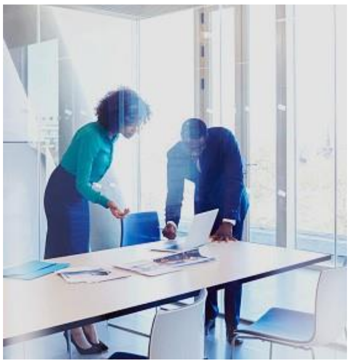
GHD Advisory



Small-scale Technology Certificate forecasts 2021-2023

Clean Energy Regulator

19 February 2021

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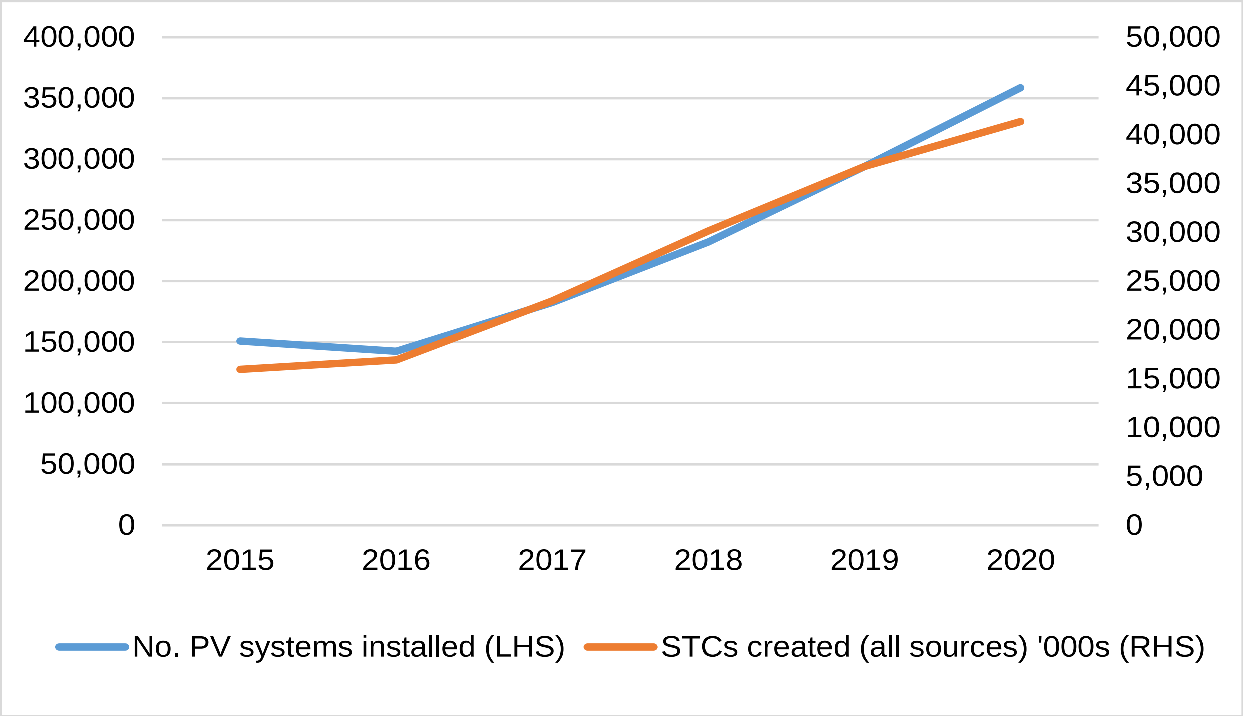
1. Executive summary

The Clean Energy Regulator (CER) administers the Small-scale Renewable Energy Scheme (SRES) that creates financial incentives for investment in eligible small-scale renewable energy systems. Eligible small-scale renewable energy systems include solar photovoltaic (PV) installations, solar water heaters (SWHs), SWH air-source heat pumps and other small generation units (SGUs). PV installations that create Small-scale Technology Certificates (STCs) have been on an upward trend since 2016 and the consequent STC creation, although still rising, has begun to do so at a slower rate since 2018 (refer to Figure 1.1, covering 2015 to 2020).

Figure 1.1 Annual small-scale PV installations and thousands of STCs created



Source: CER, Renewable Energy Certificate (REC) Registry and GHD analysis.

The CER engaged GHD (us) to provide forecasts of STC creation, based on modelling of small-scale renewable energy installations and capacity forecasts, covering the period of 2021 to 2023.[1] To fulfil this requirement, we adopted a modelling approach that links consumer characteristics (e.g. household type and size, location, income, postcode) to the demand for small-scale renewable energy installations (we call this the 'agent-based modelling approach'). The modelling adopts a machine-learning simulation approach, based on the key drivers that motivate consumers to install specific sizes and types of small-scale renewable technologies.

[1] Calendar years.

Our understanding of the key drivers for the aforementioned installations and capacity-related decisions is based on our own previous research and experience. This understanding was forged in the course of confidential project work for various clients, as well as via published Australian rooftop PV-forecast (and related) reports. In our view, the relevant decision-making drivers, which our agent-based modelling approach employs, include:

- Financial drivers, including income levels, Federal/State incentives, and cashflow considerations.
- Non-financial drivers, including neighbourhood, technological and household-type effects.

Our modelling approach had regard to the following considerations and limitations:

- The estimates for 2021 are generally informed by a more detailed, short-term focussed modelling to determine month-to-month variations in installations and the incorporation of actual data for 2020. The long-run behavioural model component then provides year-on-year growth rates for 2022 and 2023.
- Non-residential SWH projections are based on linear-regression trends, as we had insufficient data to use the agent-based modelling approach.
- We do not project any further small-scale hydro or wind installations because, unlike solar PV technologies, these mature technologies generally do not reduce in cost over time. In addition, existing capacity mostly includes legacy systems; new installations since 2017 have been sporadic and are not anticipated to occur beyond 2020.
- STC approvals depend on installation numbers, capacity, types and deeming rates; and lags between installation and STC registration. Actual times between system installation, STC application and registration vary from project to project. Hence, our forecasts of STC approvals are based on average observed lag times.

A summary of our small-scale renewable energy installations and capacity forecasts results for Australia is presented below in Figures 1.2 to 1.6. Key findings are:

- Despite an economic recession and pandemic-related travel restrictions, there was a continued increase in the total number of installations of residential PV systems in 2020, relative to 2019 (24.0% increase). This was apparent even in Victoria, where there was an extended and strict COVID-related lock-down in Melbourne during the year for 16 weeks.[2] Following a further forecast increase of 7.7% in 2021 (for Australia), the long-run growth rates forecast for 2022 and 2023 are more subdued, at 2.3% per annum on average. This is driven by reduced population growth and building activity, partially offset by continuing decreases in PV system costs, income support through the initial stages of the current recession in 2020, followed by an assumed economic recovery by 2022, bolstered by supportive Commonwealth, State and Territory government fiscal strategies. During the pandemic, there has been increased focus on home improvement by some homeowners as the home environment has also become a workplace for much more of the workforce.[3]
- There was continued increase in the total capacity of residential PV systems in 2020, relative to 2019 (34.6% increase). This was larger than the increase in the number of installations due to the increasing size of the average installation. Continued growth of 10.9% is forecast for 2021, with forecast growth rates beyond that averaging a moderate 8.8% per annum. (This means the average installation size will

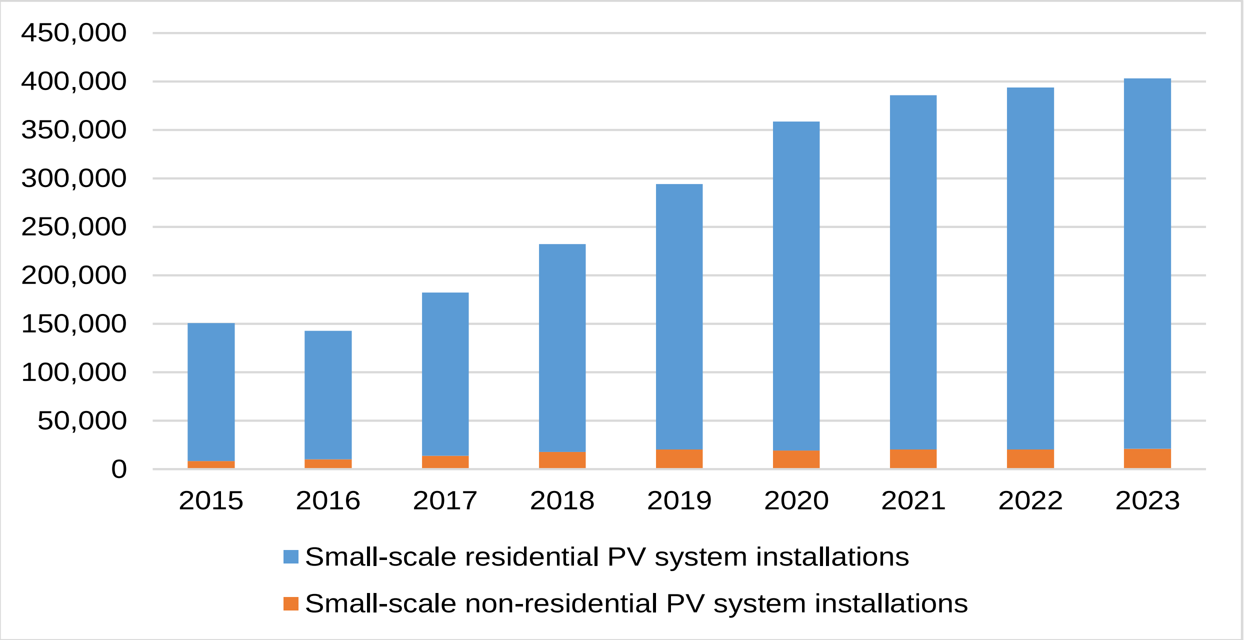
[2] See https://www.bbc.com/news/world-australia-54686812 for more information about the duration of Melbourne's Stage 4 lockdown.

[3] "COVID-19 renovation boom: How much Aussies are spending to give their houses a facelift during the pandemic", https://www.news.com.au/finance/real-estate/covid19-renovation-boom-how-much-aussies-are-spending-to-give-their-houses-a-facelift-during-the-pandemic/news-story/f87ae20e602ff97f94763426458cfe73.

continue to grow until 2023, indicating, potentially, that costs on an installed kilowatt basis are decreasing and/or a greater preference by the average consumer for clean energy sources). The long-run growth rates are aligned to underlying growth since 2016 and are confirmed by data for 2020.

