GHD

STC forecasts for 2021-2025

Final Report

Clean Energy Regulator

14 July 2021

→ **The Power of Commitment**

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Executive summary

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.3 and the assumptions and qualifications contained throughout the report.

The Clean Energy Regulator (CER) engaged GHD (us) to advise on the preparation of forecasts for small-scale technology certificates (STCs) created under the Australian Government's Small-scale Renewable Energy Scheme (SRES).[1] STCs are produced when eligible small-scale renewable energy systems are purchased; the eligible systems can include:

- Solar photovoltaic (PV) panels
- Solar water heaters (SWHs)
- Air source heat pumps (ASHPs)
- Small generation units (SGUs) other than PV systems, namely wind turbines and hydro systems.

Our forecasts include, for each technology type, the number of new installations each year, the additional installed capacity of PV systems and the number of additional STCs likely to be added to the registry, over the 2021 to 2025 period[2]. The forecasts are provided for each State/Territory (i.e., jurisdiction), as well as for Australia as a whole, and also provide a breakdown into customer types (i.e., residential and non-residential).

Approach and key observations

Using our conceptual understanding of the financial and non-financial drivers for consumers' decisions to invest in small-scale systems, we applied machine-learning techniques to predict installation and capacity for all categories of small-scale technologies covered by the SRES from 2021 to 2025. The steps that we applied in discharging our machine-learning modelling process are depicted in Figure 1.

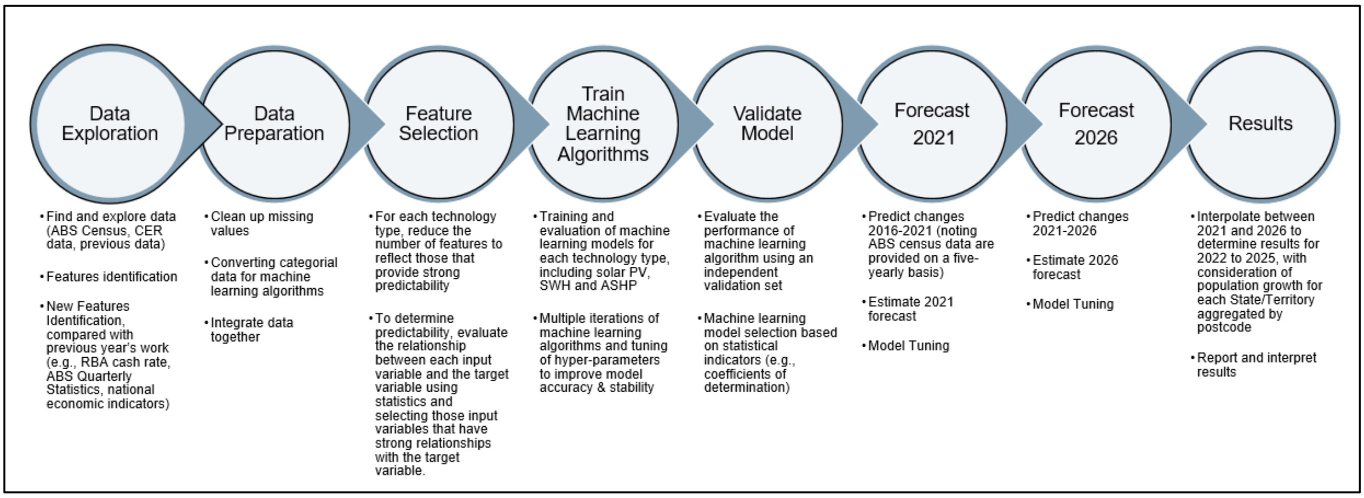

Figure 1 GHD's modelling process for determining small-scale installations and capacity forecasts

Our modelling and forecasting process consists of the following steps:

1. **Data exploration and data preparation**

   These steps focus on identifying the factors (what we refer to as 'features') that we anticipate will influence the installation and capacity forecasts over the modelling period. This is closely linked with our conceptual framework's views on the financial and non-financial drivers that motivate consumers to invest in small-scale technology.

[1] More information on the SRES is available here: http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/How-the-scheme-works/Small-scale-Renewable-Energy-Scheme

[2] Calendar years

2. **Feature selection, machine learning and model validation**

   Following the determination of the most relevant features, multiple iterations of machine learning algorithms and associated hyper parameters (values controlling the machine-learning process) were undertaken to ascertain the models that yield the best fit. The strength of the fits was validated by statistical indicators such as coefficients of determination (CoDs).

3. **Forecasting**

The models relied heavily on the use of postcode level Australian Bureau of Statistics (ABS) census data, which are published every five years. The most recent census data is from calendar year 2016. Given the modelling period is from 2021 to 2025, and the long-term forecast is principally based on data provided every five years, the selected models first generate forecasts for 2021 and 2026.

Additional model inputs include yearly population and economic data for each jurisdiction. We used forecast annual growth in these variables to weight the long-run trend outcome for intermediate years 2022 to 2025. The interpolation of year-on-year growth rates was principally guided by our population projections for each State and Territory over the modelling period.

We calculated forecast STC eligibility from the installation and capacity forecasts and applicable zone ratings and deeming factors. STC creation is then determined by observed historical lags between the timing of installation and STC registration in order to provide yearly forecasts of STCs that the CER can use to administer the SRES.

Recent growth in yearly PV installations (and capacity) culminated in a record number of installations in 2020, partly due to some projects being brought forward during the COVID-19 crisis and many homeowners' increased focus on home improvement projects. This is likely to result in a pause growth in installations in 2021. We forecast that installation growth will resume from 2022 through to the end of the forecast period, as installation costs continue to become more affordable and the population and number of houses grows. The decline forecast for non-residential installations follows a period of exceptionally strong growth and may be explained by an increasing focus of small non-residential investors on their core business, while the greater commercial opportunity lies with systems greater than 100 kW. The pause in small-scale PV take-up is supported by our analysis of the most recent months' installation data for the larger states.

ASHP installations also face a sharp dip in 2021, but thereafter grow steadily throughout the forecast period. Annual installations do not, however, reach the high levels of 2020. SWH installations decline gradually from 2022 onward. SGUs are becoming less of a practicable endeavour for most electricity consumers. We do not anticipate any SGU investments over the modelling period.

The number of STCs created each year will start to fall slightly due to the falling deeming factor[3], which is only partially offset by growth in new capacity.

Key findings (Australia)

Our key findings by technology type are summarised in Table 1.

Table 1 Systems installed, total capacity and STC creation – by technology type (2021 to 2025)

Parameter	Technology type	2020	2021	2022	2023	2024	2025
Systems installed	PV	380,493	377,774	400,982	423,816	447,542	470,485
	SWHs	41,454	43,717	42,597	41,424	40,218	39,060
	ASHPs	32,906	23,409	24,304	25,199	26,094	26,989
Total capacity (MW)	PV	3,067	2,955	3,231	3,512	3,815	4,105
STC creation ('000s)	PV	42,250	37,697	37,066	35,772	33,973	31,315
	SWHs	1,203	1,274	1,241	1,207	1,171	1,137
	ASHPs	969	835	875	918	961	1,002

[3] STCs are created upon installation, according to the future energy assumed to be produced by a PV installation of a given size and in a given location. A "deeming factor" is the number of years over which an installation is assumed to produce energy for the purposes of calculating the total lifetime energy eligible for STC creation. Since the SRES ends in 2030, PV systems in operation beyond that year will not be eligible for STCs. For the purpose of allocating STCs to newly installed systems, the 'deemed' productive life of systems installed prior to the end of 2030 cannot extend beyond that year.

Parameter	Technology type	2020	2021	2022	2023	2024	2025
	Total	44,422	39,806	39,182	37,896	36,105	33,455

Our key findings by customer type for PV systems are summarised in Table 2. The residential capacity band reflects 15 kW or less, while the non-residential capacity band reflects above 15 kW but lower than 100 kW.

Table 2 Systems installed, total capacity and STC creation for PV systems – by customer type (2021 to 2025)

Parameter	Customer Type	2020	2021	2022	2023	2024	2025
Systems installed	Residential	364,969	363,988	387,248	410,158	433,930	456,957
	Non-residential	15,524	13,786	13,734	13,658	13,612	13,528
	Total	380,493	377,774	400,982	423,816	447,542	470,485
Total capacity (MW)	Residential	2,501	2,458	2,743	3,030	3,334	3,626
	Non-residential	497	488	482	481	479	497
	Total	3,067	2,955	3,231	3,512	3,815	4,105
STC creation ('000s)	Residential	34,253	31,414	31,506	30,896	29,711	27,673
	Non-residential	7,997	6,282	5,560	4,876	4,262	3,642
	Total	42,250	37,697	37,066	35,772	33,973	31,315

Residential PV installations and capacity grow over the 2022-2025 modelling period. However, slight dips do occur in 2021 relative to 2020. This is supported by recent monthly data to June 2021, showing the number of new installations starting to decline since March 2021 in most jurisdictions. Growth is then forecast to resume strongly from 2022. In comparison, increases in non-residential installations are forecast to fall in 2021 and then stay relatively constant. This suggests some market saturation in the non-residential sector is taking place.

STC numbers trend downwards over the modelling period, reflecting that overall growth in capacity/installations figures is more than offset by the impact of the declining deeming factor.

Key findings (States/Territories)

Key PV findings by States/Territory are summarised below.

Figure 2 shows the annual number of PV installations by State/Territory. In most cases, installations decrease in 2021 (compared with 2020), followed by single-digit percentage increases over the 2021 to 2025 period. Key exceptions are:

- Northern Territory, where installations decline continuously from 2019
- Queensland, where installations are higher in 2021 than 2020, and then continue to increase
- Tasmania, where per-annum growth from 2021 to 2025 is in the double-digit region.

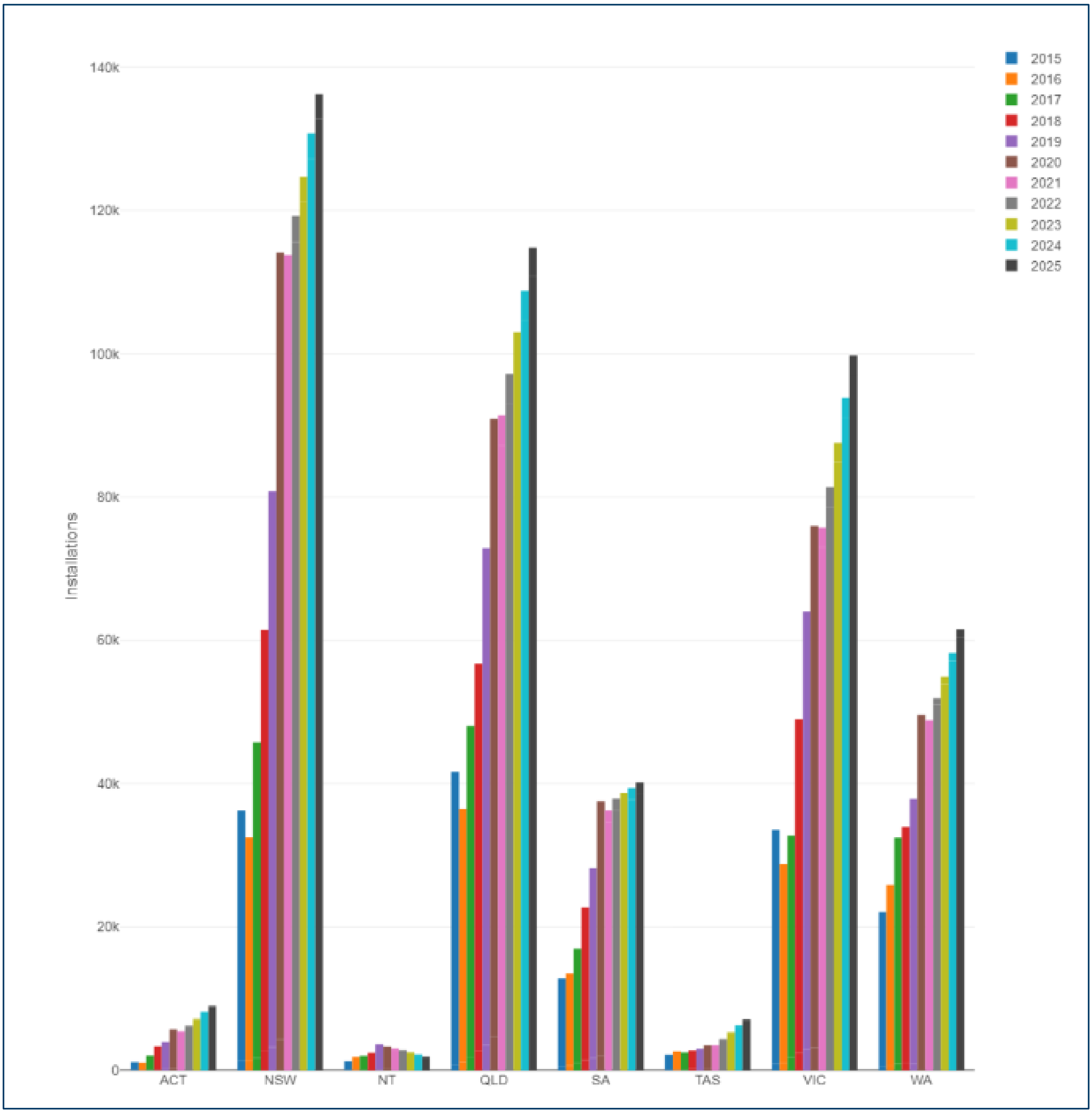

Figure 2 ***Annual number of small-scale installations by State/Territory***

Figure 3 shows the annual figures for PV capacity installed (MW) by State/Territory. Comparing the results from Figure 3 and Figure 2, we can infer that average system size is increasing (e.g., the gradient of Tasmanian capacity-installed figures over 2021 to 2025 is greater than that of installation numbers). This demonstrates the strong preference that residential consumers are having for larger PV systems to be installed.

