



# STC forecasts for 2021-2025

## Report

Clean Energy Regulator

23 December 2021

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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.*

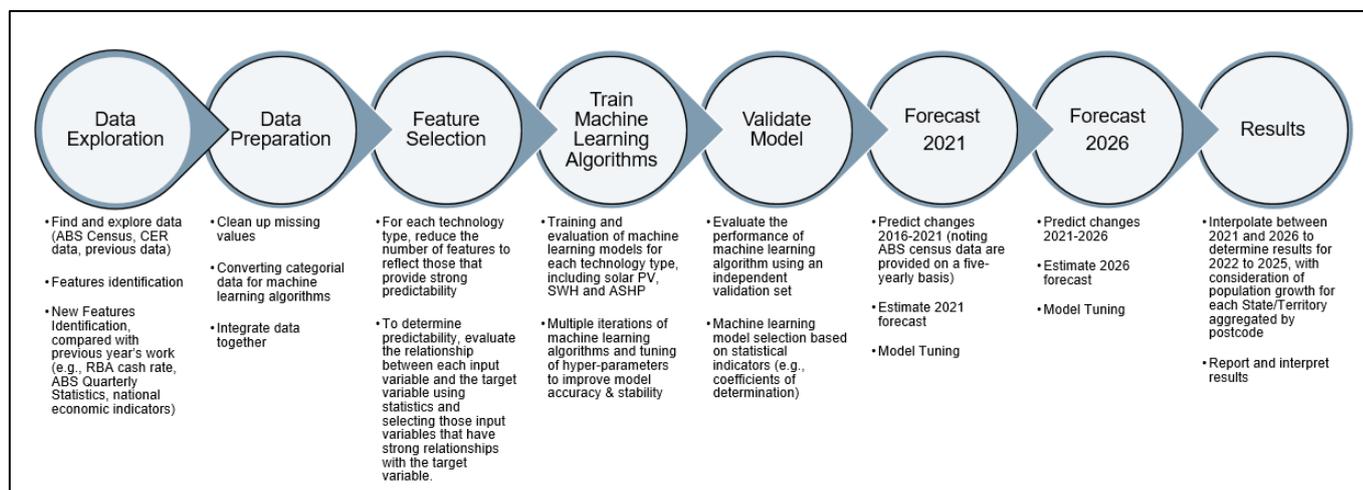
The Clean Energy Regulator (CER) engaged GHD (us) to advise on the preparation of forecasts for small-scale technology certificates (STCs) created under the Australian Government’s Small-scale Renewable Energy Scheme (SRES).<sup>1</sup> STCs are produced when eligible small-scale renewable energy systems 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 Renewable Energy Certificate Registry, over the 2021 to 2025 period<sup>2</sup>. The forecasts are provided for each State/Territory (i.e., jurisdiction), as well as for Australia, 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.

<sup>1</sup> 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>

<sup>2</sup> 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. While installation growth happens in each year of the 2021-2025 period (as installation costs continue to become more affordable and the population and number of houses grows), the rate is not as strong in 2021, evidencing the moderation in demand growth in the 2020 vs 2021 year. The decline that is forecast for non-residential installations follows a period of exceptionally strong growth, while the greater commercial opportunity lies with systems greater than 100 kW.

Overall, we project that the number of STCs that are eligible for creation each year will consistently fall due to the declining deeming factor<sup>3</sup> for PV systems, which is only partially offset by growth in new PV 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 | 2021    | 2022    | 2023    | 2024    | 2025    |
|-------------------------|-----------------|---------|---------|---------|---------|---------|
| Systems installed       | PV              | 391,921 | 405,801 | 419,873 | 434,646 | 448,983 |
|                         | SWHs            | 43,793  | 42,668  | 41,494  | 40,288  | 39,129  |
|                         | ASHPs           | 23,471  | 24,334  | 25,229  | 26,124  | 27,019  |
| Total capacity (MW)     | PV              | 3,087   | 3,521   | 3,801   | 4,101   | 4,390   |
| STC eligibility ('000s) | PV              | 42,527  | 40,338  | 38,670  | 36,486  | 33,467  |
|                         | SWHs            | 1,769   | 1,242   | 1,207   | 1,172   | 1,137   |
|                         | ASHPs           | 1,204   | 858     | 881     | 908     | 936     |
|                         | Total           | 45,500  | 42,438  | 40,758  | 38,566  | 35,540  |

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.

<sup>3</sup> 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, new PV systems 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.

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

| Parameter            | Customer Type   | 2021    | 2022    | 2023    | 2024    | 2025    |
|----------------------|-----------------|---------|---------|---------|---------|---------|
| Systems installed    | Residential     | 378,048 | 391,947 | 406,155 | 420,939 | 435,334 |
|                      | Non-residential | 13,873  | 13,854  | 13,718  | 13,707  | 13,649  |
|                      | Total           | 391,921 | 405,801 | 419,873 | 434,646 | 448,983 |
| Total capacity (MW)  | Residential     | 2,748   | 3,031   | 3,317   | 3,619   | 3,909   |
|                      | Non-residential | 495     | 490     | 484     | 482     | 482     |
|                      | Total           | 3,243   | 3,521   | 3,801   | 4,101   | 4,390   |
| STC creation ('000s) | Residential     | 35,056  | 34,764  | 33,775  | 32,214  | 29,805  |
|                      | Non-residential | 6,256   | 5,573   | 4,896   | 4,272   | 3,662   |
|                      | Total           | 41,312  | 40,338  | 38,670  | 36,486  | 33,467  |
| Deeming period       | n/a             | 10      | 9       | 8       | 7       | 6       |

Residential PV installations and capacity grow over the 2021-2025 modelling period. In comparison, non-residential installations are forecast to fall in 2021 and then stay relatively constant, suggesting that some market saturation in the non-residential sector is taking place. STC-creation 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.

### **PV installations**

Figure 2 shows the annual number of PV installations by State/Territory. In most cases, installations increase over the 2021 to 2025 period, at approximately 5% per annum. Key exceptions are:

- Northern Territory, where installations decline continuously from 2020
- South Australia, where installations are flat
- ACT and Tasmania, where per-annum growth from 2021 to 2025 is mostly in the double-digit region.

