Mid-scale technology installation and capacity forecasts 2021-2025

Final Report

Clean Energy Regulator

14 July 2021

→ The Power of Commitment

GHD Pty Ltd ABN 39 008 488 373
Level 15, 133 Castlereagh Street
Sydney, NSW 2000, Australia
T (02) 9239 7100 | **ghd.com**

Last saved date	14 July 2021 11:50 AM
Author	Michelle Cartwright, Hiresh Devaser & Richard Hickling
Project manager	Richard Hickling
Client name	Clean Energy Regulator
Project name	Mid-scale technology installation and capacity forecasts 2021-2025
Document title	Mid-scale technology installation and capacity forecasts 2021-2025 | Final Report
Revision version	Rev B
Project number	12550476

Document status

Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
A	A	MC, HD and RH	RH		HD		25 June 2021
B	B	MC, HD and RH	RH		HD		9 July 2021
C	C	MC, HD and RH	RH		HD		14 July 2021

Executive summary

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and the assumptions and qualifications contained throughout the report.

The Clean Energy Regulator (CER) engaged GHD (us) to prepare forecasts for the number of installations and capacity of mid-scale photovoltaic (PV) systems installed over the 2021 to 2025 period[1]. The forecasts are categorised by State/Territory, separated by low- and high-capacity bands (from 100 kW to 5 MW and between 5 MW and 30 MW).

Background and context

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

- Size of installation (and therefore the cost and site area required)
- Whether installed behind or in front of the meter
- 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).

Key findings

We have modelled mid-scale installation activity and prepared the forecasts on the basis of two size categories:

- "5 MW", including systems exceeding 100 kW and up to and including 5 MW; and
- "30 MW", including systems exceeding 5 MW and up to and including 30 MW.

However, we were unable to present our results in front-of-meter and behind-the-meter categories, as historical data provided by the CER did not distinguish installations and capacity in that format. Our machine-learning models rely very heavily on the historical data to produce results, and hence our modelling approach cannot identify results in front-of-meter and behind-the-meter categories.

Installations

Our key installation forecasts are summarised in Table 1 for the 5 MW category and Table 2 for the 30 MW category.

Table 1 shows that installation growth in the 5 MW category across Australia will generally grow across the 2021-25 period, with the exception for the dip in 2022. Results at a State/Territory level are mixed. While 2025 installation levels will be higher than (or the same as) 2020 levels for all jurisdictions, movements between each year differ (e.g., levels remain flat in ACT, while strong growth is evidenced in Victoria and WA).

Table 1 Forecast 5 MW PV installations (>100 kW to ≤ 5 MW)

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	6	10	6	6	6	6
NSW	92	84	76	90	94	96

[1] Calendar years

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
NT	6	10	14	24	20	16
QLD	56	62	58	68	66	68
SA	46	54	42	46	64	60
TAS	1	6	2	14	4	4
VIC	83	70	80	92	98	102
WA	15	28	24	32	34	36
Australia	**305**	**324**	**302**	**372**	**386**	**388**

Table 2 shows that installation growth in the 30 MW category across Australia is forecast to be same in 2025 compared with 2021, but more than double the number of installations added during 2020. We do not anticipate ACT, NT and TAS having any such installations over the period to 2025. There appears to be concentrations in lower capacity 100 kW to 5 MW rather than 5-30 MW installations.

Table 2 Forecast 30 MW PV installations (> 5 MW to ≤ 30 MW)

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	0[2]	0	0	0	0	0
NSW	2	4	0	8	4	8
NT	0	0	0	0	0	0
QLD	0	4	16	12	4	0
SA	3	16	0	8	12	8
TAS	0	0	0	0	0	0
VIC	8	6	0	10	6	12
WA	1	0	0	0	6	2
Australia	**14**	**30**	**16**	**38**	**32**	**30**

Capacity

Our key capacity installed forecasts are summarised in Table 3 for the 5 MW category and Table 4 for the 30 MW category. The capacity forecasts are consistent with those presented above for installations.