- There was a small decrease in the total number of residential SWHs in 2020, relative to 2019 (0.7% overall decrease, reflecting the net impact of increased replacements and fewer installations in new buildings, primarily because of a reduction in new home building). An increase of 11.2% is forecast for 2021. However, forecast growth rates for 2022 and 2023 are relatively low at 1.9% per annum on average. Projected future growth is driven almost entirely by heat pump systems installed in new buildings, reflecting recent trends in the adoption of such systems by owners/operators of new buildings (which is encouraged, in part, by existing building codes on energy-efficiency matters).
- Total approved STCs rose by 14.8% in 2020, compared with 2019. They are forecast to increase a further 3.8% in 2021. However, they are then forecast to fall over the rest of the modelling period by an average of 2.8% per annum, despite the growing capacity of installations. This is principally due to the reduction in the deeming factor for STCs, which falls to one as 2030 approaches (the fall in the deeming factor reduces the number of certificates that are created for an eligible system of a given capacity) .[4]

Figure 1.2 Annual number of small-scale PV installations – Australia



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

Figure 1.3 Annual small-scale PV capacity installed (MW) – Australia

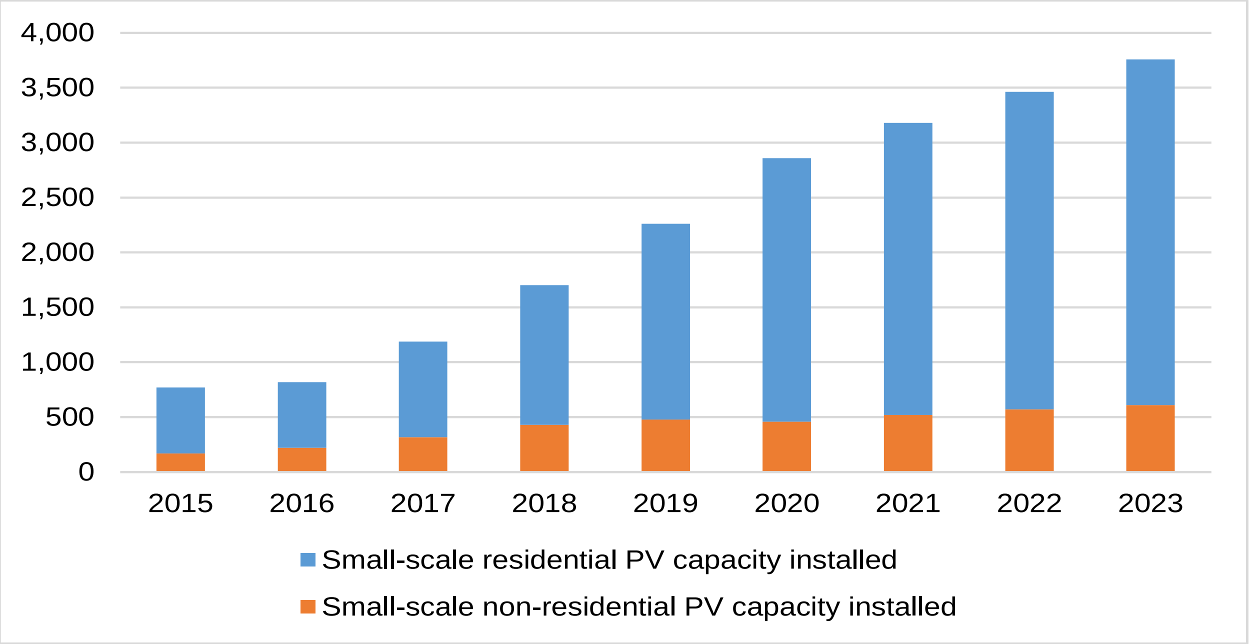


Figure 1.4 Annual number of small-scale solar water heaters installed

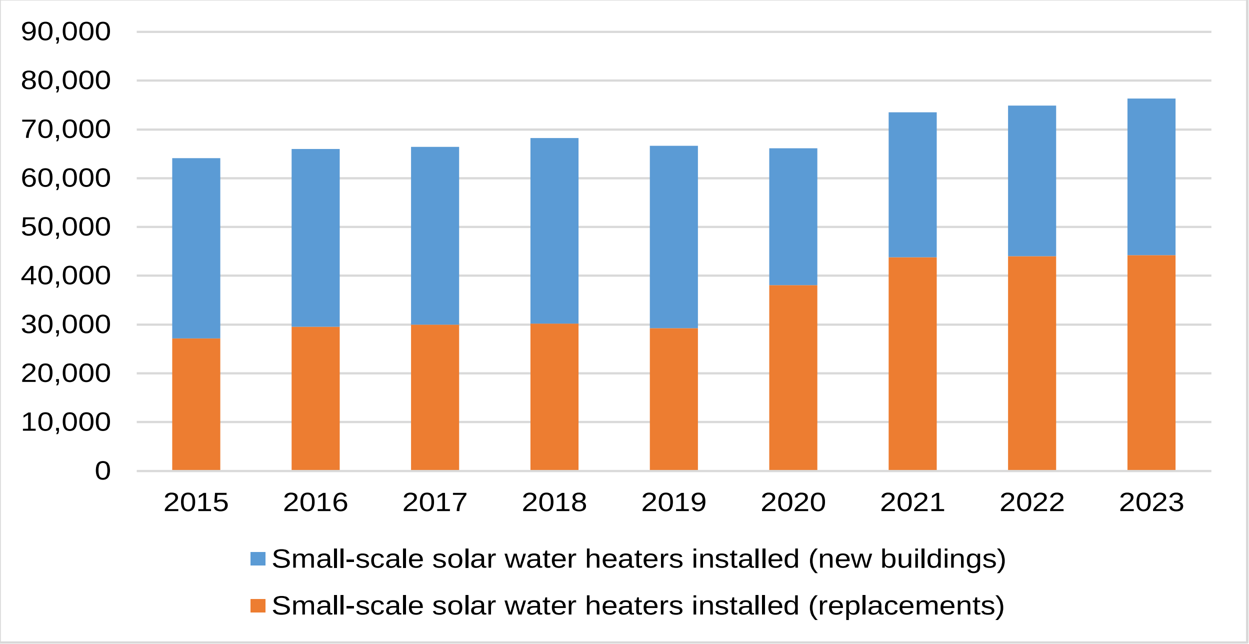


Figure 1.5 Annual small-scale wind and hydro capacity installed (MW) – Australia

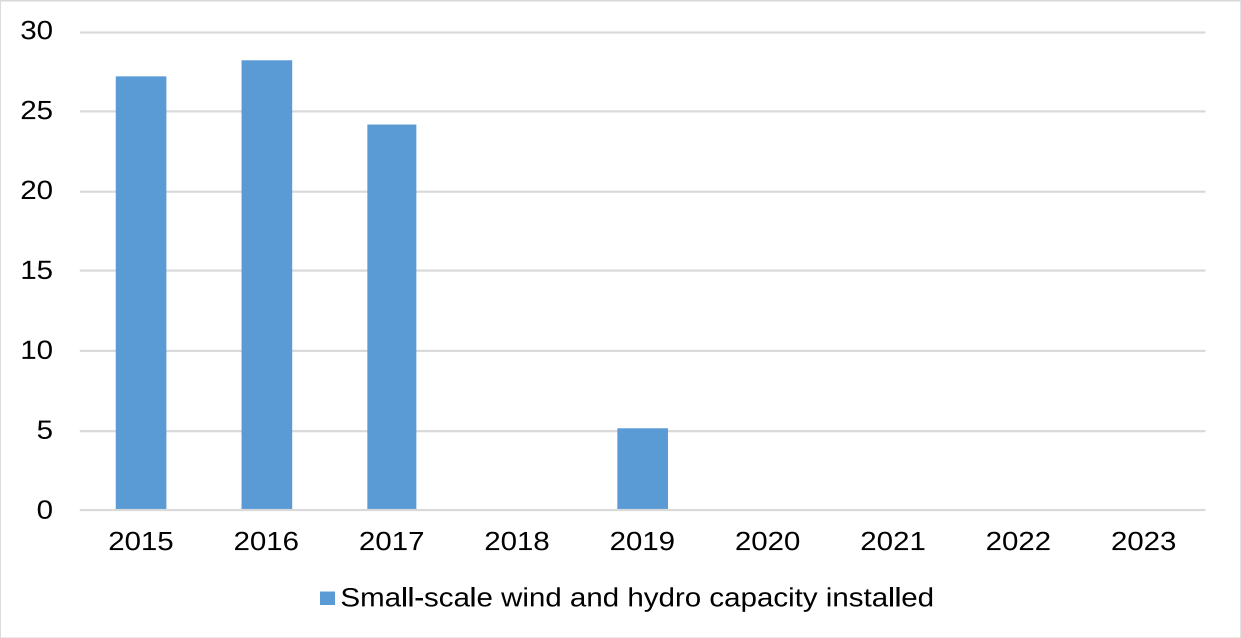
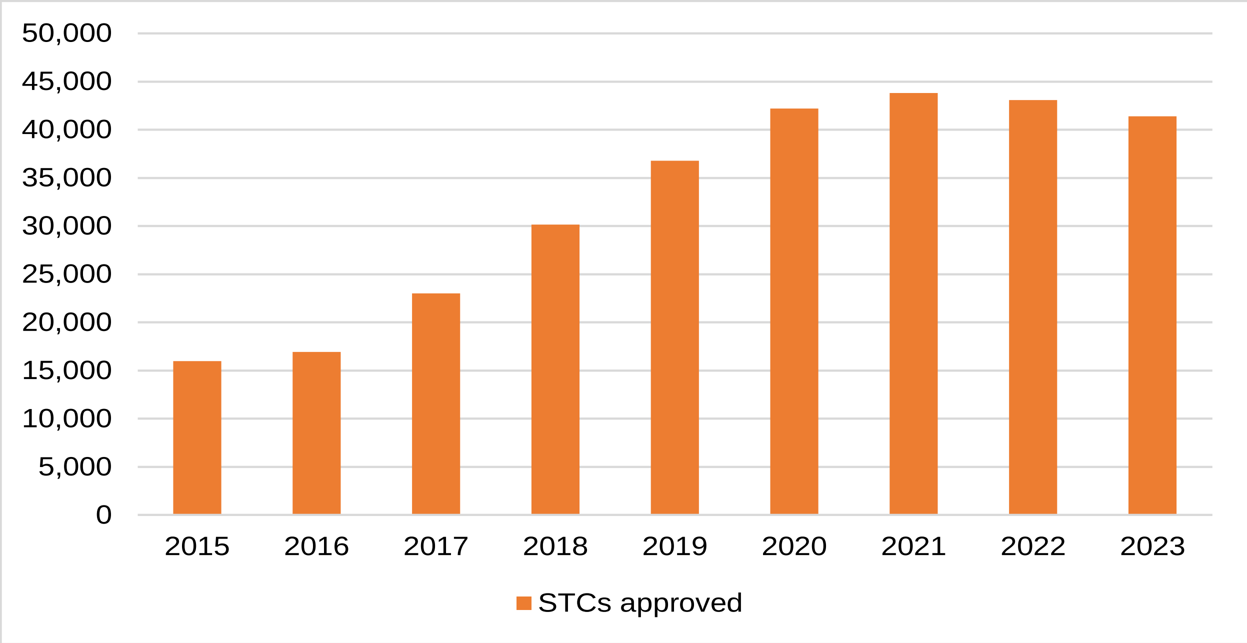


Figure 1.6 Annual number of STCs approved ('000s)– Australia



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2. Introduction

The Clean Energy Regulator (CER) administers the Small-scale Renewable Energy Scheme (SRES) that creates financial incentives for investment in eligible small-scale renewable energy systems. Eligible small-scale renewable energy systems include solar photovoltaic (PV) installations, solar water heaters (SWH), SWH air-source heat pump and other small generation units (SGUs).

In recent years, the creation of Small-scale Technology Certificates (STCs) indicates a growing use of small-scale renewable energy installations. Against this backdrop, the CER has sought an updated and revised SRES forecast to address the trends that have emerged from this data.

2.1 Purpose and scope

The CER has engaged GHD (us) to provide modelling of small-scale renewable energy installations and capacity forecasts. The forecasts are to cover the period of 2021 to 2023.[5] More detail on small-scale technology installations is set out below.

2.1.1 Small-scale technology installations

The focus of this report is on installations of those technologies that are eligible for STCs, namely:

- small PV generation units (capacity no more than 100 kilowatts (kW))
- eligible SWHs, including air source heat pumps (eligible types are registered with the CER)
- wind or hydro small generation units (capacity no more than 10 kW or 6.4 kW, respectively).

2.2 Detailed scope requirements

The CER has asked that GHD's report include the following information:

- SRES forecasts (i.e. number of small-scale technology installations, installed capacity and STCs)
- key factors affecting the type (i.e. solar PV, SWHs and other SGUs), number and size of small-scale systems installed and the trends by various categories across state and territories in Australia
- robust modelling that underpins the analysis
- clear outline of assumptions, methodology and underpinning data sets
- advice on any preference for one estimate if using more than one model
- an executive summary of the key findings of the report, written in plain English
- detailed appendices to support the modelling work including data to support figures

We have prepared a report below to address the above requirements.

[5] Calendar years.

2.3 Report structure

This report is structured as follows:

- Conceptual framework (Chapter 3)
- Data (Chapter 4)
- Results (Chapter 5).

3. Conceptual framework

This chapter sets out our conceptual framework regarding the modelling of small-scale renewable energy installations and capacity forecasts for the CER.

3.1 Modelling approach

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. Such an approach 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 make predictions on the basis of the dataset, with predictions becoming more accurate with higher volumes of data.

We have adopted a modelling approach that links consumer characteristics (e.g. household type and size, location, income and postcode) to the demand for small-scale renewable energy installations (we call this the ‘agent-based modelling approach’).