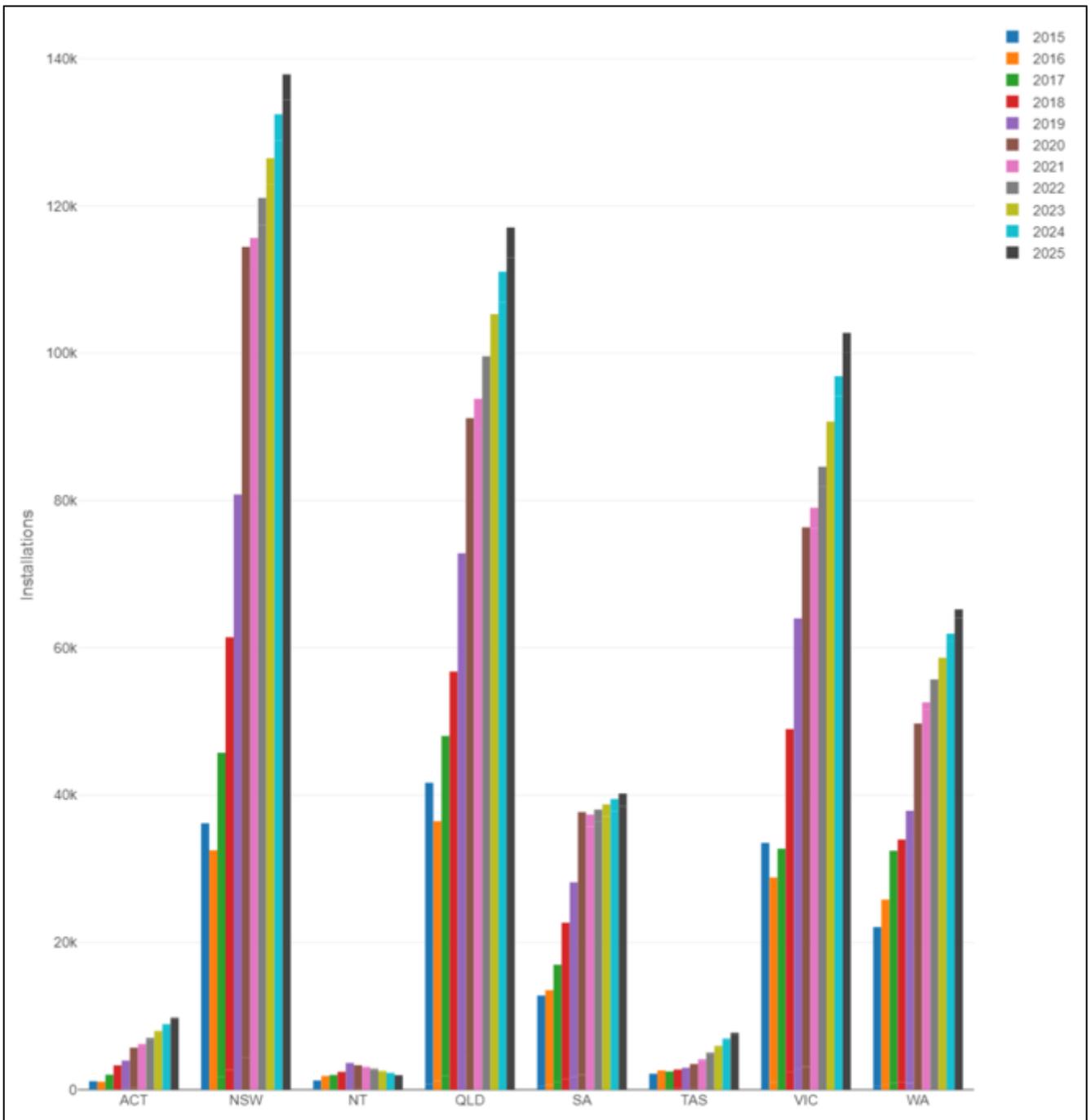


Figure 2 Annual number of small-scale installations by State/Territory

### PV capacity

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, and the gradient of the NT figures is much less steep than the decline in installation numbers). This demonstrates the strong preference that residential consumers are having for larger PV systems to be installed.

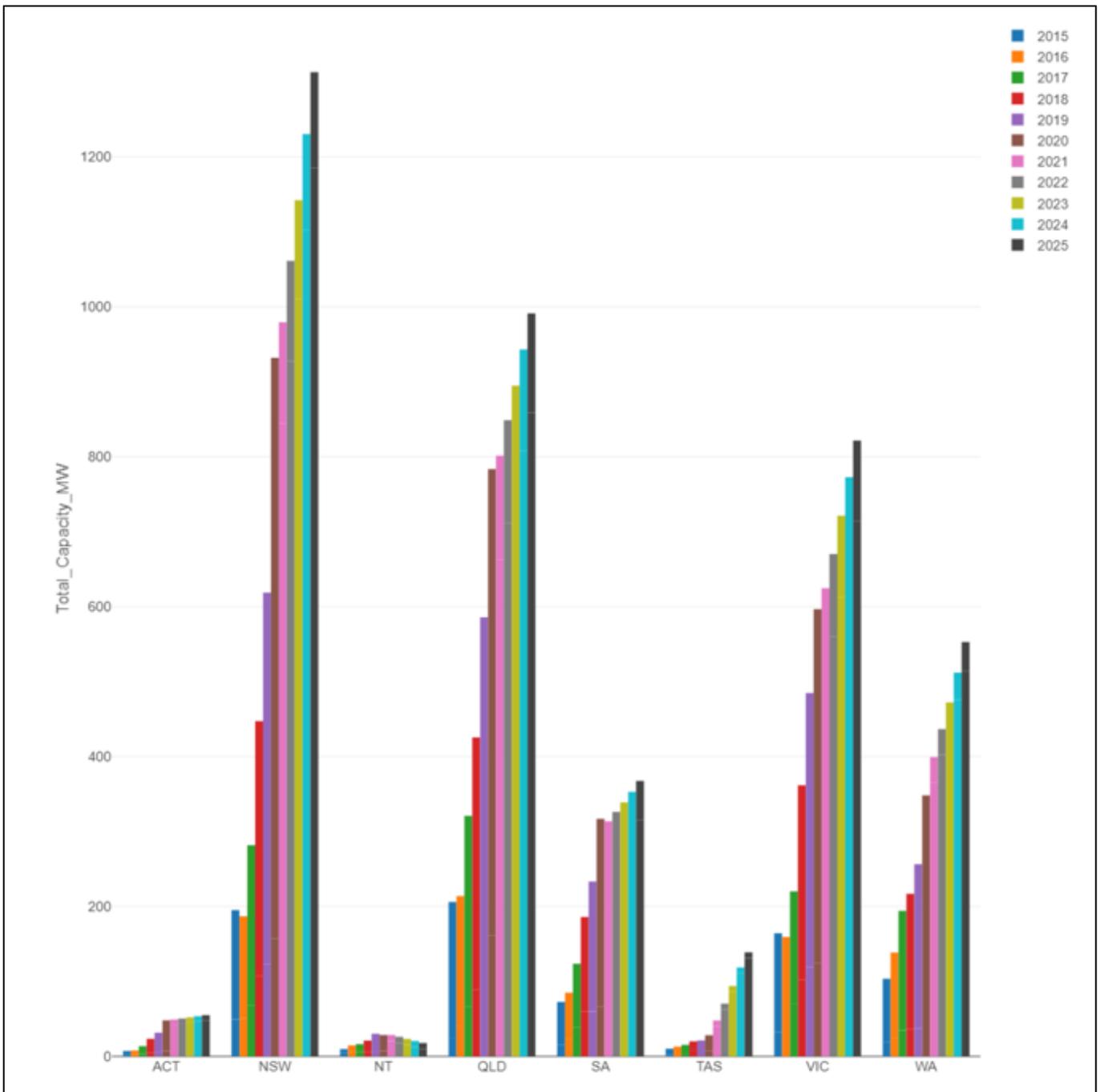


Figure 3 Annual PV capacity installed (MW) by State/Territory

### STC creation

Table 3 shows the annual number of PV-system STCs projected to be created ('000s) by State/Territory, divided by residential and non-residential sectors.

**Table 3** *STC creation ('000s) by jurisdiction (2022 to 2025) for PV systems*

| <b>Year</b>    | <b>2022</b> | <b>2023</b> | <b>2024</b> | <b>2025</b> |
|----------------|-------------|-------------|-------------|-------------|
| ACT            | 520         | 480         | 434         | 384         |
| NSW            | 10,887      | 10,546      | 10,064      | 9,278       |
| NT             | 223         | 166         | 118         | 77          |
| QLD            | 8,520       | 8,090       | 7,530       | 6,861       |
| SA             | 3,287       | 3,062       | 2,802       | 2,512       |
| TAS            | 629         | 771         | 868         | 880         |
| VIC            | 5,617       | 5,457       | 5,181       | 4,773       |
| WA             | 5,081       | 5,203       | 5,216       | 5,040       |
| ACT            | 74          | 68          | 59          | 51          |
| NSW            | 1,578       | 1,377       | 1,190       | 1,018       |
| NT             | 106         | 93          | 81          | 70          |
| QLD            | 1,578       | 1,376       | 1,199       | 1,011       |
| SA             | 556         | 492         | 435         | 379         |
| TAS            | 84          | 74          | 65          | 55          |
| VIC            | 1,137       | 1,000       | 868         | 739         |
| WA             | 461         | 416         | 375         | 340         |
| Australia      | 40,338      | 38,670      | 36,486      | 33,467      |
| Deeming period | 9           | 8           | 7           | 6           |

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# Appendices

Appendix A

# 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<sup>4</sup> 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.<sup>5</sup> 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<sup>6</sup>, 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<sup>7</sup>. 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.