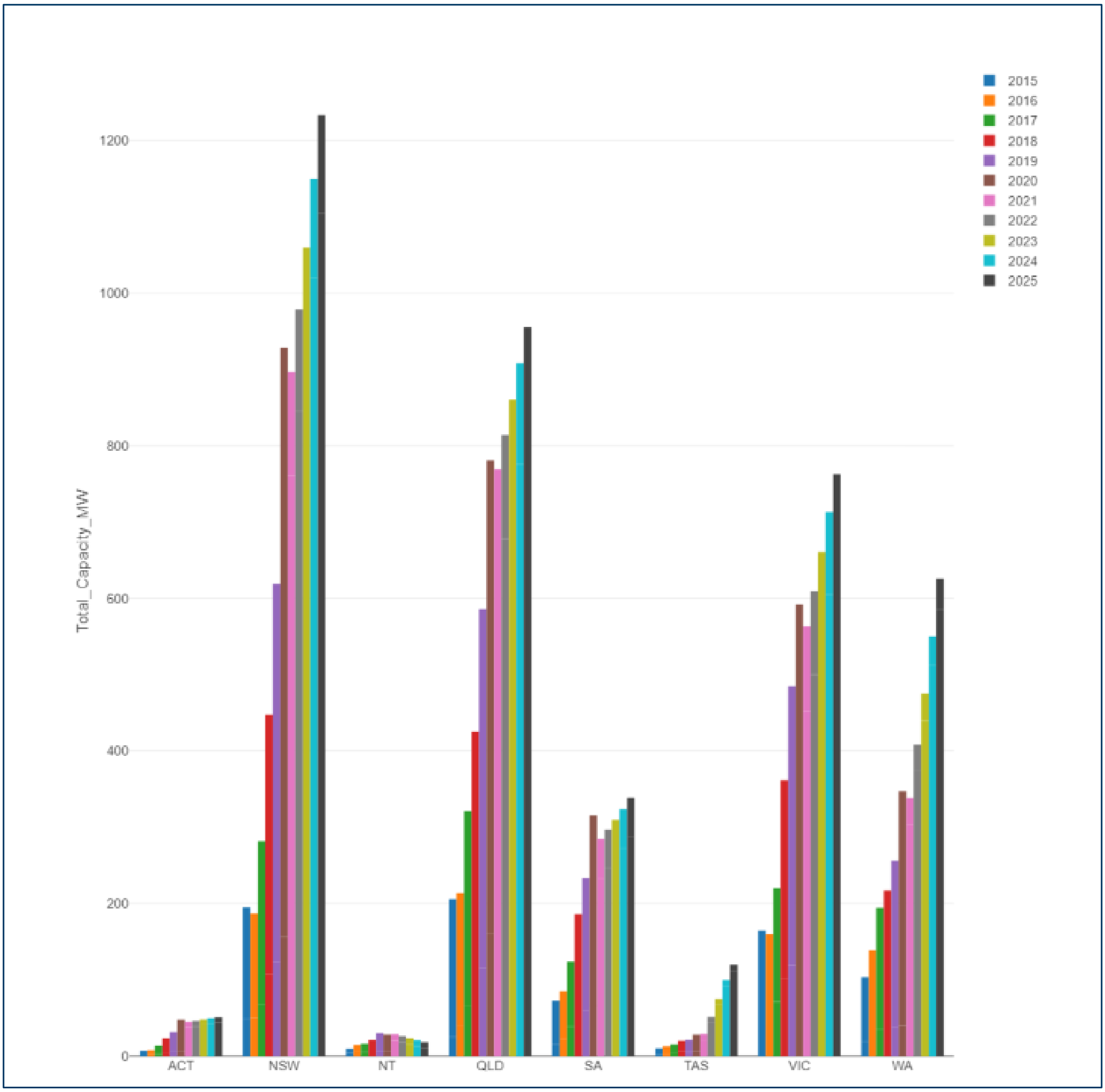

Figure 3 *Annual PV capacity installed (MW) by State/Territory*

Figure 4 shows the annual number of STCs approved ('000s) by State/Territory. It shows that, across the 2021-2025 modelling period, STC decreases are expected in all States/Territories except Tasmania and Western Australia. In particular, we observe that:

– STC growth persists in Tasmania across the 2021-25 period, albeit at a lower rate year to year
– An STC decrease occurs in 2021 in Western Australia, but is followed by growth up until 2024, before a small dip occurs in 2025.

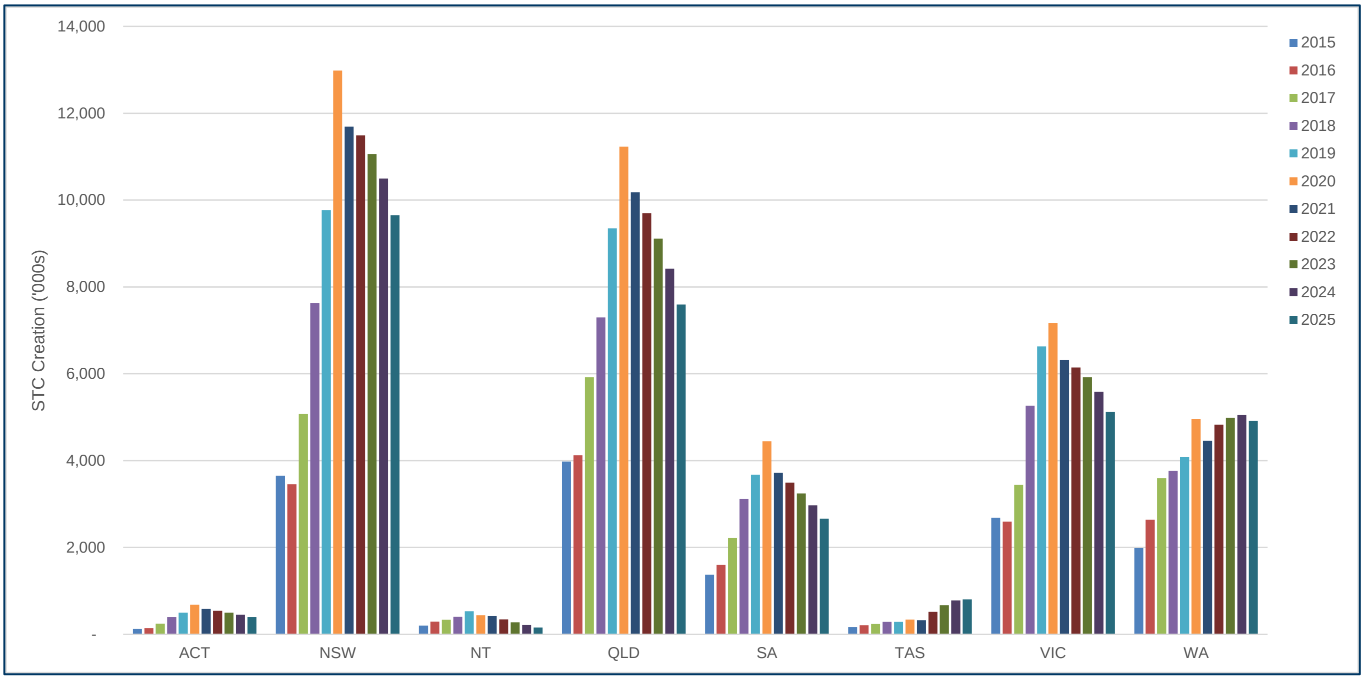

Figure 4 Annual PV STCs by State/Territory

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1. Introduction

Rooftop solar photovoltaic (PV) panels are a popular and rapidly growing source of electricity supply. They provide significant contributions to the generation fleet and to reducing greenhouse emissions from fossil-fuel-generated electricity. Solar water heaters (SWHs) and air source heat pumps (ASHPs) also appeal to many consumers who wish to reduce electricity bills and contribute to reducing carbon emissions.

In Australia, these types of technology, as well as some others, are eligible for Small-scale Technology Certificates (STCs) under the Australian Government's Small-scale Renewable Energy Scheme (SRES). The Clean Energy Regulator (CER) manages the SRES.

STCs – which effectively provide a discount on installation costs – are created on application to the CER at the time of installation of eligible small-scale technologies, based on the deemed[4] lifetime production of the respective installation.

1.1 Purpose of this report

The CER has engaged GHD (us) to advise on the preparation of forecasts for STCs created under the Australian Government's SRES.[5] As noted earlier, STCs are produced when eligible small-scale renewable energy systems are purchased; the eligible systems can include:

– PV systems up to 100 kW capacity
– SWHs, which use a solar collector to absorb heat from the sun
– ASHPs [6], which extract heat from the atmosphere using a compressor
– Other small generation units (SGUs), namely wind turbines and hydro systems.

1.2 Scope of work

The CER required us to prepare STC forecasts on a number-of-installations basis, installed-capacity basis and STC-creation basis, over the 2021 to 2025 period[7]. The forecasts need to be provided for each State/Territory, separated by technology types and customer types (i.e., residential and non-residential).

The CER has also requested that our advice include the following information or requirements:

– be written in plain English for people with little experience or technical knowledge
– an executive summary
– robust modelling supporting the analysis
– explanations of assumptions, methodology and underpinning data sets
– advice on any preference for one estimate, if using more than one model
– detailed appendices to support the modelling work, including data to support figures.

We have prepared a report to address the CER's requirements described above.

[4] STCs are created upon installation, according to the future energy assumed to be produced by a PV installation of a given size and in a given location. A "deeming factor" is the number of years over which an installation is assumed to produce energy for the purposes of calculating the total lifetime energy eligible for STC creation. Since the SRES ends in 2030, PV systems in operation beyond that year will not be eligible for STCs.
[5] More information on the SRES is available here: http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/How-the-scheme-works/Small-scale-Renewable-Energy-Scheme
[6] As the forecasts for SWHs and ASHPs have shown diff
[7] Calendar years

1.3 Limitations

This report has been prepared by GHD for the CER and may only be used and relied on by the CER for the purpose agreed between GHD and the CER as set out in sections 1.1 and 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than the CER arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report and the agreement between CER and GHD.

The opinions, conclusions and any recommendations in this report are based on market, economic and other conditions encountered and information reviewed at the date of preparation of the report. Conditions can change over relatively short periods of time. Any subsequent changes in these conditions could impact either positively or negatively on the matters referred to in this report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by the CER and others who provided information to GHD (including Government authorities) as at the date of this report, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept any liability in connection with such unverified information, including errors and omissions in the report that were caused by errors or omissions in that information.

Where this report refers to information provided by CER, GHD has considered and relied upon that information which, after due enquires, we believe to be reliable, complete and not misleading. The statements and opinions included in this report are given in good faith, and in the belief that such statements and opinions are not false or misleading. Any forecast and projections as supplied to us are based upon assumptions about events and circumstances that have not yet transpired.

Accordingly, GHD cannot provide any assurance that the estimates or forecasts will be representative of the results which will actually be achieved or events that will actually occur. Some of the information contained in this report constitutes forward-looking statements that are subject to various risks and uncertainties. Actual results, performance or achievements could be significantly different from the results or objectives expressed in, or implied by, those forward-looking statements. All third parties should undertake their own independent assessments to meet their specific needs.

1.4 Report structure

Our report is structed as follows:

– Conceptual framework and modelling approach (chapter 2)
– Results (chapter 3).

2. Conceptual framework and modelling approach

This chapter outlines the conceptual framework we adopted in shaping our modelling approach for the small-scale energy installations and capacity forecasts. The structure of this chapter is as follows:

– Agency (section 2.1)
– Overarching modelling process (section 2.2)
– Data exploration and preparation (section 2.3)
– Installation drivers (section 2.4)
– Jurisdictional initiatives affecting consumers' decisions (section 2.5)
– Model validation analysis (section 2.6)
– Model assumptions for 2021 to 2025 (section 2.7).

2.1 Agency

A key feature of our conceptual framework is the principle of 'agency'. The installation modelling recognises the agency of various classes of actors. Agent-based modelling attempts to capture the variation among individuals that is relevant to the questions being addressed by the conceptual model.

In general, agent-based modelling is underpinned by a machine-learning simulation approach. This refers to an automated process whereby a fixed set of model inputs is used to calculate a range of probable outputs. The model can learn from collected data, and it can make predictions on the basis of the dataset. Predictions become more accurate with larger volumes of data.

The machine-learning simulation approach for the engagement with the CER is based on the key drivers that motivate consumers to install specific sizes and types of small-scale technologies. For small-scale capacity and installation forecasting, agency is related to several factors, including household type and size, income and postcode location to either residential or non-residential installations. Our understanding of the key drivers is based on our previous research, which has been undertaken in the course of confidential project work for our clients, including published Australian rooftop PV forecast and related reports.

2.2 Overarching modelling process

The steps that we applied in discharging our overarching modelling process, grounded in agency principles, are depicted in Figure 5.

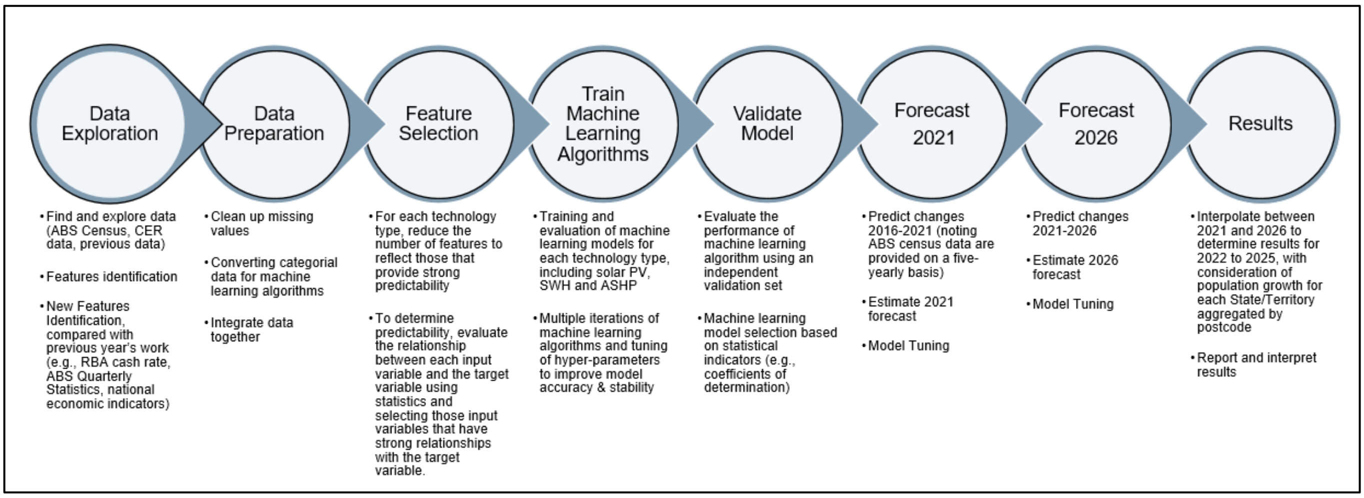


Figure 5 ***GHD's modelling process for determining small-scale installations and capacity forecasts***

The key points regarding our modelling process are as follows:

1. **Data exploration and preparation**

   These steps focus on identifying the factors (what we refer to as 'features') that we anticipate will influence the installation and capacity forecasts over the modelling period (see section 2.3). This is closely linked with our conceptual framework's views on the financial and non-financial drivers that motivate consumers to invest in small-scale technology (see section 2.4.

2. **Feature selection, machine learning and model validation**

   The most relevant features were used in forecasting future installation and capacity at postcode granularity and aggregated to jurisdictional-level forecasts. Following the determination of these features, multiple iterations of machine learning algorithms and associated hyper parameters (values controlling the machine-learning process) are undertaken to ascertain the models that yield the best fit. The strength of the fits is then validated by statistical indicators such as coefficients of determination (CoDs), discussed in section 2.3.

3. **Forecasting**

   The models relied heavily on the use of postcode level Australian Bureau of Statistics (ABS) census data, which are published every five years. The most recent census data is from calendar year 2016. Given the modelling period is from 2021 to 2025, and the long-term forecast is principally based on data provided every five years, the selected models first generate forecasts for 2021 and 2026.

   Additional model inputs include yearly population and economic data for each jurisdiction. We used forecast annual growth in these variables to weight the long-run trend outcome for intermediate years 2022 to 2025. The interpolation of year-on-year growth rates was principally guided by our population projections for each State and Territory over the modelling period. More discussion about this is provided in section 2.6.

2.3 Data exploration and preparation

The goal of the machine-learning modelling was to explore and learn patterns of past and expected future trends relating to installations and capacity. In this case, the granularity was at postcode level to represent agents of a neighbourhood, which was then aggregated to State/Territory level forecasts (see section 3 for more information).

The data exploration reviewed all the features possibly driving resident installer or agent action in regard to solar uptake. The features that we considered as potentially being relevant for residential PV, SWH and ASHP forecasts are set out in Table 3. While we did conceptually consider these features to be important, we used predictability tests to determine if the features were statistically significant; results for this are provided in section 2.6.