Our primary agent-based modelling adopts a machine-learning simulation approach, based on the key drivers that motivate consumers to install specific sizes and types of small-scale technologies. Our understanding of the key drivers is based on our previous research, undertaken in the course of confidential project work for our clients, including published Australian rooftop PV forecast and related reports.

3.1.1 Small-scale technology installations and capacity forecasts

The installation modelling recognises the agency of various classes of actors.[6] This is defined by household type and size, income and postcode location, or industry sector, as applicable to either residential or non-residential installations.

The installation modelling estimates the number of residences and businesses, and, where relevant, average system size, in each specific postcode location in Australia, for which each type of technology is both cost-effective and desirable, given the predominant underlying preferences and situation of identified agent groups pertaining to that location.

Our secondary modelling process attributes current year STC approvals to proportions of current and previous year installations, based on observed lag distributions. In particular, we:

- estimated the number of STCs attributable to new small-scale technology installations in previous years, compared to the actual number of STCs approved in respective years;
- assumed that the remaining STCs attributable to installation in a particular year were approved in the following year; and
- used the resulting historical ratio of attributable STCs to actual approved STCs to allocate the STCs attributable to current year installations between approval in the current year and approval in the following year.

[6] Included agents are differentiated by postcode location, home ownership, dwelling type, business sector and income.

3.2 Installation drivers

Previous studies[7] 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.

3.2.1 Financial drivers

In deciding to install small-scale generators, consumers will need to weigh up the upfront and ongoing costs associated with the installation, with potential returns that might arise from selling excess electricity generation back to the grid.

Financial investment drivers balance the upfront installation costs with the operational cost savings over time, compared with continued operation without the said installation.

The upfront costs for a small PV generation unit include the cost of the solar panels, support equipment (if required, for example on a flat roof), inverter, wiring and electrical connections, labour and overheads of the installer. These costs may be offset at the time of payment by the STC credit by selling the STC creation right to the installer. Our collected data for PV installation costs are generally recorded as a single installation cost.[8] 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 at certain times and selling energy back to the grid at certain times. 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.

Various consumers will face different benefit streams, depending on their location, generation capacity, consumption patterns, export percentage and tariffs. Changing financial drivers over time are addressed in agent-based modelling by constructing an investment 'payback series' relevant for a limited range of agents.

Against this backdrop, upfront installation of an average 5 kW system (after allowing for the STC discount) currently costs between $4,000 and $5,000 in Australia's largest capital cities.[9] This could be considered a hefty sum for those in the lower-income brackets. Unless such consumers are willing to finance this upfront cost via borrowings, they will not make the decision to proceed with such installations. By comparison, those with higher disposable incomes can readily afford the upfront payment.

A further dimension to the concern identified above 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. Hence, cash flow considerations are important for understanding consumers' mindsets on such purchasing decisions.

[7] For example, Sommerfeld, J. (2016) Residential Customers and Adoption of Solar PV, PhD thesis, Queensland University of Technology School of Design, Brisbane.

[8] Solar Choice https://www.solarchoice.net.au/blog/solar-power-system-prices. The manner in which the installation may be purchased may also result in differing probabilities of take-up, if faced, for example, with a choice between an up-front cash payment versus incurring an on-going borrowing cost.

[9] Solar Choice website, https://www.solarchoice.net.au/blog/solar-power-system-prices.

3.2.2 Non-financial drivers

In general, non-financial drivers may be difficult to quantify. However, we have sought to overcome this constraint as much as practicable possible in our approach, as such drivers are highly relevant for determining whether a consumer will or will not invest in small-scale installations. We characterise the non-financial drivers as: Neighbourhood; Technological; and Household-Type effects.

3.2.2.1 Neighbourhood effects

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. We have attempted to capture these kinds of effects by introducing the number of existing installations in each postcode in the previous period (lagged installations).

3.2.2.2 Technological effects

Technological factors, including co-installation of batteries, electric car ownership, having a smart meter and hence access to variable tariff rates, or participation in a demand response scheme.

Such technological 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. In the development of the model we have been mindful of abrupt changes - such as the introduction of generous feed-in-tariffs and then their later withdrawal between 2009 and 2012 – and the corresponding changes in installation numbers.

3.2.2.3 Household-Type and other effects

Household-type effects reflect heterogeneity (i.e. non-uniformity in decision making) among households and businesses, 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,[10] whereas renters in an apartment block have little (or no) opportunity or incentive to install such a system.

Similarly, for non-residential installations, different industry sectors may generally have individual characteristics that would make that would make it relatively more financially rewarding to install small-scale technologies, such as the electricity intensity of their activities.

Some communities are more environmentally conscious than others. So, although it may not make financial sense, from the perspective of the consumer, to install small-scale systems, there will be tacit pressure on

[10] In the southern hemisphere.

them 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. These effects are difficult to measure; however, they represent strong non-financial drivers that everyday consumers and small businesses/organisations face.

3.3 Federal/State/Territory initiatives affecting consumers' decisions

3.3.1 Small-scale Renewable Energy Scheme

The Australian Government's SRES[11] provides an Australia-wide incentive to install eligible small-scale renewable energy systems such as solar panel systems, small-scale wind systems, small-scale hydro systems, solar water heaters and air source heat pumps. Through the SRES, individuals and small businesses can create STCs that liable entities (usually electricity retailers) must purchase and surrender to the Clean Energy Regulator on a regular basis.

The number of STCs created by each installation depends on the type, size and location of the installation, and the "deeming" period – that is, the assumed life of the installation within the time of scheme operation up to 2030. The value of each STC is $40 (excluding GST), if sold through the STC clearing house. As an illustration, a 3 kW PV system installed on 1 September in Barton ACT would be eligible for 76 STCs, providing an effective discount on the installation cost of up to $3,040.

3.3.2 Feed-in-Tariffs for PV small generation units

A gross Feed-in-Tariff (FiT) is the price received for all energy produced by a small generation unit, while the household pays the retail price for all energy consumed. A net FiT is applied to net household energy exported to the grid, while self-generated energy that is consumed on-site represents a saving in electricity purchased.

The New South Wales (NSW) Government provided a gross FiT of 60c/kWh or a net FiT of 20c/kWh between 1 January 2010 and 31 December 2016, under which approximately 146,000 new solar households and an additional 342 MW of rooftop PV capacity were added to the grid. A gross FiT of 50c/kWh was also available in the ACT from March 2009 until June 2013, and a FiT equal to the retail consumption tariff applied in TAS at approximately the same time.

Net FiTs of 60c/kWh were available in Victoria from November 2009 to September 2011, 44c/kWh in SA from September 2010 to September 2011, 44c/kWh in Queensland from July 2008 to June 2013, between 47c/kWh (South) and 59c/kWh (North) in Western Australia (WA) and between 22c/kWh and 46c/kWh in NT.

These original FiT schemes have since closed and all current FiTs are based on net energy exports. The range of currently available FiTs is wide, ranging from 0 to 23c/kWh. With current electricity tariffs in the order of 30-plus c/kWh this means that the major financial benefit of solar installation is more likely to be from electricity savings, rather than selling self-generated energy.

[11] Refer to SRES: http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/How-the-scheme-works/Small-scale-Renewable-Energy-Scheme.

The WA Government recently announced the Distributed Energy Buyback Scheme to offer a time of use FiT designed to offer a higher payback at peak times and encourages installation of west-facing solar panels, consumption of electricity during the middle of the day when self-generation is relatively high and the use of battery storage.

3.3.3 Solar Homes program

The Victorian Solar Homes program came into effect in August 2018. Under this program, eligible Victorian households can claim a rebate up to $2,225 on the cost of buying and installing a solar PV system. The remainder of the cost can be paid through an interest-free loan. Not-for-profit community housing providers are also eligible to apply for the rebate on behalf of their tenants.

3.3.4 Interest-free loans and grants

The Next Gen program in the ACT provides rebates for eligible new battery systems that are coupled with a rooftop PV system, as well as subsidies of up to 50% of total system cost for PV systems for eligible low-income households.

Under the Empowering Homes initiative, the NSW Government recently began offering loans of up to $14,000 towards a solar PV and battery system for eligible homes in the Hunter region, as a trial of the program, which is designed to eventually be available to up to 300,000 homes across the state over the next 10 years.

The Queensland Government offers interest-free loans and grants for solar panel installation and storage. There are packages of up to $10,000 available, for loans for solar, loans and grants for battery storage and loans and grants for combined solar and battery storage.

A South Australian (SA) Government subsidy for the installation of home batteries will likely improve the financial benefits of installing solar PV for 40,000 homes in that state, as will the development of virtual power plants over time which could combine the operation of individual solar and batteries across a wide geographical area to produce mutually optimum benefits and rewards.

The WA Government is implementing several measures through its Distributed Energy Resources (DER) Roadmap to address the impacts of a large and growing volume of rooftop PV systems on the isolated South West Interconnected System (SWIS). While these measures do not provide direct financial support for the installation of roof-top PV systems, they may ensure the continuing viability of such installations to increasing levels of penetration.

3.3.5 Regulations for hot water systems

Minimum greenhouse gas intensity and efficiency standards for hot water systems have been specified in the Building Code of Australia since 2010. Jurisdictions other than Queensland, Tasmania and the Northern Territory have restricted the installation of water heaters considered to be greenhouse intensive in detached, semi-detached, terraced or town house dwellings. State building regulations and the National Construction Code thereby generally provide a strong incentive to replace existing electric resistance water heaters with solar, heat pump or compliant gas water heaters, and to install the latter types in new buildings.

VIC and NSW building standards allow the installation of new resistance water heaters but require offsets such as a rainwater tank or more efficient lighting or fixed appliances. Regulations in SA and QLD have restricted the use of resistance water heaters since 2008 and 2010 respectively.

4. Data

This section explains the short-run and long-run modelling procedures and data inputs we adopted for our analysis.

4.1 Methodology – short-run models

Short-run time series models were developed for small-scale residential PV, non-residential PV, residential solar water heaters and non-residential solar water heaters, for each jurisdiction, and within the solar water heaters for both replacement and new and for both solar thermal and heat pump types. The main purpose of the short-run models was to extrapolate historical monthly data for the most recent partial year to full year totals by examining seasonal patterns in the data. Short-run economic impacts on small-scale technology uptake were also incorporated.

Each model utilised monthly historical data from January 2016 to December 2020. Alternative models were tested that included an ordinary least squares (OLS) trend regression analysis, including dummy variables for each month and a moving average error specification, and an autoregressive distributed lag (ARDL) incorporating independent variables to account for potential differences in the depth of the current recession between jurisdictions. The final short-run models, for each jurisdiction, were:

- for residential PV installations and capacity, an ARDL incorporating the affordability of electricity in terms of the ratio of price to income and an s-shaped technology uptake curve, as well as seasonal dummies
- for non-residential PV installations and capacity, an ARDL incorporating an s-shaped technology uptake curve, as well as seasonal dummies
- for residential and non-residential solar water heaters, both solar and heat pump, new and replacement, an OLS regression against income and using seasonal dummies (the non-residential components generally lacked sufficient continuity of monthly data and so in the majority of cases heuristic judgement was used to decide if the forecast should include one or zero installations in a year)

The forecast from each respective short-run model was used to predict, for each respective category, the installations and capacity for 2021. The overlapping forecasts from the short and long-run models for 2021 were not perfectly aligned but the short-run model results were preferred as we were able to provide greater differentiation between jurisdictions according to differences in travel restrictions and consequent differences in economic outcomes.

4.2 Methodology – long-run models

The long-run models are differentiated by categories of technology and application, primarily due to different inputs reflecting the relative importance of various driving factors.

4.2.1 Small-scale PV systems and solar water heaters - residential

Solar installation choices are made for several reasons. The decision to install small-scale solar generation is typically made by the occupant of a household (i.e. an agent). Characteristics of these household occupants (e.g. postcode, level of education), can provide useful insights that helps to inform us of installation behaviour.

There may be a strong agent character and sentiment consistent across agents. Such characteristics of the agent are possible drivers of action in solar installation. Where these drivers are strong, there would be evidence of higher solar installation. The strength of agent-based modelling in this context is that the various characteristics of different agents can be associated with the specific propensity of each agent to install small-scale technologies, enabling reliable predictions into the future.

