionally more to heavy vehicles). However, from a total cost of driving perspective (i.e. $/km), they are still lower cost over their life, paying back the additional upfront cost through fuel savings within 2-3 years.

We do 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 pay back with limited additional fuel savings.

[9] There is currently a process in Australia to consider policy design options for vehicle emission standards in Australia. However, no firm legislative proposal has emerged as yet. See https://infrastructure.gov.au/vehicles/environment/emission/index.aspx

The Slow change, Fast change, High DER and Low DER scenario assumption are framed relative to these neutral scenario assumptions. In the Slow change and Low DER scenario we assume that the cost reductions are delayed by 5 years. In the Fast change and High DER scenario we assume the cost reductions are brought forward by 5 years. Fuel cells are an exception. They also receive an accelerated cost reduction in Low DER as an additional driver for lower adoption of lower electric vehicles in that scenario (i.e. via increased competition).

Given that fuel cell and electric vehicles have significantly less parts than internal combustion engines it could also have been reasonable to consider their costs reaching lower than parity with internal combustion vehicles. However, in the context of the adoption projection methodology applied here, parity already implies zero payback periods 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, we considered 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, information technology and sport features).

Table 4-1: Moderate scenario internal combustion and electric vehicle cost assumptions, real 2019 $'000

	2020	2025	2030	2035	2040	2045	2050
Internal combustion engine							
Light/small car - petrol	15	15	15	15	15	15	15
Medium car - petrol	25	25	25	25	25	25	25
Large/heavy car - petrol	41	41	41	41	41	41	41
Rigid trick - diesel	61	61	61	61	61	61	61
Articulated truck - diesel	300	300	300	300	300	300	300
Bus - diesel	180	180	180	180	180	180	180
Electric vehicle short range							
Light/small	27	21	15	15	15	15	15
Medium	47	36	25	25	25	25	25
Large/heavy	65	53	41	41	41	41	41
Rigid trick - diesel	104	92	80	70	61	61	61
Bus - diesel	269	246	223	200	180	180	180
Electric vehicle long range							
Light/small	39	28	20	20	20	20	20
Medium	59	42	30	30	30	30	30
Large/heavy	80	61	46	46	46	46	46
Rigid trick - diesel	143	125	109	95	83	82	81
Articulated truck - diesel	901	694	535	468	410	404	400
Bus - diesel	310	279	252	227	204	203	202
Plug-in hybrid electric vehicle							
Medium car - petrol	37	35	33	33	33	33	33
Large/heavy car - petrol	58	53	49	49	49	49	49
Rigid trick - diesel	N.A.	122	81	81	81	81	81

Articulated truck - diesel	N.A.	606	396	396	396	396	396
Fuel cell vehicle							
Light/small	45	35	32	27	24	22	22
Medium	50	41	37	33	30	29	28
Large/heavy	62	51	48	43	40	38	37
Rigid trick - diesel	112	96	84	77	71	70	68
Articulated truck - diesel	558	479	419	385	357	350	342
Bus - diesel	242	221	207	199	192	190	188

4.1.4 Autonomous vehicle costs and value

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 fairly 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 we value 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) use a value of 20% for the AV cost premium which would be $3,000 to $8,200 for the standard vehicle types used in our modelling. We interpret their costing approach to be focussed on a larger vehicle and longer term point of view. This matches the expectation that the first autonomous vehicles would likely be towards the larger less-budget conscious end of the market.

Based on these studies we assume AVs have a premium starting at $10,000 from 2020 decreasing to $7,500 by 2030 and remaining at that level. Given how consumers value time, significant cost reductions won’t be necessary to support growth in adoption. However, we assume the vehicles will 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 and in doing so avoiding the costs of driver’s wages 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 requiring better sensing. However, if these vehicles are able to achieve full autonomy, the avoided wages costs are a significant financial incentive.

4.2 Electricity prices

4.2.1 Retail and generation prices

Broadly speaking electricity generation prices are expected to fall in the next few years as a major expansion in renewable generation capacity is delivered. However, over the long term, prices are expected to rise again due to retirement of plant with low marginal costs (i.e. sunk capital) and the need to incorporate more balancing technologies such as storage as variable renewable shares approach. Offsetting this is the long term decline in costs of variable renewables so price increase are not expected to be only modest.

Assumed changes in residential retail prices under all scenarios follow this assumed falling and then slightly increasing trend. 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 as we discuss below.

4.2.2 Small-scale technology certificates (STCs)

While there is the option to sell to the STC Clearing House for $40/MWh, the value of STCs is largely determined on the open market that discount to that which varies according to demand and supply for certificates. The amount of certificates generated depends roughly on the solar capacity factor in different states although this calculation is not spatially detailed (i.e. involves some significant averaging across large areas). Solar generation is calculated over the lifetime but any life beyond 2030 is not counted as it is beyond the scheme period. Therefore over time the eligible solar generation is declining. Multiplying the eligible rooftop solar generation by the STCs price gives the projected STC subsidy by state shown in Figure 4-3.