Table 3 Factors and dependent features for solar users for Residential Modelling

Parameter	PV	SWH - New Installations and Replacement	ASHP - New Installations and Replacement	Basis for feature selection	Application of feature
Factors	State	State	State	States help to understand how State/Territory government policies, jurisdictions, and system pricing impact uptake.	Most machine learning algorithms do not handle categorical data well, so we perform an action called one-hot encoding to transform this category into an integer, while ensuring that there is no implied order from one entry to another.
	Postcode	Postcode	Postcode	Captures consumer idiosyncrasies for each post code	Most machine learning algorithms do not handle categorical data well, so we perform an action called one-hot encoding to transform this category into an integer, while ensuring that there is no implied order from one entry to another.
	Population	Population	Population	A higher population would suggest higher demand for installations	Total number of persons per postcode
	Age	Age	Age	The age profile of a postcode can have an impact on PV uptake. We found that as people move towards later part of their lives, they have more disposable income and wish to lower their over costs.	Number of people aged 55 or more
	Household Size	Household Size	Household Size	Larger households would suggest higher demand for installations and capacity	Number of houses in postcode with more than three bedrooms
	Dwelling Structure	Dwelling Structure	Dwelling Structure	Greater numbers of detached/semi-detached dwellings would suggest higher demand for installations	Number of households with detached or semi-detached dwelling
	Total Private Dwellings	Total Private Dwellings	Total Private Dwellings	Greater numbers of private dwellings would suggest higher demand for installations	Number of private dwellings per postcode
	Tenure Type	Tenure Type	Tenure Type	Financial stability through home ownership may have a positive relationship with installation numbers	Number of households that are owned outright or via mortgage
	Household Composition	Household Composition	Household Composition	Family households are more likely to install systems	Household Type per postcode (e.g., single person, couple)
	Education level	Education level	Education level	May have a positive relationship with installations and capacity	Number of people with tertiary or more education qualification
	Employment status	Employment status	Employment status	Employment stability may have a positive relationship with installation numbers	Number of people who are employed full time

Parameter	PV	SWH - New Installations and Replacement	ASHP - New Installations and Replacement	Basis for feature selection	Application of feature
	Median household income	Median household income	Median household income	Higher income would mean higher demand for installations and capacity	Median-household weekly income per postcode
	Electricity Price	Electricity Price	Electricity Price	Higher electricity prices may mean higher demand installations and capacity	ABS CPI index for Electricity in each capital city (as a proxy for each State/Territory)
	RBA Cash Rate	RBA Cash Rate	RBA Cash Rate	Lower cash rates would mean more disposable income for purchasing small-scale systems	Cash rates as determined by the RBA
	Economic Resources	Economic Resources	Economic Resources	Strong economic-resource pricing (which is a large share of Australia's exports) should encourage more installation and capacity activity	RBA's Index of Commodity Prices 2021
	National Economic Indicators	National Economic Indicators	National Economic Indicators	The inclusion of the National Economic Indicators was used to help understand the impact of the pandemic on the overall national economy and how that may impact uptake. By choosing to use these indicators, the models employed can continue to evolve in subsequent years, long after the COVID-19 pandemic has come to an end.	National Economic Indicators, provided by the ABS, include prices for goods debits, service credits and services debits. These indicators helped in modelling any supply constraints associated with PV uptakes. Furthermore, these indicators also help model and understand any issues in regard to slower logistics and supply chains that occurred over the last two years. An indirect financial indicator used was the number of short-term visitors arriving. This represents how many Australians chose not to have an overseas holiday and may indicate higher available incomes that may have been used in home improvements including PV systems.
	Payback Period	Payback Period	Payback Period	A lower payback period should increase demand for installation and capacity	Number of years to recover the capital costs of the investment
Dependent features	Number of Installations	Number of Installations	Number of Installations	n/a	n/a
	Capacity	n/a	n/a	n/a	n/a

The features that we considered as potentially being relevant for non-residential PV, SWH and ASHP forecasts are set out in Table 4. While we did conceptually consider these features to be important, we used predictability tests to determine if the features were statistically significant. Results for this are provided in section 2.6.

Table 4 Factors and dependent features for solar users for Non-Residential Modelling

Parameter	PV	SWH	ASHP	Basis for feature selection	Application of feature
Factors	State	State	State	States help to understand how State/Territory government policies, jurisdictions, and system pricing impact uptake.	Most machine learning algorithms do not handle categorical data well, so we perform an action called one-hot encoding to transform this category into an integer, while ensuring that there is no implied order from one entry to another.
	Year Installed	Year Installed	Year Installed	A positive relationship is expected, as popularity of small-scale technologies is expected to increase over time	Calendar year
	Number of Non-Residential Buildings	Number of Non-Residential Buildings	Number of Non-Residential Buildings	The higher the number of buildings, the greater the demand	As per Table 3
	Payback Period	Payback Period	Payback Period	A lower payback period should increase demand for installation and capacity	Number of years to recover the capital costs of the investment
	National Economic Indicators	National Economic Indicators	National Economic Indicators	The inclusion of the National Economic Indicators was used to help understand the impact of the pandemic on the overall national economy and how that may impact uptake. By choosing to use these indicators, the models employed can continue to evolve in subsequent years, long after the COVID-19 pandemic has come to an end.	National Economic Indicators, provided by the ABS, include prices for goods debits, service credits and services debits. These indicators helped in modelling any supply constraints associated with PV uptakes. Furthermore, these indicators also help model and understand any issues in regard to slower logistics and supply chains that occurred over the last two years. An indirect financial indicator used was the number of short-term visitors arriving. This represents how many Australians chose not to have an overseas holiday and may indicate higher available incomes that may have been used in home improvements including PV systems.
	Cost of solar installation	n/a	n/a	The lower the installation cost, the higher the number of installations and capacity	$/Watt figures from Solar Choice
Dependent features	Number of Installations	Number of Installations	Number of Installations	n/a	n/a
	Capacity	n/a	n/a	n/a	n/a

2.4 Installation drivers

Previous studies[8] provide empirical evidence for the widespread casual observation that both financial and non-financial drivers are important for the adoption of newly commercialised technologies. These two driver types are discussed in turn.

2.4.1 Financial drivers

Financial drivers for residential installations/capacity were accounted for in the following features underpinning our modelling: employment; income; postcode; electricity price; payback period; and RBA cash rates.

Financial drivers for non-residential installations/capacity were accounted for in the following features underpinning our modelling: cost of solar installation; payback period; and RBA cash rates.

In deciding to install small-scale generators, consumers will need to weigh up the upfront and ongoing costs associated with the installation against the potential returns that arise from selling excess electricity generation back to the grid. The upfront costs for a small PV generation unit include the cost of the solar panels, support equipment (if required, for example on a flat roof), inverter, wiring and electrical connections, labour and overheads of the installer.

These costs may be offset at the time of payment by the STC credit by selling the STC creation right to the installer. Our collected data for PV installation costs are generally recorded as a single installation cost. The observed reduction in installation costs over time nonetheless overwhelmingly reflects the falling cost of PV panels.

Financial benefits flow over the operational life of the installation from electricity bill savings as a result of consuming self-generated power and, if self-generated power exceeds required load, selling energy back to the grid. The benefits therefore depend on the frequency and total duration of self-generation in conjunction with consumption (i.e., the frequency and durations for which power produced from home-generated energy exceeds home demand levels). They also depend on the variable tariff rates for energy consumption and feed-in-tariffs for sales of self-generated energy.

Financial drivers also relate to whether the installation costs have to be paid upfront or via a loan. Installation of a typical 6 kW system (after allowing for the STC discount) currently costs between $4,230 and $5,480 in Australia's largest capital cities.[9] This could be considered a hefty sum for consumers in the lower-income brackets. Unless they can finance this upfront cost via loans, they will likely not proceed with the installations. By comparison, those with higher disposable incomes can readily afford the upfront payment.

A further dimension to consider is whether the installations are commissioned on an existing property or one about to be built. For properties about to be built, construction companies usually offer to provide a solar system as part of the build, the cost of which can be included in the housing loan. In that instance, more people would be willing to consider including such small-scale installations in their loan, as the financial impact is not borne upfront, but over the life of the housing loan. Cash-flow considerations are therefore important for understanding consumers' mindsets on such purchasing decisions.

2.4.2 Non-financial drivers

Investment in small-scale generation systems is also motivated by non-financial drivers. We characterise these drivers as: Neighbourhood; Technological; and Household-type effects.

2.4.2.1 Neighbourhood effects

Neighbourhood effects for residential installations/capacity were captured by the 'Postcode' feature in our modelling.

[8] For example, Sommerfeld, J. (2016) Residential Customers and Adoption of Solar PV, PhD thesis, Queensland University of Technology School of Design, Brisbane.
[9] See https://www.solarchoice.net.au/blog/solar-power-system-prices (accessed on 9 June 2021).

The neighbourhood effect captures subjective reaction to the potential installation of technology, which could be related to several factors. These include architectural aesthetics, the disruption required to organise and during the installation, the impact of personal environmental values on the motivation to install, a desire for greater autonomy, and a desire for prestige (including to keep abreast of trends, and to make decisions that are consistent with said trends).

We attempt to capture these effects in terms of local installation of the technology existing in the neighbourhood at the time the decision to install is made. By way of example, neighbourhoods with high incomes and double-storey houses are far more likely to have solar installations than neighbourhoods with lower incomes characterised by a mix of single-storey houses and apartment blocks.

2.4.2.2 Technological effects

Technological effects have been captured, in part, by the ‘State’ feature in our modelling.

Technological effects relate to, among other things, co-installation of batteries, electric car ownership, having smart meters and hence access to variable tariff rates, or participation in a demand response scheme. Such factors can influence the size of the installation, or the orientation of a PV system, as well as the take-up rate. If, for example, a household has a large energy consumption requirement after dark in the evening, it is likely to access greater potential electricity savings with a larger PV system if co-installed with battery storage, relative to a smaller system that may be most economical without such storage.

Technological factors in this context also include the impact of regulatory changes, including available feed-in-tariffs, which are sometimes high in early years of installation (because of government policies) and then become lower in later years.

2.4.2.3 Household-type effects

Household-type effects for residential installations/capacity have been accounted for using the Dwelling Structure, Separate House and Private Dwelling features in our modelling.

Household-type effects reflect heterogeneity (i.e., non-uniformity in decision making) among households, capturing the different opportunities or potential to benefit from such effects. The optimum residential opportunity for the installation of a PV system would be an owner-occupied detached house with a large unshaded, north-facing roof, whereas renters in an apartment block have little opportunity or incentive to install such a system.

2.4.2.4 Other effects

Some communities are more environmentally conscious than others. So, although it may not make financial sense to install small-scale systems, there may be tacit pressure on these communities to do so. For example, employees of environmentally focussed organisations, including green groups, may face unspoken pressure about the need for them to have solar-PV and SWH systems at home (if they can legally do so).

The same may be said for small businesses or green groups themselves. They too may face tacit pressure to install larger scale systems if their business is perceived to be needing to fulfil societal expectations or if located in an environmentally conscious area.

For example, a flora/fauna conservation society may feel obliged to have energy-efficient offices, meaning that small-scale technology installations would likely feature in their internal (and external) working spaces. While these effects are difficult to measure, they do represent strong non-financial drivers that everyday consumers and small businesses/organisations face. Our modelling does not explicitly account for such factors,

2.5 Commonwealth/State/Territory initiatives affecting consumers' decisions

Government initiatives are addressed by, in part, the 'State', 'Postcode', 'Payback period', 'Year installed', 'Cost of Solar installation' features in our modelling. However, the modelling does not incorporate initiative-specific features.

The initiatives that affect consumers' decisions to invest in small-scale renewable energy installations, including capacity preferences, generally relate to: purchase/installation cost offsets or rebates; low-interest loans; and feed-in tariffs.

Upon reviewing the initiatives, the primary observations are that:

- a few States/Territories are starting to favour incentives for battery-related systems, rather than traditional standalone solar PV systems.
- some regions' feed-in tariffs are starting to be determined on a time-of-use basis, rather than merely a flat fee
- SWH incentives are no longer as common.

2.5.1 Commonwealth

Beyond the SRES, the Commonwealth Government does not have any other schemes in place (e.g., rebates or low-interest loans) that subsidises small-scale renewable energy investment.

The AEMC recently published a draft rule determination allowing distribution network service providers to charge for solar exports to the grid[10], which if implemented would further reduce the value of small-scale PV system exports to the grid and may therefore reduce the financial incentive to invest in new systems. We have not incorporated the effect of this proposal into our modelling. This is partly due to the uncertainty of its implementation (we do not know with certainty how much the charge may be, when charging may practically begin or even whether DNSPs will take advantage of it), but also because it may simply provide consumers with a greater incentive to co-install batteries and larger PV systems.

2.5.2 States and Territories

Descriptions of the incentives of each State and Territory (presented from west to east) are set out below.

2.5.2.1 Western Australia

The WA Government administers the Distributed Energy Buyback Scheme (DEBS), which offers eligible customers a time-of-export payment for electricity they export to the grid, including from rooftop PV systems, batteries and electric vehicles.[11] Under previous schemes, the payments did not apply to batteries and electric vehicles, meaning that investment in batteries may increase more than otherwise would be the case.

The time-of-export payment government-mandated rates are as follows:

- 10 c/kWh for electricity exported between 3 pm to 9 pm (peak time)
- 3 c/kWh outside peak-time periods.

The implication of this approach is that households are motivated to install west-facing panels that will generate electricity in the afternoon and evening (i.e., producing more renewable energy when it is highly demanded). While this may not change the number of installations, we anticipate it will enhance the already strong trend towards increasing PV system size. The larger size may also encourage co-installation of PV panels with batteries.

2.5.2.2 South Australia

While there are incentives directly related to the installing of PV systems, the South Australian (SA) Government has in a place a Home Battery Scheme. The scheme provides all grid-connected South Australians access to

[10] https://www.aemc.gov.au/rule-changes/allowing-dnsps-charge-exports-network.
[11] See https://www.wa.gov.au/organisation/energy-policy-wa/energy-buyback-schemes

subsidies and low-interest loans, supplied by the Clean Energy Finance Corporation, for home-based batteries.[12] Current subsidy levels are as follows:

– Energy concession holders – $300 per kWh
– All other households – $200 per kWh
– Maximum subsidy per battery installation – $3000.

Although the subsidies and low-interest loans relate to the battery installation, they can be used for new rooftop solar panels serving the battery (but not for existing solar panels or for a standalone PV system). While not an SA Government initiative, we observe that the City of Adelaide (council) offers rebates of up to $1,000 for SWH systems.[13]

No government-mandated minimum feed-in tariffs exist; customers can negotiate feed-in tariffs with their retailers.

2.5.2.3 Northern Territory

The Northern Territory (NT) Government has a scheme in place related to home batteries, namely the Homes and Business Battery Scheme. It provides a $6,000 grant to, among other parties, NT homeowners for purchasing and installing PV systems with a battery and inverter, or for homeowners that already have a PV system, for purchasing a battery and inverter.[14] In our view, the size of this grant is potentially large enough to encourage adoption of a larger system.

As of 5 November 2020, the NT Government announced a standard feed-in tariff of 8.3 cents per kWh, reflecting approximately a third of the previous tariff.[15]

2.5.2.4 Tasmania

The Tasmanian Energy Efficiency Loan Scheme, which provided Tasmanians with no-interest loans to assist in purchasing eligible energy-efficient products, came to an end on 30 April 2019. However, there is a government-mandated minimum feed-in tariff – 8.471 cents per kWh in the 2020-21 financial year (9.4% lower than the 2019-20 financial year).[16]

2.5.2.5 Victoria

The Solar Homes Program solar PV rebate assists eligible Victorian households and rental property owners to install solar panels.[17] It provides eligible Victorian households with a rebate of up to 50% (capped at $1,850) of the purchase cost to install PV panels.

A similar incentive exists for solar battery systems, with rebates up to $4,174 for the previous financial year.[18] There is additional assistance offered, including no-interest loans to complement the rebates. We consider that this reduces the effective cost that is incurred by low-income households. Where solar panels are not suitable, the Victorian Government provides a rebate of up to $1,000 on SWH systems.[19]

Access restrictions include, among other things, owners have a combined household taxable income of less than $180,000 per year and must be living in an owner-occupied dwelling valued at under $3 million.

In addition to this scheme, there are minimum government feed-in tariffs, as established by the Essential Services Commission of Victoria (see Table 5). These are time-of-use driven, rather than a flat-fee arrangement.