In these times of harnessing ‘big data’, increased computing power provides the opportunity to utilise detailed agent data representative of agents making decisions regarding solar installation. Aggregating from postcode level household agency provides insight and meaningful patterns of past behaviour to model likely future behaviour. Where direct agent activity is not captured with application for certificates, data mining harnesses such insights in an ethical manner for inferences to future agent behaviour.

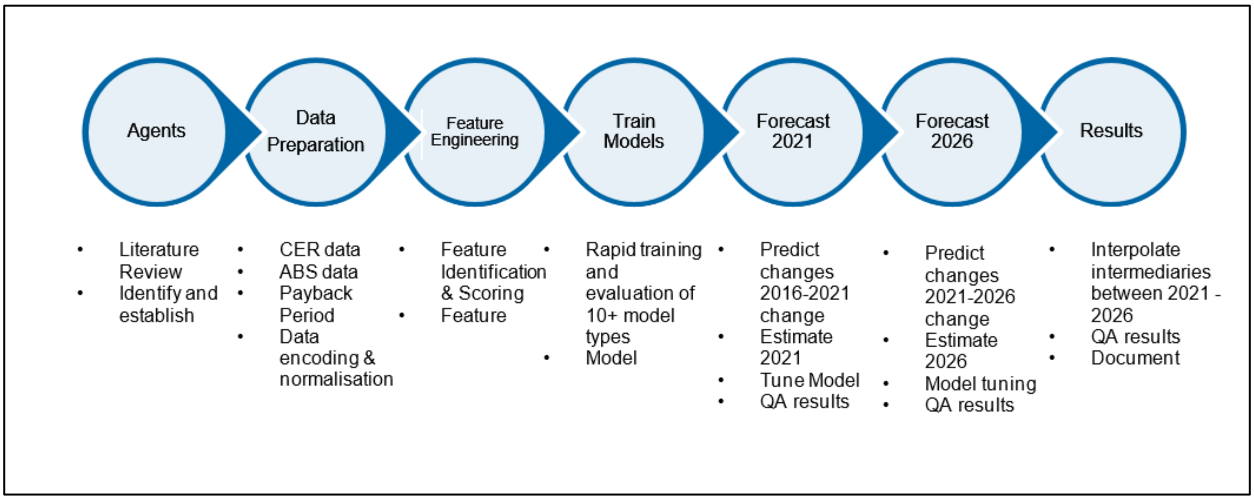
Many previous models have been based on a small number of agents, even agents outside of Australia. This study utilised Australian agents matched on a postcode level to the solar installers. Many data sets and sources were examined to represent the agent. The requirement being for a data set collected consistently across all of Australia meant very few data sets were available. Mining for data to match the over 2 million known solar installers registered with CER was time-consuming and challenging.

Of all available data sets known in public and private domain the most accessible, covering all of Australia, in the time and budget available was the extensive and comprehensive data held by the Australian Bureau of Statistics (ABS). Harnessing the data was possible due to its high curation and standardisation. The data represented the most consistent data collection spatially and temporally in order to match the over 2 million data points on solar installers.

Agent characters were mined extensively for residential installers and this mapped to the CER-provided data for small-scale residential for both solar rooftop photovoltaic (PV) and solar water heater (SWH). Additional minor factors were mined for non-residential installations of small-scale PV and SWH. We note that non-residential-size rooftop solar is classified by CER over 15 kW and for water heaters over 700 L. Analyst judgement was required to find a proxy in the available data where possible to represent the agent factor of interest for this modelling.

Data received from CER were aggregated at postcode level to calculate number of installations, capacity and STCs from the years 2006 to 2016. These aggregated data by postcode were then mapped with ABS dwelling and income data to give a sense of dwelling and income characteristics for every postcode (Figure 4.1). Federal/State/Territory-based incentives are included in the data in the form of payback period.

Figure 4.1 Overview of modelling-approach[12] for small-scale sector



4.2.2 Small-scale PV systems and solar water heaters – non-residential

Non-Residential Solar PV and SWH forecast methodology was different than residential as it did not include ABS dwelling and income data. Data from CER was aggregated by state to calculate number of installations and capacity for non-residential SGUs on a yearly basis from 2014 onwards. The dataset was further enriched by adding in non-residential data from ABS, solar installation cost and Federal/State/Territory-based incentives in the form of payback-period.

4.2.3 Small-scale hydro and wind generation units

Most existing small-scale hydro and wind was installed prior to 2015 and only one system was installed in 2019 and none in 2020. There was no underlying expectation of ongoing system cost reduction, so it was assumed that the most likely forecast for years 2021 to 2023 is zero.

4.2.4 Other commentary

In addition to the long-run behavioural models, we also conducted time series analysis on the various small-scale technology segments to inform the 2021 starting point for the long-run model-based forecasts.

4.3 Model set-up

Data framing and problem definition conversion into a modelling scenario were time-consuming steps, given the limitation of the data available from CER and publicly available sources. The data selection and preparation were also lengthy steps in the process. Examination by graphical/data analysis allowed a method of change between time periods to be set. This was important as the CER data on installations showed less volatile agent activity from 2014. The challenge with the data amassed was that with numerous factors being utilised, standardising the change was required and this was performed by using percentage changes. See Appendix A for detail on these matters.

[12] Modelling results were generated until 2026 but results for this engagement need be provided till 2023 only.

Table 4-1 Factors and dependent features for solar users for each category

Parameter	Solar PV - Residential	Solar PV – Non-Residential	SWH -Residential (New Installations & Replacement)	SWH - Non-Residential
Factors	Dwelling Size	State	Dwelling Size	State
	Separate Dwelling	Year Installed	Separate House	Year Installed
	Private Dwelling	Cost of Solar Installation ($/W)	Private Dwelling	Number of Non-Residential Buildings
	Employment	Number of Non-Residential Buildings	Employment	
	Education	Payback Period	Education	
	Age over 55		Age over 55	
	Population		Population	
	Owners		Owners	
	Median Household Income		Median Household Income	
	Affordability		Electricity Price	
	Payback Period		State	
	Electricity Price		Postcode	
	State			
	Postcode			
Dependent features	Number of Installations	Number of Installations	Number of Installations	Number of Installations
	Capacity	Capacity		

By structuring the data sets to maximise the learning from change over time, the most detailed data were used in the models. Building the models and structuring the data for each category was extensive given the multi-million data points under consideration. Test runs and methods of deployment were undertaken to ensure the viability of the proposed operations for this worked appropriately.

4.4 Underpinning data sets

Below, we discuss the data used to prepare the models for each type of technology.

4.4.1 Small-scale solar PV

Where the type of premises at which a PV system is installed is unknown, the installation is assumed to be residential where its size is 15 kW or less, with anything larger assumed to be non-residential

Financial inclusions are as listed in Table 4.2 and include the cost of solar installation and payback period. The data used are detailed in Appendix B.

Table 4-2 Financial Data items used including to construct payback series and affordability

Item	Description	Source
Installation cost	Average system cost by size and location, including GST and STC discount	Solar Choice
Electricity tariffs	Determination of default market offer prices, Consumer Price Index	AER, ABS
Electricity consumption	Electricity consumption benchmarks	AER
Usage patterns	Typical load and generation profiles	Ausgrid
Household income	Average household income by postcode	ABS

Non-financial inclusions are as listed in Table 4-3. As there were few influencing non-financial factors of non-residential installation identified the data discovery from state and year installed from CER data was utilised.

Table 4-3 Table 4.3 Non-Financial Solar PV Residential Data

Factors Included in the Model	Source
Dwelling Size	ABS
Separate House	ABS
Private Dwelling	ABS
Employment	ABS
Education	ABS
Age over 55	ABS
Population	ABS
Owners	ABS
State	CER
Postcode	CER

4.4.2 Solar water heaters

SWH installation was modelled in solar thermal, heat pump, residential, non-residential, replacement and new building segments, Table 4-4 shows the factors that were generally allowed for in the models.

Only household income and electricity price were included as financial influences modelled for residential SWHs. The prices of such systems were not available. No financial factors were modelled for non-residential SWH; the prices for these systems were not available either. As there were only a few influencing non-financial factors of non-residential installation identified, the data discovery from number of non-residential buildings and year installed from CER data was utilised.

Table 4-4 Table 4.4 Non-Financial SWH Residential Data New and Replacement

Factors Included in the Model	Source
Dwelling Size	ABS
Separate House	
Private Dwelling	
Employment	
Education	
Age over 55	
Population	
Owners	
State	CER
Postcode	

4.5 Model validation analysis

4.5.1 Model Construction

By structuring the data sets to maximise the learning from change over time, the most data was used in the models. Building the models and structuring the data for each category was extensive given the multi-million data points under consideration. The entire model flowchart is included in Figure 4.2 (see below).

The categories examined by a model included solar PV and SWHs for residential and non-residential customers. For each category, separate model components were run for installation numbers and capacity, residential and non-residential.

Once the above-mentioned data was consolidated the model preparation addressed the correlated factors which were removed. This sought to ensure the model was not overburdened with double representation of data. The process of data normalisation was completed to ensure consistent scales of data representation across all factors under consideration. The training data sets were prepared and set into the format required for modelling.

Model training worked through three types of machine learning algorithms[13] for each category on training data and each model performance was scored and evaluated on test data (Appendix C). A quality review was undertaken to prevent 'overfitting' of the learnt model.[14] The models were built, run and deployed on the GHD.ai platform, which has access to numerous machine learning algorithms. To forecast the number of installations and capacity, different regression algorithms were run for each small-scale technology group. Based on the features of each prepared input dataset, the GHD.ai platform recommended the best model fitted to that data utilising features which best explains the variability in the data. For the model for each

[13] These include: Regression, in which combinations of variables are examined in simple causal, additive relationships; Decision Tree. which divides a collection of data into successively smaller segments such that data within each segment are more alike and more distinct from other segments, and in which boosting takes misclassified data from the previous decision tree model run and trains it on a second model in order to reduce error and capture all data characteristics in the subsequent model; and Ensemble modelling, in which a number of modelling options are deployed simultaneously and the most effective model is utilised, measured according to pre-set evaluation criteria.

[14] 'Overfitting' means that too detailed a modelling activity is undertaken such that the 'big picture of change' is lost in detail that may be more reflective of noise than genuine trends.

category, features of low significance to that model were removed to ensure the most appropriate algorithm was constructed with the most significantly contributing features.

A final model was set up for each category using the most appropriate performing algorithm and only the most significant features. Once model tuning was completed and associated forecast data prepared, each model tailored for a particular category was prepared to be deployed in forecasting of solar installations and capacity.

4.5.2 Model Feature for Forecasting

Model features that added most to the association of factors modelled at postcode level for every category of data are listed in Table 4-5 and Table 4-6 below.

