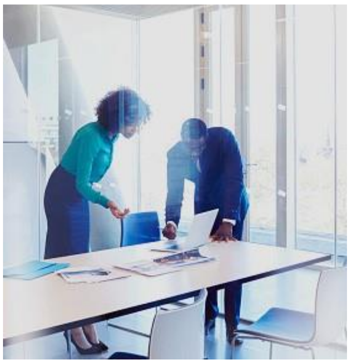
GHD Advisory



Small-scale technology certificate (STC) creation and mid-scale photovoltaic (PV) installation forecasts

Clean Energy Regulator

23 October 2020

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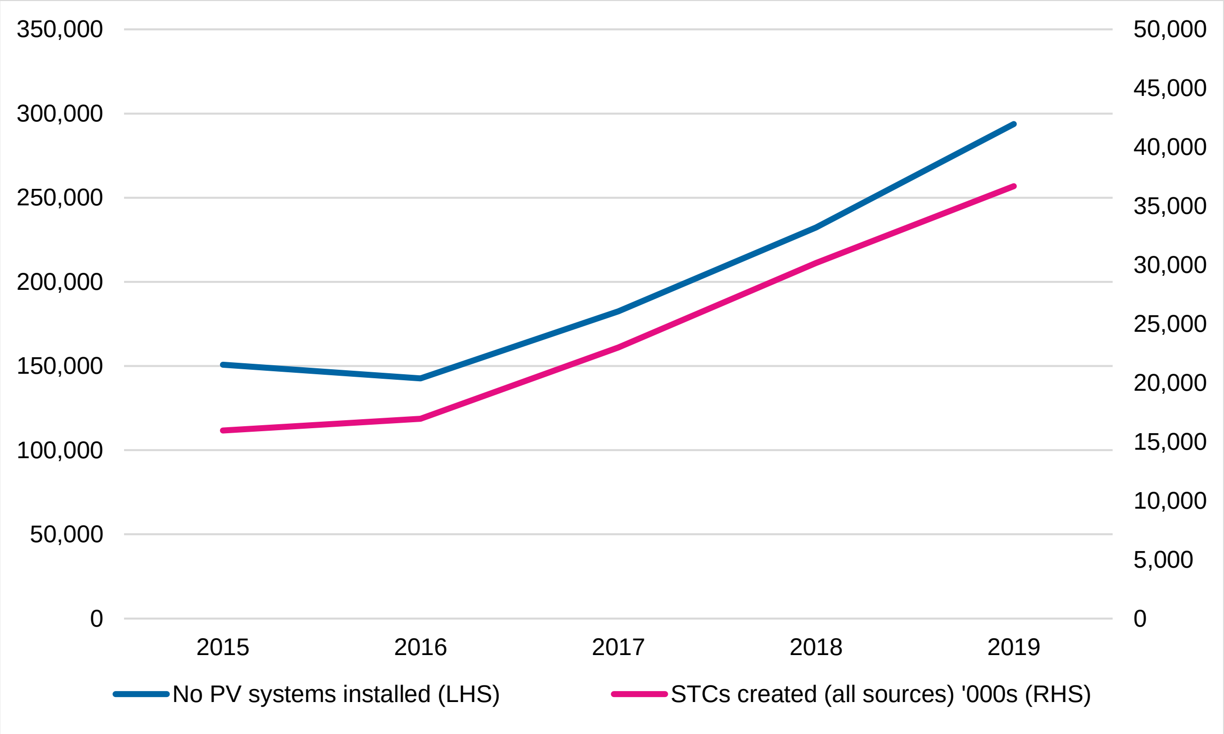
1. Executive summary

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 (SWH), SWH air-source heat pumps and other small generation units (SGUs).

Recent activity in relation to small-scale technology certificates (STCs) shows recent upward trends in small-scale PV installations and STC creation (refer to Figure 1.1).

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



Source: Clean Energy Regulator, Renewable Energy Certificate (REC) Registry and GHD estimates for 2020.

The CER engaged GHD (us) to provide modelling of small and mid-scale renewable energy installations and capacity forecasts, covering the period of 2020 to 2024[1]. To fulfil this requirement, we adopted a modelling approach that links consumer characteristics (e.g. household type and size, location, income, postcode etc.) to the demand for small- and mid-scale renewable energy installations (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 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. This understanding was forged in the course of confidential project work for our 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.

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

- The estimates for 2020 are generally informed by a short-run time series model, incorporating seven months of actuals. The long-run behavioural model then provides year-on-year growth rates to 2024.
- Non-residential water heater projections are based on linear-regression trends due to insufficient data. We do not project any further small-scale hydro or wind installations because unlike PV these technologies are not expected to reduce in cost over time, existing capacity mostly includes legacy systems and new installations since 2017 have been sporadic.
- STC approvals are based on installation numbers and types, including historical lags between installation and STC registration. We cannot predict actual times between system installation, STC application and registration which vary from project to project.

A summary of our small- and mid-scale renewable energy installations and capacity forecasts results for Australia is presented over the six figures below (Figure 1.2 to Figure 1.7). Key findings from our summary results are:

- There is a sharp increase in the forecast total number of installations of residential PV systems in 2020[2], relative to 2019 (18.3% increase). We expect growth rates beyond that to be far more subdued, at 2.3% per annum on average. This is driven by continuing falls in system costs, income support through the initial stages of the current recession and a likely increased focus on home improvement as the home environment has also become a workplace for more of the workforce.
- There is a spike in the forecast total capacity of residential PV systems in 2020, relative to 2019 (22.2% increase). Growth rates beyond that are moderate, averaging 7.5% per annum. This growth is aligned to underlying growth rates since 2016 and is partially confirmed by data for 2020 to date.
- There is a sharp decrease in the forecast total number of residential SWHs in 2020, relative to 2019 (22.0% decrease). However, we forecast growth rates thereafter to become positive, at 4.0% per annum on average. Projected future growth is driven almost entirely by heat pump systems installed in new building, reflecting recent trends and encouraged by existing building codes.
- Forecast total STCs increase in 2020 and 2021, but then fall over the rest of the forecast period, despite the growing capacity of installations. This is principally due to the falling deeming factor in the STC calculation, which falls to one as 2030 approaches. (This will reduce the number of certificates that can be created for an eligible system).

[2] Based on actual data to end-July 2020.