Figure 4-3: Assumed STC subsidy available to rooftop solar and small scale solar systems by state

4.3 Electricity tariff structures

4.3.1 Current status

Electricity tariff structures are important in determining the return on investment from customer adoption of small-scale embedded technologies and, perhaps importantly for the electricity system, how they operate those technologies. The vast majority of residential and some small scale business customers have what we will call 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. Both types of business tariff structures reflect the fact that, at a wholesale level, the time at which electricity is consumed and at what rate does affect its 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.

4.3.2 Future developments

While retailers make business-like TOU and demand tariff structures available to residential customers in addition to flat tariffs their adoption is very low. There is a significant body of literature examining why this is the case which we will not review here. For both efficiency and equity purposes both regulators (e.g. AEMC, 2012) and the electricity supply chain (e.g. CSIRO and ENA, 2017) would prefer to see greater residential adoption of the more cost reflective TOU and demand tariffs.

There are no current policies which would force residential customers to adopt alternative tariff structures and as such one could consider the prospects for greater residential adoption are considered low without a change in policy. Moving to these alternative residential tariff structures inherently requires customers to be more aware and, if concerned, manage on a daily basis their electricity load profile. Battery storage with automated operating instructions could potentially offer customers a way to adopt new tariffs without having to actively manage their daily load. Moreover, new energy service companies already operate businesses which act as a customer’s agent in managing the battery storage operation, minimising their power bill under TOU or demand tariff structures and offering demand management services to the grid.

4.3.3 Assumed smart tariff structures

These considerations of range of potential developments in residential tariffs are the reasoning behind why we have adopted alternative assumptions for the rate of adoption of smart tariffs in Table 3-3. However to implement these scenarios we need to assume a specific smart tariff structure in each year of the projection period. For TOU tariffs this is a difficult task because the time of day when certain rates might apply will shift with the change in customer behaviour. For example, grater adoption of rooftop solar and electric vehicles could mean low rates for night time power usage are no longer appropriate. Demand tariffs which are structured to reduce demand during the evening peak could be constructed over time by assuming they continue to draw the same ratio of revenue from their volume ($/KWh) and demand ($/kW) components.

Most studies of battery behaviour under either TOU or demand conclude that these tariffs will drive coincident battery owner behaviour around the start and end of the time defined demand or usage periods. While it might be effective in reducing peak demand it undermines the key purpose of the smart tariffs which is to increase diversity of demand across the day. It replaces a peak demand problem with an edge of peak demand problem that might be worse than the peak demand problem if the scale of installed batteries is large enough.

The system could persist with offering demand and TOU tariffs to battery owners for several years but as adoption increases it will need to offer alternative approaches to battery control. Given the large number of potential batteries to coordinate the most direct route would be for battery owners to pass control of the battery to an aggregator who can learn by experience the value of demand response to the system and reward its battery owning participants accordingly. The value of that demand response is already partially defined by the premium of price during peak periods in each state. It could also be defined by the lowest bill a battery owner could achieve from participation in conventional retail tariffs. That is, an aggregator ought to be able to lure customers to the aggregation scheme so long as it can offer to improve or match their current best bill outcome. This annual rebates was calculated as an intermediate model output to be in the range of $100-400 per annum depending on the state and customer size.

For commercial customers who were already on some type of peak demand avoidance tariffs, the premium they could be paid for adjusting their load would be smaller. Also note that, since commercial load profiles have a closer match to solar output profiles and are more amenable to avoiding peaks, they will have significantly less incentive to take up battery storage. This situation differs in the SWIS where, if customers can reduce their demand over the peak intervals used to calculate their individual reserve capacity requirement (IRCR) obligation, they could save up to $200 per kW of reduced load.

4.3.4 Implications of tariffs and incentives for battery operating regimes

Under flat tariffs customers will set their battery to do two things:

- If solar exports are detected and the battery is not full, charge
- If solar imports are detected and the battery is not empty, discharge

This is a relatively simply onsite algorithm to implement and may generally come as part of the battery manufacturers standard settings at present.

Under demand or TOU tariff an onsite algorithm can be tuned to avoid grid imports during the peak demand/pricing period. Apart from shifting any solar power output, this could involve charging the battery from the grid at low price periods (under TOU) and also charging the battery just before the peak period (TOU or demand tariff structure). This behaviour would be more likely on low solar output days and for system where the size of the solar system is smaller relative to consumption. A battery provider or an energy service company might be employed to continuously tune the battery regime since retailer pricing structures change over time requiring updating of the optimal strategy.

Under virtual power plant arrangements an aggregator controls the battery to meet the demands of an independent system operator (called the distribution system operator when activating distribution system located resources). Such arrangements do not yet exist but are in the early planning stages[10]. In VPP mode, the battery is given over to the single objective of meeting the generation sector's needs but may return to the default mode of shifting solar power on site when not called upon. The battery is discharged to its fullest whenever and whenever is deemed useful for the system rather than respond to onsite needs.