Table 4-5 Important features used in forecasting the number of residential solar users

Fuel Source	SGU Installation Type	Factors Included in the Model
Solar PV	Solar PV - Residential	Dwelling Size
		Separate House
		Private Dwelling
		Age over 55
		Population
		Owners
		Median Household Income
		State
		Postcode
Solar Water Heaters*	SWH – Residential New Installations SWH – Residential Replacement	Dwelling Sze
		Separate House
		Private Dwelling
		Employment
		Education
		Age over 55
		Population
		Owners
		Median Household Income
		Electricity Price
		State
		Postcode

** There were neither insignificant nor strong drivers identified in model feature selection to explain SWH uptake. With no reason to exclude any characteristic of agent activity from model influence all the factors were included in the model for forecasting*

Figure 4.2 Overview of approach for generating modelling results

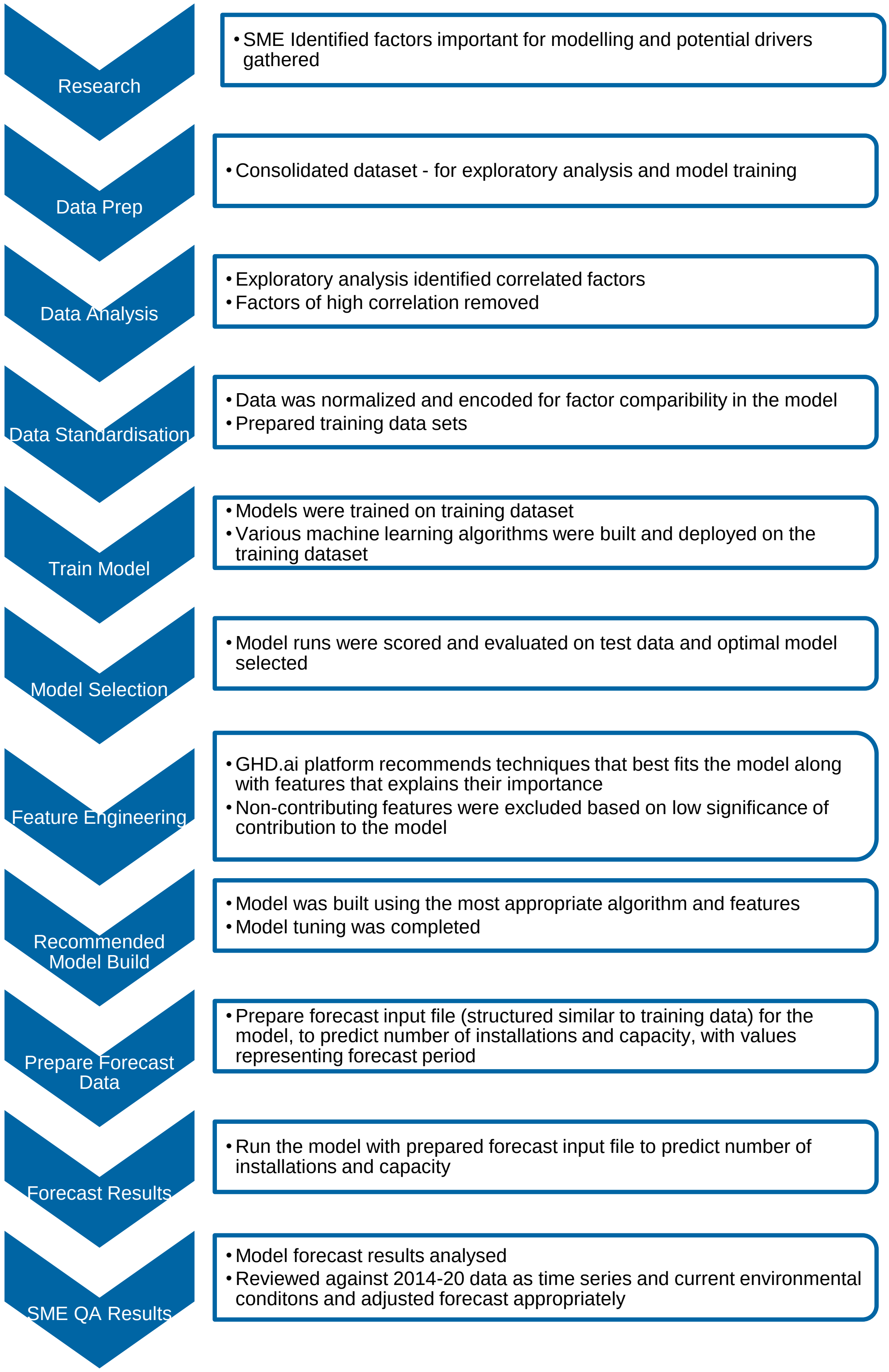


Table 4-6 Important features used in forecasting the number of Non-Residential solar users

Fuel Source	SGU Installation Type	Factors Included in the Model
Solar PV	Solar PV – Non-Residential	State Year Installed Cost of Solar Installation Number of Non-Residential Buildings Payback Period
Solar Water Heater *	SWH – Non-Residential	Year Installed Number of Non-Residential Buildings

** There were neither insignificant nor strong drivers identified in model feature selection to explain SWH uptake. With no reason to exclude any characteristic of agent activity from model influence all the factors were included in the model for forecasting.*

4.6 Forecasting Factor Assumptions

The impact of COVID restrictions on both local and global movement has been seen in the economy and large falls in both income and employment have occurred during 2020. It is too early to determine with certainty the full depth of impact and length of the current recession. However, we have assumed that income support and other measures put in place by Commonwealth, State and Territory governments will minimise the financial impacts of COVID-related disruptions to economic activity and support the return to economic growth in the second half of 2021. Additionally, economic activity is assumed to respond quickly when movement restrictions are lifted. The impacts of the current recession influence the modelled forecasts through our assumptions about future employment and income.

However, we have assumed that, with the freeing up of government-imposed restrictions on activity, economic activity will respond quickly. The impacts of the current recession influence the modelled forecasts through our assumptions about future falls in employment and income.

Longer term effects of the current COVID restrictions may include permanent changes in investment and consumption patterns, such as those related to working from home, international and domestic travel and the split between services supplied outside the home – such as eating out – and services generated within the home. Such effects are not explicitly captured by our models.

Affordability of installation of small-scale technologies was calculated as up-front cost as a proportion of income. Income was median household income drawn from ABS data. All forecasting factors were completed at a national level instead of at postcode level (levels recorded in Appendix D).

4.6.1 Long-run model inputs

The factors used in the forecasting models are detailed in Table 4-7 and Table 4-8.

Table 4-7 Solar PV and Solar Water Heater – Residential Forecasting Factors

Fuel Source	Factors
Solar PV & SWH – Residential	Dwelling Size Separate House Private Dwelling Age over 55 Population Owners
Solar PV & SWH – Residential	Median Household Income
Solar PV & SWH – Residential	Payback Period
Solar PV & SWH – Residential	Employment

Table 4-8 Solar PV and SWH – Non-residential Forecasting Factors (change from 2019)

Fuel Source	Factors
Solar PV – Non-residential	Installation Cost ($/W)
Solar PV – Non-residential	Payback Period
Solar PV and SWH - Non-residential	Number of non-residential buildings

A check of forecast results was made against 2014-20 data and current environment known factors.

4.6.2 Short-run model inputs

Explanatory variables for the short-run model were determined by their intuitive impact on technology uptake, ability to distinguish between each jurisdiction and statistical significance. Inputs included electricity prices, which when rising provide greater motivation to invest to save money in the future, and State Final Demand, which is representative of the average income of electricity consumers.

Table 4-9 and Table 4-10 show the year-on-year average changes that we assumed for the inputs to the short-run model, where the years 2018/19 and 2019/20 are actual outcomes. The future year changes result from differential quarterly change assumptions for each jurisdiction. Jurisdictions are expected to experience differential economic downturns largely because of differential degrees of restricted movement and impacts on export industries in response to COVID-19 outbreaks.

Table 4-9 Nominal electricity price changes

Year	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
2018/19	10.3%	-0.9%	1.2%	-6.2%	-2.1%	2.1%	3.2%	7.3%
2019/20	0.4%	-3.4%	0.5%	-5.4%	-2.5%	2.0%	-2.6%	0.6%
2020/21	-2.5%	-5.4%	0.0%	-10.7%	-7.5%	-1.4%	-6.8%	0.0%
2021/22	-1.8%	-4.0%	1.1%	-6.2%	-6.9%	-4.9%	-13.2%	1.8%
2022/23	6.9%	7.7%	1.4%	2.5%	3.7%	2.7%	4.9%	1.8%

Table 4-9 above is based mostly on Australian Energy Market Commission (AEMC)[15] data for National Electricity Market (NEM) regions. It reflects falling generation costs in the NEM for 2020/21 and 2021/22, due to increasing installation of low marginal cost renewable plant, prior to the retirement of large-scale fossil fuel plant, resulting in a tightening of the demand-supply balance.

The 2020/21 price for WA in Table 4-9 is based on the A1 residential tariff rate published by Synergy[16] and the 2020/21 price for NT is the standard residential rate published by Utilities Commission.[17] Future years' increases for WA and NT are based on CPI increases projected by each jurisdiction's respective Treasury.

Table 4-10 Financial year changes in real State Final Demand

Year	ACT	NSW	NT	QLD	SA	TAS	VIC	WA
2018/19	4.2%	2.0%	-17.2%	0.9%	1.5%	4.4%	3.5%	-1.4%
2019/20	3.1%	-2.0%	-4.8%	-0.2%	-2.1%	-0.2%	-1.3%	0.8%
2020/21	-0.9%	-1.5%	0.0%	0.7%	-1.3%	-0.3%	0.7%	0.5%
2021/22	3.5%	2.5%	0.5%	3.5%	4.8%	3.5%	3.9%	3.8%
2022/23	3.0%	2.3%	1.0%	2.8%	3.0%	3.5%	3.2%	2.3%

Table 4-10 is based on economic forecasts most recently published for each jurisdiction's 2020/21 Budget.[18] As State Final Demand projections are not provided for ACT and QLD, these have been imputed from the projections of Gross State Product. No projection is published for Tasmania for 2022/23, so the same growth rate as the previous year has been assumed.

[15] AEMC (2020) Residential Electricity Price Trends 2020, https://www.aemc.gov.au/sites/default/files/2020-12/2020%20Residential%20Electricity%20Price%20Trends%20report%20-%2015122020.pdf.

[16] Refer to: https://www.synergy.net.au/Global/Synergy-Price-changes-2020.

[17] Refer to: https://utilicom.nt.gov.au/electricity/price-regulation/electricity-retail-pricing.

[18] ACT Government, August 2020 Economic and Fiscal Update; NSW 2020-21 Budget, Budget Paper No. 1; Northern Territory Budget 2020-21, Budget Paper No. 2; Queensland Treasury, Budget Strategy and Outlook 2020-21; Government of South Australia, State Budget 2020-21, Budget Statement Budget Paper 3; Tasmanian Government, The Budget, Budget Paper No.1; Victorian Budget 2020-21 Putting People First, Strategy and Outlook Budget Paper No. 2; Western Australia State Budget 2020-21, Budget Paper No. 3 Economic and Fiscal Outlook.

5. Results

This section sets out and explains our small-scale technology installation modelling results. Detailed results for energy installations and capacity forecasts for small-scale technology are provided in a separate spreadsheet (**GHD's results for the CER**).

5.1 Findings

For many electricity consumers in Australia, there is conceptually a clear benefit in investing in a small-scale PV system. 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.

The cost of installation continues to fall, and additional motivation may be related to solar PV's ability to reduce environmental impacts and the potential it gives to gain greater control over the supply of and cost of energy. We consider these factors underlie a clear historical trend in increasing penetration, with the limiting factors in the long run being location and roof-space availability and ownership. Since the penetration rate (in terms of available roof space) is far from saturation level in most postcodes, we would have every reason to expect recent high take up rates to continue, subject to a relatively short pause due to financial constraints.

In the case of solar water heaters, the landscape is more complicated, as multiple technology bundle choices are available, albeit less so for multiple dwelling and non-residential buildings. Unlike the cost of PV panels, there is no underlying scale or efficiency related cost fall for water heaters. The up-front cost for solar thermal is relatively expensive compared with alternative water heating technologies. The operational cost of water heating is affected by the availability of off-peak tariffs.

Electrical water heating powered by complementary PV generation may be a viable alternative to solar thermal for many consumers, in which case the running cost of the water heater may be less important than the initial installation cost. Heat pump water heaters are the most efficient but often represent the highest capital cost, while the space they require could also be a drawback. Installations of electrical water heaters of whatever type that coincide with PV generation installation are likely to justify a relatively higher capacity of PV in order to power the water heating load with self-generated electricity. We would expect a resumption of growth in solar water heaters based on recent growth in installations of heat pump types and in new separate homes. Solar hot water is not feasible in a wide range of non-residential buildings.

Small wind or hydro generation is not generally a practical possibility for most electricity consumers, and we do not anticipate growth in the number of these types of generation units in the future.

5.2 Summary of forecasts for Australia

Table 5-1 summarises our historical analysis and forecasts for years 2021 onwards, for small-scale system installation, generation capacity and related STC creation.