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

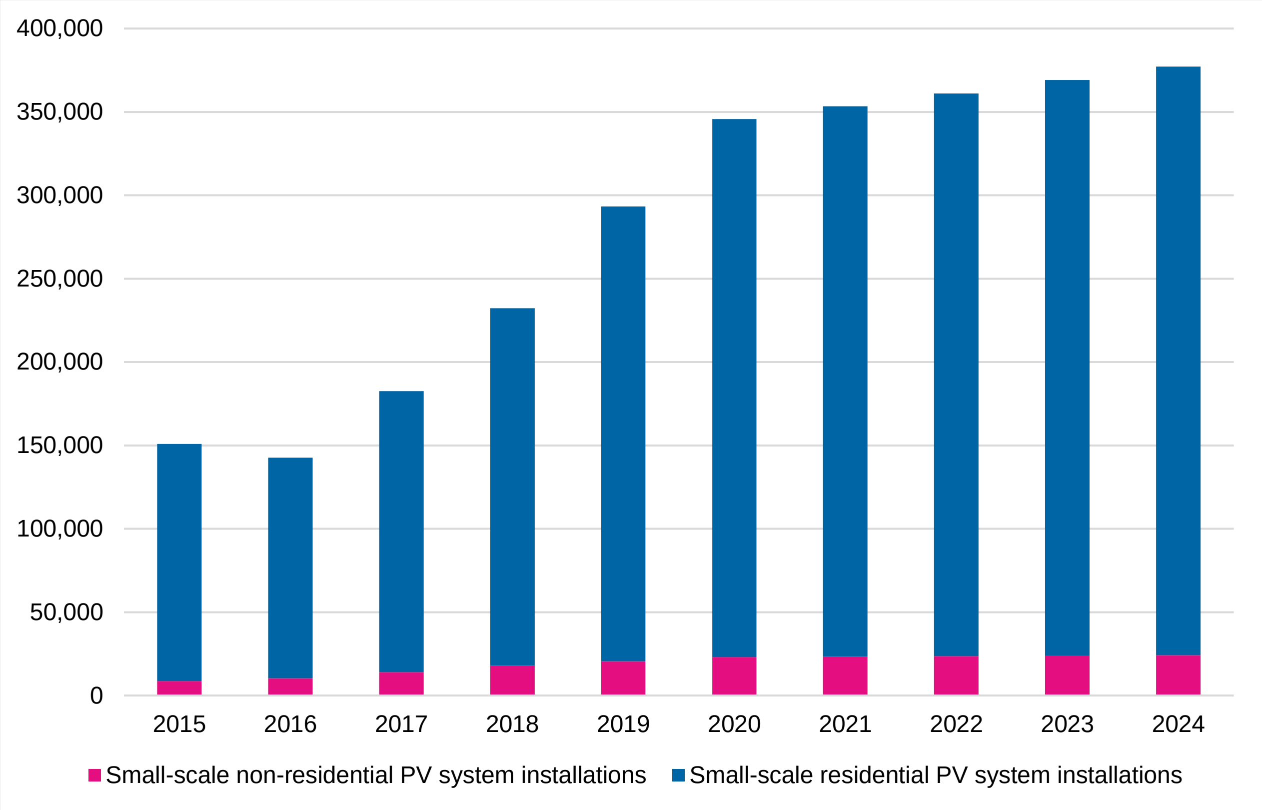


Figure 1.3 Annual small-scale PV capacity installed (MW) – Australia

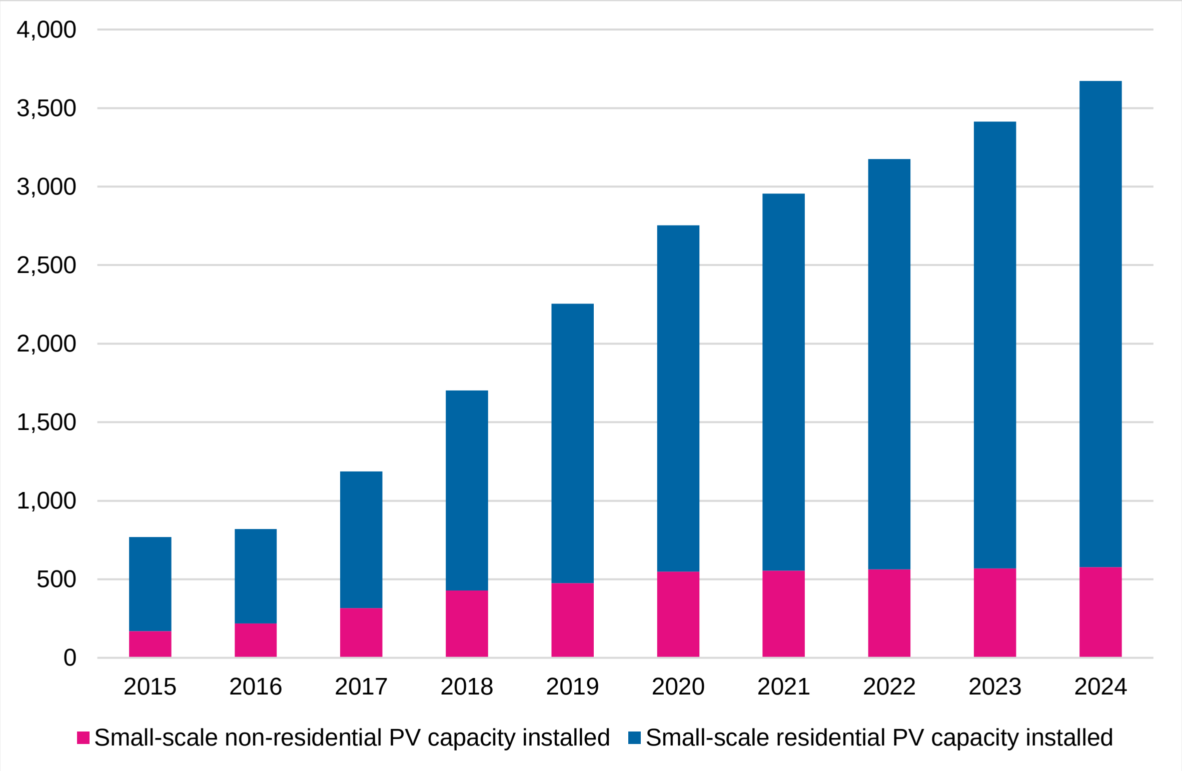


Figure 1.4 Annual number of small-scale solar water heaters installed

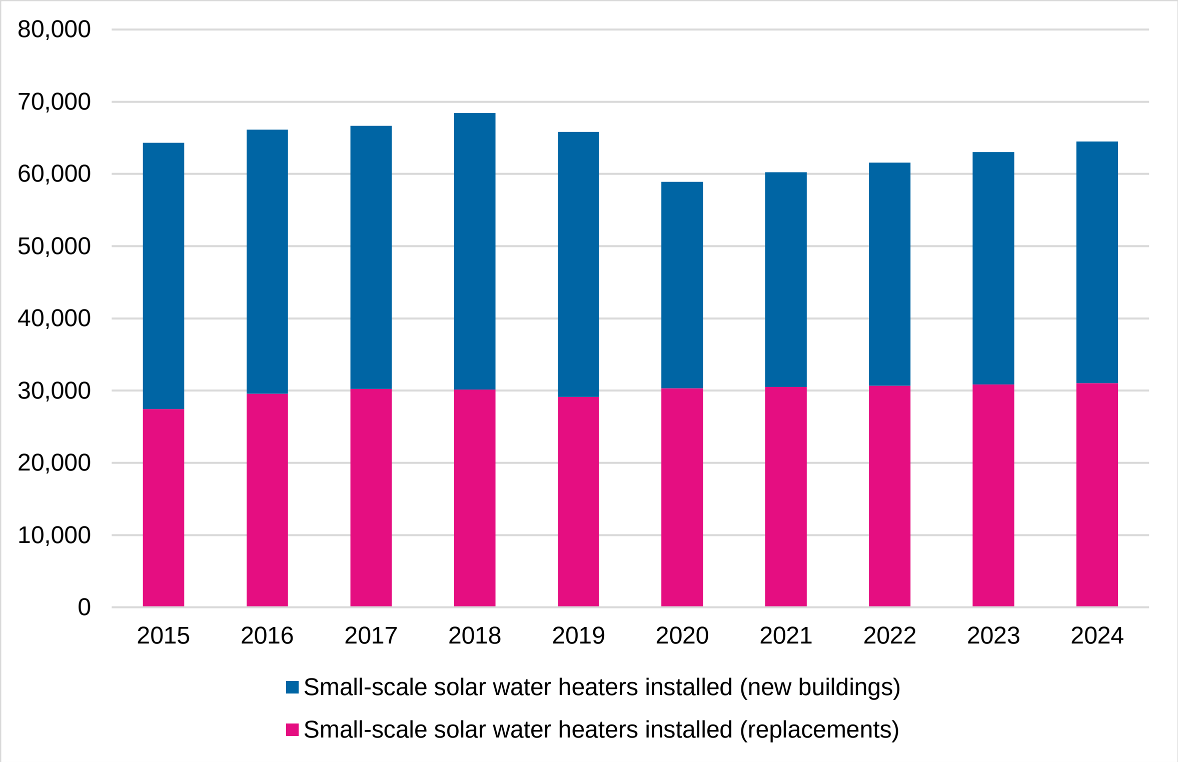


Figure 1.5 Annual small-scale wind and hydro capacity installed (MW) – Australia

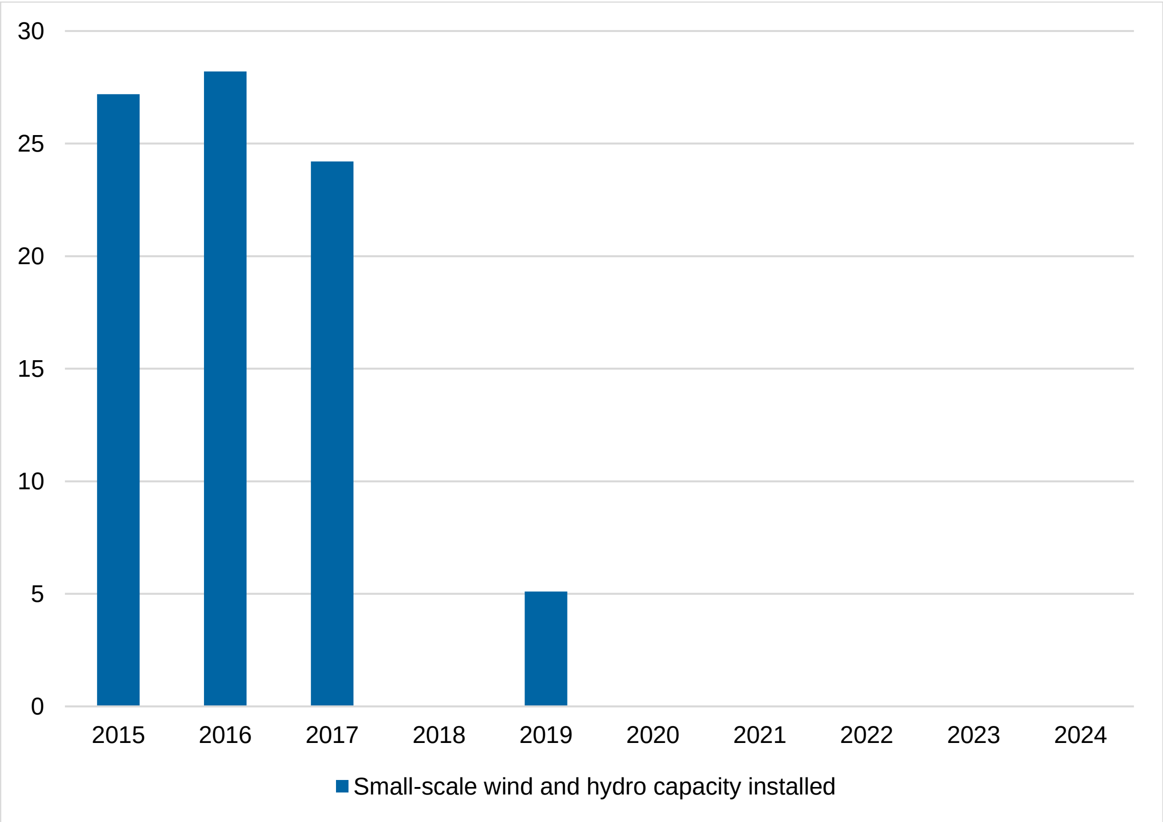


Figure 1.6 Annual number of STCs approved – Australia

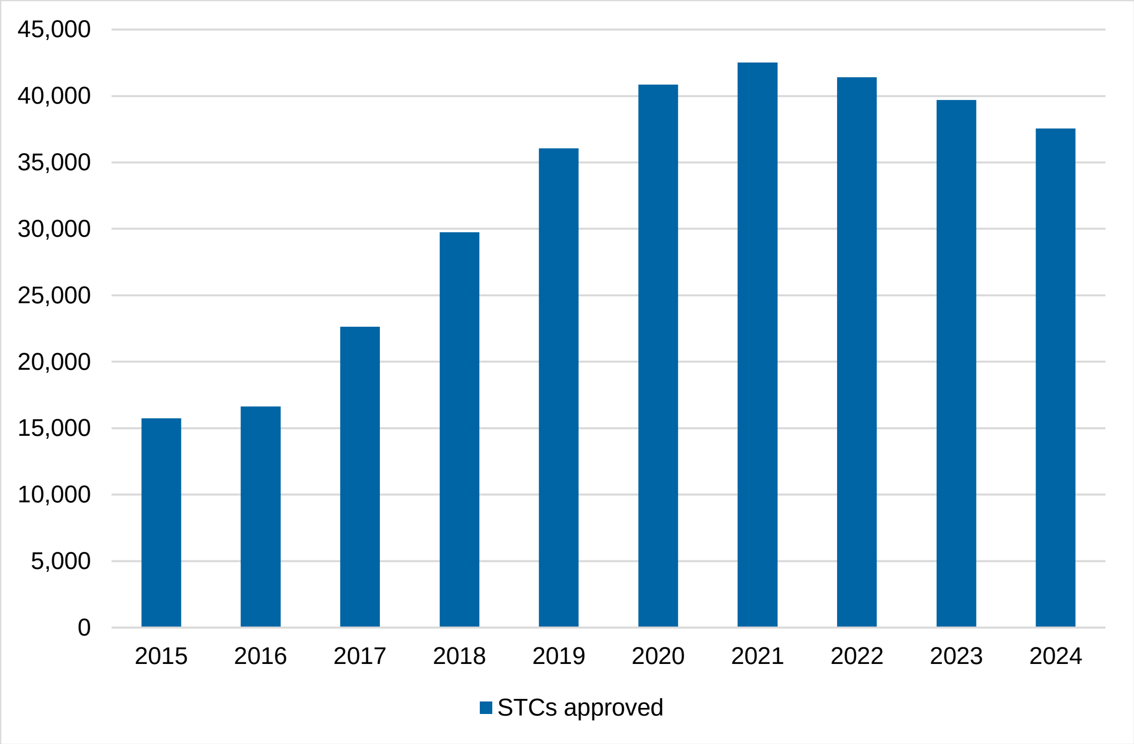
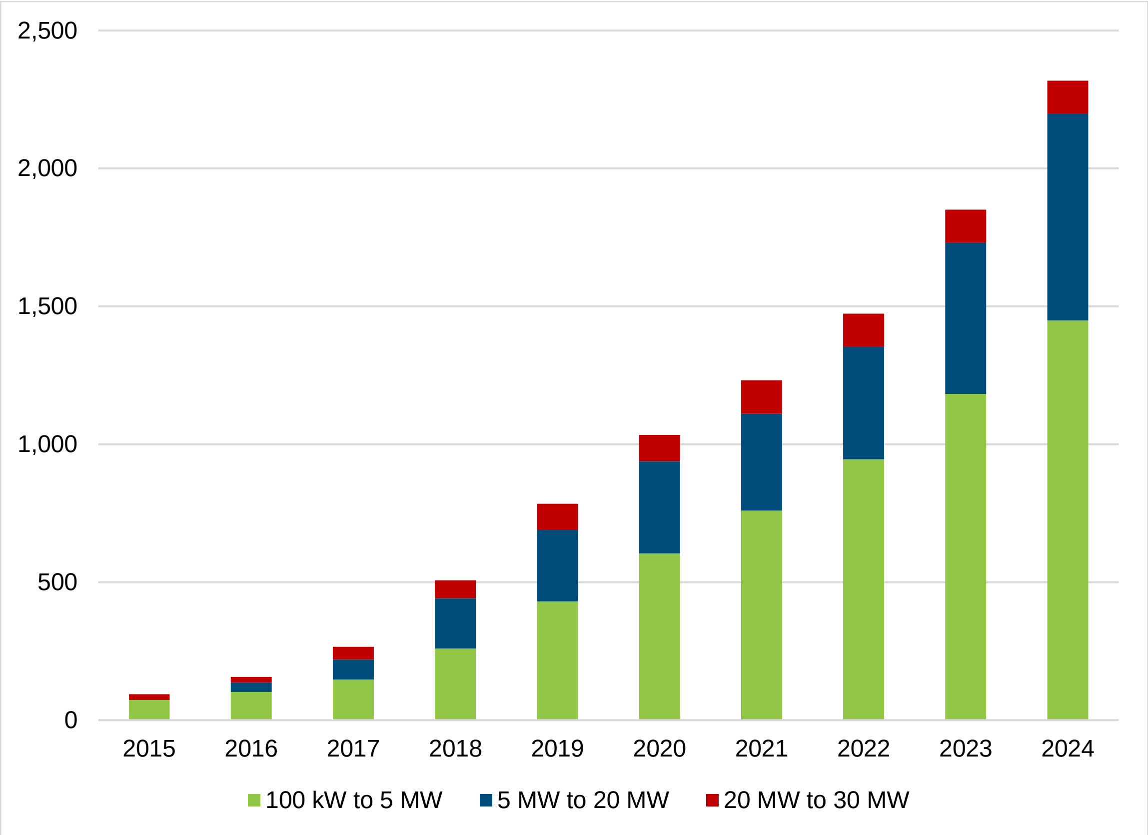


Figure 1.7 Cumulative installation of mid-scale PV capacity (MW)



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GHD has prepared the modelling of small and mid-scale renewable energy installations and capacity forecasts set out in section 5 of this report ("Results") using information reasonably available to the GHD employee(s) who prepared this report, including assumptions and judgments made by GHD. The Results have been prepared for the purpose agreed between CER and GHD and the Results must not be used for any other purpose.

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 technological 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 *and* mid-scale renewable energy installations and capacity forecasts. The forecasts are to cover the period of 2020 to 2024[3]. More detail on small- and mid-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)

2.1.2 Mid-scale technology installations

The CER has also asked us to model and forecast the demand for installing mid-scale PV generation units. These are sized at more than 100 kW and are therefore eligible for Large-scale Generation Certificates (LGCs), rather than STCs).

Maximum capacity modelled is 30 MW, which is the size at which generation units connecting to the National Electricity Market (NEM) must be registered with the Australian Energy Market Operator (AEMO)[4]:

- greater than 100 kW up to and including 5 MW
- More than 5 MW, up to and including 20 MW
- More than 20 MW, up to and including 30 MW

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)

[3] Calendar years

[4] Generating units that predominantly supply an individual customer's premises without significant export are usually granted automatic exemption from registration. Other small generators may need to apply to AEMO for an exemption from registration. Registered participants incur registration fees. Only registered participants are individually dispatched into the market.

- 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
- expected national mid-scale solar PV installations and capacity by various categories and capacity bands across state and territories in Australia
- a bottom-up analysis of known pipelines and announcements of mid-scale systems
- robust modelling that underpins the analysis
- clear outline of assumptions, methodology and underpinning data sets
- an analysis of the mid-scale solar PV market, including key factors driving the market's demand and supply
- 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, including small and mid-scale renewable energy projections
- detailed appendices to support the modelling work including data to support figures

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

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- and mid-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, postcode etc.) to the demand for small- and mid-scale renewable energy installations (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, as well as mid-scale PV generation installations. Our understanding of the key drivers is based on our own previous research, undertaken in the course of confidential project work for our clients, as well as 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[5]. 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 2020 installations between approval in 2020 and approval in 2021.

3.1.2 Mid-scale technology installations and capacity forecasts

Mid-scale PV systems cover a range of installation types, including variation in:

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

- Size of installation (and therefore the cost and site area required)
- Whether installed behind or in front of the meter (whether installed primarily for self-use or essentially as a power station)