Table 5 Current minimum feed-in tariffs in Victoria

Period	Weekday	Weekend	Rate (cents per kWh)
Off-peak	10 pm to 7 am	10 pm to 7 am	9.1

[12] See https://homebatteryscheme.sa.gov.au/about-the-scheme
[13] See https://www.cityofadelaide.com.au/about-council/grants-sponsorship-incentives/sustainability-incentives-scheme/
[14] See https://businessnt.smartygrants.com.au/homeandbusinessbatteryscheme
[15] See https://www.solarquotes.com.au/systems/feed-in-tariffs/nt/
[16] See https://www.economicregulator.tas.gov.au/electricity/pricing/feed-in-tariffs
[17] See https://www.energy.gov.au/rebates/solar-pv-panel-rebate#:~:text=The%20program%20provides%20eligible%20Victorian,average%204kW%20solar%20PV%20system.
[18] See https://www.solar.vic.gov.au/solar-battery-rebate
[19] See https://www.solar.vic.gov.au/solar-hot-water-rebate

Period	Weekday	Weekend	Rate (cents per kWh)
Shoulder	7 am to 3 pm, 9 pm to 10 pm	7 am to 10 pm	9.8
Peak	3 pm to 9 pm	n/a	12.5

2.5.2.6 New South Wales

The NSW Government administers the Empowering Homes program. It is an interest-free loan to install solar panels or solar battery systems in some parts of NSW, covering 16 regions and 204 postcodes.[20] The loans range from $8,000 to $14,000, depending on the payment period and whether new solar panels support the battery system. Almost identical to the Victorian scheme, an eligible applicant must not, among other things, have annual household income exceeding $180,000.

While there are no minimum feed-in tariffs, the Independent Pricing and Regulatory Tribunal publishes benchmark rates. The benchmark range is 6.0-7.3 cents per kWh in the 2020-21 financial year.[21]

2.5.2.7 Australian Capital Territory

The Sustainable Household Scheme will provide most Canberrans (some ACT areas excluded) with access to zero-interest loans of between $2,000 to $15,000 for rooftop PV systems and household battery storage systems.[22] This is comparable to allowing for such installations to be wrapped up within a new home loan.

While the scheme is not means tested on an income basis, a key restriction is that the 2020-21 Unimproved Value of the property to which the installation occurs must be below:

– $750,000 for non-unit titled dwellings; or
– $200,000 for unit titled dwellings based on the unit entitlement percentage.

In addition, there is the Next Gen Battery Storage Program, under which registered residents can get up to:

– $15,000 worth of interest-free loans to install solar batteries in their homes
– $825 per kW rebate off batteries.

The program is likely to encourage larger PV system installations than would the case without the initiative.

No government-mandated minimum feed-in tariffs exist; customers can negotiate feed-in tariffs with their retailers.

2.5.2.8 Queensland

No incentives currently exist regarding the offsetting, or having low-interest loans, for purchasing and installing PV and other renewable systems.

Households in regional Queensland (i.e., outside South East Queensland) can benefit from a Queensland Government minimum feed-in tariff of 7.861 cents per kWh; however, the tariff decreases to 6.583 cents per kWh from 1 July 2021.[23,24] The rest of Queensland can negotiate market-based feed-in tariffs with their retailers.

2.6 Machine-learning model validation analysis

2.6.1 Feature selection

Validation of the machine learning models showed that not all of the listed features contribute strongly to explain the behaviour of the agent installer. The features found to significantly explain agent installer behaviour are listed in Table 6 and Table 7; these features were used to produce our results. The relative importance (ordinal, not cardinal) of the features is explained in Appendix A-3-3.

[20] See https://energysaver.nsw.gov.au/households/solar-and-battery-power/empowering-homes-solar-battery-loan-offer
[21] See https://energysaver.nsw.gov.au/households/solar-and-battery-power/feed-tariff-rates
[22] See https://www.actsmart.act.gov.au/what-can-i-do/homes/sustainable-household-scheme
[23] See https://www.qca.org.au/project/customers/solar-feed-in-tariffs/regional-queensland-feed-in-tariff-2020-21/
[24] See https://www.qca.org.au/project/customers/solar-feed-in-tariffs/regional-queensland-solar-feed-in-tariff-2021-22/

One of the features that we consider requires additional explanation relates to the national economic indicators. As noted earlier, national economic indicators include prices for goods debits, service credits and services debits. These indicators helped in modelling any supply constraints associated with PV uptakes.

Our ML models looked at a range of national indicators and found that out of the 151 National Indicators that we measured we used 42 in the small-scale models including Goods Debits (6), Services Credits (13), Services Debits (14) & Short Term Visitors (9). The full list of variables we initial considered is provided in Appendix A-1-1.

Table 6 Important features used in forecasting the residential solar installations and capacity

Fuel Source	SGU Installation Type	Features Included in the Model
Solar PV	Residential Installation	Population
		Separate House
		Owners
		Household Composition
		Education
		Employment
		Income
		Electricity Price
		Payback Period
		Economic Resources
		RBA Cash Rate
		National Economic Indicators
		Electricity Price
		State
		Postcode
Solar PV	Residential Capacity	Population
		Separate House
		Owners
		Household Composition
		Education
		Employment
		Income
		National Economic Indicators
		Private Dwelling
		Resources
		State
		Postcode
SWHs	Residential New	Population
		RBA Cash Rate
		Household Composition
		Education
		National Economic Indicators
		Income
		Resources

Fuel Source	SGU Installation Type	Features Included in the Model
		Owners
		Separate Houses
		Dwelling Size
		Private Dwellings
		Employment
		Education
		State
		Postcode
SWHs	Replacement Installations	Population
		Age >55
		RBA Cash Rate
		Household Composition
		National Economic Indicators
		Private Dwellings
		Owners
		Separate Houses
		Education
		State
		Postcode
ASHPs	Residential - New Installations	Population
		RBA Cash Rate
		Household Composition
		Education
		National Economic Indicators
		Income
		Resources
		Owners
		Separate Houses
		Dwelling Size
		Private Dwellings
		Employment
		Education
		State
		Postcode
ASHPs	Residential - Replacement Installations	Population
		Age > 55
		RBA Cash Rate
		Household Composition
		National Economic Indicators
		Private Dwellings
		Owners

Fuel Source	SGU Installation Type	Features Included in the Model
		Separate Houses
		Education
		State
		Postcode

Table 7 Important features used in forecasting Non-Residential solar installations and capacity

Fuel Source	SGU Installation Type	Factors Included in the Model
Solar PV	Non-Residential Installation	State Year Installed Cost of Solar Installation Number of Non-Residential Buildings Payback Period National Economic Indicators
Solar PV	Non-Residential Capacity	State Year Installed Cost of Solar Installation Number of Non-Residential Buildings Payback Period
SWHs[25]	SWHs – Non-Residential[26]	State Year Installed Number of Non-Residential Buildings Payback Period National Economic Indicators
ASHP	ASHPs - Non-residential	State Year Installed Number of Non-Residential Buildings Payback Period National Economic Indicators

2.6.2 Preferred models

Models of the data were trained and validated by machine learning, underpinning by running multiple classification algorithms and hyper-parameter combinations to most accurately model agent installation and capacity. This then allowed us to shortlist several models:

– **Linear Regression:** One of the simplest models that tries to fit features along a linear line to determine the forecast. Whilst we rarely use these models, we use linear regression as a benchmark to help understand the uplift provided when using more sophisticated machine learning models.

– **Decision trees**: diagrams assisting with ascertaining a course of action or displaying statistical probabilities.

– **Random Forest**: A random forest is a classification and regression algorithm that consist of hundreds of decision trees. It makes use of some advance features to ensure it creates a set of uncorrelated forest of trees whose overall combined prediction is more accurate than that of any individual decision tree.

– **CatBoost**: an algorithm for gradient boosting on decision trees. Gradient boosting is a machine-learning technique for regression and classification problems. Boosting is an iterative model tuning procedure where new model iterations are influenced by the outcome of the formerly built model to weight training samples relative to its importance.

[25] SWHs and ASHP were modelled separately, for both residential and non-residential sectors for replacement and new building segments.
[26] SWH non-residential data were very sparse, making it difficult to determine trends with a robust CoD.

– **XGBoost**, which stands for eXtreme Gradient Boosting. It is an implementation of gradient-boosted decision trees designed for speed and performance.

For each model scenario, we fed the data into our AutoML logic and told it to build 10 versions for each model mention above. That is, for every scenario, we ran 50 simultaneous machine learning models and then we evaluated the best model based on their combined R^2 and RMSE scores:

- **R Squared (R^2):** is a statistical measure that represents the proportion of the variance for forecast number (uptake or MW) that's explained by the input factors. This is one of the most common measures of a model's fit and accuracy.
- **Root Mean Square Error (RMSE):** Whilst R^2 is a common measure, it can be incorrectly manipulated by outliers, so we also evaluate models using the RMSE. The RMSE is the standard deviation of the forecast errors. RMSE is a measure of how spread out these errors (or residuals) are from the final forecast.

2.6.2.1 Residential

Our AutoML logic selected one of the Random Forest models as the most appropriate for developing the forecasts for residential installations and capacity relating to the PV, SWH and ASHP (new or replacement) technology types.[27] We adopted a data-health check approach to reach this view. This involved assessing missing values, outliers, and sparsity of the data. The CoDs achieved for:

– Installations, ranged from 0.47 to 0.63 (Appendix A-3-4). That is, between 47% and 63% of the variation of the installation forecasts can be explained by the dependent variables we selected for determining installations.

– Capacity, was 0.59. That is, 59% of the variation of the capacity-installed forecasts can be explained by the dependent variables we selected for determining the capacity-installed numbers.

2.6.2.2 Non-Residential

Our results for the most appropriate models to apply for non-residential installations and capacity were mixed (Appendix A-3-4). We found that for:

– Installations, the Random Forest approach worked best for PV (CoD of 0.94), but that a CatBoost approach was more appropriate for SWHs (CoD of 0.65). While the results for ASHP indicated the CatBoost approach was most appropriate, the CoD of 0.22 we obtained indicates that the modelling fit was not very strong.

– Capacity, the Random Forest approach worked best for PV (CoD of 0.94).

2.7 Model assumptions (2021-2025)

Our modelling adopted several macro-level assumptions for the 2021-2025 period. The key assumptions relate to population growth, household incomes, national economic indicators (including the cash rate set by the RBA); electricity prices; and building and dwellings. Details about each of these key assumptions are provided below.

2.7.1 Population growth

Population was from ABS estimates assuming internal Australian migration is permanent. All projected population numbers are consistent with ABS official numbers and thus in-line with official federal government statistics. ABS provides estimates on population by state, region and age group up to 2066 based on a range of assumptions:

– Medium Fertility

– Medium Life Expectancy

– Medium Net Overseas Migration

– Medium Interstate flows

– Month: December.

[27] We did not apply long-run modelling for SGUs, as the data were sparse, and it would be inappropriate to apply this modelling approach.

The last known estimated resident population (June 2020) was used to determine the percentage of an age group and region to a particular postcode. This give populations from 2001 to 2026 by age group and month (Census date was August, Estimated Resident Population (ERP) in June and Projected in December).

This more granular approach shows how different postcodes are growing and shrinking by different rates by age group. Population by age group was extrapolated for every month from August 2001 through to December 2026 through the use min-max normalisation statistical transformation. On this basis, we were able to estimate monthly population change between an initial starting point and the endpoint.

2.7.2 Household income

A key limitation that we faced during our analysis was that census data for 2021 were not available, as this census has not yet occurred. Hence, we had to rely heavily on the 2016 census data, which we note is considerably out of date. However, it is the most appropriate data source for us, and is consistent with the approach that we adopted for the previous engagement with the CER.

The Median Household Income use was based on the same approach as Population without forecast changes to Median Household Income after the 2016 census date. We chose to repeat this value up to 2025. This is important as it provides mathematical and economic stability to the model outside of census years.

2.7.3 Socio-economic Indexes

The Socio-economic Indexes for Areas (SEIFA) used the same approach as Population, again not forecasting changes to SEIFA after the 2016 census date. We have chosen to repeat this value up to 2025 for education and employment. This means that we are unable to determine if postcodes have become more or less educated or disadvantaged since the last census. It has been well documented that significant movements of households to regional Australia has taken place over the last two years which will have a significant impact of SEIFA but it unclear if this trend will reverse once the economy fully recovers. SEIFA will be recalculated as part of the 2021 census with results expected to released by August 2022.

2.7.4 National economic indicators (including the cash rate)

We have assumed that the national economy will rapidly recover as the population becomes fully vaccinated. In past economic downturns it has taken between 3-5 years to fully recover, however these were based on market volatilities and economic bubbles bursting. With a pandemic-lead economic downturn, it is expected the market will regain more confidence as more people are vaccinated and return to normal levels of mobility. As such, GHD has assumed that the economy will slowly grow from July 2021 until it reaches pre-pandemic levels expected to happen by Jan 2023. Note this assumes that 80% of the population gets vaccinated and that vaccines used are shown to be effective against current and future strains of the COVID-19 virus.

The relevant 42 National Economic indicators were used at a national level to measure and estimate the impact of COVID-19 and associated downturn in the market. As noted earlier in the report, these relate to the following indicators:

- Total goods debits
- Services credits
- Services debts
- Total services
- Number of Short-term residents returning
- Number of Short-term visitors arriving.

In relation to cash rates, we did not consider it appropriate to speculate on the direction of these variables over the modelling period. Cash-rate decisions are affected by numerous factors, such as inflation levels, housing-market strength and global macroeconomic conditions. We assumed that the cash rate remains unchanged at 0.10% over the modelling period, which is not incompatible with the RBA's Statement (Monetary Policy Decision) in July 2021 that interest rates are unlikely to be considered to be lifted until 2024 at the earliest.[28]

2.7.5 Electricity prices

We have captured historical movements in electricity prices in each State/Territory using the electricity component of the Consumer Price Index[29]. We reviewed published information addressing future residential electricity price trends over the 2021 to 2025 period, including AEMC[30] and the WA Government[31] and acknowledge that variable electricity rates[32] are generally expected to remain fixed or go down slightly in all jurisdictions up until 2023. Due to the variability between jurisdictions and the incomplete information for the full period up until 2025, we have assumed for simplicity that electricity prices in each State/Territory remain unchanged in real terms.

In considering the future direction of electricity prices, the supply-demand balance in major wholesale markets (the NEM and the SWIS) are likely to play the predominant role. In that regard new renewable generation entering these markets is contributed to lower average costs

– The expected extent of retail competition, which should continue to drive prices down if competition continues to increase
– the AEMC's contemplation of rule changes related to the facilitating increased of solar-PV installation and battery-storage systems in homes, which may raise electricity prices if grid exports from homes and small businesses is controlled more rigorously[33]
– The closure of Liddell Power Station, which may raise prices in New South Wales and ACT.

Given the impact on electricity prices could occur in either direction, we considered it more appropriate to assume that electricity prices would remain unchanged over the modelling period.

2.7.6 Buildings and Dwellings

The total approach for the number of buildings and dwellings was the same as Population, with the following adjustments applied:

– Census year data provided total dwellings
– Years other than census the number of building approvals by Statistical Area 2 guided predictions of the total number of dwellings by postcode.
– Two Machine Learning Models (Random Forest) were used to extrapolate monthly data and forecast forward to 2026 for building approvals. The modelling is detailed in Appendix A-1-1.
– The forecast building approvals were used to predict total number of dwellings through a separate Machine Learning (Random Forest) model.

[28] See https://www.rba.gov.au/media-releases/2021/mr-21-13.html
[29] Australian Bureau of Statistics, Consumer Price Index, 6401.0, Quarterly, Table 9.
[30] AEMC (2020) Residential Electricity Price Trends, https://www.aemc.gov.au/market-reviews-advice/residential-electricity-price-trends-2020.
[31] Western Australian Budget 2020-21. The WA Government announced an electricity price freeze for 2020-21.
[32] Changes in variable electricity tariffs with fixed components remaining the same will result in lower overall changes in average electricity costs.
[33] See https://www.aemc.gov.au/news-centre/media-releases/new-plan-make-room-grid-more-home-solar-and-batteries

3. Results

This section summarises our small-scale technology installation modelling results. More detailed results are contained in a separate report to the CER.

3.1 Overarching observations

For many electricity consumers in Australia, there is conceptually a clear benefit in investing in PV systems. Whether configured as a PV system only, or combined with battery storage, or perhaps sized to offset the cost of electrical water heating, the benefit is represented in terms of electricity purchase savings that more than outweigh the capital and operating costs of the system they install.

As the cost of PV installation continues to fall, additional motivation may derive from its ability to reduce environmental impacts and the potential to gain greater control over the supply of and cost of energy. We consider these to be the main factors driving the trend in increasing PV penetration, with the limiting factors in the long run being the availability of roof space and ownership/control of that roof space.