Table 3 Forecast total capacity installed for 5 MW installations (>100 kW to ≤ 5 MW)

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	2	4	2	2	2	2
NSW	53	34	39	52	53	60
NT	2	6	9	12	11	5
QLD	25	30	34	42	39	45
SA	20	21	26	27	42	36
TAS	0	2	1	5	2	2
VIC	35	34	34	37	44	49
WA	11	20	7	17	22	27
Australia	**149**	**151**	**152**	**194**	**215**	**225**

Table 4 Forecast total capacity installed for 30 MW installations (>5 MW to ≤ 30 MW)

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	0	0	0	0	0	0
NSW	13	26	0	62	31	57
NT	0	0	0	0	0	0
QLD	0	21	161	115	52	0
SA	21	103	0	53	87	53
TAS	0	0	0	0	0	0
VIC	72	50	0	92	51	78
WA	6	0	0	0	55	18
Australia	**112**	**200**	**161**	**322**	**276**	**205**

Contents

Table index

Figure index

Appendices

Appendix A

1. Introduction

Mid-scale photovoltaic (PV) systems reflect a capacity range of greater than 100 kW and up to and including 30 MW in size. These systems may be accredited under the Large-scale Renewable Energy Target (LRET) scheme, culminating in the production of Large-scale Generation Certificates (LGCs).

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

– 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).

1.1 Purpose of this report

The Clean Energy Regulator (CER) has engaged GHD (us) to advise on the preparation of forecasts for installations and installed capacity for mid-scale photovoltaic (PV) systems over the 2021 to 2025 period[3]. The forecasts need to be provided for each State/Territory, separated by capacity bands (>100 kW to ≤ 5 MW and > 5 MW to ≤ 30 MW).

1.2 Limitations

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

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

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

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

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

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

Where this report refers to information provided by CER, GHD has considered and relied upon that information which, after due enquires, we believe to be reliable, complete and not misleading. The statements and opinions included in this report are given in good faith, and in the belief that such statements and opinions are not false or

[3] Calendar years

misleading. Any forecast and projections as supplied to us are based upon assumptions about events and circumstances that have not yet transpired.

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

1.3 Report structure

Our report is structed as follows:

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

2. Conceptual framework and modelling approach

This chapter outlines the conceptual framework we adopted in shaping our modelling approach for the mid-scale energy installations and capacity forecasts. A key feature of our framework is the principle of ‘agency’.

2.1 Agency

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

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

The machine-learning simulation approach for the engagement with CER is based on the key drivers that motivate consumers to install specific sizes and types of mid-scale technologies. Our understanding of the key drivers is based on our previous research, which has been undertaken in the course of confidential project work for our clients.

2.2 Long-run modelling and forecasting process

Our overall modelling process is presented in Figure 1.