The assumed long term shares of the adoption of alternative battery operation regimes reflects the current types of tariffs faced by residential and commercial customers and the assumed progression of the scenario towards adoption of tariffs and incentives that support the broader electricity system's needs. While the pathways for states will differ due to different starting point, we are effectively assuming a convergence in incentives by holding long term assumptions to be the same in each state.

Table 4-2: Assumed proportions of battery storage operating regimes across residential customers

Year	Battery operation regimes	Shift solar	Shift solar and avoid peak	Virtual power plant
	Tariff / incentive	Flat	TOU / demand	Rebate / discounted bill
	Control	Onsite algorithm	Onsite algorithm	Aggregator / distribution system operator
2030	Neutral	90%	6%	4%
	Slow change	85%	9%	6%
	Fast change	50%	30%	20%
	High DER	40%	36%	24%
	Low DER	93%	5%	3%
2050	Neutral	80%	2%	18%
	Slow change	85%	2%	14%
	Fast change	30%	7%	63%
	High DER	25%	8%	68%
	Low DER	90%	1%	9%

[10] https://www.energynetworks.com.au/open-energy-networks-consultation-paper

Table 4-3: Assumed proportions of battery storage operating regimes across commercial customers

Year	Battery operation regimes	Shift solar	Shift solar and avoid peak	Virtual power plant
	Tariff / incentive	Flat	TOU / demand	Rebate / discounted bill
	Control	Onsite algorithm	Onsite algorithm	Aggregator / distribution system operator
2030	Neutral	18%	72%	10%
	Slow change	17%	68%	15%
	Fast change	10%	40%	50%
	High DER	8%	32%	60%
	Low DER	19%	74%	8%
2050	Neutral	8%	72%	20%
	Slow change	9%	77%	15%
	Fast change	3%	27%	70%
	High DER	3%	23%	75%
	Low DER	9%	81%	10%

4.4 Income and customer growth

4.4.1 Gross state product

Gross state product (GSP) assumptions by scenario are presented in Table 4-4. These assumptions are used to project commercial vehicle numbers and are relevant for calibrating adoption functions where income is part of the adoption readiness score.

Table 4-4: Annual percentage growth in GSP by state and scenario

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australian Capital Territory	Northern Territory
Slow	1.3	1.6	2.5	1.5	2.5	1.0	2.1	2.7
Moderate	2.2	2.6	3.3	2.2	3.2	1.8	3.0	3.2
Fast	3.0	3.4	4.0	2.9	3.9	2.5	3.7	3.7

4.4.2 Customers

Customer growth assumption by scenario are shown in Table 4-5. These assumptions are relevant for establishing current market share of solar and battery customers and converting projected adoption shares back to number of installations.

Table 4-5: Annual percentage rate of growth in customers by state and scenario

	New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	Australian Capital Territory	Northern Territory
Slow change, Low DER	0.9	1.1	1.3	0.6	2.0	0.2	1.2	0.5
Neutral	1.0	1.3	1.5	0.7	2.2	0.3	1.5	0.5
Fast change, High DER	1.1	1.5	1.7	0.8	2.4	0.4	1.7	0.6

4.5 Separate dwellings and home ownership

4.5.1 Separate dwellings

Owing to rising land costs in our large cities where most residential customers live, there has been a trend towards faster building of apartments compared to detached houses (also referred to as separate dwellings in housing statistics). As a result we expect the share of separate dwellings to fall over time in all scenarios. The assumptions for the neutral scenario were built in extrapolating past trends resulting in separate dwellings occupying a share of just below 60% by 2050, around 6 percentage points lower than today. The Slow change/Low DER and Fast change/High DER scenario assumptions were developed around that central projection.