We find that recent rapid growth in yearly PV installations (and capacity) is likely to pause in 2021 and then resume through to the end of the forecast period, as installation costs continue to become more affordable and the number of houses grows. The slight decline forecast for 2021 as a whole, mainly in non-residential installations, follows a period of exceptionally strong growth which may be explained by some bringing forward of projects during the initial COVID-19 crisis. This is further seen by the sudden decrease in building approvals in the second half of 2020 which is a leading indicator when it comes to PV installations for both new dwellings and home improvements. The pause in small-scale PV take-up is supported by our analysis of the most recent months' installation data for the larger states.

ASHP installations also face a sharp dip in 2021, but thereafter grow steadily throughout the forecast period. Annual installation do not, however, reach the high levels of 2020. SWH installations decline gradually from 2022 onward. SGUs are becoming less of a practicable endeavour for most electricity consumers. We do not anticipate any SGU investments over the modelling period.

The number of STCs created each year will start to fall slightly due to the falling deeming factor[34], which is only partially offset by growth in new capacity.

3.2 Australia-wide small-scale technology forecasts

A summary of our forecast findings by PV, SWHs and ASHPs is provided in this subsection.

3.2.1 Residential PV

Table 8 shows residential PV installation, capacity and STC forecasts. We observe that the results over the 2021 to 2025 period would indicate a linear trend. As noted earlier, our machine-learning approach determines the forecast installation and capacity figures for 2021 and 2026. An interpolation approach, weighted by the forecast year-to-year population growths, is then applied to derive the figures for 2022 to 2025. This explains the apparent linearity of results over the modelling period.

Table 8 Residential PV installations, capacity, average system size and STC creation

Parameter	2020 (actual)	2021	2022	2023	2024	2025
Installations	364,969	363,988	387,248	410,158	433,930	456,957
Total capacity (MW)	2,501	2,458	2,743	3,030	3,334	3,626

[34] STCs are created upon installation, according to the future energy assumed to be produced by a PV installation of a given size and in a given location. A "deeming factor" is the number of years over which an installation is assumed to produce energy for the purposes of calculating the total lifetime energy eligible for STC creation. Since the SRES ends in 2030, PV systems in operation beyond that year will not be eligible for STCs. For the purpose of allocating STCs to newly installed systems, the 'deemed' productive life of systems installed prior to the end of 2030 cannot extend beyond that year.

Parameter	2020 (actual)	2021	2022	2023	2024	2025
Average system size (kW)	6.9	6.8	7.1	7.4	7.7	7.9
STC creation (‘000s)	34,253	31,414	31,506	30,896	29,711	27,673

Key observations on the forecast additions to residential PV are that:

– A slight dip (less than 1%) in installations occurs in 2021 (relative to 2020), followed by an average increase of 5.6% per annum over the rest of the modelling period, in line with increasing population and new house construction. The slight 2021 decrease is explained by the fact that during 2020, a significant number of working homeowners spent more time at home yet did not suffer reduced income (due to working from home). This appears to have brought forward some spending on home improvements - including purchasing PV systems - from 2021 to 2020. This is consistent with the general trend observed over March 2021 to June 2021 in the populous states, where installation numbers have started to fall sharply in NSW, Queensland and Victoria, unlike the same period during 2020.

  However, growth in annual installations is forecast to resume from 2022 onwards, as falling PV panel costs continue to decline and dwelling numbers increase. As ‘national economic indicators’ was not a dominant feature of our modelling (see A-3-3), any supply-side constraints affecting PV uptake would not be recognised as having a significant impact in our modelling results.

– We do not anticipate market saturation to be an issue in the vast majority of postcodes, however we acknowledge that our residential installations forecast will result in a substantial increase in residential rooftop PV penetration by 2025, even though around one third of new installations are expected to be on new properties rather than existing buildings.

– A slight dip of 1.7% dip in capacity is forecast for 2021, but this is followed by relatively large increases averaging 10.2% per annum over the forecast horizon. As capacity rises faster than the number of installations, this results in the average system size rising steadily from 6.8 kW in 2021 to 7.9 kW by 2025. We consider that a major driver of increasing system size is falling PV-system installation costs.

– The general trend is for STCs to decrease, reflecting that overall growth in capacity/installations figures is more than offset by the impact of the deeming factor35.

– Whilst the overall trends appear linear, this masks more complex progression at the postcode level, in which some postcodes with already high penetration have relatively low growth, which is partially offset by growth in lower penetration postcodes. These micro-trends tend to offset one another when the forecasts are rolled-up to a jurisdictional level.

3.2.1.1 2021 results – validating short-run observations

Given the observed dip in 2021 for residential PV installations compared with those of 2020, we sought to corroborate whether our machine-learning result was consistent with short-term trend observations. To do this, we reviewed how the first six months of 2021 have compared with those for 2020.

At an Australia-wide level, the trend over the six months we observe is portrayed in Figure 6. Numbers for 2021 have been higher than 2020, except in the month of June, where installations have been significantly lower. Over March 2021 to June 2021, a sharp downward trend in installations exists. In comparison, while there was a dip in April 2020 compared with March 2020, increases do occur in May and June 2020. Overall, while the 2021 numbers are 5% higher than those in 2020 over the six months considered, we do not expect this to be sustained over the rest of the year.

[35] STCs are created upon installation, according to the future energy assumed to be produced by a PV installation of a given size and in a given location. A “deeming factor” is the number of years over which an installation is assumed to produce energy for the purposes of calculating the total lifetime energy eligible for STC creation. Since the SRES ends in 2030, PV systems in operation beyond that year will not be eligible for STCs.

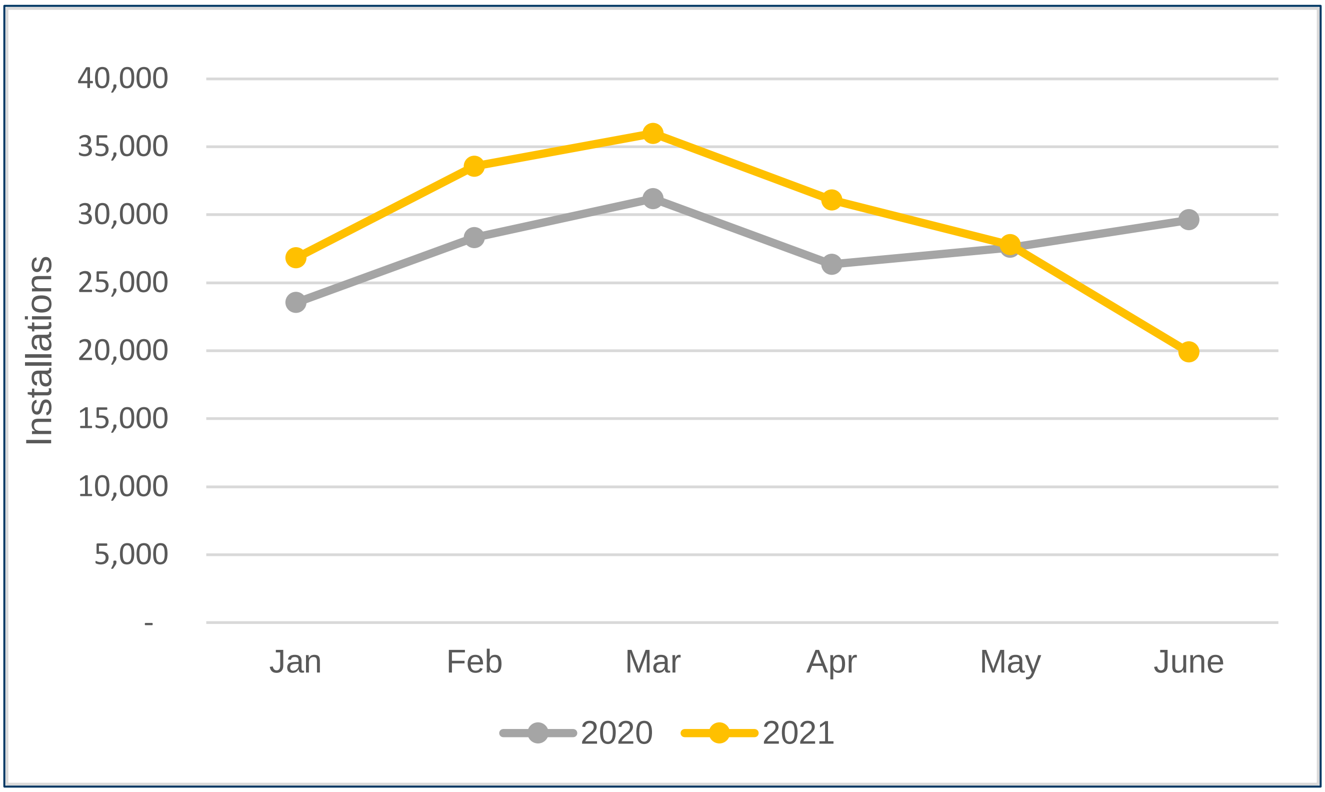


Figure 6 ***Comparison of residential PV installations, for first six months of 2021 with those of 2020 (Australia)***

Jurisdictional-level results are presented in Figure 7. Similar trends are observed for the jurisdictions with the largest installation demands, namely NSW, Victoria, Queensland and Western Australia. In addition, total-demand levels are lower for South Australia and Northern Territory. This supports our view that 2021 installation levels are likely to be lower than 2020 by the end of the year.

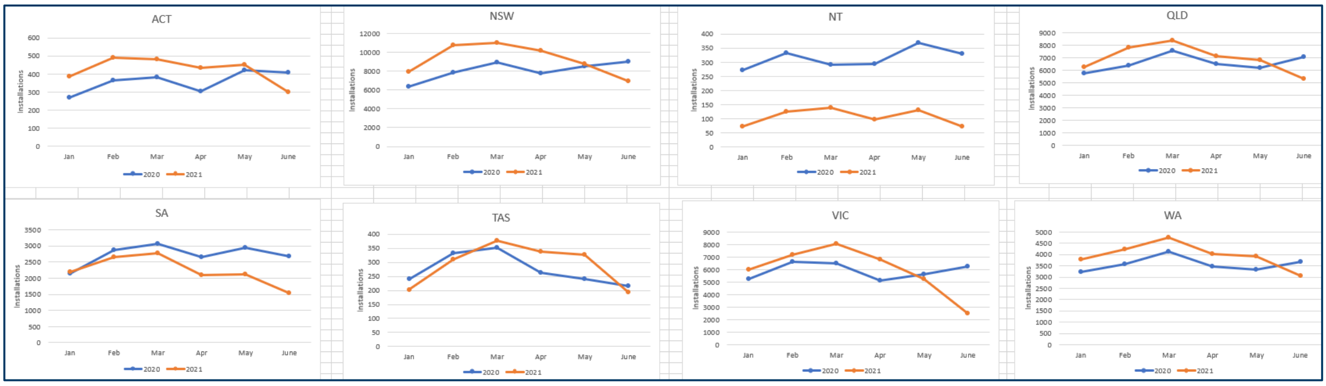


Figure 7 ***Comparison of residential PV installations, for first six months of 2021 with those of 2020 (by jurisdiction)***

Given the observations above, we sought to test our position by running a short-run model. We extrapolated historical monthly data for the most recent partial year (i.e., January 2021 to June 2021) to full year totals by examining seasonal patterns and trends in the data. We used an error, trend, seasonal (ETS)[36] model to perform the extrapolation. The ETS models did forecast that 2021 installation numbers would be lower than those of 2020. Accordingly, we consider it appropriate to retain our machine learning model's result for 2021.

[36] ETS models are a family of time series models with an underlying state space model consisting of a level component, a trend component (T), a seasonal component (S), and an error term (E). We also had considered using auto-regressive integrated moving average (ARIMA) models for the extrapolation. However, given the RMSE of the ETS model was lower than that of the ARIMA model, we used the ETS model to validate our findings.

3.2.2 Non-residential PV

Table 9 shows non-residential PV installation, capacity and STC forecasts.

Table 9 Non-residential PV installations, capacity, average system size and STC creation

Parameter	2020 (actual)	2021	2022	2023	2024	2025
Installations	15,524	13,786	13,734	13,658	13,612	13,528
Total capacity (MW)	566	497	488	482	481	479
Average system size (kW)	36.4	36.0	35.6	35.3	35.3	35.4
STC creation (‘000s)	7,997	6,282	5,560	4,876	4,262	3,642

Key observations on the non-residential PV forecasts are that:

– An 11.3% dip in installations is forecast for 2021, followed by a plateauing of demand over the rest of the modelling period. The total-capacity forecasts follow suit.

– Similar forecast growth rates for installation and capacity resulting in little change to the average system size of around 35 kW. This suggests that the demand for non-residential system size is price inelastic, appearing to be less responsive, compared with residential PV systems. However, the addition of just under 500 MW per year to non-residential PV capacity remains at a hefty growth rate. Apart from the potential financial benefits of installing PV, the feasibility of doing so for many businesses depends on, among other things, the type and area of roof and/or surrounding land availability.

– Similar to the installation and total-capacity numbers, STC-creation forecasts fall. However, they do so at a faster rate, due to the impact of the deeming factor.

3.2.3 Residential SWHs and ASHPs

Table 10 shows residential SWH and ASHP installation and STC forecasts.

Table 10 Residential SWHs and ASHPs installations and STC creation

Parameter	2020 (A)	2021	2022	2023	2024	2025
SWHs – installations	41,448	43,700	42,584	41,410	40,204	39,045
ASHPs – installations	32,903	23,397	24,292	25,187	26,082	26,977
SWH STC creation (‘000s)	1,202	1,272	1,240	1,205	1,170	1,136
ASHP STC creation (‘000s)	969	833	873	916	960	1,001

Key observations on the forecast residential SWH and ASHP forecasts are that:

– SWH installations are forecast to rebound in 2021 due to a strong housing market and the relative cost of competing technologies. This is because SWH installations reflect a mix of the needs of the ‘new building’ market and ‘replacement’ market. While the installation numbers for the replacement market fall, those for the new building market are growing strongly in 2021 (23% compared with 2020) due to high levels of new-housing demand. However, beyond 2021, we do not anticipate the building market numbers to be as strong as 2021, resulting in an overall decline. The average rate of decrease over 2021 to 2025 is 2.8% per annum. STC numbers follow suit.

– ASHP installations are forecast to drop sharply, by nearly 29% in 2021. This follows strong growth in 2020 when significant demand is brought forward from future years. Growth over the rest of the modelling is forecast to resume at approximately 3.6% per annum on average. STC numbers follow suit.

3.2.4 Non-residential SWHs and ASHPs

Table 11 shows the non-residential SWH and ASHP installation and STC forecasts.

Table 11 Non-residential SWHs and ASHPs installations and STC creation

Parameter	2020 (A)	2021	2022	2023	2024	2025
SWHs – installations	6	17	13	14	14	15
ASHPs – installations	3	12	12	12	12	12
SWH STC creation (‘000s)	1.1	2.1	1.6	1.6	1.6	1.9
ASHP STC creation (‘000s)	0.6	1.4	1.4	1.4	1.4	1.4

Key observations for non-residential SWH and ASHP demand is that the numbers are very small, albeit higher than the actuals observed in 2021. STC-creation numbers do not vary materially over the 2021 to 2025 period.

3.3 States/Territories small-scale forecasts

Key PV findings by States/Territory are summarised below.

Figure 8 shows the annual number of PV installations by State/Territory. In most cases, installations decrease in 2021 (compared with 2020), followed by single-digit percentage increases over the 2021 to 2025 period. Key exceptions are:

- Northern Territory, where installations decline continuously from 2019
- Queensland, where installations are higher in 2021 than 2020, and then continue to increase
- Tasmania, where per-annum growth from 2021 to 2025 is in the double-digit region.