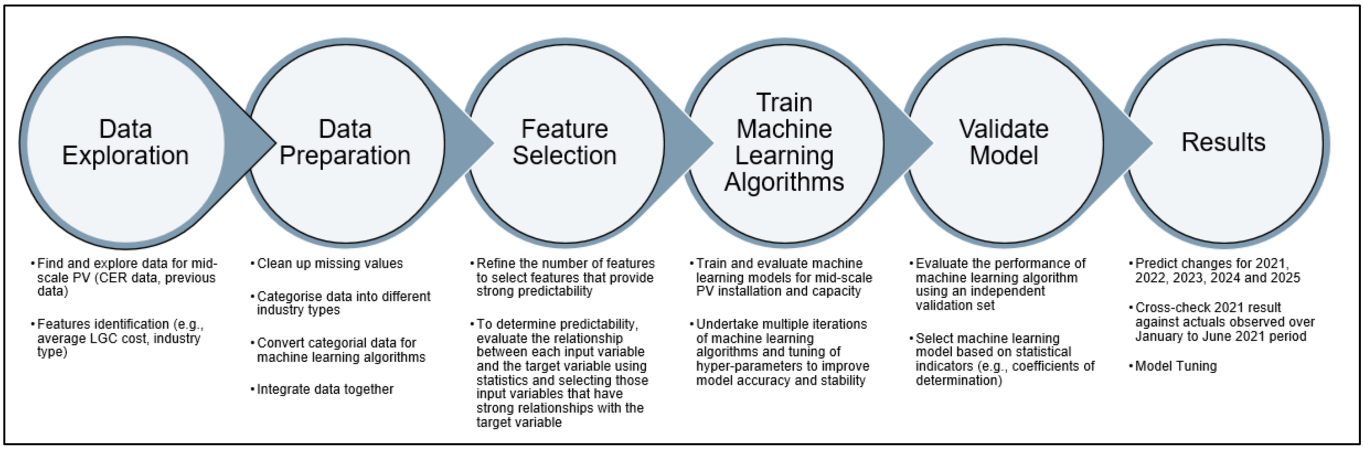

Figure 1 The modelling process for determining mid-scale PV installations and capacity forecasts

The key points regarding our modelling process are as follows:

1. The data-exploration and data-preparation steps focus on identifying the factors (what we refer to as ‘features’) that we anticipate will influence the installation and capacity forecasts over the modelling period. Section 2.3 provides information on the features that we considered could be relevant.
2. The goal of the machine-learning modelling was to explore and learn patterns of past and expected future trends relating to installations and capacity. Following the determination of the most relevant features, multiple iterations of machine learning algorithms and associated hyper parameters (values controlling the machine-learning process) are undertaken to identify the models that yield the best fit. This is explained in more detail in section 2.4.
3. The selected models then generate capacity and installation results for each year of the 2021-25 modelling period.

2.3 Short-run modelling

As a partial verification of our long-run forecasts, we developed monthly times series models to produce forecasts of installations and capacity for the period June to December 2021 and beyond. We were able to best capture the impact of seasonality and trends in the monthly data using either Autoregressive Integrated Moving Average (ARIMA) or error, trend, seasonal (ETS)[4] models. However, we found that the resulting forecasts developed in this way for 2021 as a whole were comparable with the forecasts produced by the long-run model. As a result, our final forecasts are entirely derived using the long-run model.

2.4 Installation/capacity drivers

Typically, mid-scale PV 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 LGCs. We have sought to capture these factors, where possible, in our modelling. Note the small variance in wholesale electricity prices over the time period forecast meant that it played little significance in the modelling.

Non-financial drivers exist also. Businesses may face pressure to reduce their carbon footprint to remain competitive, and community groups may wish to offset their grid-sourced energy consumption to reflect the wishes of the community. The underlying drivers are sometimes difficult to capture in an empirical model, but are nonetheless appropriate to acknowledge as important in consumers' decision making.

The data-exploration process sought to capture the considerations described above, by reviewing all the features possibly driving installer or agent action in regard to mid-scale investments. The features set out in Table 5.

Table 5 Relevant features for forecasting mid-scale PV installations and capacity

Dependent factors	Features	Description	Data source
Number of installations by size category Total capacity in each size category	Year	Calendar year in which the installation took place	CER
	State/Territory	The State/Territory that the installation took place in	CER
	Installation Cost	The average system cost by size and location, including GST and STC discount	Solar Choice
	Capacity Size	Capacity installed in MW terms[5].	CER
	Energy Consumption	Total Net Energy Consumption in Australia, by Industry (in PJ terms)	Australian Government Department of Industry, Science, Energy and Resources (DISER)
	Industry Type	Accounting for whether the installation/capacity relates to the following sectors: commercial; education; solar farms; health; government; recreation; utility; and transport	Australian Government, DISER
	Average LGC cost	Cost of LGCs	Energy Council of Australia
	Wholesale Electricity Price	Regional prices for NEM regions, WEM prices for Western Australia.	AEMO

All the features that we considered as being relevant, except for average LGC costs for installations, and wholesale electricity price satisfied the strong-predictability hurdles.