Table 5-1 Small-scale generation units and solar water heater installations Australia

Parameter	2017	2018	2019	2020	2021	2022	2023
Number of PV systems installed	182,445	232,250	294,222	358,653	385,650	393,900	403,080
Number of hydro and wind systems installed	12	0	1	0	0	0	0
Total capacity MW	1,210	1,702	2,265	2,857	3,180	3,464	3,758
Number of solar water heaters installed	66,447	68,238	66,632	66,139	73,520	74,910	76,350
STCs created '000s	22,995	30,166	36,769	41,355	45,390	44,356	42,554
Pending audit				1,066	1,170	1,143	1,096
Surplus from previous year				2,244	2,286	2,507	2,454
STCs approved	22,995	30,166	36,769	42,205	43,809	43,079	41,375

Figure 5.1 to Figure 5.5 further illustrate our forecast small-scale renewable energy installations and capacity forecasts results for Australia. Key findings are:

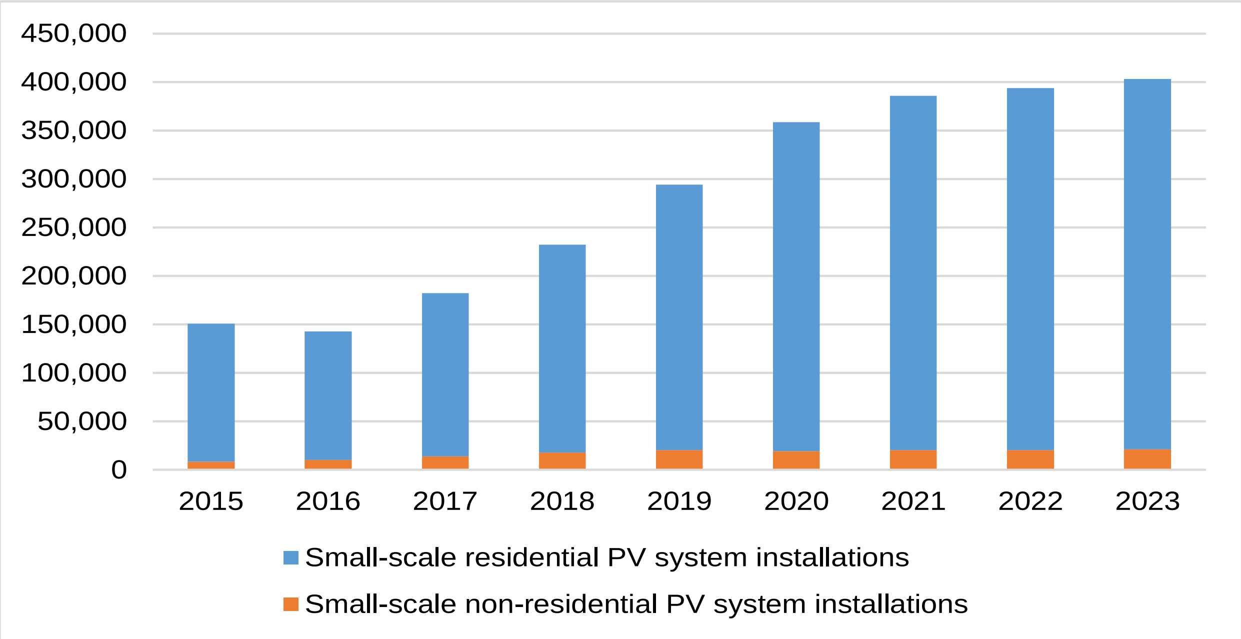
- Despite an economic recession and pandemic-related travel restrictions, there was a continued increase in the total number of installations of residential PV systems in 2020, relative to 2019 (24.0% increase). This was apparent even in Victoria, where there was an extended and strict COVID-related lock-down in Melbourne during the year for 16 weeks.[19] Following a further forecast increase of 7.7% in 2021 (for Australia), the long-run growth rates forecast for 2022 and 2023 are more subdued, at 2.3% per annum on average. This is driven by reduced population growth and building activity, partially offset by continuing decreases in PV system costs, income support through the initial stages of the current recession in 2020, followed by an assumed economic recovery by 2022, bolstered by supportive Commonwealth, State and Territory government fiscal strategies. During the pandemic, there has been increased focus on home improvement by some homeowners as the home environment has also become a workplace for much more of the workforce.[20]
- There was continued increase in the total capacity of residential PV systems in 2020, relative to 2019 (34.6% increase). This was larger than the increase in the number of installations due to the increasing size of the average installation. Continued growth of 10.9% is forecast for 2021, with forecast growth rates beyond that averaging a moderate 8.8% per annum. (This means the average installation size will continue to grow until 2023, indicating, potentially, that costs on an installed kilowatt basis are decreasing and/or a greater preference by the average consumer for clean energy sources). The long-run growth rates are aligned to underlying growth since 2016 and are confirmed by data for 2020.
- There was a small decrease in the total number of residential SWHs in 2020, relative to 2019 (0.7% overall decrease, reflecting the net impact of increased replacements and fewer installations in new buildings, primarily because of a reduction in new home building). An increase of 11.2% is forecast for 2021. However, forecast growth rates for 2022 and 2023 are relatively low at 1.9% per annum on average. Projected future growth is driven almost entirely by heat pump systems installed in new buildings, reflecting recent trends in the adoption of such systems by owners/operators of new buildings (which is encouraged, in part, by existing building codes on energy-efficiency matters).

[19] See https://www.bbc.com/news/world-australia-54686812 for more information about the duration of Melbourne's Stage 4 lockdown.

[20] "COVID-19 renovation boom: How much Aussies are spending to give their houses a facelift during the pandemic", https://www.news.com.au/finance/real-estate/covid19-renovation-boom-how-much-aussies-are-spending-to-give-their-houses-a-facelift-during-the-pandemic/news-story/f87ae20e602ff97f94763426458cfe73.

- Total approved STCs rose by 14.8% in 2020, compared with 2019. They are forecast to increase a further 3.8% in 2021. However, they are then forecast to fall over the rest of the modelling period by an average of 2.8% per annum, despite the growing capacity of installations. This is principally due to the reduction in the deeming factor for STCs, which falls to one as 2030 approaches (the fall in the deeming factor reduces the number of certificates that are created for an eligible system of a given capacity). [21]