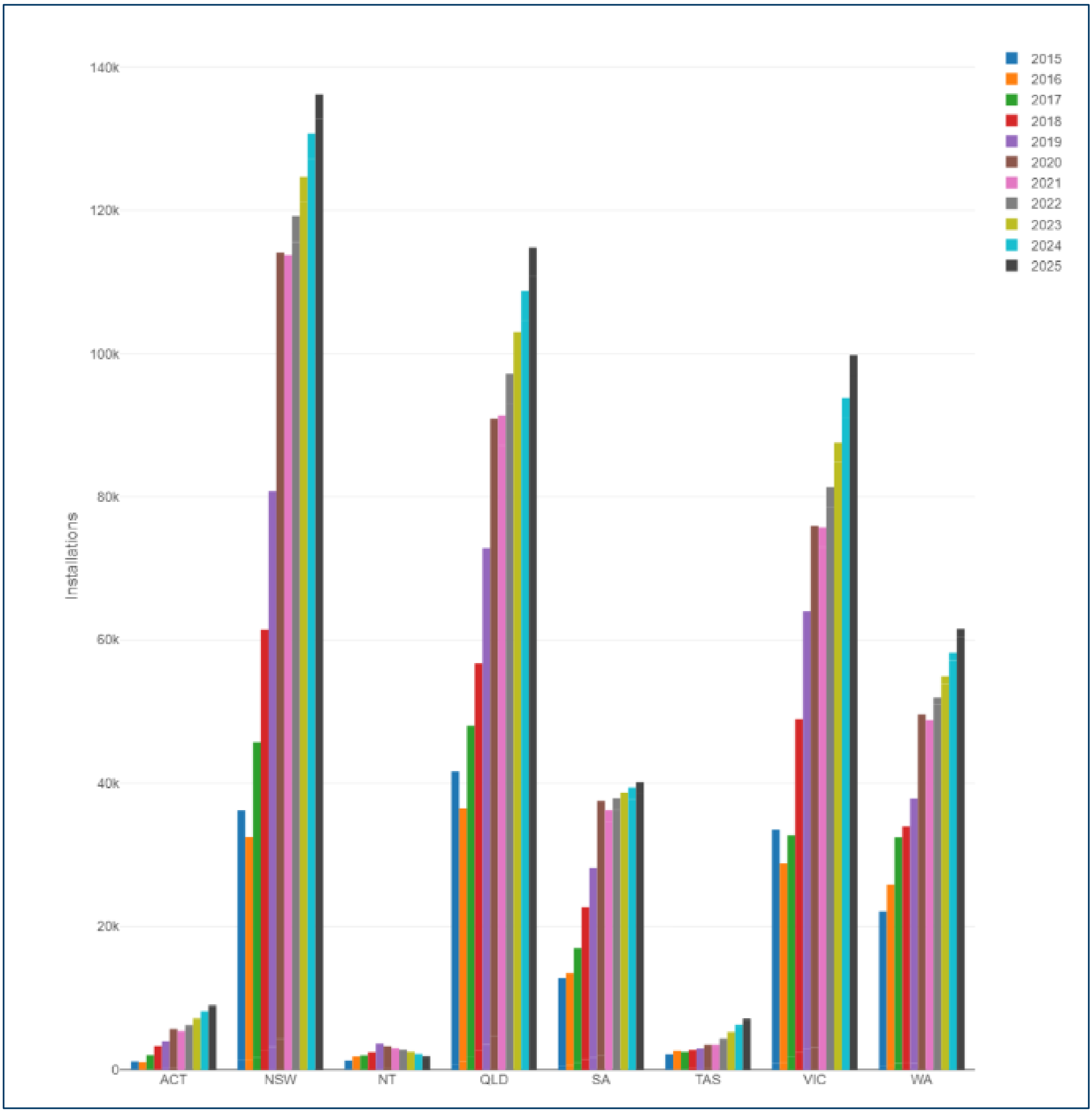


Figure 8 ***Annual number of small-scale installations by State/Territory***

Figure 9 shows the annual figures for PV capacity installed (MW) by State/Territory. Comparing the results from Figure 9 and Figure 8, we can infer that average system size is increasing (e.g., the gradient of Tasmanian capacity-installed figures over 2021 to 2025 is greater than that of installation numbers). This demonstrates the strong preference that consumers, in general, are having for larger PV systems to be installed.

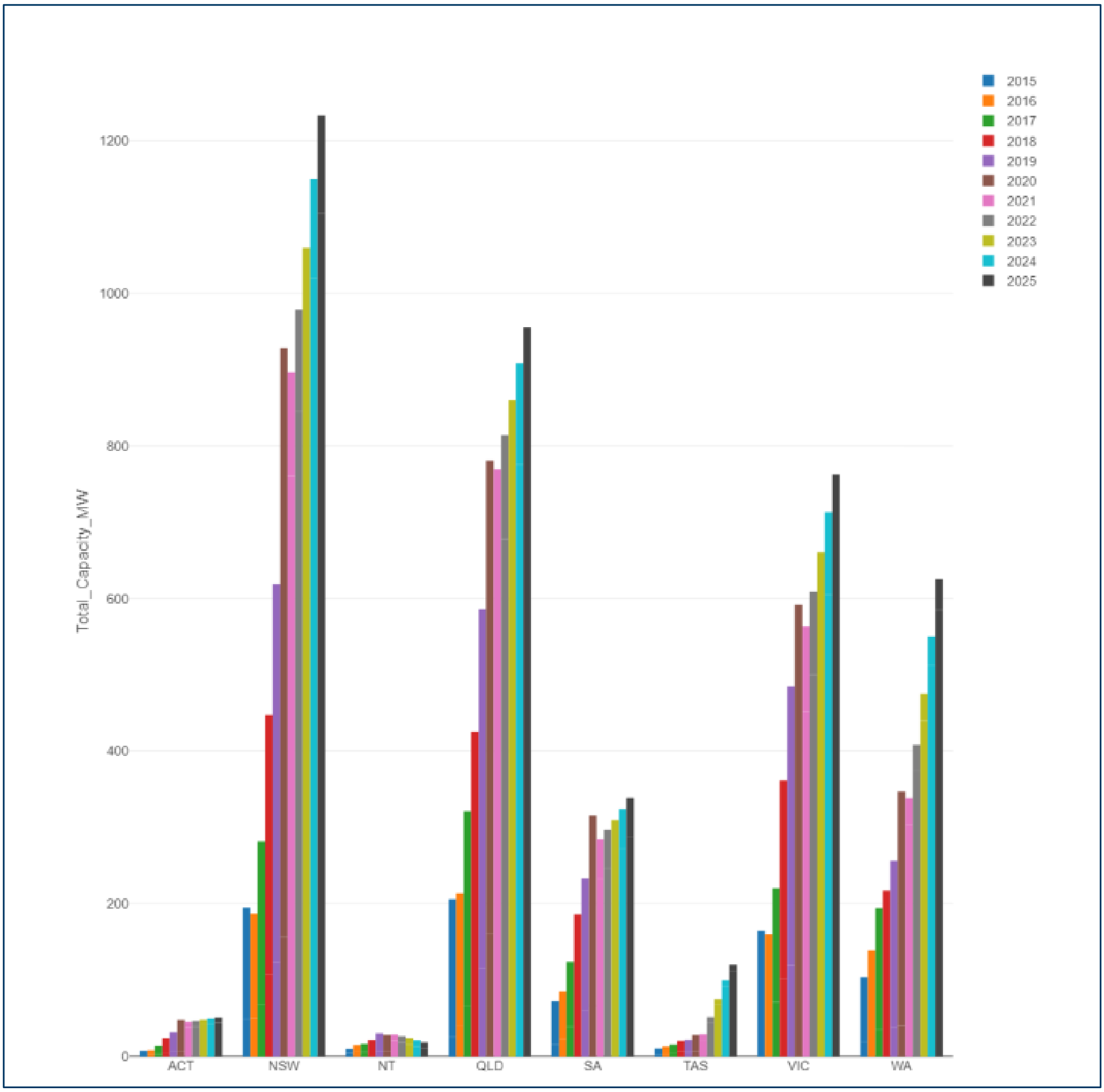


Figure 9 *Annual PV capacity installed (MW) by State/Territory*

Figure 10 shows the annual number of STCs approved ('000s) by State/Territory. It shows that, across the 2021-2025 modelling period, STC decreases are expected in all States/Territories except Tasmania and Western Australia. In particular, we observe that:

– STC growth persists in Tasmania across the 2021-25 period, albeit at a lower rate year to year
– An STC decrease occurs in 2021 in Western Australia, but is followed by growth up until 2024, before a small dip occurs in 2025.

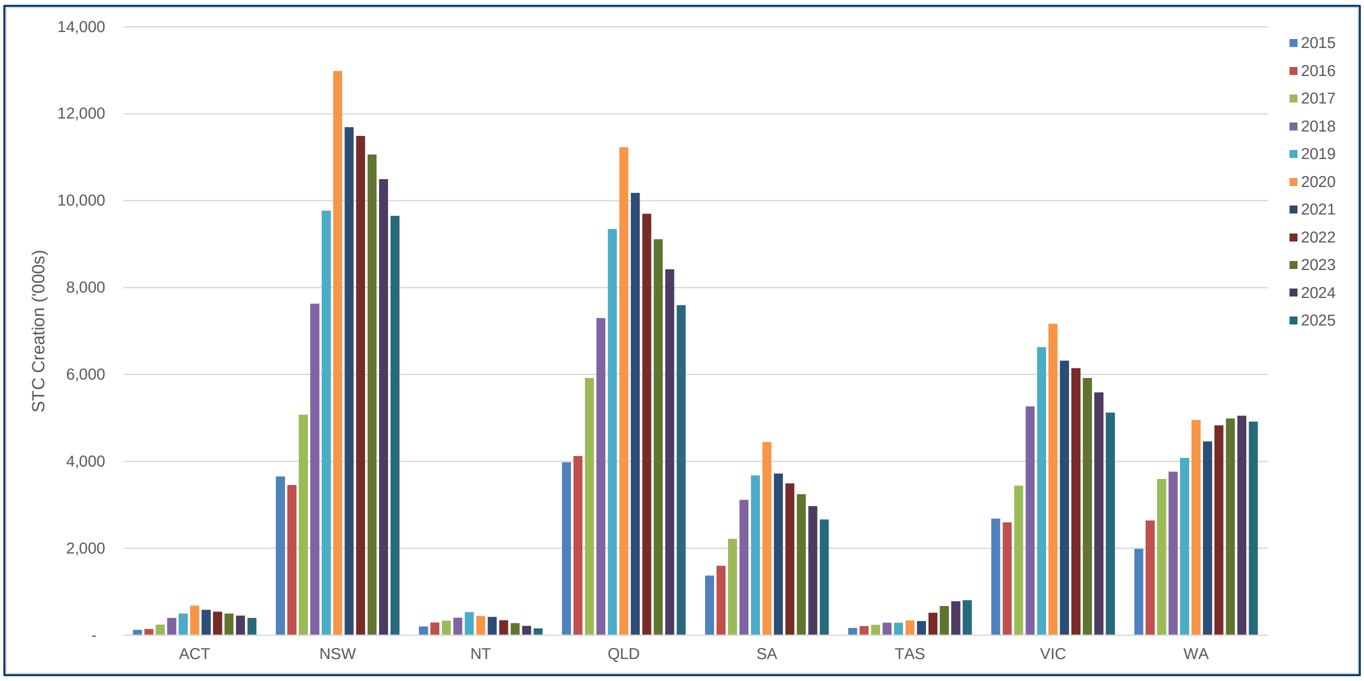


Figure 10 Annual PV STCs by State/Territory

Glossary

Acronym	Meaning
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AEMC	Australian Energy Market Commission
AER	Australian Bureau of Statistics
AI	Artificial Intelligence
ASGC	Australian Standard Geographical Classification
ARIMA	Auto-regressive integrated moving average
ASHP	Air Source Heat Pump
CER	Clean Energy Regulator
CoD	Coefficient of Determination
DEBS	Distributed energy buyback scheme (Western Australia)
ERP	Estimated Resident Population
ETS	Error, Trend & Seasonal
kWh	Kilowatt hour
LGC	Large-scale generation certificates
ML	Machine learning
MW	Megawatts
NSW	New South Wales
NT	Northern Territory
PV	Photo-voltaic
SA	South Australia / South Australian
SEIFA	Socio-economic Indexes for Areas
SGU	Small-scale generation units
SRES	Small-scale Renewable Energy Scheme
STC	Small-scale Technology Certificate
SWH	Solar water heater
W	Watt
WA	Western Australia / Western Australian

Appendix A

A-1 Detailed model description

A-1-1 Data collation

Residential solar PV and solar water heater data was received from CER and aggregated at postcode level from 2006-2016 data. Aggregated data was mapped to ABS dwelling and income data, representing dwelling and income characteristics for each postcode. Australia-wide and State/Territory-based incentives are included in the data in the form of payback period.

Non-residential solar PV and solar water heater data was utilised from 2014 forward, due to earlier data inconsistencies and less detailed data characteristics held in CER data.

For the 2021 analysis, there has been improvements in accuracy by taking a more granular approach.

- **Census Years:** We expand census data to be population by postcode and age group
- **Standardise Postcodes:** We adjust Postcodes since the POA codes and definitions changed for each census date. We use POA 2016 codes for all postcodes
- **Estimated Population:** For each year between 2001 and 2020 we used the ABS' Estimated Resident Population by age group and Statistical Area Level 2 (ABS_ERP_ASG2016). We used these as population numbers as at the end of June for their respective year.
- **SA2 to Postcode:** We then broke these estimate resident population from a SA2 level to Postcode level. This is based on a series of sophisticated mappings based on the Australian Standard Geographical Classification (ASGC). This provides us with annual populations by age and postcode from 2001 to 2020 inclusive. (2021 numbers yet to be released).
- **Projected Population:** ABS provides estimates on population by state, region and age group up to 2066 based on a range of assumptions. We have used these official numbers with the following assumptions:
  - Medium Fertility
  - Medium Life Expectancy
  - Medium Net Overseas Migration
  - Medium Interstate flows
  - Month: December
- **Region to Postcode:** we use the last known estimated resident population (June 2020) to determine the percentage of an age group and region to a particular postcode. This now gives us populations from 2001 to 2026 by age group and month (Census date are August, ERP in June and Projected in December).
- **Extrapolated Population by Month:** we then extrapolate the population by age group for every month from August 2001 through to December 2026 through the use min-max normalization statistical transformation. We use the previous known population and the next known population and the months difference between each one to calculation the change in population for each month.

The Median Household Income uses the same approach as Population with the following adjustments:

- We do not forecast changes to Median Household Income after the 2016 census date. We have chosen to repeat this value up to 2025. This is important as it provides mathematical and economic stability to the model outside of census years.

The SEIFA uses the same approach as Population with the following adjustments: We do not forecast changes to SEIFA after the 2016 census date. We have chosen to repeat this value up to 2025. This is important as it provides mathematical and economic stability to the model outside of census years.

Building approvals were extrapolated forward using two Machine Learning Models (Random Forest) to help in the extrapolation of months and forecasts to 2026. Model 1 forecast and extrapolated months between Jan 2020 and Jan 2023 accounting for short term trends associated with Covid and Natural disasters. Model 2 forecasted and extrapolated months between Jul 2021 and Dec 2026 accounting for long term trends.

Model 1 and 2 overlapped between Jul 2021 and Jan 2023. For this we developed a linear weighting system for each model where the weights equal 1. For model 1, Jul 2021 had a weight of 1 with each month decreasing in a linear way until Jan 2023 which has a weight of 0. Model 2 weight was 1 – Model 1 weight. For months Jul 2021 to Jan 2023 the final dwelling was equal to the following:

{Model 1 Weight} * {Model 1 Forecast} + {Model 2 Weight} * {Model 2 Forecast}

Once we had all building approvals forecasted, we then use these numbers to predict total number of dwellings. This was done through a separate Machine Learning (Random Forest) model.