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<sup>4</sup> 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.

<sup>5</sup> 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>

<sup>6</sup> As the forecasts for SWHs and ASHPs have shown diff

<sup>7</sup> 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 structured 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 4.

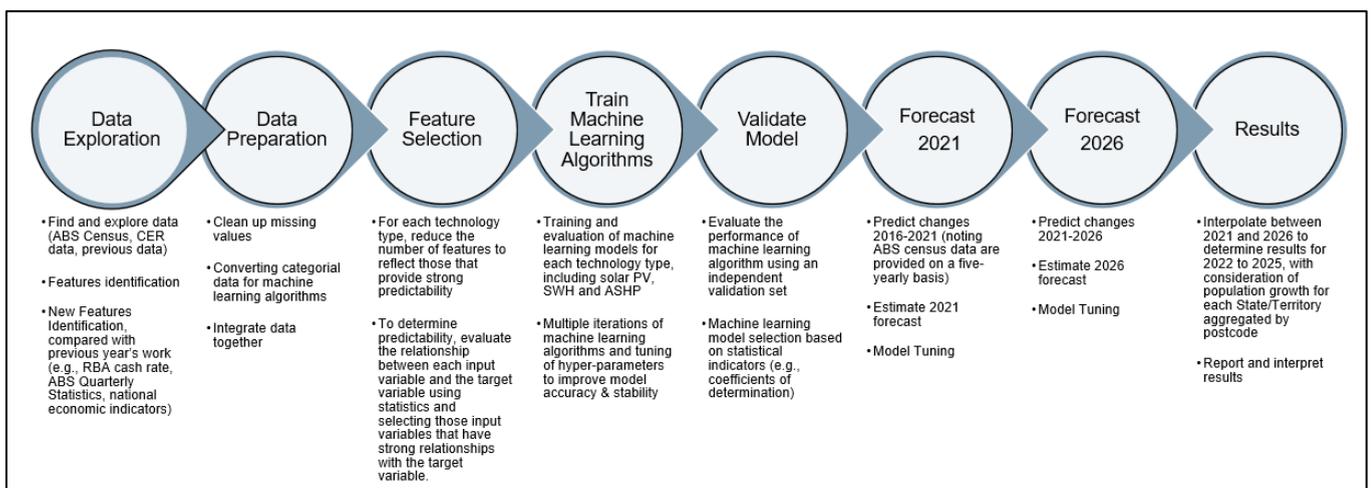


Figure 4 GHD’s modelling process for determining small-scale installations and capacity forecasts

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 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 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 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 5. 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 5** 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<sup>8</sup> 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 (which accounts for STC discounts) 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.<sup>9</sup> 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.

<sup>8</sup> For example, Sommerfeld, J. (2016) Residential Customers and Adoption of Solar PV, PhD thesis, Queensland University of Technology School of Design, Brisbane.

<sup>9</sup> 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. 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 published a rule determination allowing distribution network service providers to charge for solar exports to the grid<sup>10</sup>, 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.<sup>11</sup> 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

<sup>10</sup> <https://www.aemc.gov.au/rule-changes/allowing-dnsps-charge-exports-network>.

<sup>11</sup> 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.<sup>12</sup> 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.<sup>13</sup>

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 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.<sup>14</sup> 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.<sup>15</sup>

### 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).<sup>16</sup>

### 2.5.2.5 Victoria

The Solar Homes Program solar PV rebate assists eligible Victorian households and rental property owners to install solar panels.<sup>17</sup> 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.<sup>18</sup> 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.<sup>19</sup>

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 6). These are time-of-use driven, rather than a flat-fee arrangement.

**Table 6** 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                  |
| Shoulder | 7 am to 3 pm, 9 pm to 10 pm | 7 am to 10 pm | 9.8                  |

<sup>12</sup> See <https://homebatteryscheme.sa.gov.au/about-the-scheme>

<sup>13</sup> See <https://www.cityofadelaide.com.au/about-council/grants-sponsorship-incentives/sustainability-incentives-scheme/>

<sup>14</sup> See <https://businessnt.smartygrants.com.au/homeandbusinessbatteryscheme>

<sup>15</sup> See <https://www.solarquotes.com.au/systems/feed-in-tariffs/nt/>

<sup>16</sup> See <https://www.economicregulator.tas.gov.au/electricity/pricing/feed-in-tariffs>

<sup>17</sup> See <https://www.energy.gov.au/rebates/solar-pv-panel-rebate#:~:text=The%20program%20provides%20eligible%20Victorian,average%204kW%20solar%20PV%20system.>

<sup>18</sup> See <https://www.solar.vic.gov.au/solar-battery-rebate>

<sup>19</sup> See <https://www.solar.vic.gov.au/solar-hot-water-rebate>

| Period | Weekday      | Weekend | Rate (cents per kWh) |
|--------|--------------|---------|----------------------|
| 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.<sup>20</sup> 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.<sup>21</sup>

### 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.<sup>22</sup> 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.<sup>23,24</sup> 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 7 and Table 8; these features were used to produce our results. The relative importance (ordinal, not cardinal) of the features is explained in Appendix A-3-3.

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.

<sup>20</sup> See <https://energysaver.nsw.gov.au/households/solar-and-battery-power/empowering-homes-solar-battery-loan-offer>

<sup>21</sup> See <https://energysaver.nsw.gov.au/households/solar-and-battery-power/feed-tariff-rates>

<sup>22</sup> See <https://www.actsmart.act.gov.au/what-can-i-do/homes/sustainable-household-scheme>

<sup>23</sup> See <https://www.qca.org.au/project/customers/solar-feed-in-tariffs/regional-queensland-feed-in-tariff-2020-21/>

<sup>24</sup> See <https://www.qca.org.au/project/customers/solar-feed-in-tariffs/regional-queensland-solar-feed-in-tariff-2021-22/>

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 initially considered is provided in Appendix A-1-1.

**Table 7** 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   |
|                              |                          | State                          |
| Postcode                     |                          |                                |
| Solar PV                     | Residential Capacity     | Population                     |
|                              |                          | Separate House                 |
|                              |                          | Owners                         |
|                              |                          | Household Composition          |
|                              |                          | Education                      |
|                              |                          | Employment                     |
|                              |                          | Income                         |
|                              |                          | National Economic Indicators   |
|                              |                          | Private Dwelling               |
|                              |                          | Resources                      |
|                              |                          | State                          |
|                              |                          | Postcode                       |
|                              |                          | SWHs                           |
| RBA Cash Rate                |                          |                                |
| Household Composition        |                          |                                |
| Education                    |                          |                                |
| National Economic Indicators |                          |                                |
| Income                       |                          |                                |
| Resources                    |                          |                                |
| Owners                       |                          |                                |
| Separate Houses              |                          |                                |
| Dwelling Size                |                          |                                |
| Private Dwellings            |                          |                                |

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

Table 8 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<br>Year Installed<br>Cost of Solar Installation<br>Number of Non-Residential Buildings<br>Payback Period<br>National Economic Indicators |
| Solar PV           | Non-Residential Capacity             | State<br>Year Installed<br>Cost of Solar Installation<br>Number of Non-Residential Buildings<br>Payback Period                                 |
| SWHs <sup>25</sup> | SWHs – Non-Residential <sup>26</sup> | State<br>Year Installed<br>Number of Non-Residential Buildings<br>Payback Period<br>National Economic Indicators                               |
| ASHP               | ASHPs - Non-residential              | State<br>Year Installed<br>Number of Non-Residential Buildings<br>Payback Period<br>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.
- **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 mentioned 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<sup>2</sup> and RMSE scores:

- **R Squared (R<sup>2</sup>):** 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.