- Industry sector (particularly if installed to offset site load, as this may determine the energy use intensity)
- Whether grid-connected or standalone (and therefore whether the primary purpose is to offset the need to purchase power, generate into the electricity market or replace existing gas or diesel generated electricity)
- Whether roof or ground mounted, fixed or tracking (technical characteristics determined by the site, size required and whether maximisation of the efficiency and daily duration of generation is important)

Generally speaking, however, such systems are installed for financial motives: either to reduce or eliminate power purchases of grid supplied electricity, to replace expensive local gas or diesel generation, or to make money in the electricity markets. In each case some primary determinants of financial success are the same: wholesale electricity prices (whether directly or via its influence on the long-term contract market) and the expected price of Large-scale Generation Certificates (LGCs).

3.2 Installation drivers

Previous studies[6] 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[7]. 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

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

[7] Solar Choice https://www.solarchoice.net.au/blog/solar-power-system-prices. The manner in which the installation 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.

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[8]. 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 aforementioned concern 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.

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- or mid-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.

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

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[9], 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 them more or less prone 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 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 (as long as they can legally do so).

The same can be said for small businesses or green groups themselves; they too may face tacit pressure to install mid-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 highly energy-efficient offices, meaning that mid-scale 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[10] 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 are able to 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

[9] In the southern hemisphere.

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

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.

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 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.

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.

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.

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 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

In addition to the long run behavioural models we also conducted time series analysis on the various small-scale technology and mid-scale segments to inform the 2020 starting point for the long-run model-based forecasts. Below we explain both the short-run and long-run modelling procedures and data inputs.

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. Each model utilised monthly historical data from January 2016 to July 2020, in a trend regression analysis with dummy variables for each month and a moving average error specification. The forecast from each model was used to predict, for each respective category, the installations and capacity for the remaining months of 2020.

In the case of the mid-scale PV capacity modelling, the short-term forecast for 2020 consists of actual installed capacity recorded in CER supplied data for the first 7 months of 2020, plus projects in the database but yet to be accredited, plus 5 months of the long run forecast for 2020, representative of the remainder of 2020 (the months of August to December 2020).

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 particular 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 basing solar uptake on agent based modelling is that the activity is evidence of sentiment of the agent and representation of the agent character in both the structure and the dwelling occupants can be utilised in propensity of solar uptake 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.