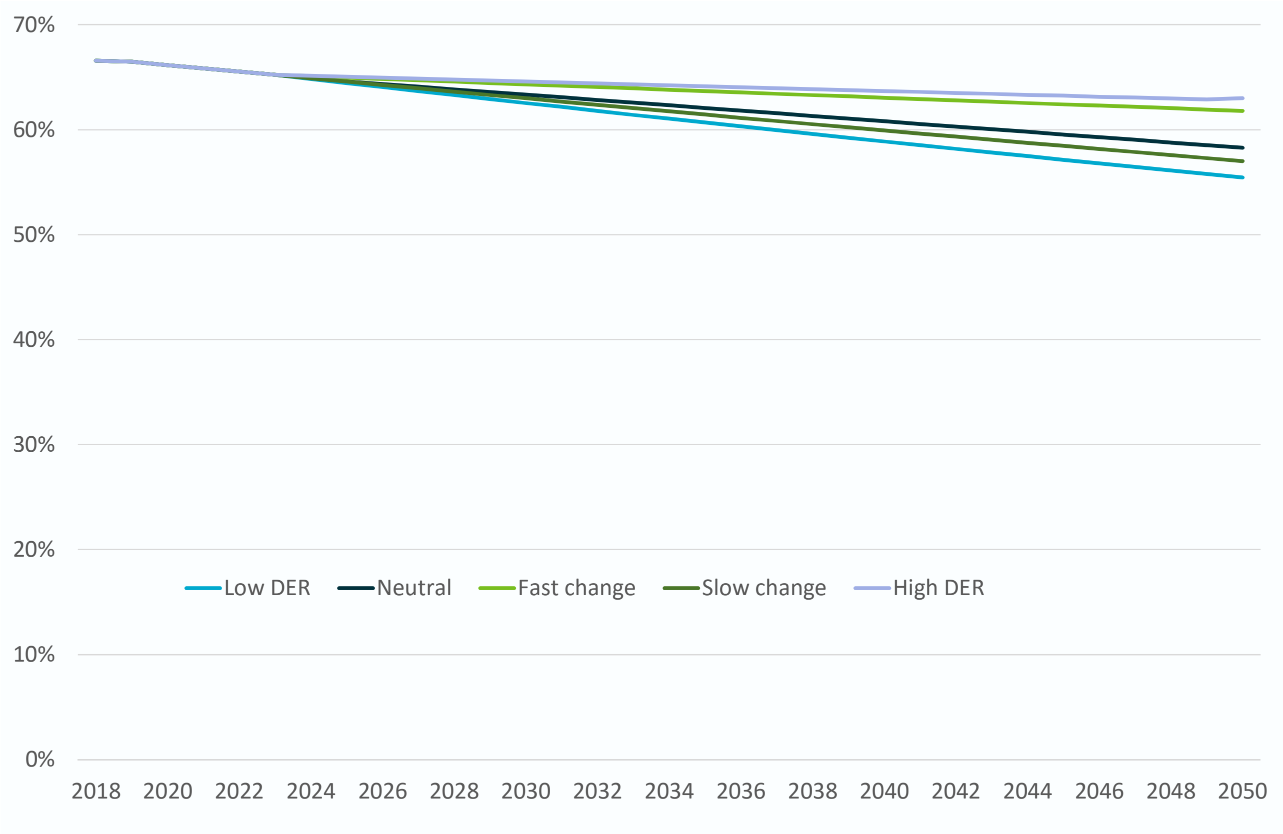

Figure 4-4: Assumed share of separate dwellings in total dwelling stock by scenario

4.5.2 Home ownership

While not a hard constraint, home ownership increases the ability of occupants to modify their house to include small-scale embedded technologies. Home ownership (which includes homes owned outright as well as mortgaged) increased rapidly post-World War II and was steady at around 70 percent for the remainder of last century. However, in the last 15 years ABS Census data as reported by AIHW (2017) shows that home ownership has been declining and was an average 65.5% in 2016 with the largest declines amongst young people (25 to 34), although all ages below 65 experienced a consistent decline between Censuses.

In the long run we might expect the housing market to respond by providing more affordable home ownership opportunities. However, we must also acknowledge that 15 years represents a persistent trend. As such, under the Neutral scenario, we assume the trend continues and we apply the rate of decline in the last 15 years to the year 2050. Under the Slow change and Low DER scenarios we assume the slightly faster trend of the last 5 years prevails, leading to a slightly faster reduction in home ownership rates relative to the neutral scenario. Under the Fast change and High DER scenarios we assumed a slower rate of decline in home ownership consistent with the trend of the last 25 years representing a slowing in the rate of decline relative to recent history.