Our ML models looked at a range of national indicators and found that out of the 151 National Indicators that we measured we used 42 in the small-scale models including Goods Debits (6), Services Credits (13), Services Debits (14) & Short Term Visitors (9).Those indicators utilised in the models are marked with an asterisk (*):

– Total Goods Debits – Current Prices in AUD $M for
    - Capital Goods
    - Capital Goods Not Elsewhere Specified (NES)
    - Household Electrical Items
    - Iron and Steel
    - Machinery and Industrial Equipment*
    - Other Parts for Capital Goods
    - Primary Industrial Supplies Not Elsewhere Specified (NES)*
    - Processed Industrial Supplies Not Elsewhere Specified (NES)*
    - Goods_Debits_Original_Current_Prices_AUD_Millions__Total_goods_debits

– Total Goods Debits – Seasonally Adjusted in AUD $M for
    - Capital Goods
    - Capital Goods Not Elsewhere Specified (NES)
    - Household Electrical Items
    - Iron and Steel
    - Machinery and Industrial Equipment*
    - Other Parts for Capital Goods
    - Primary Industrial Supplies Not Elsewhere Specified (NES)*
    - Processed Industrial Supplies Not Elsewhere Specified (NES)*
    - Goods_Debits_Original_Current_Prices_AUD_Millions__Total_goods_debits

– Services Credits – Current Prices in AUD $M for
    - Business travel*
    - Charges for the use of intellectual property n.i.e
    - Construction
    - Education-related personal travel*
    - Financial services
    - Freight transport*
    - Government goods and services n.i.e*
    - Gross inward insurance claims payable
    - Gross inward insurance premiums receivable
    - Insurance and pension services

- Other business services - Professional and management consulting*
  - Other business services - Research and development services*
  - Other business services - Technical trade related and other bus*
  - Other Business Services*
  - Other personal travel*
  - Other transport*
  - Passenger transport*
  - Personal travel
  - Personal, cultural and recreational services
  - Personal, cultural and recreational services - Other personal, c
  - Services
  - Telecommunications, computer and information services
  - Tourism related services
  - Transport*
  - Travel*
- Services Debits – Current Prices in AUD $M for
  - Business travel*
  - Charges for the use of intellectual property n.i.e.
  - Construction
  - Education-related personal travel*
  - Financial services
  - Freight transport*
  - Government goods and services n.i.e*
  - Gross outward insurance claims receivable
  - Gross outward insurance premiums payable
  - Insurance and pension services
  - Maintenance and repair services n.i.e
  - Manufacturing services on physical inputs owned by others
  - Other business services - Professional and management consulting*
  - Other business services - Research and development services*
  - Other business services - Technical, trade-related and other businesses*
  - Other business services*
  - Other personal travel*
  - Other transport*
  - Passenger transport*
  - Personal travel*
  - Personal, cultural and recreational services
  - Personal, cultural and recreational services - Other personal
  - Services
  - Telecommunications, computer and information services
  - Tourism related services
  - Transport*
  - Travel*

- Total Services – Seasonally Adjusted Prices in AUD $M for
  - Credits, Maintenance and repair services n.i.e
  - Credits, Manufacturing services on physical inputs owned by others
  - Debits, Maintenance and repair services n.i.e
  - Services credits
  - Services debits
- Number of Short Term Residents Returning for the following reasons:
  - Business*
  - Conference
  - Education
  - Employment
  - Holiday
  - Visiting_Friends
  - Other
  - Total
- Number of Short Term Visitors Arriving for the following reasons:
  - Business*
  - Conference*
  - Education*
  - Employment
  - Holiday*
  - Visiting Friends*
  - Other*
  - Total*

Economic Resources were defined by the Index of Commodity Prices 2021 (see Appendix A-2-5).

A-1-2 Data treatment

Factor data was normalised over a scale of 1-100, or percentage, in order to have factor compatibility and not over-weight one factor over another. Utilisation of percentage change over time periods from 2006-2011 and 2011-2016. Dwellings numbers in growth suburbs were clipped to represent the actual limit of the growth over time.

A-1-3 Modelling nuances

The model was trained on 2006-2011 and 2011 – 2016 dataset to predict installation and capacity changes to 2021 and 2026. Initial analysis and data review ensured an understanding of the correlated features in the data set, correlated features were removed.

Feature acceptance was by co-efficient of determination (i.e., CoD). In the area of prediction, the co-efficient of determination represents the strength of the feature's contribution to predicting the target outcome.

The balance of feature inclusion is against increasing model error. During validation testing, model feature addition with minimal model error is accepted. Features contributing substantially model error are removed.

Forecasting utilises these learnt coefficients of regions (postcode) with macro-economic coefficients to forecast installation and capacity.

A-2 Detailed data sources

The detailed data sources that we used, or referred to, in our analysis are set out below.

A-2-1 ABS dataset definition

We collated ABS census data at a postcode level for calendar years 2006, 2011 and 2016[37]. We also used data from other ABS sources. Table 12 sets out the descriptions of the ABS data we employed in our modelling.

Table 12 Description of ABS dataset information

Factors	Dataset	Description
Population	Population (Medium scenario)	Total number of persons per postcode
Age Distribution	Place of residence on census night by age	Number of people aged 55 or more
Median Household Income	Median total family income ($/week)	Median household income per postcode
Education Level	Non-School qualification: Level of education	Number of people with tertiary or more education qualification
Employment Status	LFHRP Labour Force	Number of people who are employed full time
Total Private Dwellings	STRD Dwelling Structure	Number of private dwellings per postcode
Dwelling Structure (Separate House)	STRD Dwelling Structure	Number of households with detached or semi-detached dwelling
Tenure Type (Owner)	TEND Tenure Type	Number of households that are owned outright or mortgage
Household Size (Dwelling Size)	BEDDRD Number of houses with 3 bed or more	Number of houses in postcode with more than 3 bedrooms
Family Household Composition	HCFMD Family Household Composition	Household Type per postcode (e.g., single person, couple)
Persons per Dwelling	NPRD Number of persons in dwelling	Number of persons per dwelling per postcode
National Economic Indicators	Various	Measure and estimate the impact of COVID-19 and associated downturn in the market

[37] The ABS 2021 Census has not yet been undertaken.

A-2-2 Solar prices – residential

Average solar prices for residential systems ($ per Watt basis) have been declining over the past decade (see Figure 11). In fact, from October 2020 onwards, prices have fallen below the $1 per Watt mark.

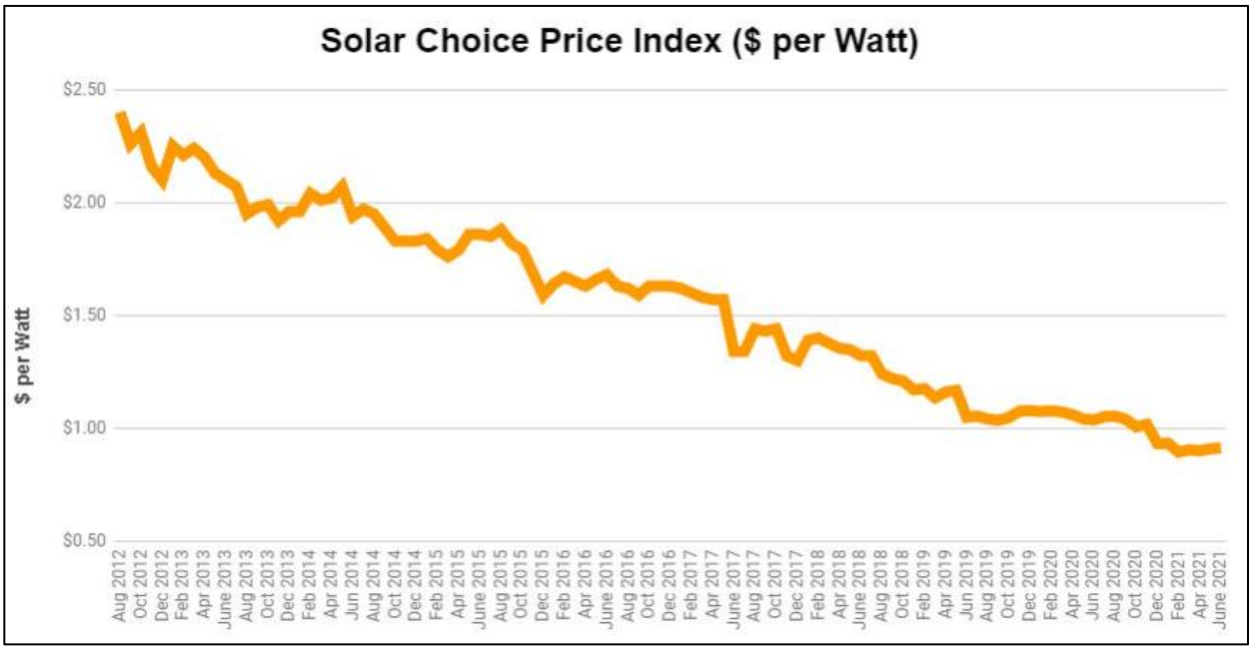


Figure 11 Solar prices for residential systems (source (as of 1 June 2021): https://www.solarchoice.net.au/blog/solar-power-system-prices)

A-2-3 Solar prices – non-residential

Average solar prices for non-residential systems ($ per Watt basis) have been declining over the past seven years (see Figure 12). As of May 2021, average prices for such systems across Australia are trending down towards the $1 per Watt mark, with some capital cities falling below the $1 per Watt mark.

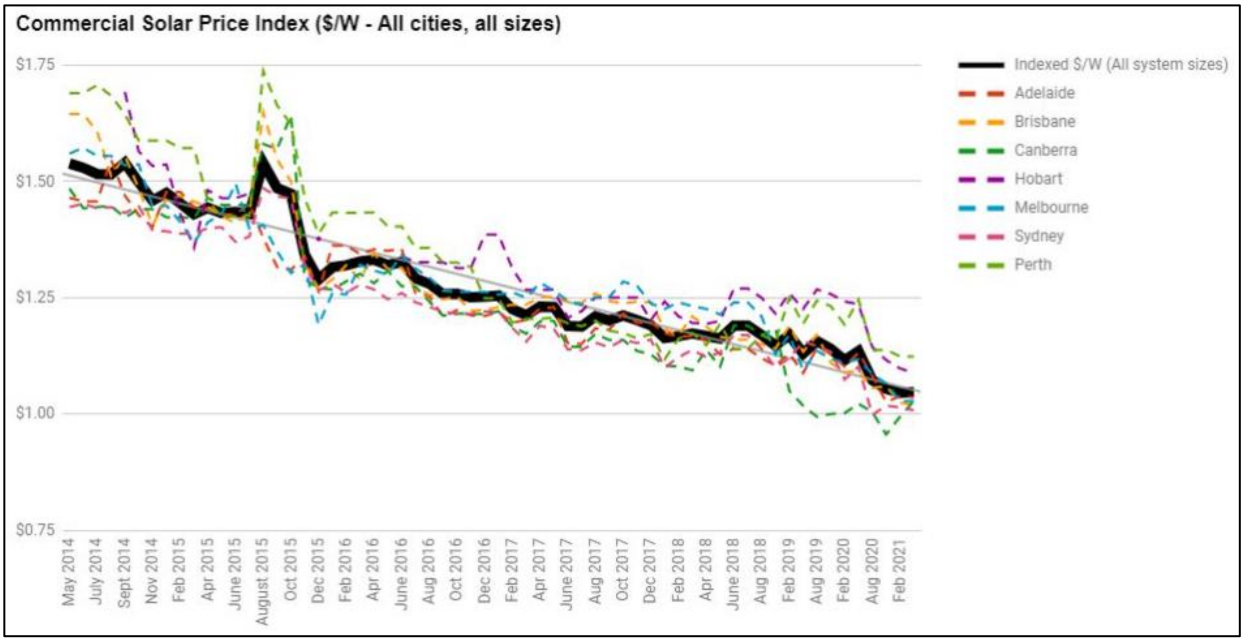


Figure 12 Solar prices for non-residential systems (source (as of 1 June 2021): https://www.solarchoice.net.au/commercial-solar-power-system-prices)

A-2-4 Average Large-scale Generation Certificate spot prices

Large-scale Generation Certificates (LGCs) arise when a power station has produced electricity generated from renewable sources, known as 'eligible electricity'. One LGC can be created per megawatt hour (MWh) of eligible electricity generated by a power station.[38]

We observe that LGC spot prices are forecast to drop sharply over the next five years (see Figure 13).

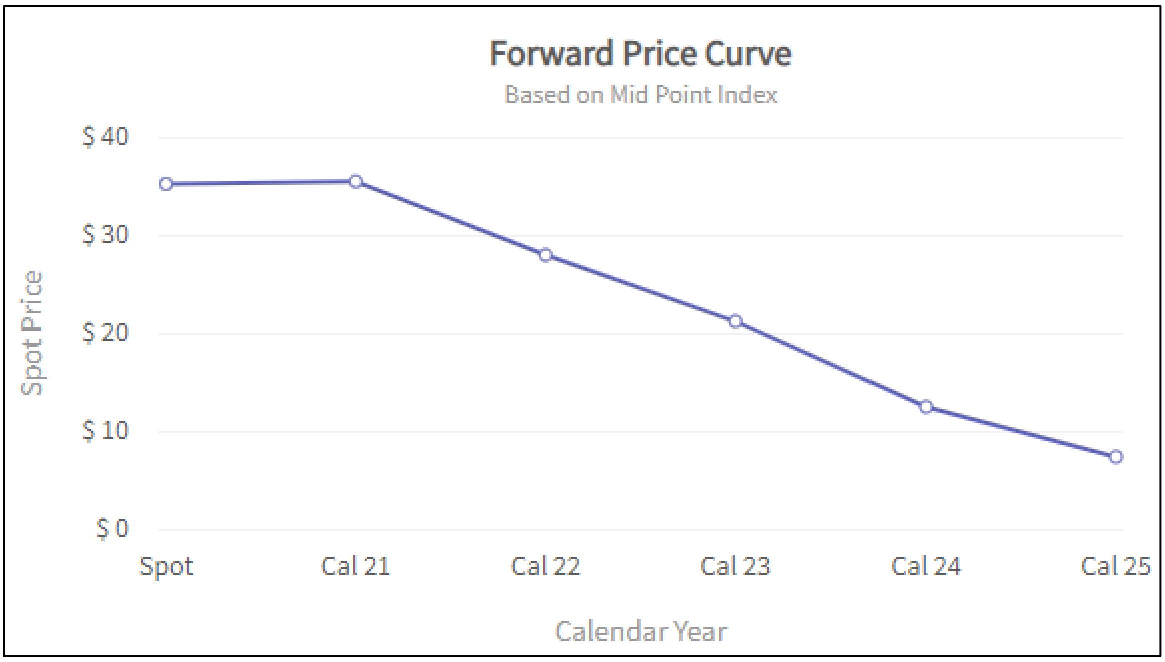


Figure 13 ***Forward price curve for LGCs (source (as of 1 June 2021): http://lgc.mercari.com.au/)***

A-2-5 Other data sources

Other data sources that we referred to during our analysis include:

- Historical cash RBA rates (since January 2001). We assumed cash rates would be retained at 0.1%.
- System costs value of STCs – Solar Choice https://www.solarchoice.net.au/blog/solar-power-system-prices
- Electricity consumption benchmarks – AER https://www.aer.gov.au/retail-markets/retail-guidelines-reviews/electricity-and-gas-bill-benchmarks-for-residential-customers-2017
- Electricity prices – AER $s https://www.aer.gov.au/retail-markets/retail-guidelines-reviews/retail-electricity-prices-review-determination-of-default-market-offer-prices-2020-21, ABS index (CPI table 9) https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6401.0June%202020?OpenDocument
- Solar generation profile (capacity and insolation)/typical average residential consumption profile: percentage export; and cost saving and export earnings
- Economic Resources - Index of Commodity Prices 2021 | RBA https://www.rba.gov.au/statistics/frequency/commodity-prices/2021/

[38] See http://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Power-stations/Large-scale-generation-certificates for more information.