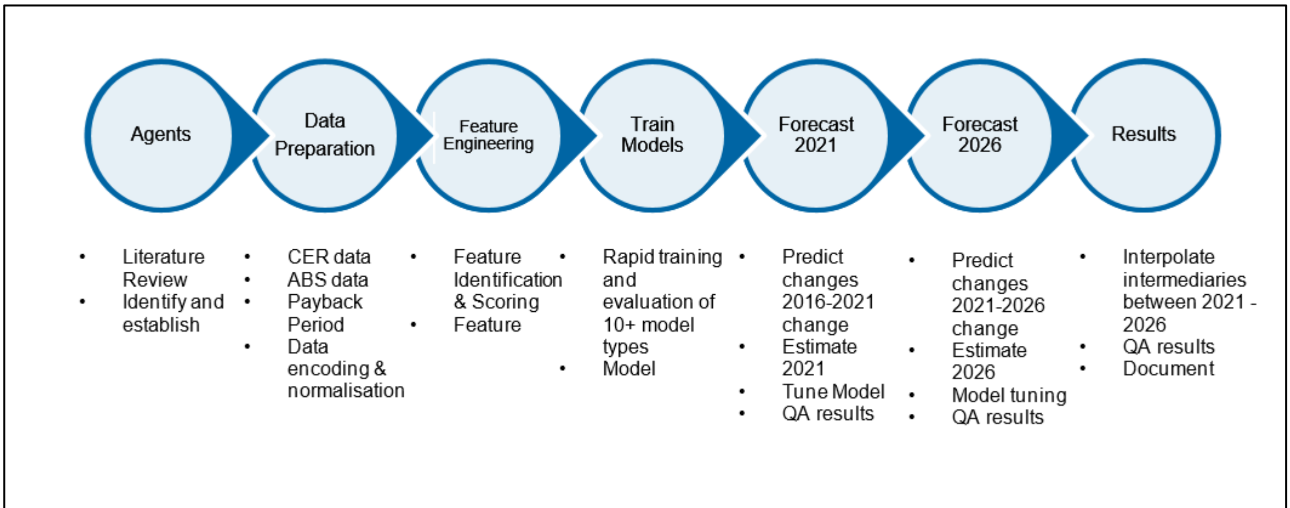
Of all available data sets known in public and private domain the most accessible, covering all of Australia, in the time and budget available was the extensive and comprehensive data held by the Australian Bureau of Statistics (ABS). Harnessing the data was possible due to its high curation and standardisation. This 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 and also midscale PV installations. 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 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 (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[11] 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.

[11] Modelling results were generated until 2026, but results for this engagement need be provided till 2024 only

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 year 2020 – 2024 is zero.

4.2.4 Mid-scale PV systems

Data supplied by CER contains detailed information on the number of mid-scale systems installed and registered including the location and name of the organisation where unit was installed. The data were provided from 2001 until July 2020. The dataset supplied by CER containing current and proposed mid-scale installations was segmented based on the type of market segment where unit was installed.

The following market segments were able to be distinguished for differential modelling:

- Commercial
- Education
- Solar Farm
- Health
- Government
- Others (i.e. Recreational, Utility, Transport and Unknown).

The mid-scale systems were then modelled by capacity band to forecast number of PV installations and installed capacity by market segment. The following capacity bands are taken into account for modelling:

- 100 kW – 1 MW
- 1 MW - 5 MW
- 5 MW – 10 MW
- 10 MW – 20 MW
- 20 MW – 30 MW.

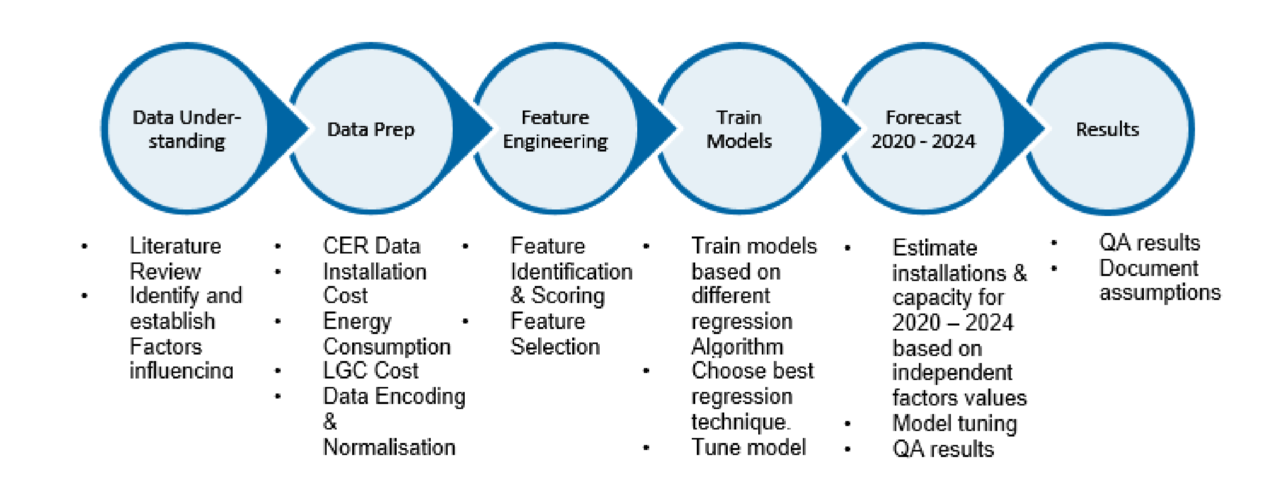
However, as the significance of the results was questionable at these levels for the smaller jurisdictions, the results are reported on the slightly more aggregated capacity bands of 100 kW to 5 MW, 5 MW to 20 MW and 20 MW to 30 MW.

The modelling method applied to mid-scale systems was otherwise similar to the method used for small-scale non-residential systems (refer to Figure 4.2). This resulted in forecasts of mid-scale installation numbers, total capacity and capacity band by market segment.

4.2.5 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 2020 starting point for the long-run model-based forecasts.

Figure 4.2 Overview of modelling methodology for mid-scale sector



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 was a lengthy step in this process. Examination by chart, graph and 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. Table 4-1 shows the included empirical factors for each type of technology category. 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 more detail on these matters.

By structuring the data sets to maximise the learning from change over time the most detailed 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. Test runs and methods of deployment were undertaken to ensure the viability of the proposed operations for this work.

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 is detailed in Appendix B.

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	Mid-scale
Factors	Dwelling Size	State	Dwelling Size	State	State
	Separate Dwelling	Year Installed	Separate House	Year Installed	Industry Category
	Private Dwelling	Cost of Solar Installation ($/W)	Private Dwelling	Number of Non-Residential Buildings	Year Installed
	Employment	Number of Non-Residential Buildings	Employment		Cost of Solar Installation ($/W)
	Education	Payback Period	Education		Energy Consumption (PJ)
	Age over 55		Age over 55		Avg. LGC Cost ($/MWh)
	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	Number of Installations
	Capacity	Capacity			Capacity

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

The impact of COVID restrictions in regard to 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 at present to determine the full impact and length of the current recession.

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	
Private Dwelling	
Employment	
Education	
Age over 55	
Population	
Ownership	
State	CER
Postcode	

4.4.2 Solar water heaters

Solar water heater 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 solar water heaters. Price of systems was not available. No financial factors were modelled for non-residential solar water heaters. Price of systems was not available. As there were 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	
Ownership	
State	CER
Postcode	

4.4.3 Solar PV - mid-scale

The model for mid-scale technology was categorised by year installed. Financial factors influencing midscale installation were considered: installation cost and average yearly Large-scale Generation Certificate (LGC) Cost.

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 4.3 (see overleaf).

The categories examined by a model included: solar PV and SWHs for residential and non-residential customers; and mid-scale PV installations. For each category, separate models 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.

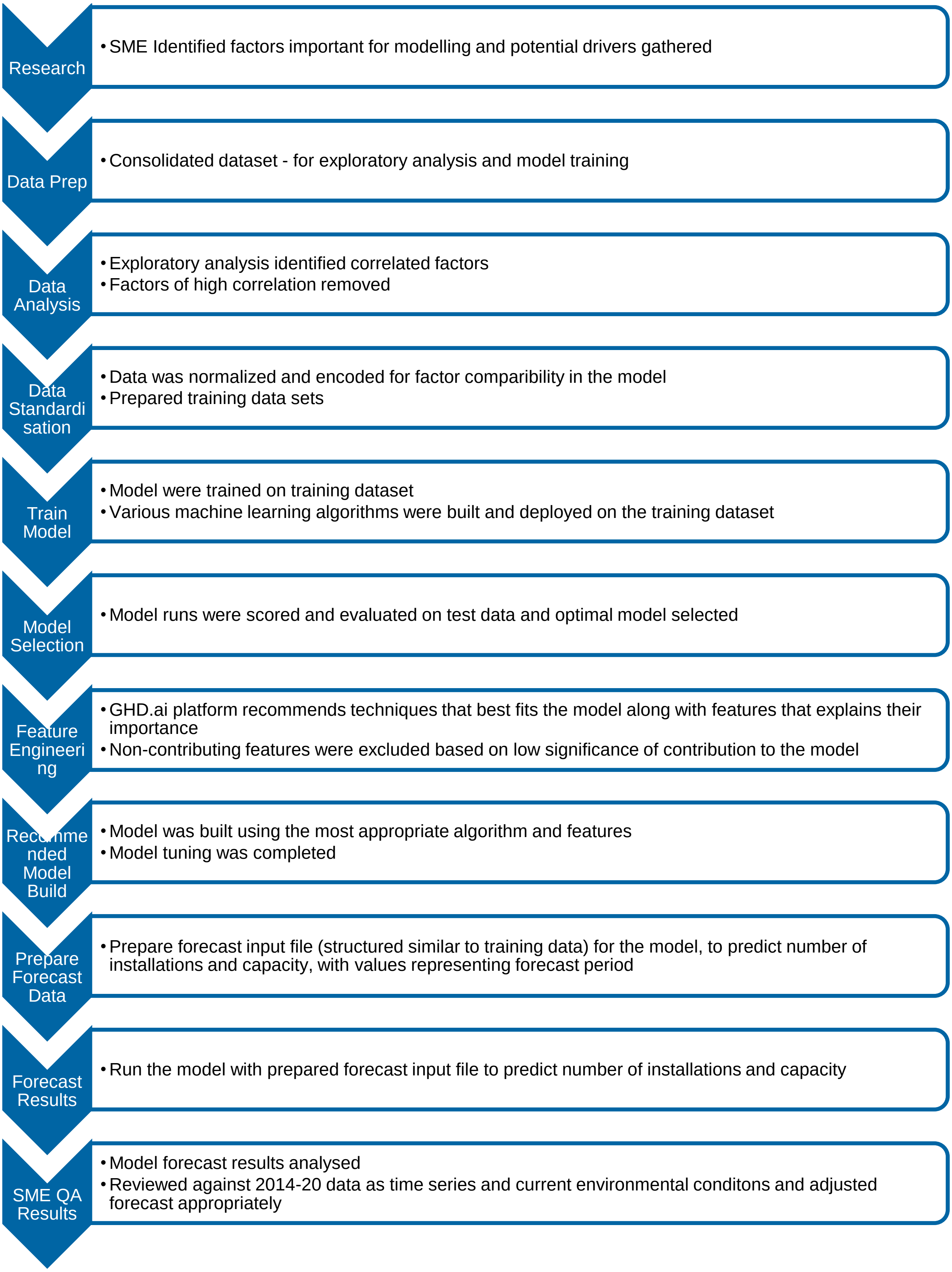
Model training worked through many machine learning algorithms[12] for each category on training data and each model performance was scored and evaluated on test data (Appendix C). A quality review was undertaken to prevent 'overfitting' of the learnt model[13]. The models were built, run and deployed on GHD.ai platform which has access to numerous machine learning algorithms. To forecast number of installations and capacity, different regression algorithms were run for each small-scale and mid-scale technology category. Based on the features of each prepared input dataset, 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 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.