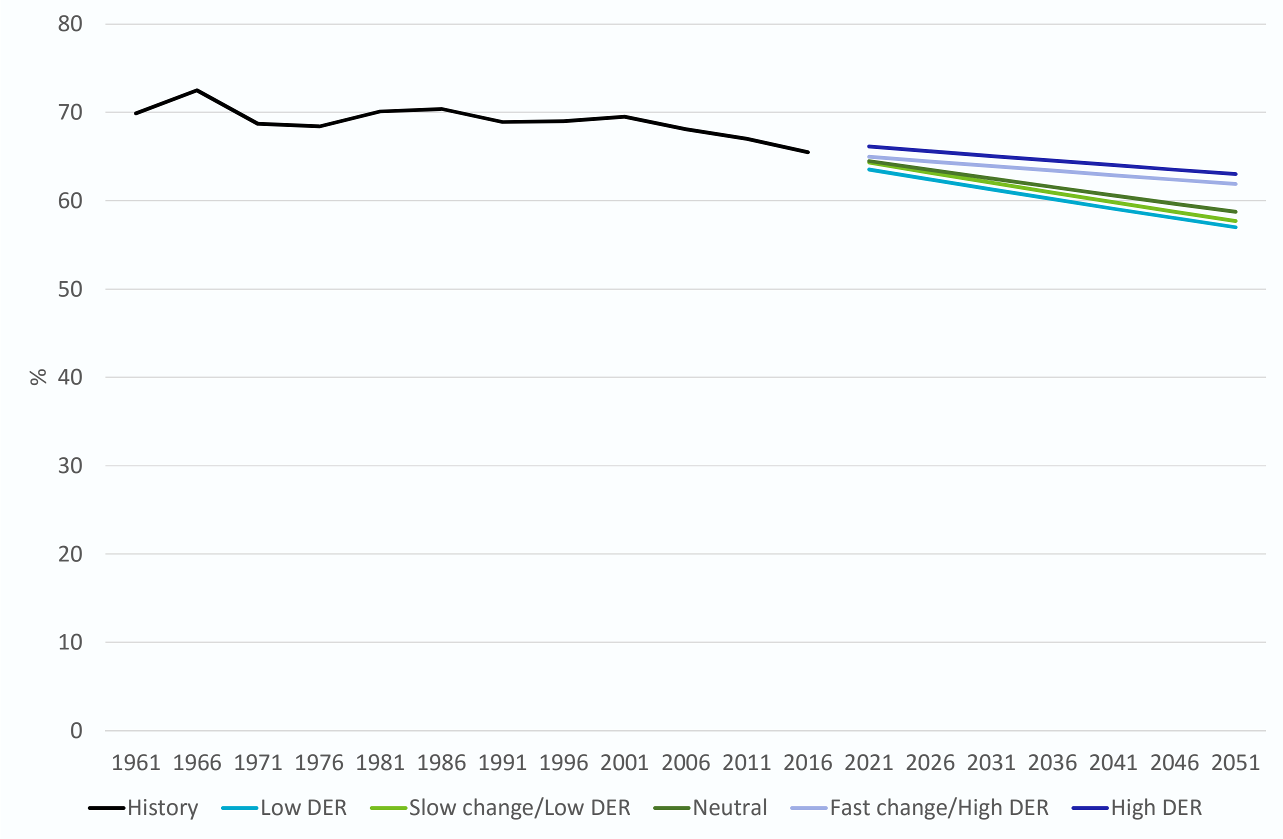

Figure 4-5: Historical (ABS Census) and projected share of homes owned outright or mortgaged, source AIHW (2017)

4.6 Vehicle market segmentation

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

In Table 4-6 we list eight non-financial factors that might limit the size of a vehicle market segment. These are generally based around limits faced by households because the relevant data for households is easier to access. However we argue that many of the limitations apply equally to businesses or if not there is an equivalent concept (see the last column). Each row describes the share of households in that 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 used the calibrate the consumer technology adoption curve saturation rates such that the indicated rate of sales will apply once the vehicle has reached a low payback period (i.e. once financial constraints are no longer an issue), whenever that may occur.

The market shares across vehicles 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 ABS statistical area level 2) to vary significantly from the average according to their demographic characteristics)

Table 4-6: Non-financial imitations on electric and fuel cell vehicle uptake and the calculated maximum market share

		Neutral	Slow change	Fast change	High DER	Low DER	Rationale/formula	Equivalent business constraint
Limiting factors (residential)								
Separate dwelling share of households	A	58%	57%	62%	63%	55%	Based on housing industry forecasts	Businesses located on standalone site
Share of home owners	B	59%	58%	62%	63%	57%	Based on historical trends	Business not renting their site
Share of landlords who enable (passively or actively) EV charging onsite	C	50%	25%	75%	80%	20%	Data not available. Assumed range of 20-80%	Same
Off-street parking/private charging availability	D	37%	31%	45%	47%	29%	Assume 80% of separate dwellings have off-street parking. Formula=(0.8*A*B)+(0.8*A*(1-B)*C)	Same
Public charging availability	E	30%	15%	45%	50%	10%	Availability here means at your work/regular daytime parking area or in your street outside your house. Assumptions are based on this type of charging being the least financially viable.	Same
Share houses that have two or more vehicles	F	60%	58%	62%	65%	55%	Based on historical trends	Share of businesses with two or more fleet vehicles
Share of houses where second vehicle is available for long range trips	G	70%	67%	72%	75%	65%	Assumed range of 65-75%. 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	20%	25%	10%	5%	30%	Based on laggards generally being no larger than a third of customers. High DER 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	20%	25%	10%	5%	30%	As above with High DER assuming a collapse in 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	80%	75%	90%	95%	70%	Assumed that only a laggard proportion would object to this arrangement	Same
Fuel stations with access to hydrogen supply chain	K	50%	20%	80%	65%	25%	Data not available due to uncertainty. Assume range of 20-80%. Fast change assumes supply chain is boosted by hydrogen export industry	Same
Maximum market share								
Short range electric vehicles		14%	10%	19%	23%	8%	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		54%	35%	81%	92%	27%	Key limitation is charging and customer who would prefer ICE. Formula=(1-H)*(D+E)	
Plug-in hybrid electric vehicles		57%	37%	85%	97%	29%	*More acceptable to those that prefer ICE. Formula=(1-(H+10%))*(D+E)*	
Fuel cell vehicles		40%	15%	72%	62%	18%	Formula=(1-H)*K	
Autonomous ride share vehicles		56%	54%	60%	64%	52%	Formula=J*F+(1-F)*I	

Table 4-7: Shares of different electric vehicle charging behaviours by 2050 based on limiting factor analysis