[4] ETS models are a family of time series models with an underlying state space model consisting of a level component, a trend component (T), a seasonal component (S), and an error term (E).
[5] Note: existing capacity is included as a category influencing further installations. Although this plays the role of a lagged dependent variable in the capacity model, we justify its inclusion representing a "demonstration effect", that is more visible examples promotes more rapid take-up.

2.4.1 Modelling assumptions

Once the relevant features were confirmed, assumptions for 2021 to 2025 period on what values the features should take were made. Key assumptions included:

- A 5% per annum decrease in installation costs from 2021 to 2025, based on historical trends from Solar Choice's website. While we acknowledge some recent flattening of these trends, we believe further long-run cost reductions in real terms is warranted.
- Average LGC costs reflecting Mercari's forward price curves (Mid-Point Index) for each year of the modelling period. A downward trend in LGC prices is observed (see Figure 4 in Appendix A-2-1)
- A 1.1% per annum increase in total energy consumption in Australia from 2021 to 2025, based on the observed compound annual growth rate achieved over the past five years[6].

More details around the assumptions, including the supporting references, are documented in Appendix A-3.

2.5 Machine learning models and validation

In the process of data framing and problem definition and conversion into a model, the limited mid-scale data provided by CER was augmented with industry data in this data set (as per the industry classifications set out in Appendix A-1) in order to map industry energy use intensity (see Appendix A-1). The determination of the most relevant features was undertaken by unsupervised machine learning dimensionality reduction. Multiple iterations of supervised machine learning, both linear and non-linear classification algorithms were undertaken. Many algorithms and associated hyper parameters (values controlling the machine-learning process) were utilised and assessment made to ascertain the models that yielded the best fit. This then allowed us to shortlist four machine learning models:

- **Decision tree**: a branching assessment to assist with ascertaining a course of action or displaying statistical probabilities explaining data variance.
- **Random Forest**. This approach consists of a large number of combined decision trees predictions. The prediction of each line of decision tree is assessed against known data. Each decision tree's accuracy is calculated as a 'vote' for the decision tree model. As there are a number of models, the accumulative vote from the ensemble of models is utilised to reflect those prediction tree models which reflect the classification of data most accurately, that is receives the most votes.
- **CatBoost**: an algorithm for gradient boosting on decision trees. Gradient boosting is a machine-learning technique for regression and classification problems. Boosting is an iterative model tuning procedure where new model iterations are influenced by the outcome of the formerly built model to weight training samples relative to its importance.
- **XGBoost**, which stands for eXtreme Gradient Boosting. It is an implementation of gradient-boosted decision trees designed for speed and performance.

We determined that the Random Forest approach was the most appropriate model for forecasting the installation and capacity figures. In particular, we achieved a coefficient of determination (CoD) of:

- 0.70 for installation. That is, our model could explain 70% of the variation observed in the forecasting results.
- 0.78 for capacity. That is, our model could explain 78% of the variation observed in the forecasting results.

More information on the statistical indicators we used to validate our selected of the Random Forest approach is provided in Table 6. Apart from high CoD the better modelling method has a lower mean absolute error and lower root mean square error, which was seen (Table 6) in the selected models

Table 6 Selected models for mid-scale PV installations and forecasts

PARAMETER	SELECTED MODEL	ROOT MEAN SQUARE ERROR (RMSE)	MEAN ABSOLUTE ERROR (MAE)	CODs
Installation	Random Forest	5.74	3.38	0.70

[6] Australian Government (2020) Australian Energy Statistics Update 2020, Table F, https://www.energy.gov.au/publications/australian-energy-update-2020.