[12] Regression: relationship between variables is examined in a simple causal, additive relationship, Decision Tree Decision Tree divides a collection of data into successively smaller segments so the segments are more like each other and more different to others, the boosting refers to where misclassified data in the previous decision tree model run is trained on in a second model in order to reduce error and capture all data characteristics into a subsequent model. Ensemble modelling: is where a number of modelling options are deployed simultaneously and the most effective model is utilised, measured according to pre-set evaluation criteria.

[13] 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.

Figure 4.3 Overview of approach for generating modelling results



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 to Table 4-7 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 Heater*	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 was 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.*

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 was 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.*

Table 4-7 Important features used in forecasting the number of Mid-scale users

Fuel Source	SGU Installation Type	Factors Included in the Model
Mid-Scale PV	Mid-scale PV	Market Segment
		Year Installed
		Cost of Solar Installation
		Energy Consumption
		Avg. LGC Cost

4.5.3 Forecasting Factor Assumptions

The impact of COVID restrictions in regard to 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 at present to determine the full impact and length of the current recession. However, we have made the assumption that, with the freeing up of government-imposed restrictions on activity, economic activity will respond fairly 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 – 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).

The factors used in the forecasting models are detailed in Table 4-8 and Table 4-9.

Table 4-8 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 4-9 Solar PV, SWH and Mid-Scale – Non-residential Forecasting Factors (change from 2019)

Fuel Source	Factors
Solar PV – Non-residential	Installation Cost ($/W)
Solar PV – Non-residential	Payback Period
Solar PV and SWH - Non-residential	Number of non-residential buildings
Mid-Scale System	Avg. LGC Price($/MWh)
Mid-Scale System	Mean Energy Consumption (PJ)
Mid-Scale System	Installation Cost ($/W)

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

5. Results

This section summarises and explains our small-scale and mid-scale technology-installation modelling results. Detailed results for technology installations, capacity and STC forecasts, for both small- and mid-scale technology, are reported to the CER in a separate spreadsheet (**GHD's results for the CER**).

5.1 Small-scale technology-installation modelling results

For the majority of 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 the vast majority of 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 2020 onwards, for small-scale system installation, generation capacity and related STC creation.

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

Parameter	2018	2019	2020	2021	2022	2023	2024
Number of PV systems installed	232,250	293,315	345,690	353,290	361,130	369,070	377,220
Number of hydro and wind systems installed	0	1	0	0	0	0	0
Total capacity MW	**1,702**	**2,259**	**2,754**	**2,955**	**3,176**	**3,413**	**3,673**
Number of solar water heaters installed	68,446	65,805	58,894	60,217	61,586	63,010	64,493
STCs created '000s	**30,172**	**36,601**	**40,005**	**41,764**	**40,489**	**38,791**	**36,670**
Pending audit			1,030	1,075	1,042	998	943
Surplus from previous year			2,233	2,230	2,358	2,291	2,199
STCs approved	**30,172**	**36,601**	**40,866**	**42,527**	**41,419**	**39,708**	**37,565**

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:

- There is a sharp increase in the forecast total number of installations of residential PV systems in 2020[14], relative to 2019 (18.3% increase). We expect growth rates beyond that to be far more subdued, at 2.3% per annum on average. This is driven by continuing falls in system costs, income support through the initial stages of the current recession and a likely increased focus on home improvement as the home environment has also become a workplace for more of the workforce.
- There is a spike in the forecast total capacity of residential PV systems in 2020, relative to 2019 (22.2% increase). Growth rates beyond that are moderate, averaging 7.5% per annum. This growth is aligned to underlying growth rates since 2016 and is partially confirmed by data for 2020 to date.
- There is a sharp decrease in the forecast total number of residential SWHs in 2020, relative to 2019 (22.0% decrease). However, we forecast growth rates thereafter to become positive, at 4.0% per annum on average. Projected future growth is driven almost entirely by heat pump systems installed in new building, reflecting recent trends and encouraged by existing building codes.
- Forecast total STCs increase in 2020 and 2021, but then fall over the rest of the forecast period, despite the growing capacity of installations. This is principally due to the falling deeming factor in the STC calculation, which falls to one as 2030 approaches. (This will reduce the number of certificates that can be created for an eligible system).

[14] Based on actual data to end-July 2020.