Figure 5.1 Annual number of small-scale PV installations – Australia



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

Figure 5.2 Annual small-scale PV capacity installed (MW) – Australia

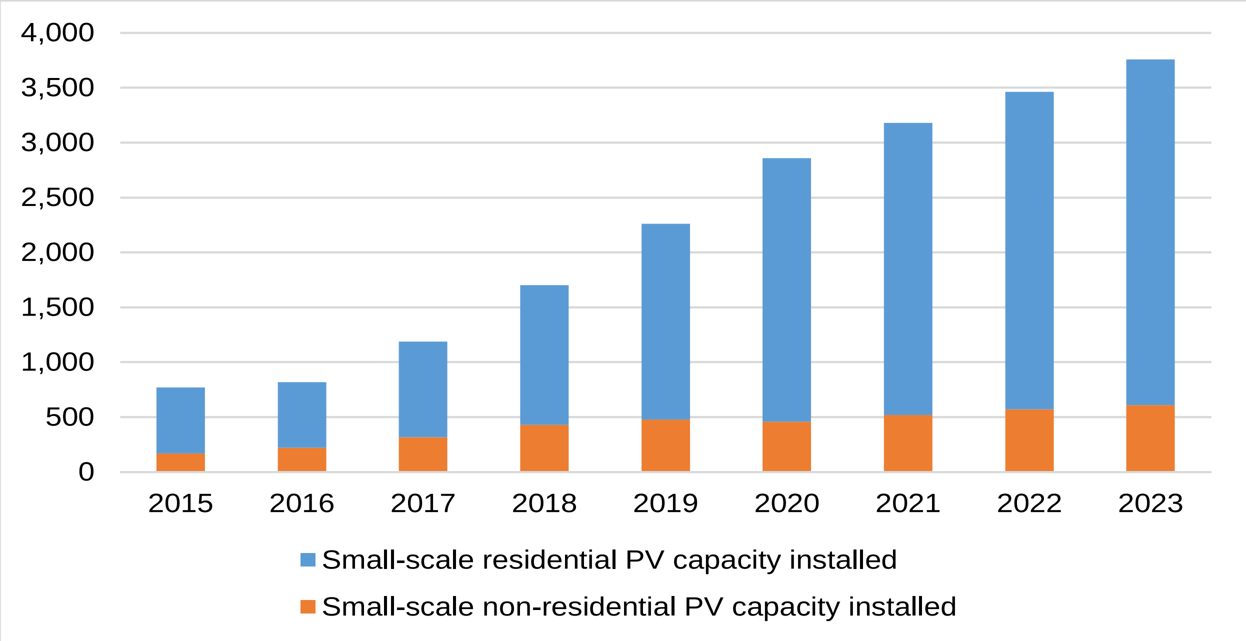


Figure 5.3 Annual number of small-scale solar water heaters installed

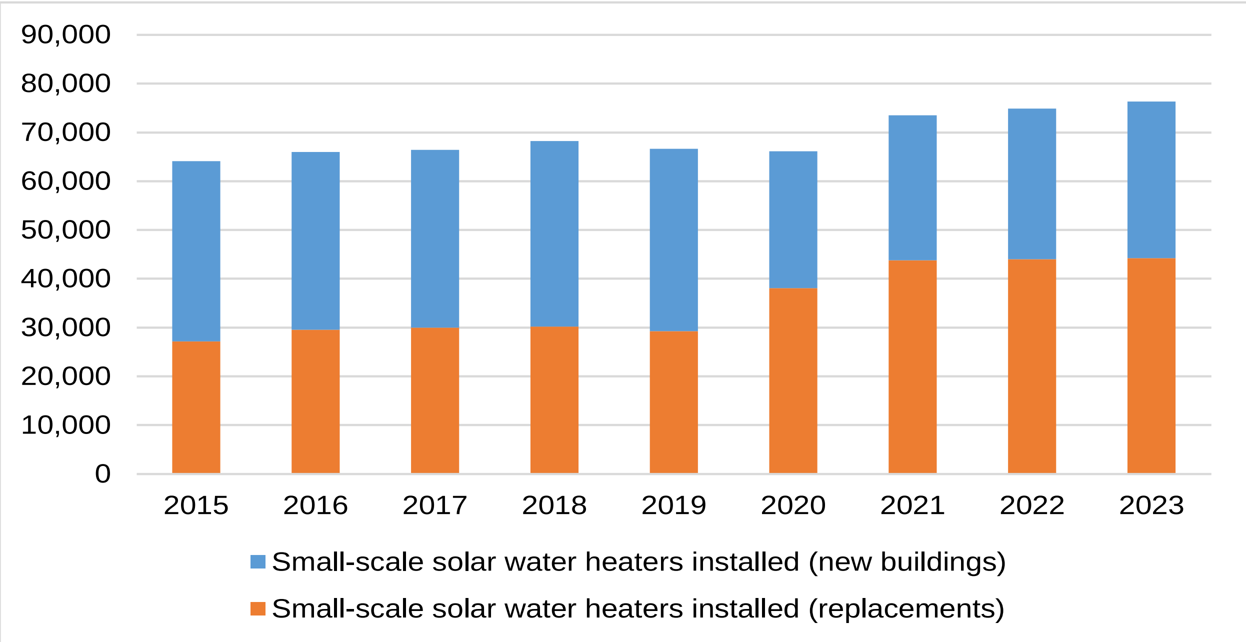


Figure 5.4 Annual small-scale wind and hydro capacity installed (MW) – Australia

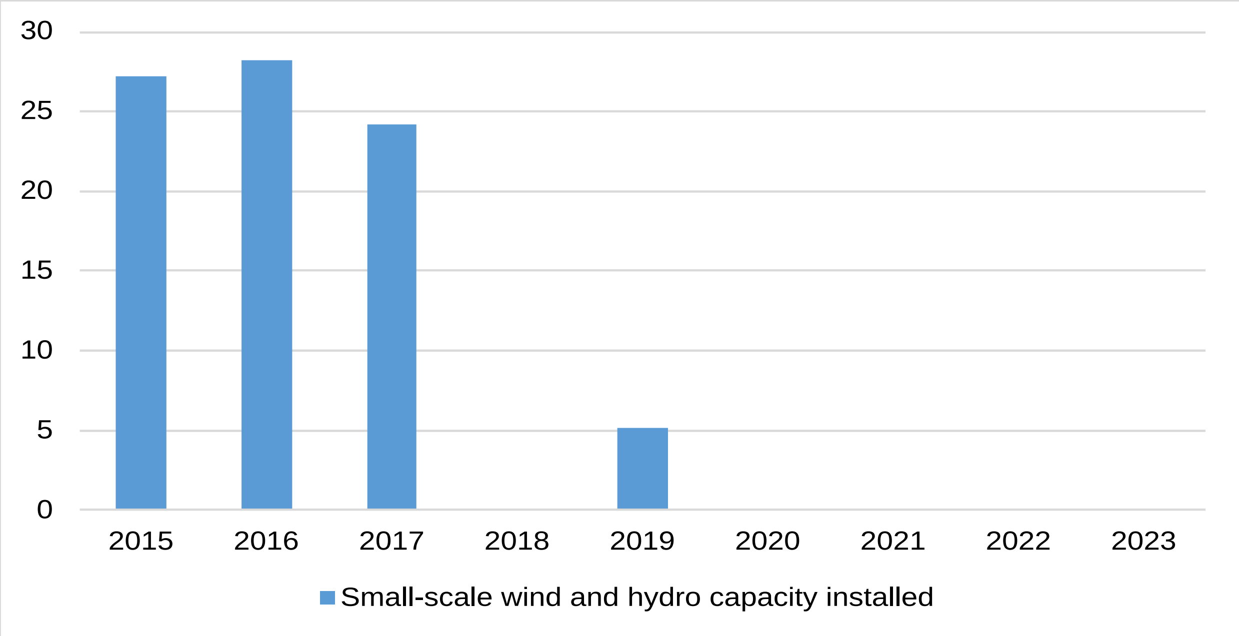
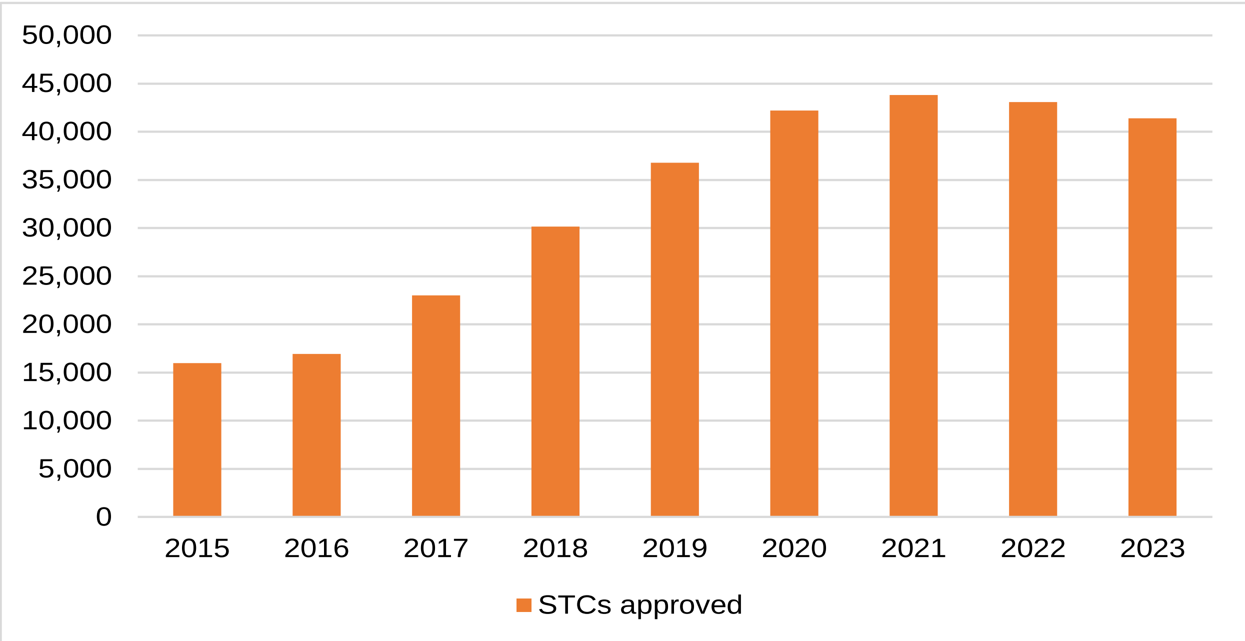


Figure 5.5 Annual number of STCs approved ('000s)– Australia



5.3 Summary of forecasts for individual States and Territories

Figure 5.6 to Figure 5.8 present our PV installations and capacity, and total STC forecasts for each State and Territory. Key findings are:

- Generation capacity installed each year remains at relatively high levels, both due to the number of installations and increasing average system size (Figure 5.6 and Figure 5.7)
- The number of STCs approved in each forecast year nonetheless decreases slightly after 2021, as the deeming period decreases (Figure 5.8).

Figure 5.6 Annual number of small-scale PV installations – by State/Territory

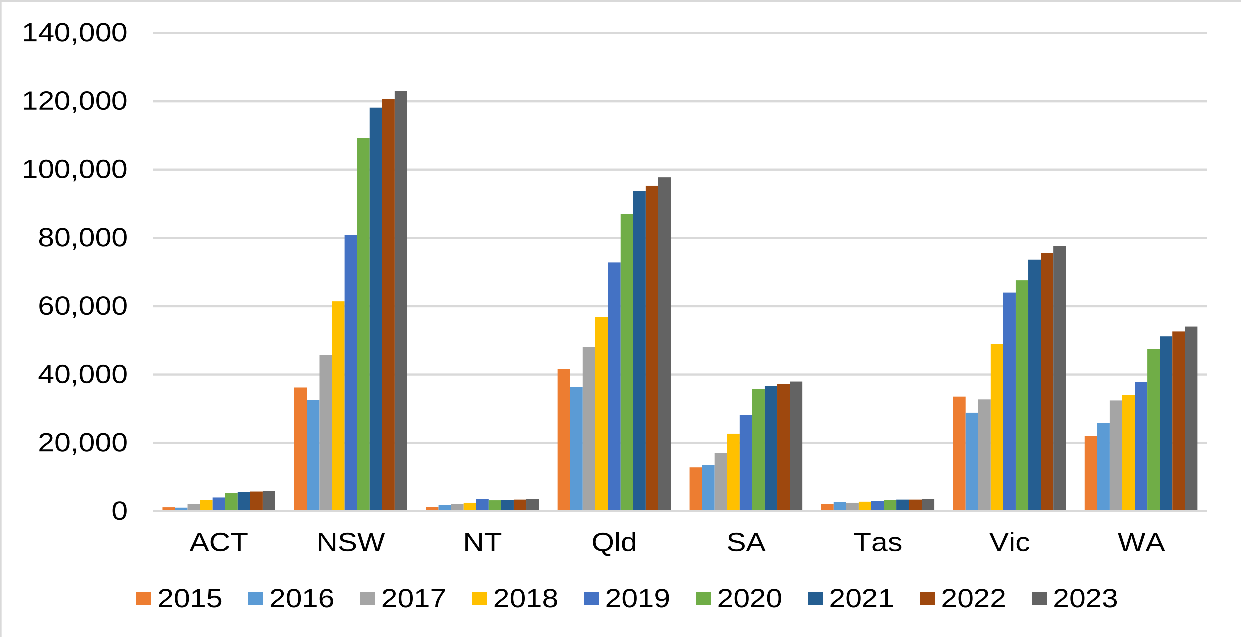


Figure 5.7 Annual small-scale PV capacity installed (MW) – by State/Territory

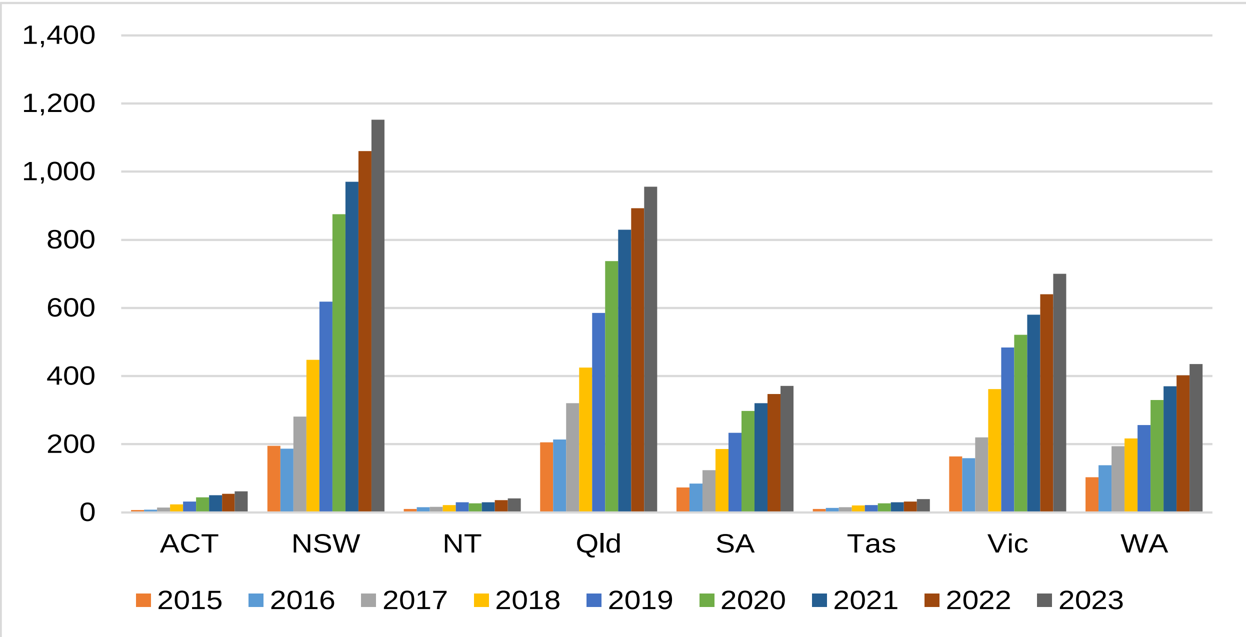
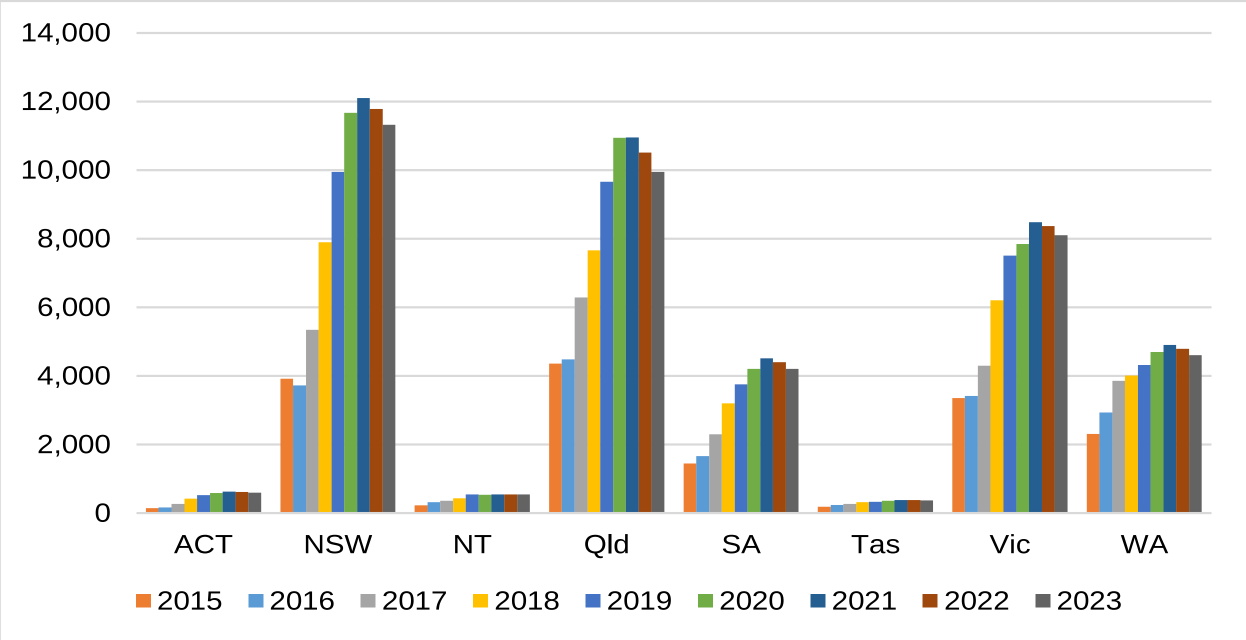


Figure 5.8 Annual number of total STCs approved ('000s) – by State/Territory



GHD Advisory

Appendices

Appendix A Detailed model description

For residential solar PV and solar water heater: Data received from CER was aggregated at Postcode level to calculate number of installations, capacity and STCs from year 2006 – 2016. These aggregated data by postcode were then mapped with ABS dwelling and income data to give a sense of dwelling and income characteristics for every postcode. Federal/State/Territory-based incentives are included in the data in the form of payback period.