A-3 Model construction

A-3-1 Solar PV and SWHs – residential assumptions

Factors listed in Table 13 for Solar PV uptake is based on the study undertaken by Queensland University of Technology – Residential customers and adoption of Solar PV. Other key points are that:

- Dwelling and Income characteristics from ABS is mapped to postcode level where possible. Postcodes where ABS data is not available is excluded from the model training dataset.
- Payback Period, as per Appendix A-2-5.
- Solar Installation Costs are taken from the Solar Choice website, reflecting average installation costs ($/Watt) of all residential capacity sizes.
- Electricity Costs, as per Appendix A-2-5.
- Economic Resources, as per Appendix A-2-5.

Table 13 Solar PV and SWH Residential Forecasting Factors

Fuel Source	Factors	*2021*	*2022*	*2023-2026*
Solar PV and SWH - Residential	State Postcode Population Separate House Owners Household Composition Electricity Price National Economic Indicator	As per notes in A-1-1	As per notes in A-1-1	As per notes in A-1-1
Solar PV and SWH - Residential	Education Economic Resources RBA Cash Rate	As per notes in A-1-1	As per notes in A-1-1	As per notes in A-1-1
Solar PV and SWH - Residential	Median Household Income %	-0.75 %	-1.25%	10%
Solar PV and SWH - Residential	Payback Period	4	3	3
Solar PV and SWH - Residential	Employment %	-6.15%	-0.75%	5%

A-3-2 Solar PV and SWHs – non-residential assumptions

The payback period for non-residential Solar PV (see Table 14) is assumed to be the same as residential Solar PV.

- Cost of solar installations ($/W) is taken from Solar Choice non-residential solar system prices (10 kW – 100 kW). Average solar system prices of all non-residential capacity sizes for each state are considered in the model
- Non-residential SWH projections are based on linear-regression trends due to insufficient data
- Number of non-residential buildings is taken from ABS data 8731.0 – Buildings Approvals, Australia.

*Table 14 Solar PV, Solar Water Heater – Non-residential Forecasting Factors**

Fuel Source	Factors	2021	2022	2023-2026
Solar PV – Non-residential	Cost of Installation ($/W)	-2%	-2%	-2%
Solar PV – Non-residential	Payback Period	4	3	3
Solar PV and SWH - Non-residential	Number of non-residential buildings	Unchanged	Unchanged	Unchanged

** Where a percentage or term 'unchanged' is mentioned, it is referenced from 2020 period.*

A-3-3 Relative contribution of factors in models

The following factors graphs show the relative importance of model features used in the various models.

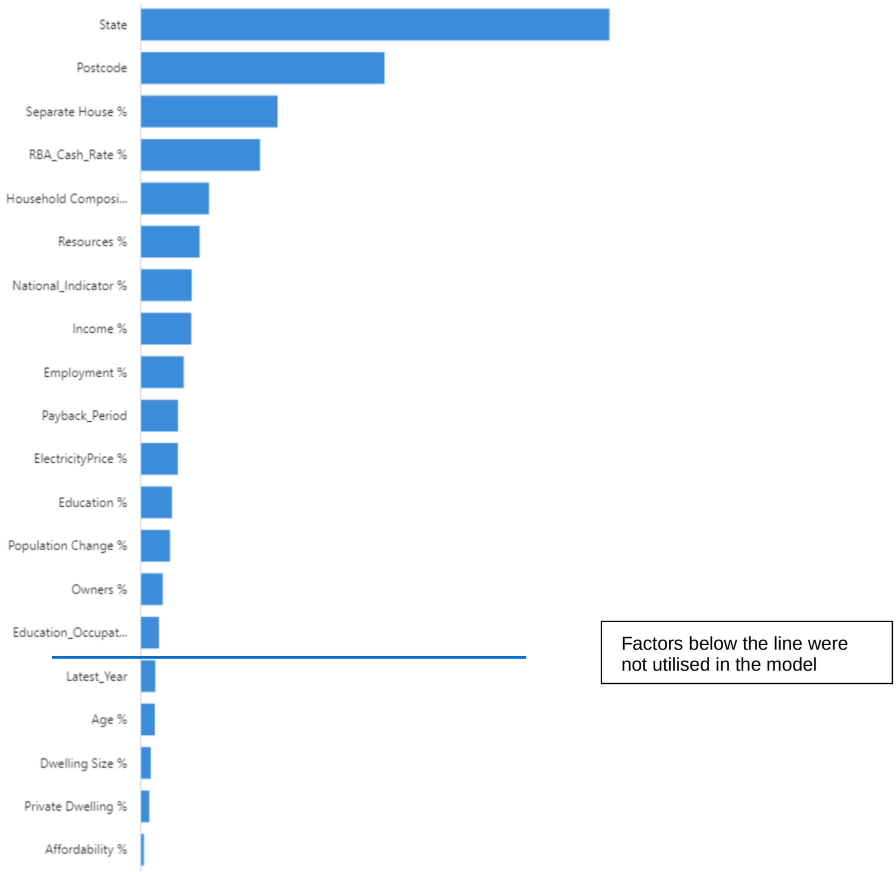


Figure 14 ***Solar PV: Residential installation model factor contribution***

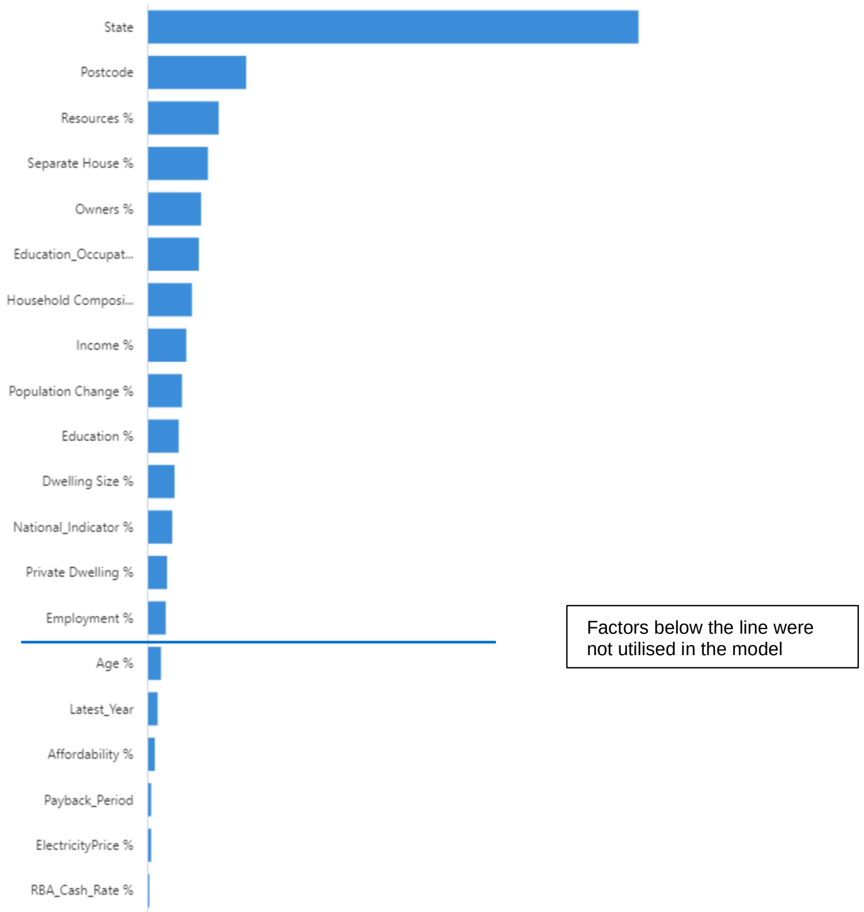


Figure 15 Solar PV: Residential capacity model factor contribution

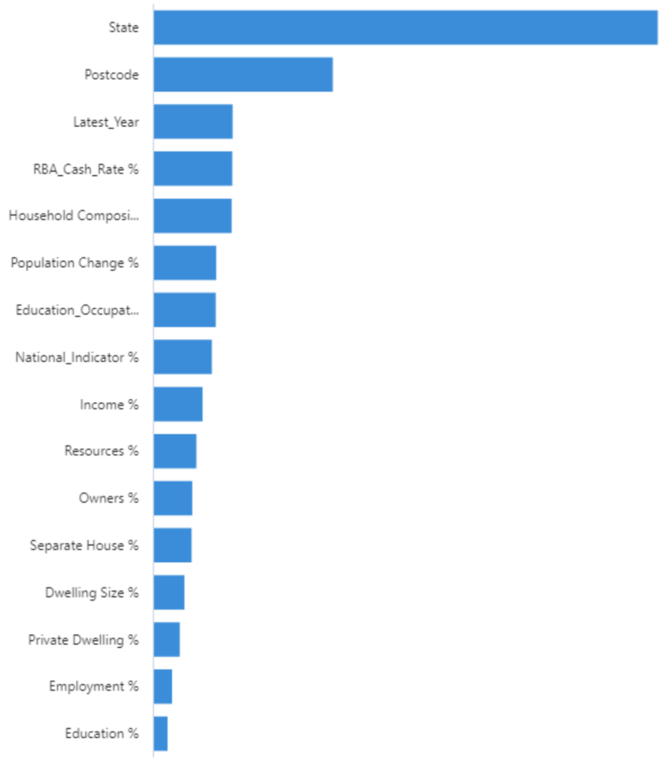


Figure 16 ***SWH: Residential new installation model factor contribution***

Note the contribution of Age and Electricity Price were negligible in this model

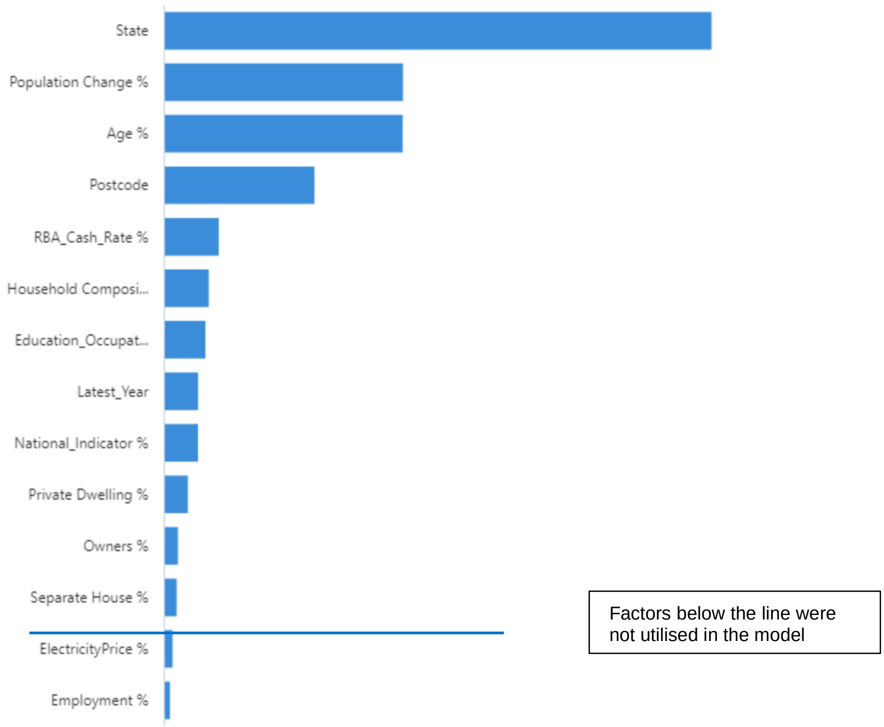


Figure 17 ***SWH: Residential replacement installation model factor contribution***

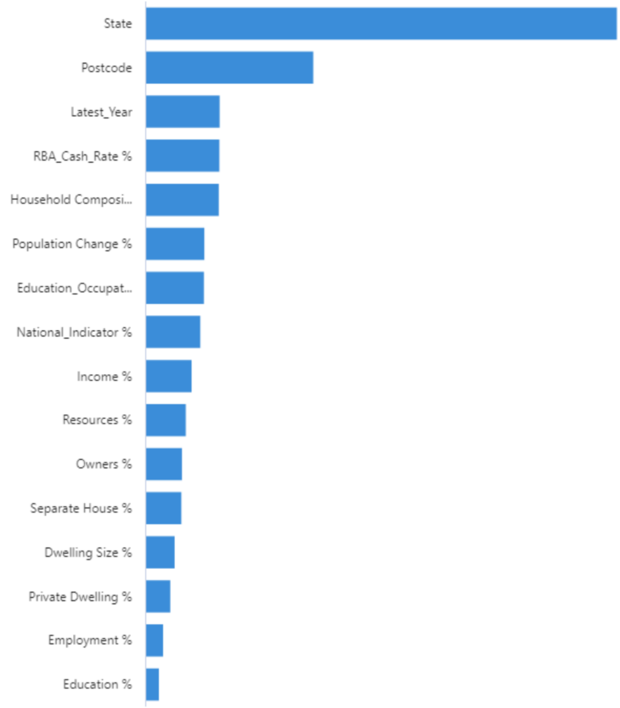
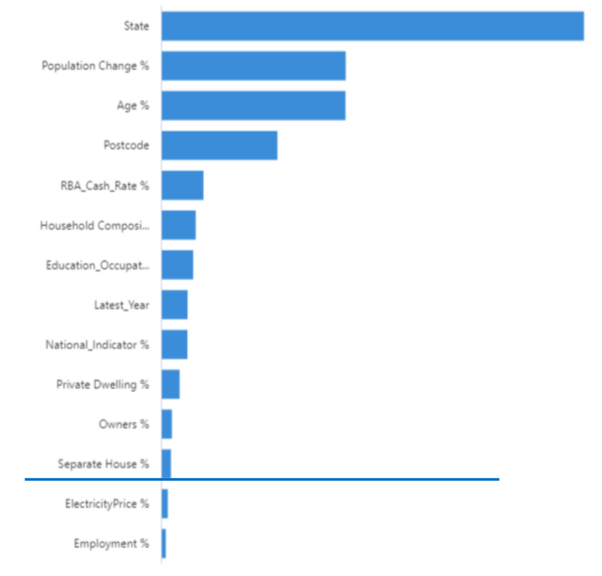


Figure 18 ASHP: Residential new installation model factor contribution



Factors below the line were not utilised in the model

Figure 19 ASHP: Residential replacement installation model factor contribution

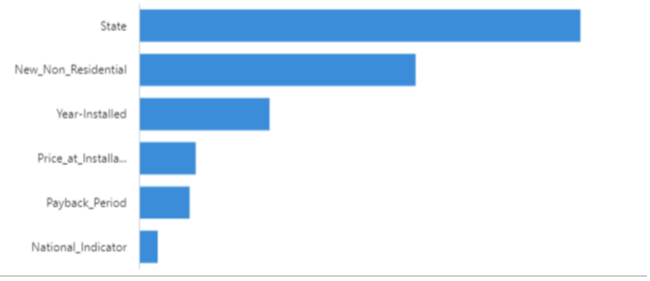


Figure 20 ***Solar PV: Commercial installation model factor contribution***

Figure 21 ***Solar PV: Commercial capacity model factor contribution***

A-3-4 Description of performance of preferred model

See Table 15 for our selected models for each technology types and customer type.

Table 15 ***Selected models for each technology type and customer type***

PARAMETER	SCALE	TYPE	FUEL SOURCE	MODEL	ROOT MEAN SQUARE ERROR (RMSE)	MEAN ABSOLUTE ERROR (MAE)	CoDs
INSTALLATION	Small Scale	Non-Residential	Solar Panels	Random Forest	464.6	306.77	0.94
			Solar Water Heater	CatBoost	25.69	11.39	0.65
			ASHP	CatBoost	19.35	13.07	0.22
		Residential	Solar Panels	Random Forest	135.95	45.76	0.63
			Solar Water Heater (New)	Random Forest	353.19	175.88	0.47
			Solar Water Heater (Replacement)	Random Forest	364.29	153.3	0.49
			ASHP (New)	Random Forest	353.19	175.88	0.47
			ASHP (Replacement)	Random Forest	364.29	153.3	0.49
CAPACITY	Small Scale	Non-Residential	Solar Panels	Random Forest	16.37	11.06	0.94
		Residential	Solar Panels	Random Forest	1689.25	963.3	0.59

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