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

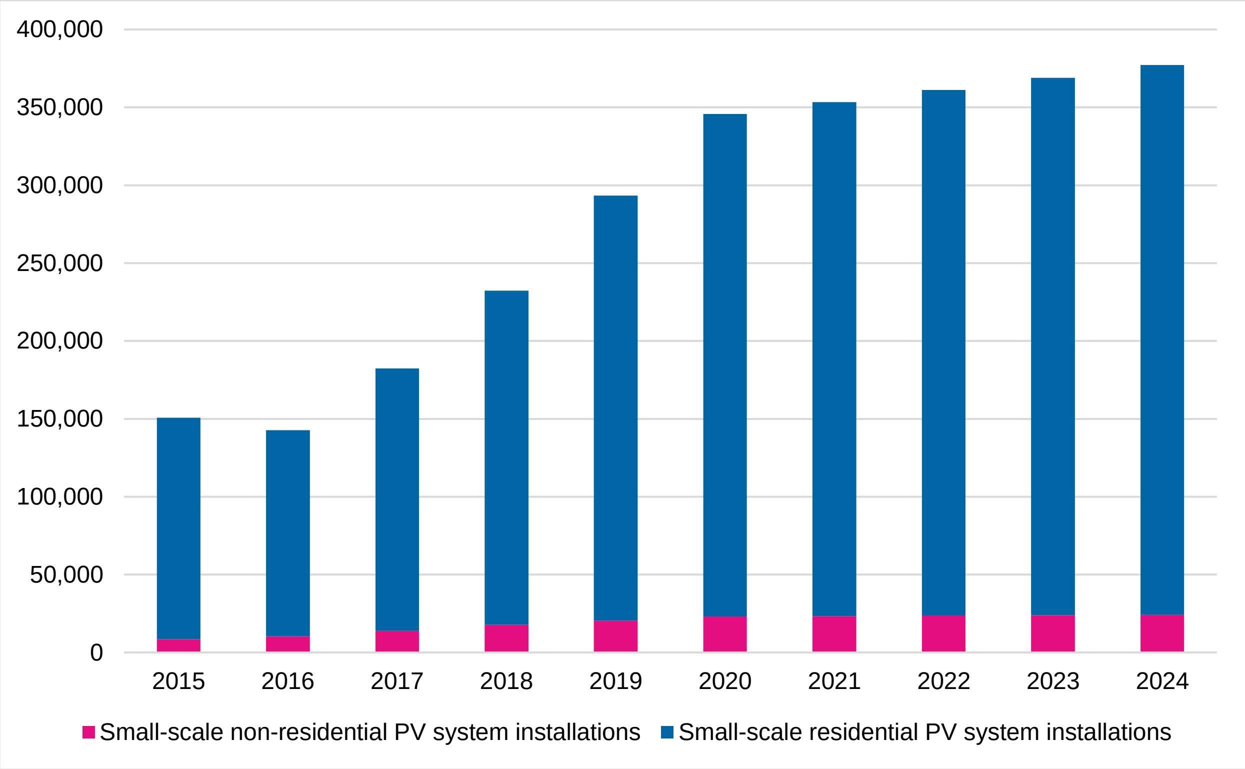


Figure 5.2 Annual small-scale PV capacity installed (MW) – Australia

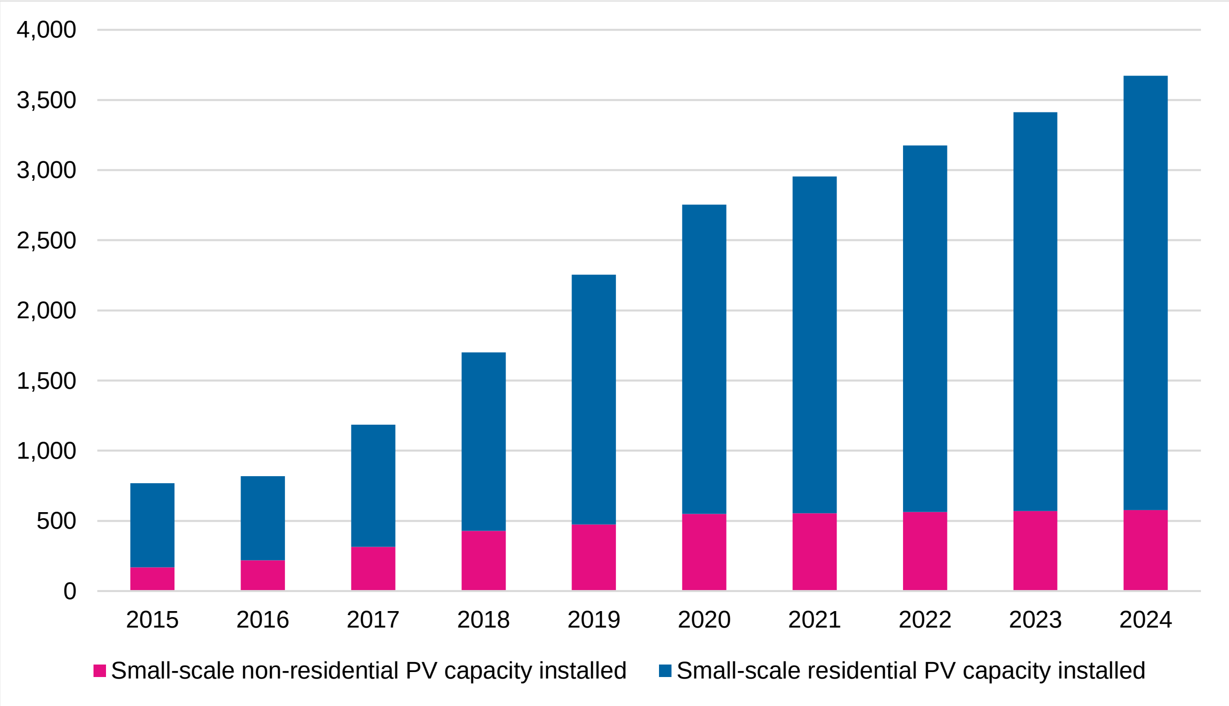


Figure 5.3 Annual number of small-scale solar water heaters installed

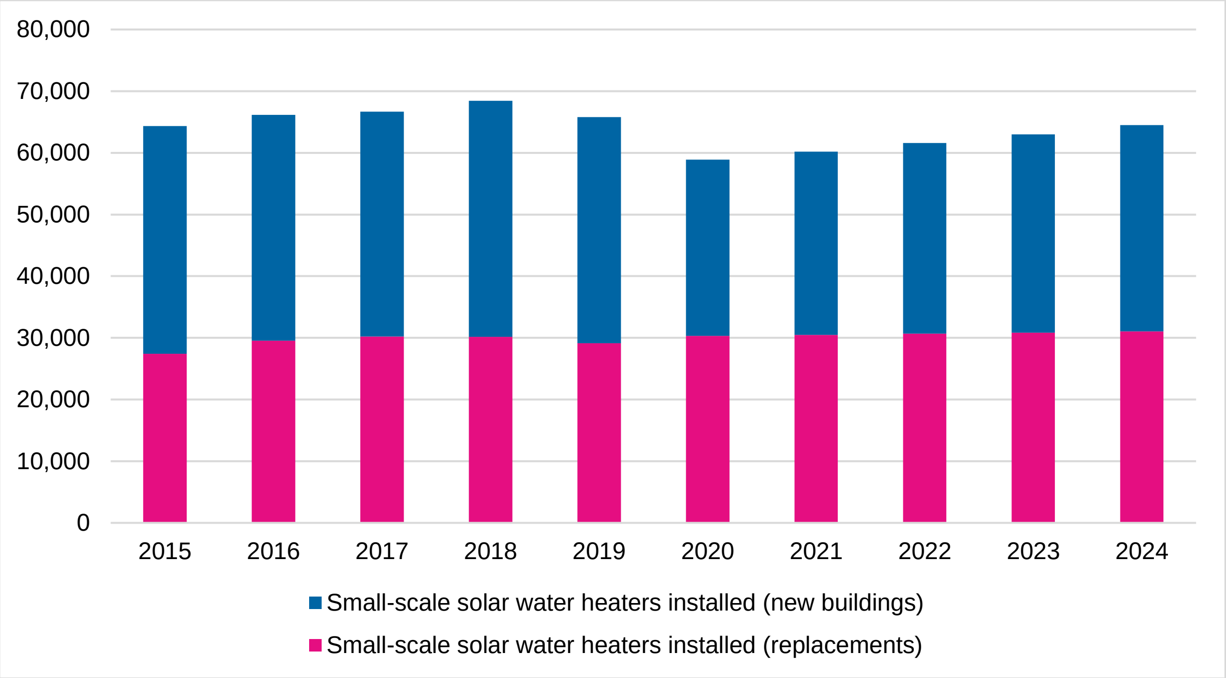


Figure 5.4 Annual small-scale wind and hydro capacity installed (MW) – Australia

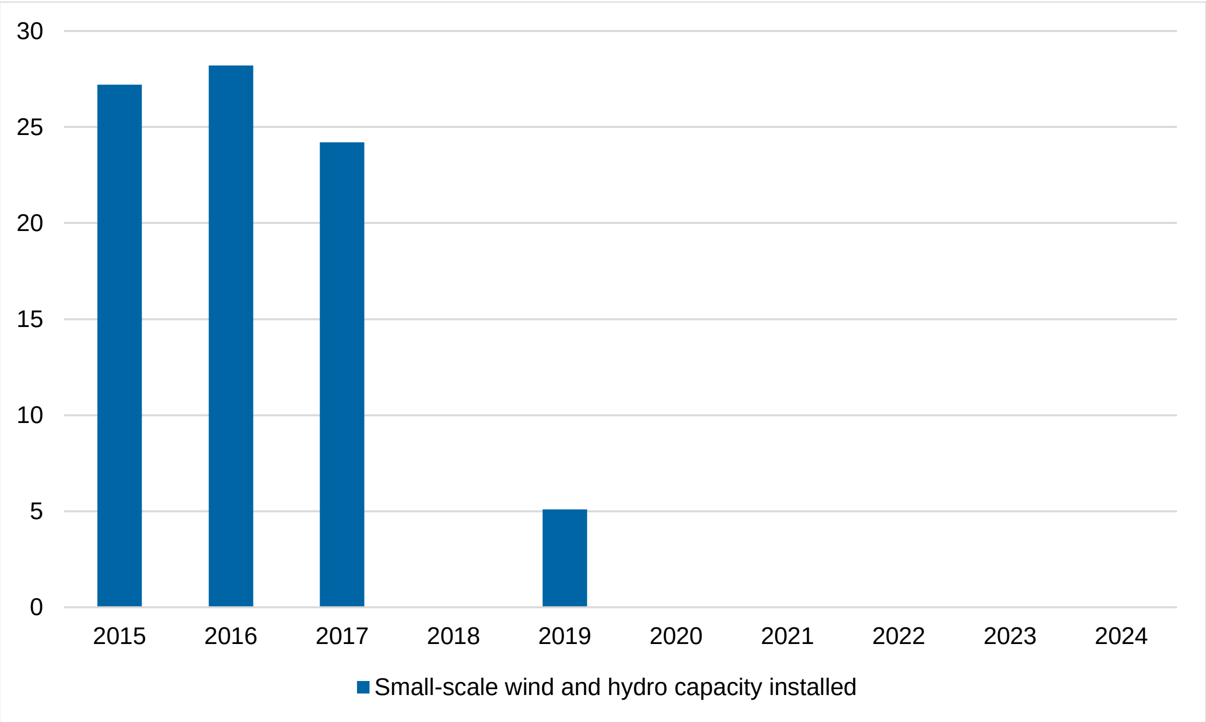
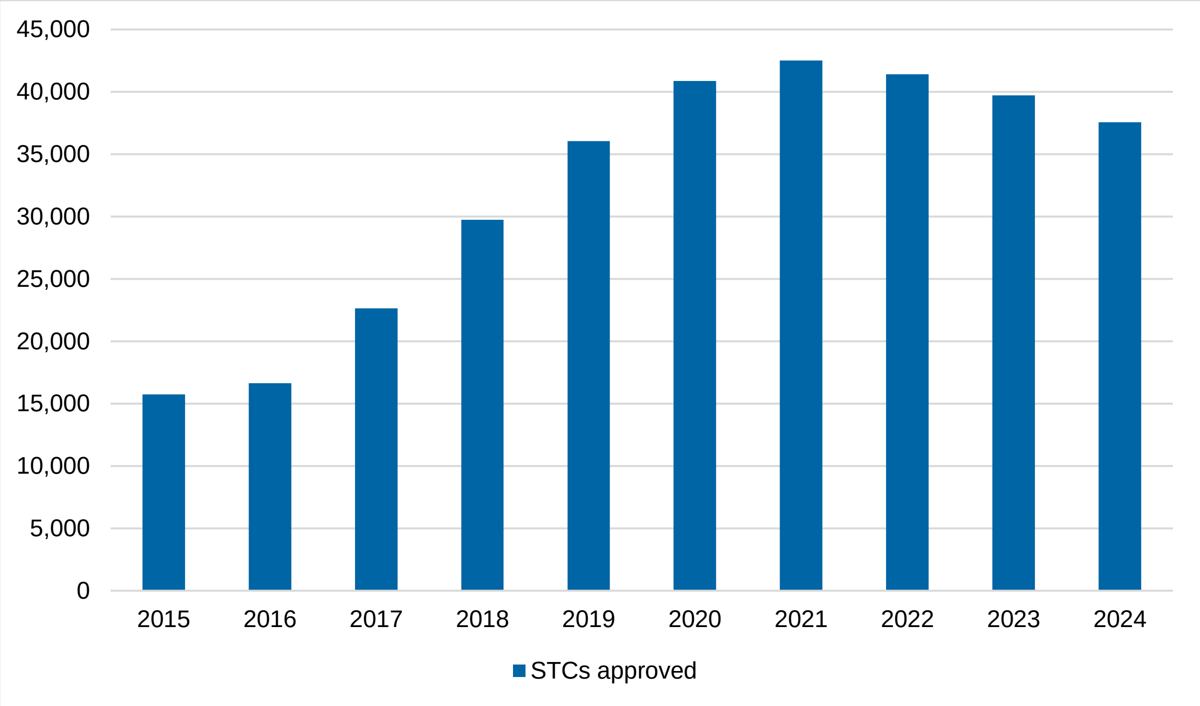


Figure 5.5 Annual number of STCs approved – Australia



5.3 Summary of small-scale technology 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, as the deeming period decreases (Figure 5.8).