	Neutral	Slow change	Fast change	High DER	Low DER	Rationale/formula
Limiting factor						
Customers accessing tariffs that support prosumer behaviour and system integration L	20%	15%	70%	75%	10%	Scenario assumption
Residential vehicles						
Home charging convenience profile	30%	26%	13%	6%	26%	Formula=(1-L)*D or (1-L)*D*(1-E) for High DER scenario to account for vehicle to home group
Home charging night/off peak aligned	7%	5%	31%	18%	3%	Formula=L*D or L*D*(1-E) for High DER scenario to account for vehicle to home group
Vehicle to home charging pattern (day time public charge, provide all household consumption while at home)	0%	0%	0%	23%	0%	Vehicle to home is only assumed in High DER scenario. Other relevant constraints are public charging and off-street parking to connect to home. Formula=D*E
Public charging highway fast charge	5%	5%	5%	5%	5%	90%+ of driving is within 30km of home
Public charging solar aligned	58%	64%	50%	48%	66%	Residual
Commercial vehicles						
Light commercial						
LCV - Daytime convenience	76%	85%	30%	25%	90%	Non-highway kilometres. Formula=(1-L)*0.95
LCV - Daytime adjusted for solar alignment	19%	15%	70%	75%	10%	Non-highway kilometres. Formula=L*0.95
LCV highway fast charge	5%	5%	5%	5%	5%	Assume similar pattern to residential driving

Trucks & buses morning peak convenience	76%	81%	29%	24%	86%	Non-highway kilometres. Formula=(1-L)*0.95
Trucks & buses solar aligned	19%	14%	67%	71%	10%	Non-highway kilometres. Formula=L*0.95
Trucks & buses highway fast charge	5%	5%	5%	5%	5%	Assume similar pattern to residential driving

4.7 After life electric vehicle batteries and vehicle to home

Once electric vehicles are established 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 ten times larger than the average 10kWh 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.

We rule out using electric vehicle batteries after their on-vehicle life. Such a scheme would only make sense if electric vehicles frequently replaced their batteries well before their expected shelf lives of 10 years[11]. That is, they reach the end of their cycle life before their shelf life expires. The end of cycle life is where the battery degrades to 70-80% of its rated capacity and lithium ion batteries are typically rated at around 5000 cycles where a cycle is full charge-discharge (down to 5% and up to last 5% capacity). The average vehicle in Australia travels 11,000km per year. For an SREV vehicle 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%. Even 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 have a long range electric vehicle where the daily depth of charge/discharge would be even lower.

Given the expected under-working of electric vehicle batteries it therefore makes more 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, to play it safer 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 both off-street parking (for when the vehicle is at home) and parking at their normal place of daytime parking (i.e. at work 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 what is expected to be, in the long term as solar generation capacity increases, the lowest priced period for electricity from the grid. 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. At least one current manufacturer has taken this concept forward[12].

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[11] "Shelf life" is used here as a proxy for all other life reducing impacts other than cycle life such as ambient temperature, pressure, venting and loss of electrolyte. See Cavanagh et al (2015)

[12] https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/vehicle_to_home.html

4.8 Shares of electric vehicle charging behaviour

Besides informing the technology adoption, the maximum market shares identified in Table 4-6 are also used, together with other assumptions, to determine what shares of different electric vehicle charging profiles should be applied by 2050 (Table 4-7). The key additional assumption is to assign the percentage of customers that are participating in tariffs or other incentives which support prosumer and electricity system supporting behaviour which is a scenario assumption.

For residential vehicles we assume a small amount of highway charging consistent with the observation from many trip studies that 90% of driving is within local areas. The amount of home charging is calculated from the amount of off-street parking (calculated in Table 4-6). Charging at home is split between convenience and solar aligned charging based on the tariff and other incentives assumptions. The formula for High DER is modified to allow for an amount of customers to run their home off their vehicles 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.

Commercial charging profiles are already reasonably well aligned to the daytime but could be even more aligned with solar generation to support the electricity system. Current tariffs faced by the commercial sector emphasise avoiding peak periods. We assume that, signing up to new tariffs or incentives would imply shifting that part of daytime charging which is not aligned with solar generation times into that time.

4.9 Vehicle fleet size

To be completed as part of modelling phase – the cost of EVs and AVs impacts road transport demand and passengers per vehicle and therefore fleet size

Figure 4-6: Historical and projection national road vehicle fleet by scenario

4.10 Rooftop solar and battery storage market segmentation

For both residential and commercial customers the market that can most easily adopt rooftop solar are those customer with a separate building that they own. Multi-occupant buildings or those that are not owner require more complex arrangements (business models) in order to extract and share the value of rooftop solar. This latter group is therefore a smaller market segment. Table 4-8 and

Table 4-9 outline how large these market segments are assumed to be in each scenario and their implications for the overall size of the rooftop solar market. The assumptions re based on housing and ownership data discussed elsewhere in this report. The availability of commercial building data is not as good as residential and consequently there is greater uncertainty in those assumptions.