<sup>25</sup> SWHs and ASHP were modelled separately, for both residential and non-residential sectors for replacement and new building segments.

<sup>26</sup> SWH non-residential data were very sparse, making it difficult to determine trends with a robust CoD.

- **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.<sup>27</sup> 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 0.62) and ASHPs (CoD of 0.52). 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.

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.

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

## 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 have 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 be 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 debits
- 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.<sup>28</sup>

## 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<sup>29</sup>. We reviewed published information addressing future residential electricity price trends over the 2021 to 2025 period, including AEMC<sup>30</sup> and the WA Government<sup>31</sup> and acknowledge that variable

<sup>28</sup> See <https://www.rba.gov.au/media-releases/2021/mr-21-13.html>

<sup>29</sup> Australian Bureau of Statistics, Consumer Price Index, 6401.0, Quarterly, Table 9.

<sup>30</sup> AEMC (2020) Residential Electricity Price Trends, <https://www.aemc.gov.au/market-reviews-advice/residential-electricity-price-trends-2020>.

<sup>31</sup> Western Australian Budget 2020-21. The WA Government announced an electricity price freeze for 2020-21.

electricity rates<sup>32</sup> 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<sup>33</sup>
- 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.

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<sup>32</sup> Changes in variable electricity tariffs with fixed components remaining the same will result in lower overall changes in average electricity costs.

<sup>33</sup> 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.

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. While installation growth happens in each year of the 2021-2025 period (as installation costs continue to become more affordable and the population and number of houses grows), the rate is not as strong in 2021, evidencing the moderation in demand growth in the 2020 vs 2021 year. The decline that is forecast for non-residential installations follows a period of exceptionally strong growth, while the greater commercial opportunity lies with systems greater than 100 kW.

Overall, we project that the number of STCs that are eligible for creation each year will consistently fall due to the declining deeming factor<sup>34</sup> for PV systems, which is only partially offset by growth in new PV capacity.

### 3.2 Australia-wide small-scale technology forecasts

Our key findings by technology type are summarised in Table 9.

*Table 9 Systems installed, total capacity and STC creation – by technology type (2021 to 2025)*

| Parameter               | Technology type | 2021    | 2022    | 2023    | 2024    | 2025    |
|-------------------------|-----------------|---------|---------|---------|---------|---------|
| Systems installed       | PV              | 391,921 | 405,801 | 419,873 | 434,646 | 448,983 |
|                         | SWHs            | 43,793  | 42,668  | 41,494  | 40,288  | 39,129  |
|                         | ASHPs           | 23,471  | 24,334  | 25,229  | 26,124  | 27,019  |
| Total capacity (MW)     | PV              | 3,087   | 3,521   | 3,801   | 4,101   | 4,390   |
| STC eligibility ('000s) | PV              | 42,527  | 40,338  | 38,670  | 36,486  | 33,467  |
|                         | SWHs            | 1,769   | 1,242   | 1,207   | 1,172   | 1,137   |
|                         | ASHPs           | 1,204   | 858     | 881     | 908     | 936     |
|                         | Total           | 45,500  | 42,438  | 40,758  | 38,566  | 35,540  |

Our key findings by customer type for PV systems are summarised in Table 10. The residential capacity band reflects 15 kW or less, while the non-residential capacity band reflects above 15 kW but lower than 100 kW.

<sup>34</sup> 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, new PV systems 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.

**Table 10** Systems installed, total capacity and STC creation for PV systems – by customer type (2021 to 2025)

| Parameter            | Customer Type   | 2021    | 2022    | 2023    | 2024    | 2025    |
|----------------------|-----------------|---------|---------|---------|---------|---------|
| Systems installed    | Residential     | 378,048 | 391,947 | 406,155 | 420,939 | 435,334 |
|                      | Non-residential | 13,873  | 13,854  | 13,718  | 13,707  | 13,649  |
|                      | Total           | 391,921 | 405,801 | 419,873 | 434,646 | 448,983 |
| Total capacity (MW)  | Residential     | 2,748   | 3,031   | 3,317   | 3,619   | 3,909   |
|                      | Non-residential | 495     | 490     | 484     | 482     | 482     |
|                      | Total           | 3,243   | 3,521   | 3,801   | 4,101   | 4,390   |
| STC creation ('000s) | Residential     | 35,056  | 34,764  | 33,775  | 32,214  | 29,805  |
|                      | Non-residential | 6,256   | 5,573   | 4,896   | 4,272   | 3,662   |
|                      | Total           | 41,312  | 40,338  | 38,670  | 36,486  | 33,467  |
| Deeming period       | n/a             | 10      | 9       | 8       | 7       | 6       |

Residential PV installations and capacity grow over the 2021-2025 modelling period. In comparison, non-residential installations are forecast to fall in 2021 and then stay relatively constant, suggesting that some market saturation in the non-residential sector is taking place. STC-creation 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 PV findings by States/Territory are summarised below.

### 3.2.1 PV installations

Figure 5 shows the annual number of PV installations by State/Territory. In most cases, installations increase over the 2021 to 2025 period, at approximately 5% per annum. Key exceptions are:

- Northern Territory, where installations decline continuously from 2020
- South Australia, where installations are flat
- ACT and Tasmania, where per-annum growth from 2021 to 2025 is mostly in the double-digit region.