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

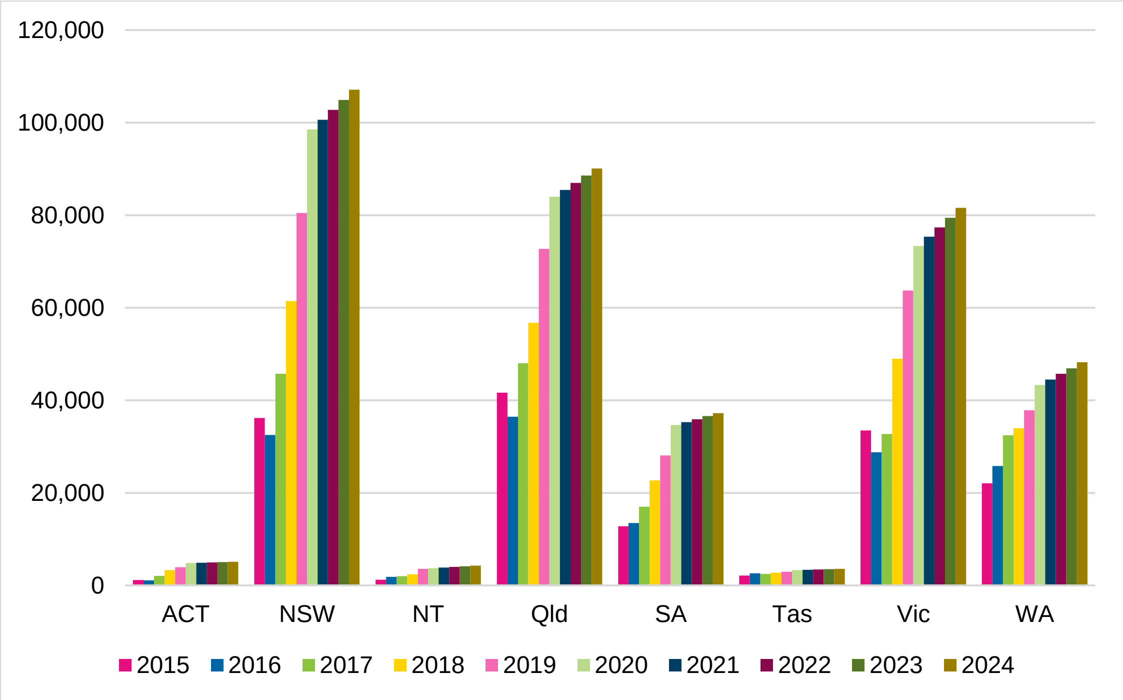


Figure 5.7 Annual small-scale PV capacity installed (MW) – by State/Territory

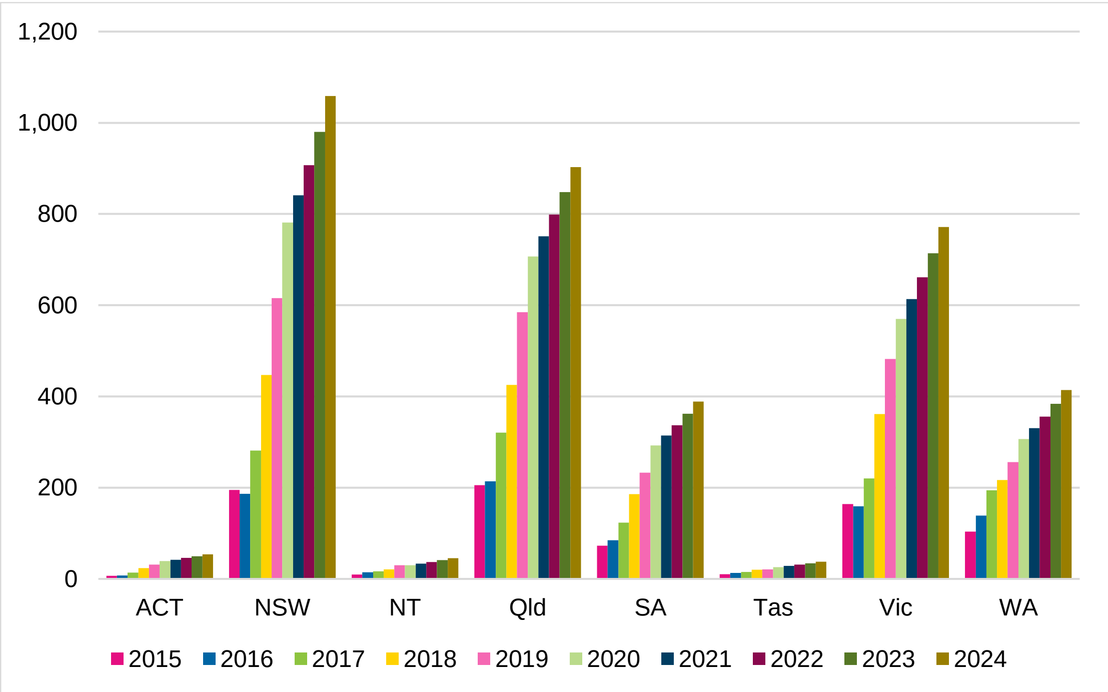
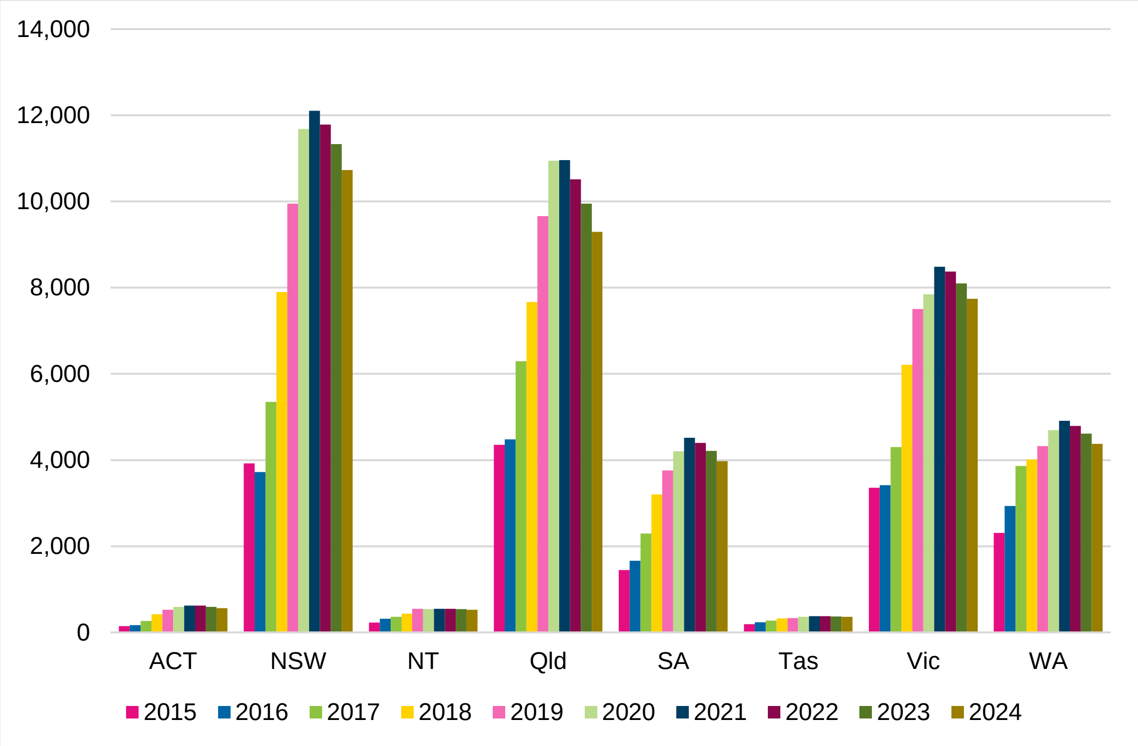