Some factors were not collected as comparable factors in 2006 and 2011 and these were mapped, and adjustments made, to ensure a comparative base for the data. Utilisation has been made of percentage change over time periods from 2006 to 2011 and 2011 to 2016.

Since ABS data is available for year 2006, 2011 and 2016, the model considers installation, capacity and ABS dwelling, income and other characteristics changes in 5-year period i.e. 2006 – 2011 and 2011 and 2016. The model is then trained on 2006 – 2011 and 2011 and 2016 dataset to predict installation and capacity changes in year 2021 and 2026 based on 5-year changes in the independent factors as shown in the figure below.

Note data was normalised over a scale of 1-100, or percentage, to have factor comparability and not over-weight one factor over another.

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

Time-series analysis was further done to QA results from the model and forecasted values from the model for year 2021 – 2023 were adjusted based on the annual growth from 2014 – 2020 data and other current or future environment conditions. Initial data analysis ensured an understanding of correlated factors in the data. Factors were removed where correlation occurred so as to not represent a factor twice in the model.

The evaluation method for feature acceptance to the model was either by co-efficient of determination or variance: statistical measures representing the difference between variables under comparison in terms of how much one can explain the other. When used in the area of prediction, the co-efficient of determination represents the strength of the factor's contribution to predicting the target outcome.

The error rates for each additional model feature were examined and when little error reduction occurs for the addition of a factor there was no merit in adding the complication of that factor to the model. That factor was removed and the final model constructed using only the influential factors for each model, for each of installation and capacity for the technology categories of SGU and SWH, for both residential and non-residential sectors. Modelling for residential was also considered for new and existing buildings.

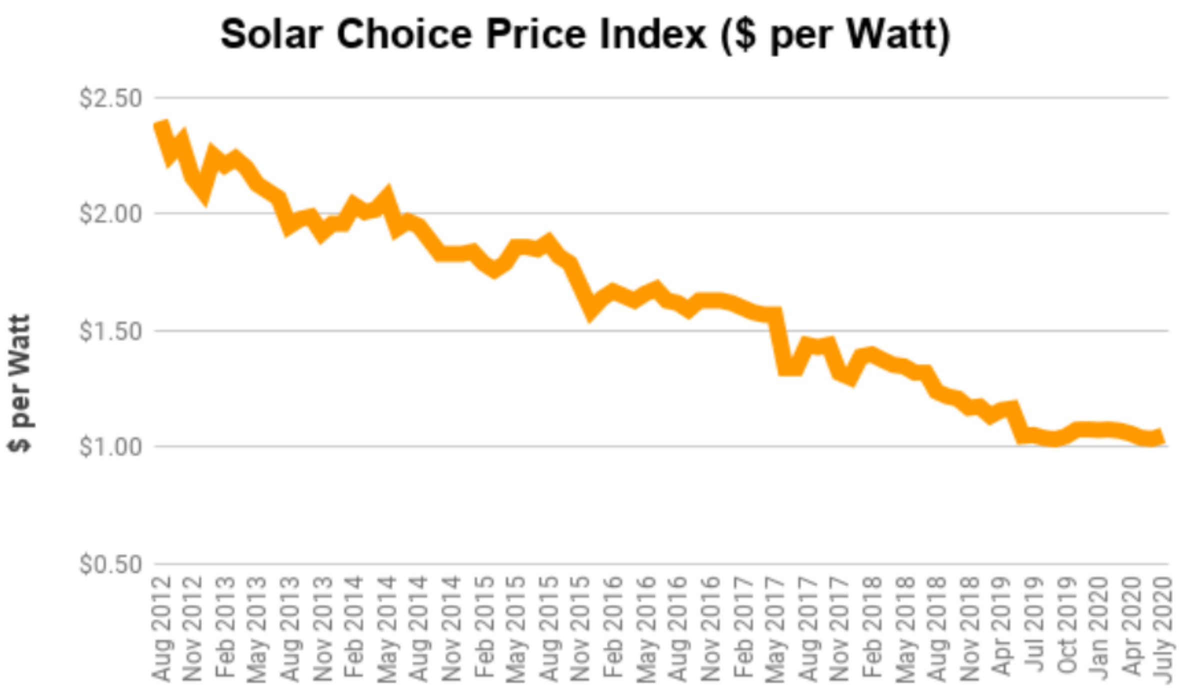
Appendix B Detailed data sources

1. ABS Dataset Definition

ABS data is collated at postcode level for year 2006, 2011 and 2016. Features mentioned in chapter 4 looks at % change in non-financial factors for these periods.

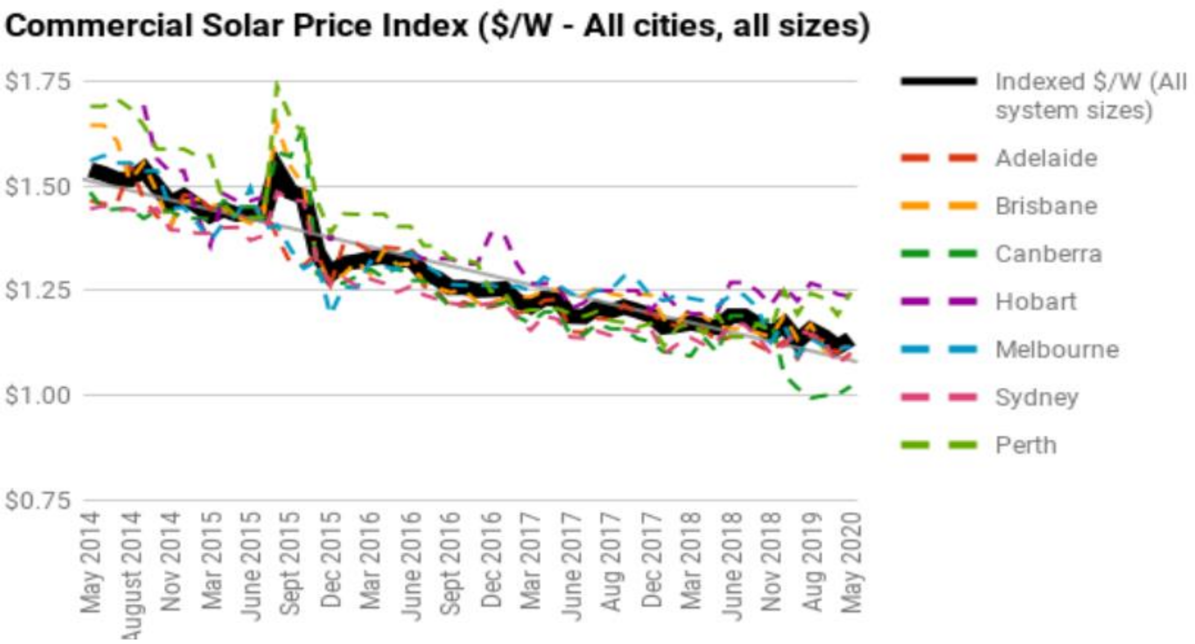
ABS Factors	Data Set from ABS	Description (Data taken for modelling residential small-scale systems)
Population	Population	Total number of persons per postcode
Median Household Income	Median total family income ($/week)	Median household income per postcode
Age Distribution	Place of residence on census night by age	Number of people with age 55 or more
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 - P36	Number of houses in postcode with more than 3 bedrooms

2. Solar Price – Residential



https://www.solarchoice.net.au/blog/solar-power-system-prices

3. Solar Price – Commercial



https://www.solarchoice.net.au/blog/commercial-solar-pv-price-index-for-august-2020/

4. Average LGC spot price ($/MWh)

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
35	28	43	80	93	83	45	35	30	30	30

https://www.energycouncil.com.au/analysis/traders-taxes-and-renewable-energy-certificates/

5. Total Net Energy Consumption in Australia, by Industry (PJ)

2013	2014	2015	2016	2017	2018	2019
5317	5264	5272	5357	5334	5334	5334

https://www.energy.gov.au/publications/australian-energy-update-2019 ; *Table E*

6. Other data sources

NPV or payback index for various system sizes and locations

- 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 → % export → cost saving and export earnings.

Appendix C Model Construction

Solar PV and SWH – Residential Assumptions:

- Factors listed in Table 4.1 for Solar PV uptake is based on the study undertaken by Queensland University of Technology – Residential customers and adoption of Solar PV.
- 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 Assumptions, as per point 6 Appendix B.
- Solar Installation Cost is taken from Solar Choice website and is average installation cost ($/w) of all residential capacity sizes.
- There are no strong drivers that influences solar water heater uptakes. Time series analysis was done to further validate and adjust forecasted numbers.
- Electricity Cost assumptions, as per section 6 Appendix B (see page immediately above).

Solar PV and SWH – Non-residential Assumptions:

Payback period for non-residential Solar PV is assumed to be 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 is considered in the model.
- Non-residential water heater 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.

Constructed Model Success Criteria

<table>
<tr><th>PARAMETER</th><th>SCALE</th><th>TYPE</th><th>FUEL SOURCE</th><th>DETERMINISTIC METRIC</th><th>MODEL</th><th>VALUE</th></tr>
<tr><td rowspan="2">CAPACITY</td><td rowspan="2">Small Scale</td><td>Commercial</td><td>Solar Panels</td><td>Coefficient of Determination</td><td>Linear Regression</td><td>0.55</td></tr>
<tr><td>Residential</td><td>Solar Panels</td><td>Spearman Correlation</td><td>Voting Ensemble</td><td>0.78</td></tr>
<tr><td rowspan="4">INSTALLATION</td><td rowspan="4">Small Scale</td><td rowspan="2">Commercial</td><td>Solar Panels</td><td>Coefficient of Determination</td><td>Linear Regression</td><td>0.62</td></tr>
<tr><td>Solar Water Heater</td><td>Coefficient of Determination</td><td>Decision Forest Regression</td><td>0.22</td></tr>
<tr><td rowspan="2">Residential</td><td>Solar Panels</td><td>Spearman Correlation</td><td>Voting Ensemble</td><td>0.8</td></tr>
<tr><td>Solar Water Heater (New Installations / Replacements)</td><td>Explained Variance</td><td>Voting Ensemble</td><td>0.24</td></tr>
</table>

Appendix D Forecasting

Solar PV and Solar Water Heater Residential Forecasting Factors

Fuel Source	Factors	2020	2021	2026
Solar PV & SWH – Residential	Dwelling Size % Separate House % Private Dwelling % Age over 55 % Population % Owners %	Unchanged similar 2011 – 2016 growth expected	Unchanged similar 2011 – 2016 growth expected	Unchanged similar 2011 – 2016 growth expected
Solar PV & SWH – Residential	Median Household Income %	-0.75 %	-1.25%	10%
Solar PV & SWH – Residential	Payback Period	4	3	3
Solar PV & SWH – Residential	Employment %	-6.15%	-0.75%	5%

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

Fuel Source	Factors	2020	2021	2022	2023
Solar PV – Non-residential	Installation Cost ($/W)	-2%	-2%	-2%	-2%
Solar PV – Non-residential	Payback Period	4	3	3	3
Solar PV and SWH - Non-residential	Number of non-residential buildings	Unchanged	Unchanged	Unchanged	Unchanged

** Where a percentage or term ‘unchanged’ is mentioned, it is referenced from 2019 period.*

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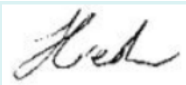
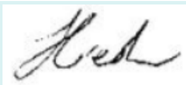
01	Richard Hickling	Hiresh Devaser		Hiresh Devaser		16/11/2020
Final	Richard Hickling	Hiresh Devaser		Hiresh Devaser		20/01/2021

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