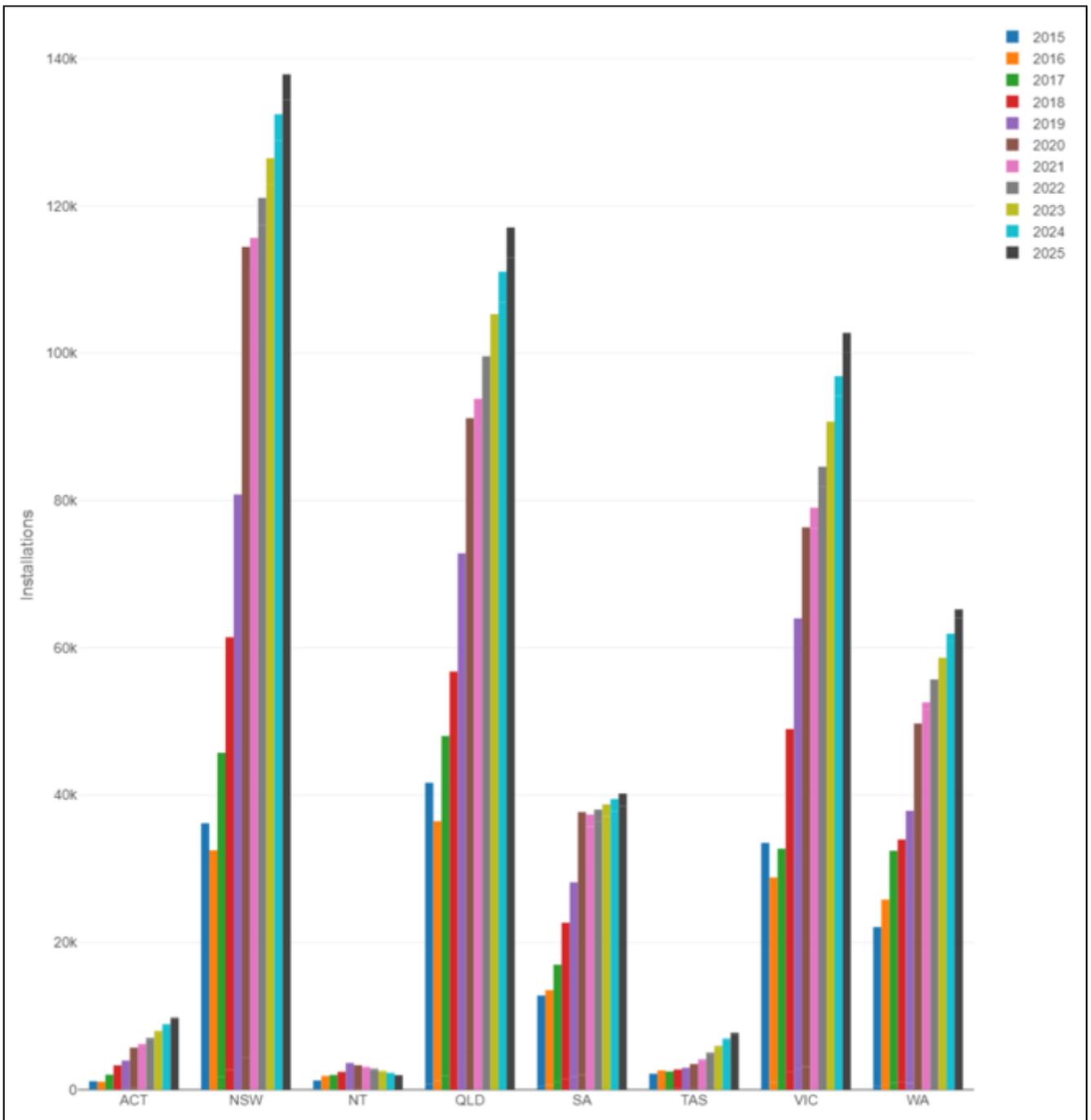


Figure 5 Annual number of small-scale installations by State/Territory

### 3.2.2 PV capacity

Figure 6 shows the annual figures for PV capacity installed (MW) by State/Territory.

Comparing the results from Figure 6 and Figure 5, 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, and the gradient of the NT figures is much less steep than the decline in installation numbers). This demonstrates the strong preference that residential consumers are having for larger PV systems to be installed.

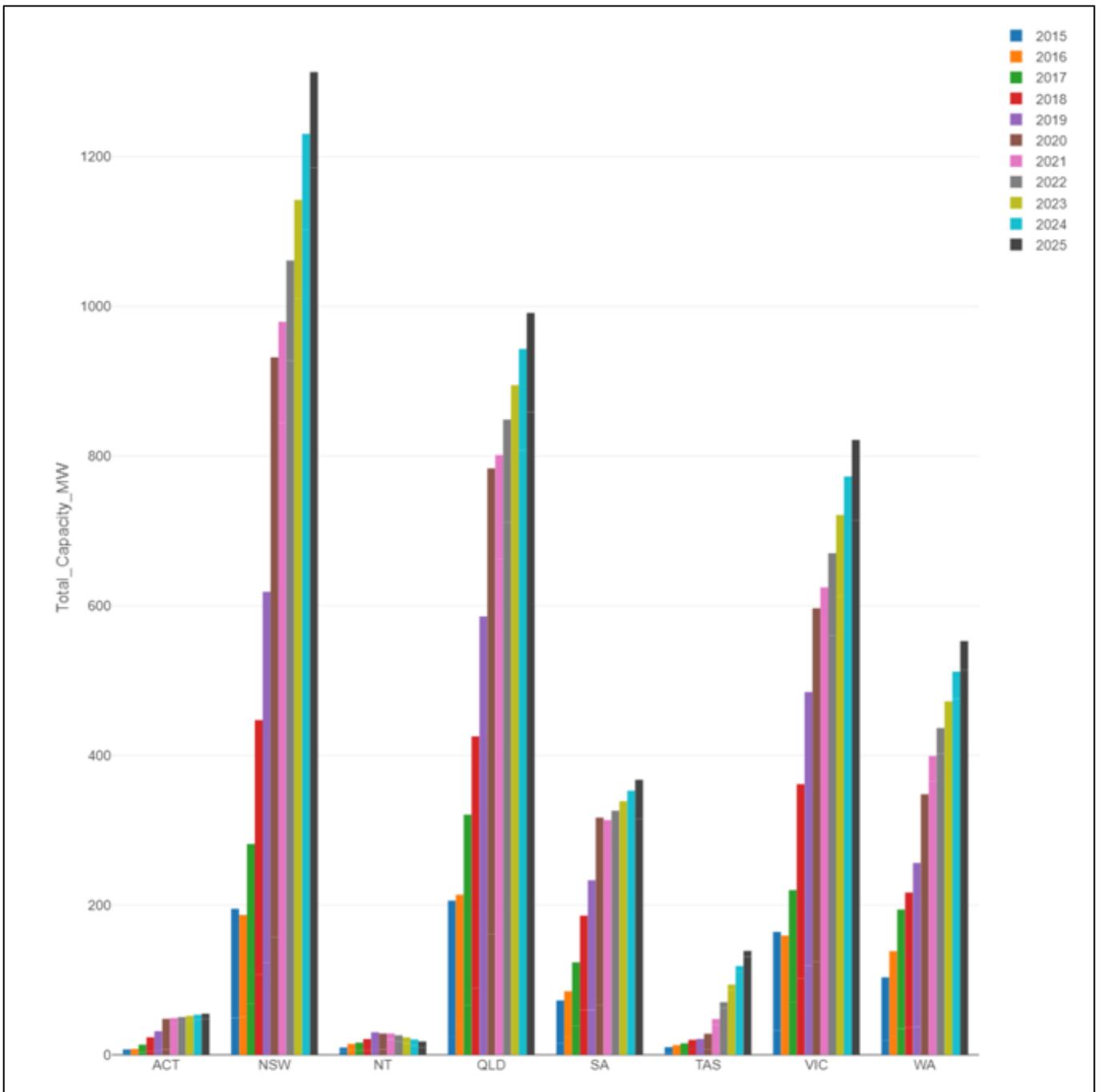


Figure 6 Annual PV capacity installed (MW) by State/Territory

### 3.2.3 STC creation

Table 11 shows the annual number of PV-system STCs projected to be created ('000s) by State/Territory, divided by residential and non-residential sectors.

**Table 11** STC creation ('000s) by jurisdiction (2022 to 2025) for PV systems

| <b>Year</b>    | <b>2022</b> | <b>2023</b> | <b>2024</b> | <b>2025</b> |
|----------------|-------------|-------------|-------------|-------------|
| ACT            | 520         | 480         | 434         | 384         |
| NSW            | 10,887      | 10,546      | 10,064      | 9,278       |
| NT             | 223         | 166         | 118         | 77          |
| QLD            | 8,520       | 8,090       | 7,530       | 6,861       |
| SA             | 3,287       | 3,062       | 2,802       | 2,512       |
| TAS            | 629         | 771         | 868         | 880         |
| VIC            | 5,617       | 5,457       | 5,181       | 4,773       |
| WA             | 5,081       | 5,203       | 5,216       | 5,040       |
| ACT            | 74          | 68          | 59          | 51          |
| NSW            | 1,578       | 1,377       | 1,190       | 1,018       |
| NT             | 106         | 93          | 81          | 70          |
| QLD            | 1,578       | 1,376       | 1,199       | 1,011       |
| SA             | 556         | 492         | 435         | 379         |
| TAS            | 84          | 74          | 65          | 55          |
| VIC            | 1,137       | 1,000       | 868         | 739         |
| WA             | 461         | 416         | 375         | 340         |
| Australia      | 40,338      | 38,670      | 36,486      | 33,467      |
| Deeming period | 9           | 8           | 7           | 6           |

# 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:

$$\{\text{Model 1 Weight}\} * \{\text{Model 1 Forecast}\} + \{\text{Model 2 Weight}\} * \{\text{Model 2 Forecast}\}$$

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<sup>35</sup>. 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*

| <b>Factors</b>                      | <b>Dataset</b>                               | <b>Description</b>  |
|-------------------------------------|--|---|
| 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 |

<sup>35</sup> 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 7). In fact, from October 2020 onwards, prices have fallen below the \$1/W mark.