Figure 5.8 Annual number of total STCs approved – by State/Territory

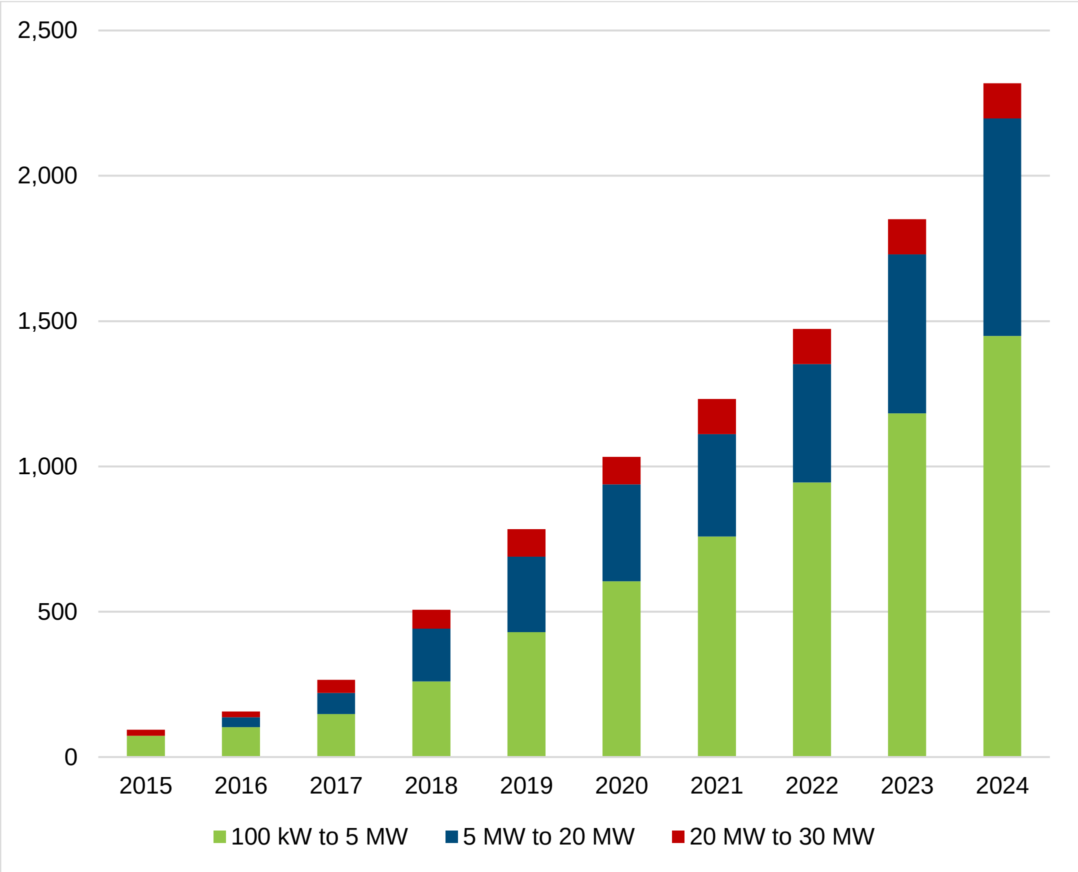


5.4 Mid-scale technology-installation modelling results

The motivation for commercial businesses and not-for-profit organisations, or for small power station investors, to invest in solar PV is varied. However, they are all likely to be primarily driven to reduce cost of energy to their primary business, or to make money from the energy markets.

A prime consideration making such investments increasingly attractive is the falling cost of installing solar PV relative to the ongoing cost of alternative sources of energy. As an increasingly beneficial financial option for many small and medium size enterprises we therefore expect these types of installations to become increasingly common. Our forecast for mid-scale PV capacity installed to 2024 is shown in Figure 5.9. Although constrained during 2021 by the expected poor economic outlook, our forecast increases are driven in the longer term by falling installation costs and the maintenance of relatively high electricity prices and LGC prices.

Figure 5.9 Cumulative installation of mid-scale PV capacity (MW)



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 takes into account 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, in order 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 2020 – 2024 were adjusted based on the annual growth from 2014 – 2019 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 in order 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 of factors influencing feature for each model: installation or capacity for the set categories, SGU, SWH for residential and non-residential. Modelling for residential was also considered for new and existing buildings.

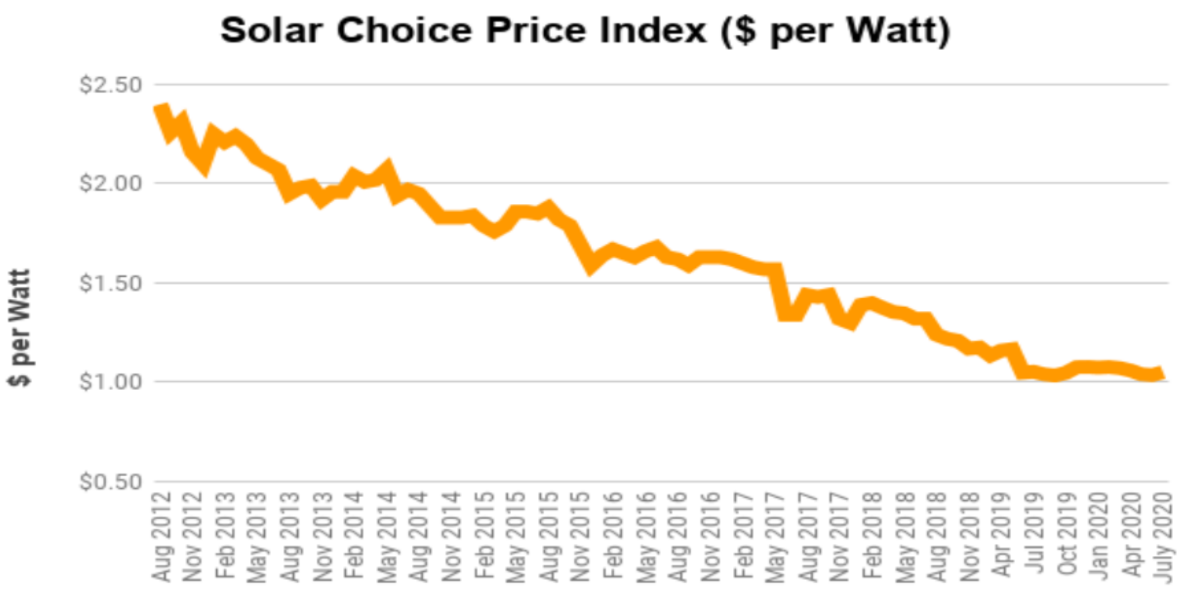
Appendix B Detailed data sources

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.

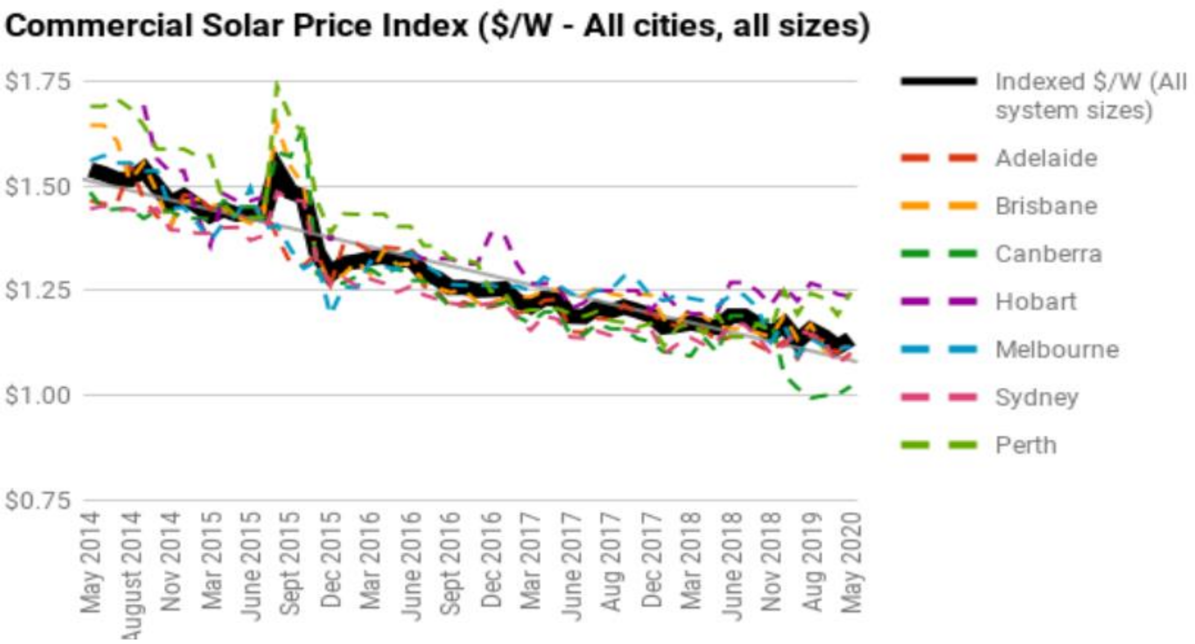
ABS Factors	Data Set from ABS	Description (Data taken for modelling residential small-scale systems)
Population	Population	Total number of persons per postcode
Median Household Income	Median total family income ($/week)	Median household income per postcode
Age Distribution	Place of residence on census 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 is 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	2024
35	28	43	80	93	83	45	35	30	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.

Mid-Scale Assumptions:

- Data provided by CER has column with power station status as ‘Accredited’ or ‘Under Application’. Only records with power station status as ‘Accredited’ is used in the modelling. Power station with status as ‘Under Application’ is considered as future project and is adjusted in the forecasted period.
- Electricity Cost assumptions, as per point 6 Appendix B.
- Installation cost assumptions, as per point 6 Appendix B.
- LGC Cost assumptions, as per point 6 Appendix B.

Constructed Model Success Criteria

PARAMETER	SCALE	TYPE	FUEL SOURCE	DETERMINISTIC METRIC	MODEL	VALUE
CAPACITY	Small Scale	Commercial	Solar Panels	Coefficient of Determination	Linear Regression	0.55
		Residential	Solar Panels	Spearman Correlation	Voting Ensemble	0.78
	Mid-Scale	Commercial	Solar Panels	Coefficient of Determination	Decision Forest Regression	0.42
INSTALLATION	Small Scale	Commercial	Solar Panels	Coefficient of Determination	Linear Regression	0.62
			Solar Water Heater	Coefficient of Determination	Decision Forest Regression	0.22
		Residential	Solar Panels	Spearman Correlation	Voting Ensemble	0.8
			Solar Water Heater (New Installations / Replacements)	Explained Variance	Voting Ensemble	0.24
	Mid - Scale	Commercial	Solar Panels	Coefficient of Determination	Neural Network Regression	0.71

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 and Mid-Scale– Non-residential Forecasting Factors*

Fuel Source	Factors	2020	2021	2022	2023	2024
Solar PV – Non-residential	Installation Cost ($/W)	-2%	-2%	-2%	-2%	-2%
Solar PV – Non-residential	Payback Period	4	3	3	3	3
Solar PV and SWH - Non-residential	Number of non-residential buildings	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged
Mid-Scale System	Avg. LGC Price ($/MWh)	35	30	30	30	30
Mid-Scale System	Mean Energy Consumption (PJ)	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged
Mid-Scale System	Installation Cost ($/W)	1.16	1.09	1.02	0.94	0.9

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

Level 9 145 Ann Street Brisbane QLD 4000 Australia
GPO Box 668 Brisbane QLD 4001 Australia

61 7 3316 3000
advisory@ghd.com

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		Name	Signature	Name	Signature	Date
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