Table 4-8: Non-financial limiting factor and maximum market share for residential rooftop solar

		Neutral	Slow change	Fast change	High DER	Low DER	Rationale/formula
Limiting factors							
Separate dwelling share of households	A	58%	57%	62%	63%	55%	Based on housing industry forecasts
Share of home owners	B	59%	58%	62%	63%	57%	Based on historical trends
Multi-occupant buildings able to set up internal retailing of solar	C	10%	3%	25%	30%	0%	Scenario assumption
Single occupant building owners able to sell directly to occupant or another peer (virtually)	D	5%	2%	13%	15%	0%	Scenario assumption. Landlords of single occupant buildings have more barriers to retailing
Rooftop solar maximum market share		49%	37%	76%	85%	32%	Formula=(A*B)+C+D

Table 4-9: Non-financial limiting factor and maximum market share for commercial rooftop solar

		Neutral	Slow change	Fast change	High DER	Low DER	Rationale/formula
Limiting factors							
Separate dwelling share of businesses	A	40%	38%	42%	43%	37%	Data limited. Scenario assumption
Share of business building owners	B	30%	28%	32%	33%	27%	Data limited. Scenario assumption
Multi-occupant buildings able to set up internal retailing of solar	C	10%	3%	25%	30%	0%	Scenario assumption
Single occupant building owners able to sell directly to occupant or another peer (virtually)	D	5%	2%	13%	15%	0%	Scenario assumption. Landlords of single occupant buildings have more barriers to retailing
Rooftop solar maximum market share		27%	15%	51%	59%	10%	Formula=(A*B)+C+D

The market share limits are imposed on average. However, the modelling allows individual locations (modelled at the ABS statistical area level 2) to vary significantly from the average according to their demographic characteristics).

The battery storage market is assumed to be a subset of the rooftop solar market since the main motivation for storage is improve the utilisation and financial returns from rooftop solar. The exception is commercial customers who may use storage to minimise capacity costs, particularly in Western Australia where capacity market costs are shared out according to customer contribution to demand peaks.

Appendix A Additional data assumptions

In this appendix we outline some key additional assumptions that were used to develop the adoption projections in addition to the scenario specific assumptions discussed in the body.

A.1 Technology performance data

Each technology can be described by a small number of performance characteristics with energy efficiency being a common one whilst others are specific to the technology. The following tables outline key performance data for rooftop solar, battery storage and electric vehicles.

A.1.1 Rooftop solar

Rooftop solar generation profiles were sourced from the AEMO 2016 NTNDP data assumptions for NEM states. Table A.1 shows the average capacity factors from these production profiles. [This data will change – additional weather year data has been provided by state]

Apx Table A.1 Rooftop solar average annual capacity factor by state

	Capacity factor
New South Wales	0.14
Victoria	0.13
Queensland	0.16
South Australia	0.15
Tasmania	0.12
Western Australia (SWIS)	0.15
Northern Territory	0.16

Residential solar system sizes are set by the scenario assumption at 5kW. Given the much better match between commercial customer load profiles and solar output profiles, commercial solar system sizes are assumed to be matched to average daily peak.

Rooftop solar systems have been advertised with higher panel to invert capacity ratios recently. This likely reflects the fact that subsidies are available on rooftop solar capacity. Licensing conditions for installers require that the inverter is no less than 75% capacity. Hence we might see an offer for 6.6kW solar with a 5kW inverter. Subsidies per watt solar power capacity are declining (see discussion of STCs in the body of the report) and being replace with rebate or low interest loans. Therefore we would expect the current trend towards higher solar to inverter ratio to ease slightly. However, with the requirement for new inverters to provide reactive power which in that mode can only deliver 80% of the available real solar power, a larger inverter relative to the solar panel may become more the norm. Our assumptions is that the ratio is currently increasing and will peak at 1.15:1 converging towards 1:1 on average in the long run.

The average share of rooftop solar installed with a north orientation appear to be around 90%, with mostly West followed by east by being the remainder[13]. We assume the ratio of north falls to 70% by 2050 (with the other orientations proportionally gaining) owing to those buildings with less favourable orientations being in the late follower group. There is also expected to be greater incentive for west orientation due to more customers responding to incentives to reduce demand during peak times.

A.1.2 Battery storage

For battery storage sizing we have chosen not to optimise size since the current market tends to only offer limited size ranges. We have looked at popular battery sizes and matched a larger battery to our large customer profiles and a battery around half that size to other customers (see Table A.2). Note that we do not need to explore large batteries because, with a maximum power discharge and charge rate of the battery size in kWh divided by 2.6 for the largest battery can absorb all power from a 5kW solar system. As such there would be little to gain from any larger battery size given rooftop solar size restrictions.

For commercial customers the battery system size in kWh is set proportional to the smaller of the two popular residential system battery to solar ratios. Commercial systems should need a lower storage to solar ratio because their solar is much better matched to the commercial load profile.