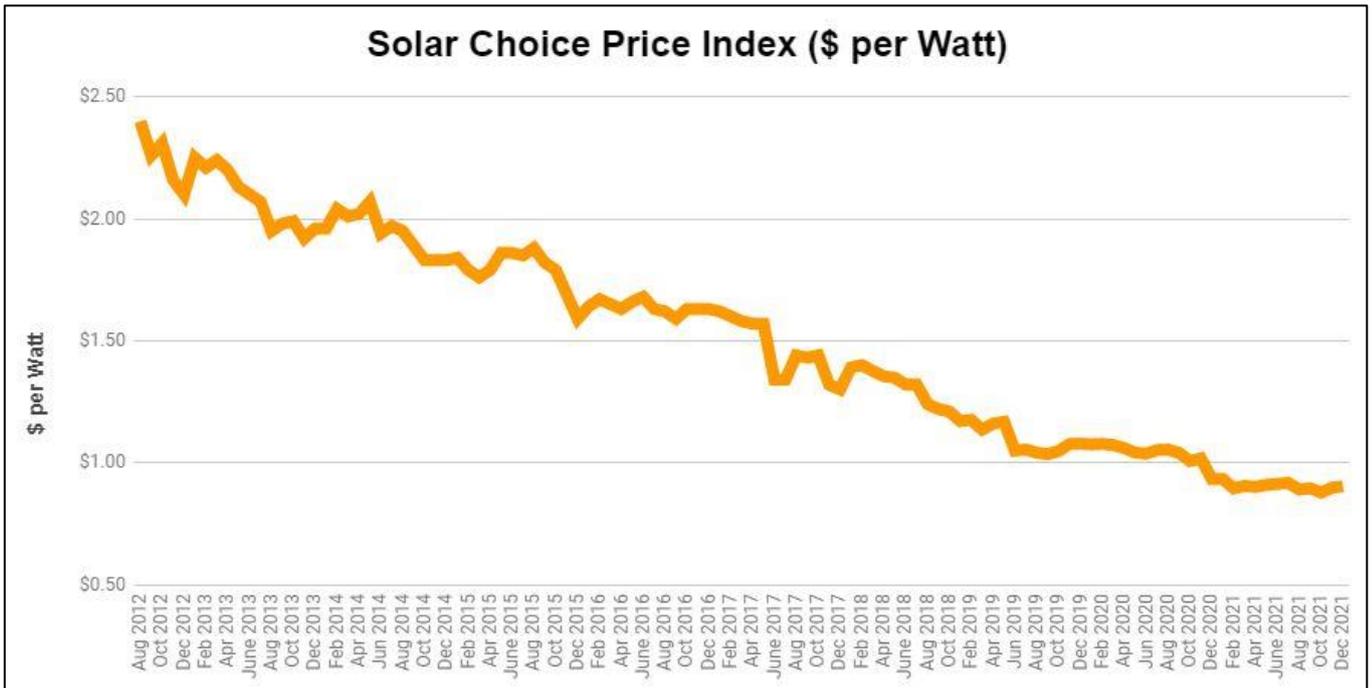


Figure 7 Solar prices for residential systems (source (as of 8 Dec 2021): <https://www.solarchoice.net.au/blog/solar-power-system-prices>)

## 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 8). As of November 2021, some capital cities have seen average prices dip below the \$1/W mark.

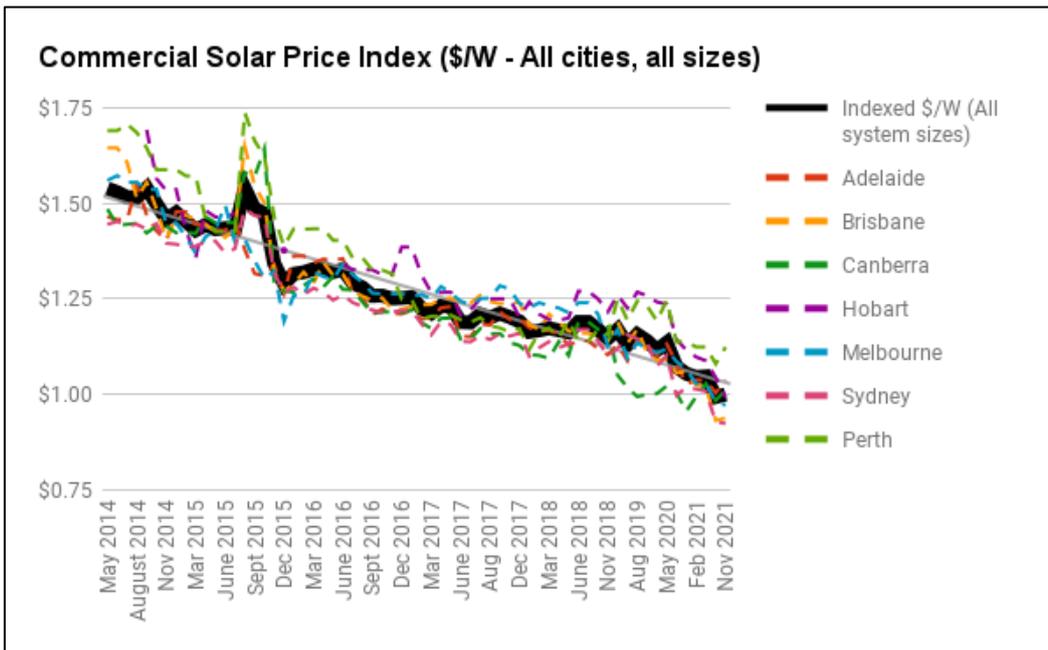


Figure 8 Solar prices for non-residential systems (source (as of 8 Dec 2021): <https://www.solarchoice.net.au/commercial-solar-power-system-prices>)

## 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.<sup>36</sup>

We observe that LGC spot prices are forecast to drop sharply over the next five years (see Figure 9).

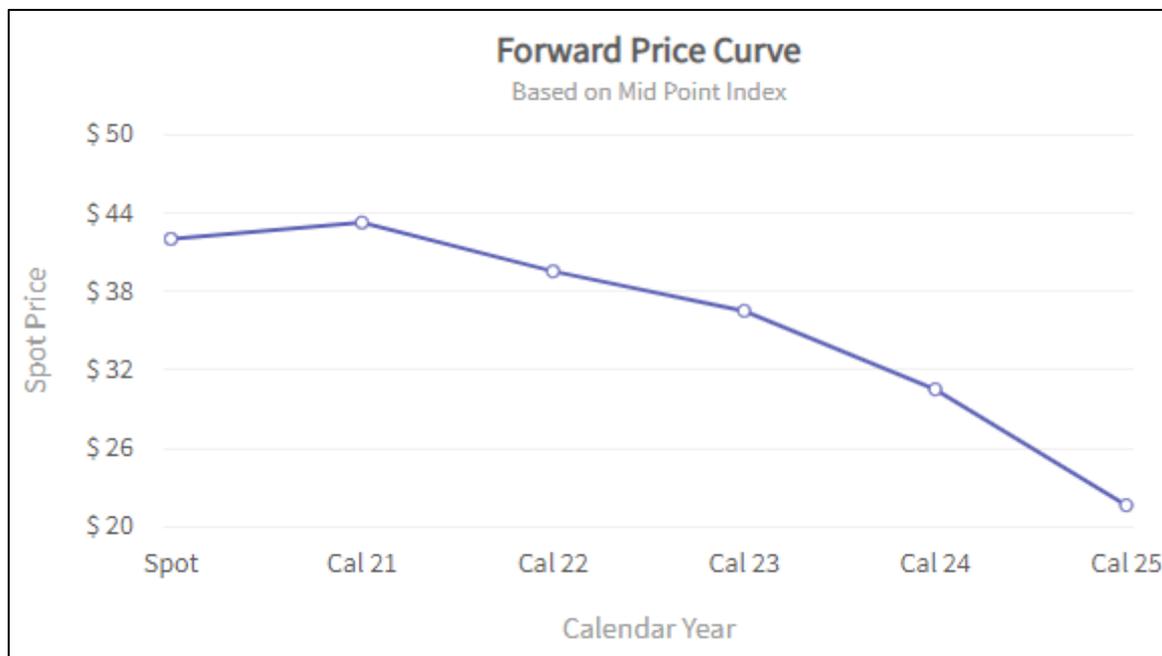


Figure 9 Forward price curve for LGCs (source (as of 8 June 2021): <http://lgc.mercari.com.au/>)

## 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/>

<sup>36</sup> 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<br>Postcode<br>Population<br>Separate House<br>Owners<br>Household Composition<br>Electricity Price<br>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<br>Economic Resources<br>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.

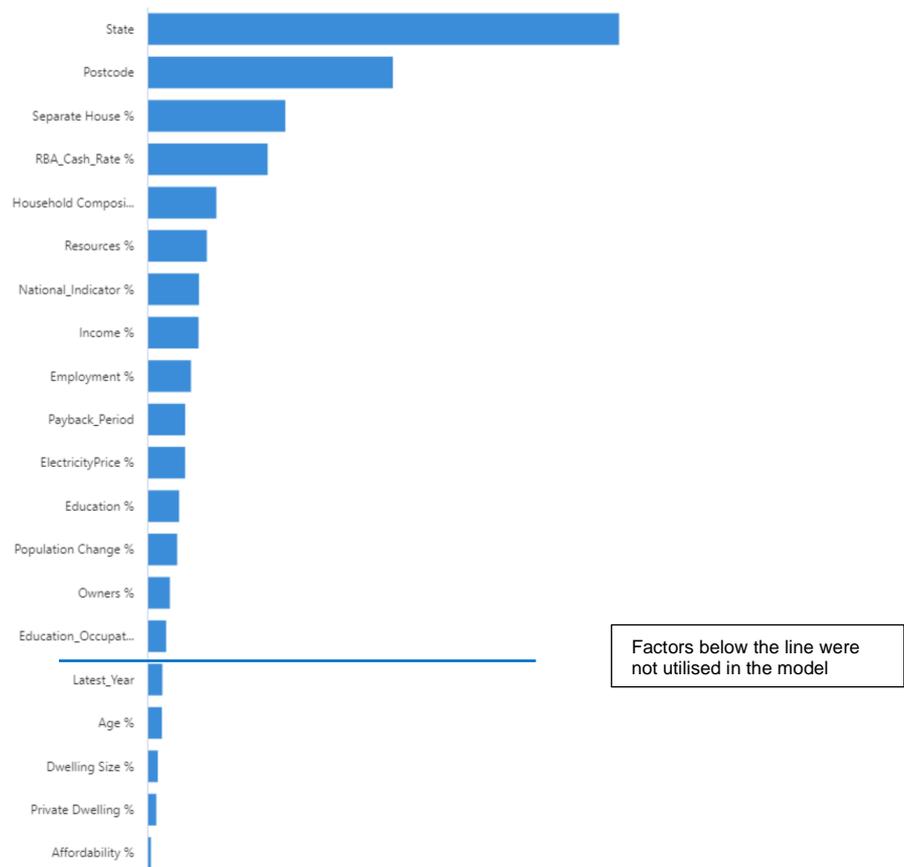


Figure 10 Solar PV: Residential installation model factor contribution

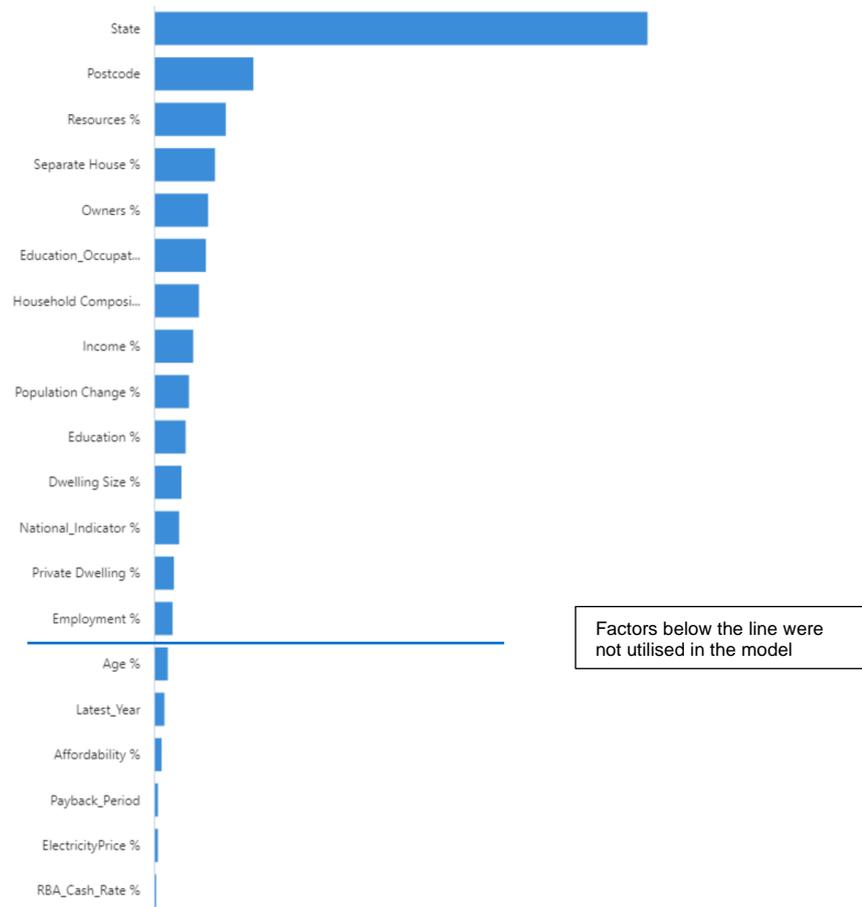
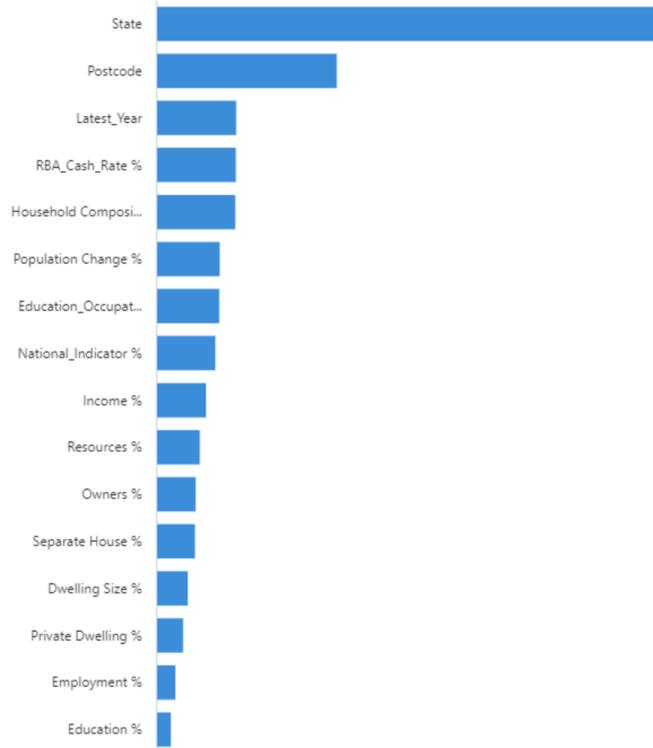
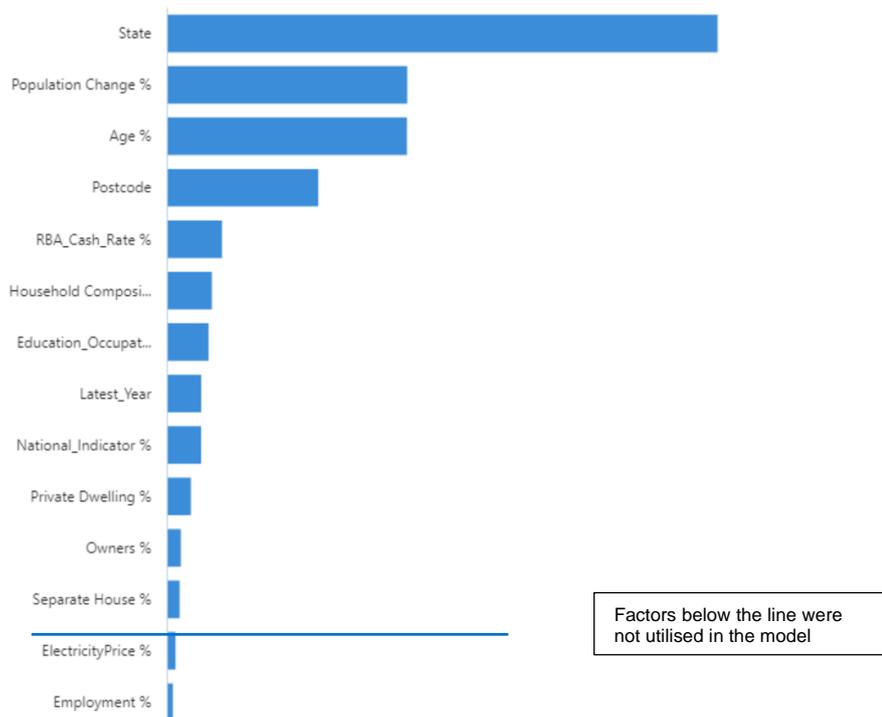