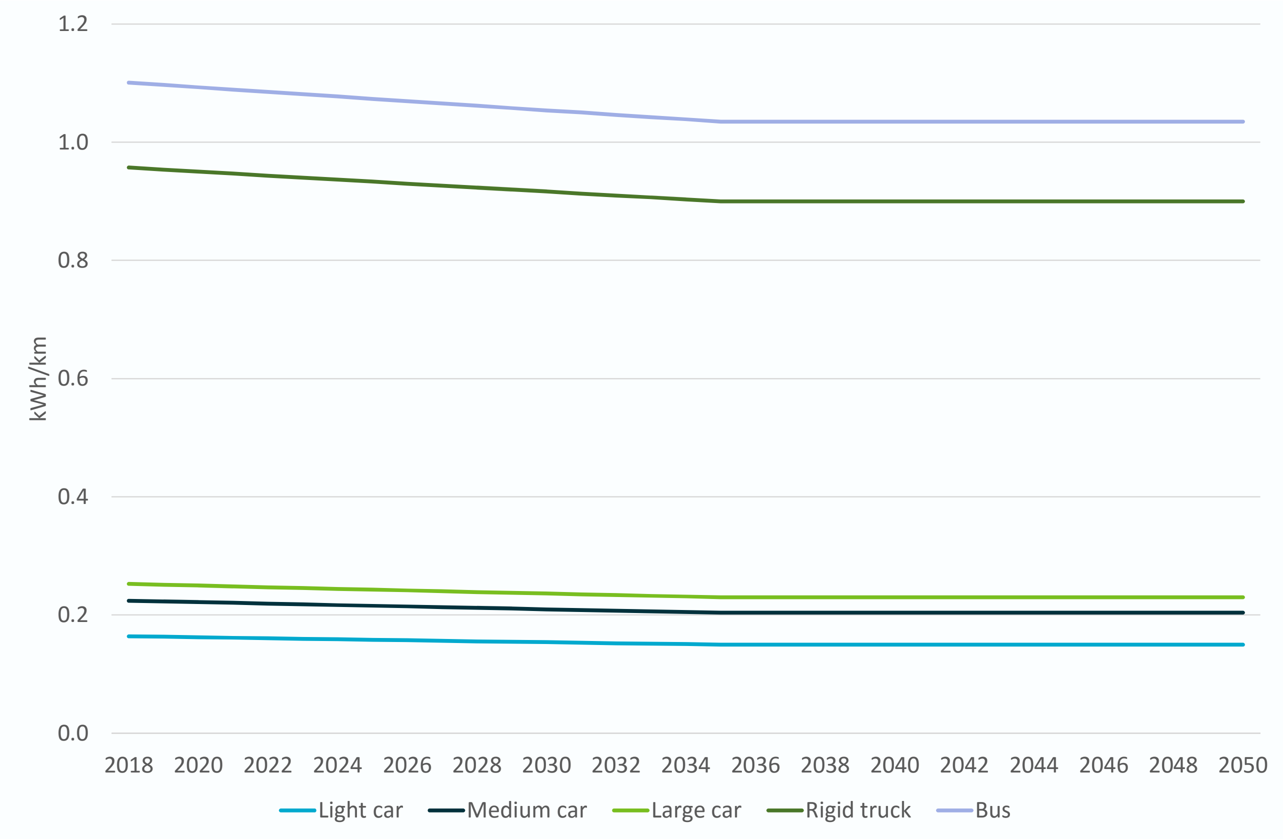
Apx Table A.2 Battery storage performance assumptions

Characteristic	Assumption
Round trip efficiency	85%
Maximum charge or discharge or rated capacity	95%
Rated capacity	Large residential: 14kWh, otherwise: 7kWh Commercial: approximately 140% the solar capacity which itself is set at proportional to average daily peak demand
Maximum power in kW	Rated capacity divided by 2.6

A.1.3 Electric and fuel cell vehicles

The key performance characteristic for electric and plug-in hybrid electric vehicles is their fuel efficiency. Figure A.1 shows the assumed vehicle fuel efficiency per kilometre by mode for electric vehicles.

[13] https://pvoutput.org/



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

The key determinant of fuel efficiency is vehicle weight with the lightest vehicles having the lowest electricity consumption per kilometre. The batteries which store the electricity of course add to total vehicle weight and we assume some improvement in battery energy density over time leads to a steady improvement in fuel efficiency up to around 2035 and plateaus thereafter. Historically, internal combustion engine fuel efficiencies have tended to plateau unless there is significant fuel price pressure (with engine improvements traded off for better acceleration or more comfort, safety and space). We assume electric vehicles will follow the same trend.

A.2 Customer load profiles

Australia still faces difficulty in accessing public load profiles due to privacy considerations. For that reason we use a mixture of synthetic and real customer load profiles. For residential data we started with around 5000 New South Wales Ausgrid profiles from the Smart Grid Smart Cities program and found the 5 most representative profiles and their ten nearest neighbours using clustering analysis. We then synthetically created 50 profiles for each other distribution network area but subtracting the differences between the most residential zone substations in each network relative to Ausgrid’s most residential zone substation. This process should adjust for differences in timing (daytime hours) and climate but is probably not sufficient to account for all differences in gas versus electricity use, for example, between different states. The SGSC data set did include people with and without gas and with and without hot water control but the proportions won’t match other states.

For commercial load profiles we use a small number from previous work and adjust them using the same zone substation method (this time selecting zone substations that are commercial heavy). In using a smaller set our assumptions is that commercial profiles vary less than residential.

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