Figure 11 Solar PV: Residential capacity model factor contribution

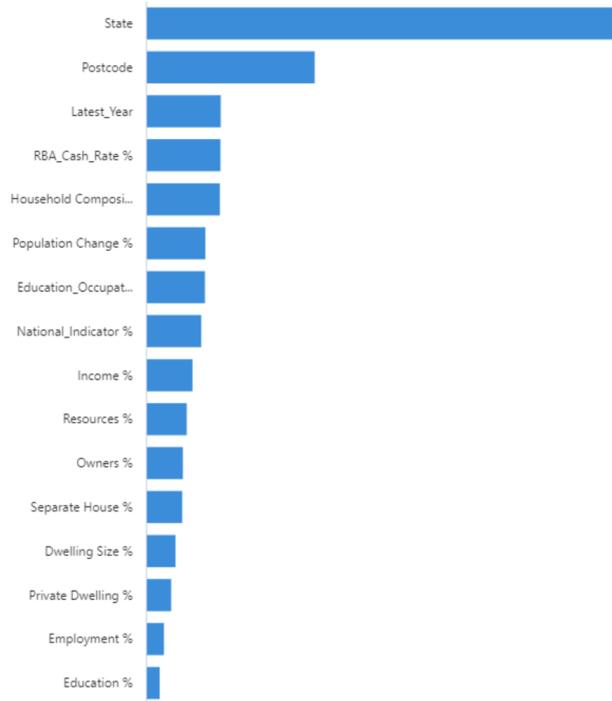


**Figure 12** SWH: Residential new installation model factor contribution

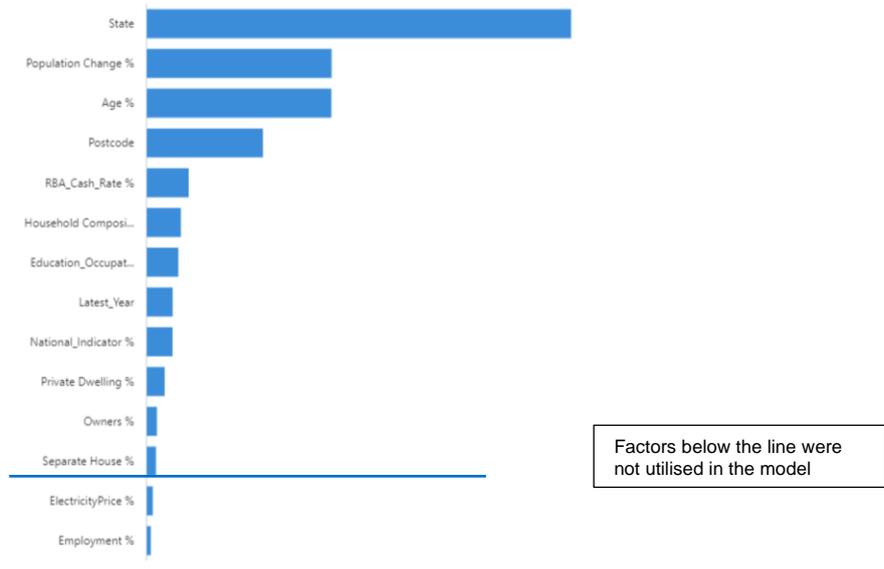
Note the contribution of Age and Electricity Price were negligible in this model



**Figure 13** SWH: Residential replacement installation model factor contribution



**Figure 14** ASHP: Residential new installation model factor contribution



Factors below the line were not utilised in the model

**Figure 15** ASHP: Residential replacement installation model factor contribution

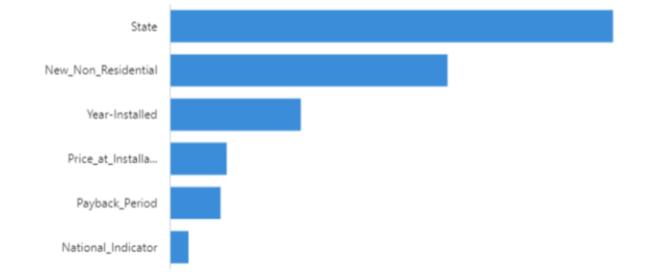


Figure 16 Solar PV: Commercial installation model factor contribution



Figure 17 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 | 462.83                        | 303.77                    | 0.94 |
|              |             |                 | Solar Water Heater               | CatBoost      | 27.02                         | 12.44                     | 0.62 |
|              |             |                 | ASHP                             | CatBoost      | 16.16                         | 11.45                     | 0.52 |
|              |             | 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 | 16.71                         | 11.24                     | 0.94 |
|              |             | Residential     | Solar Panels                     | Random Forest | 1689.25                       | 963.30                    | 0.59 |



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