PARAMETER	SELECTED MODEL	ROOT MEAN SQUARE ERROR (RMSE)	MEAN ABSOLUTE ERROR (MAE)	CODs
Capacity	Random Forest	4.26	2.10	0.78

Note model accuracy may be improved by removing high or low data points, scaling more strongly, adding more variables or looking at the data in a more granular manor. These steps can be completed however there is a trade off in loss of information, an overfitted model and extra computational power which more often does not add to the model in a material manner. If data extremes were removed or a strong scaling with such scarce data a large amount of detail in the data would be lost. More variables attributed to the scarce data points would weight the new information over the inherent actual data. Adding more variables more often results in overfitting of modelling of historic events which is then not a useful tool for forecasting. Machine learning operates by a principle called Occam's Razor which states the explanation should be kept to the bare minimum sufficient for explaining the phenomenon. Occam's law along with the consideration of the extensive computational power and time that these models utilised without exhaustion prior a result, encouraged acceptance of a sufficiently high CoD of over 70 %.

3. Results

This section summarises our mid-scale technology installation modelling results.

3.1 Overarching observations

The motivation for commercial businesses and not-for-profit organisations, or for small power station investors, to invest in mid-scale PV systems 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 PV relative to the ongoing cost of alternative sources of energy. As an increasingly beneficial financial option for many small- and medium-sized enterprises, we would typically expect these types of installations to become increasingly common. Our modelling results are set out below.

3.2 Key findings

We have modelled mid-scale installation activity and prepared the forecasts on the basis of two size categories:

– “5 MW”, including systems exceeding 100 kW and up to and including 5 MW; and
– “30 MW”, including systems exceeding 5 MW and up to and including 30 MW.

However, we were unable to present our results in front-of-meter and behind-the-meter categories, as historical data provided by the CER did not distinguish installations and capacity in that format. Our machine-learning models rely very heavily on the historical data to produce results, and hence our modelling approach cannot identify results in front-of-meter and behind-the-meter categories.

3.2.1 Installations

Our key installation forecasts are summarised in Table 7 for the 5 MW category and Table 2 for the 30 MW category. Table 7 shows that installations in the 5 MW category across Australia will generally grow across the 2021-25 period, except for a slight dip in 2022. Results at a State/Territory level are mixed. While 2025 installation levels will be higher than (or the same as) 2020 levels for all jurisdictions, movements between each year differ (e.g., levels remain flat in ACT, while NT levels have no apparent trend).

Table 7 Forecast 5 MW PV installations

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	6	10	6	6	6	6
NSW	92	86	84	96	100	102
NT	6	10	14	22	18	14
QLD	56	60	60	70	68	70
SA	46	50	42	46	62	62
TAS	1	6	2	12	4	4
VIC	83	72	84	96	102	106
WA	15	26	22	28	30	34
Australia	**305**	**320**	**314**	**376**	**390**	**398**

Table 8 shows that installation growth in the 30 MW category across Australia is forecast to be same in 2025 compared with 2021, but more than double the number of installations added during 2020. We do not anticipate ACT, NT and TAS having any such installations over the period to 2025. There appears to be concentrations in lower capacity 100 kW to 5 MW installations rather than 5-30 MW installations.

Table 8 Forecast 30 MW PV installations

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	0	0	0	0	0	0
NSW	2	4	0	8	4	8
NT	0	0	0	0	0	0
QLD	0	4	16	12	4	0
SA	3	16	0	8	12	8
TAS	0	0	0	0	0	0
VIC	8	6	0	10	6	12
WA	1	0	0	0	6	2
Australia	**14**	**30**	**16**	**38**	**32**	**30**

We also forecast installations numbers by industry type (see Figure 2), covering both the 5 MW and 30 MW categories. Industry type is defined by the nature of the business based on the registered name for business activity in CER provided data (using keywords) and is listed in Appendix A-1-1.

While the commercial sector reflects the dominant share of installations over the modelling period, its dominance decreases over time as solar-farms and installations in other sectors expand, potentially reflecting reducing mid-scale system installation costs and making PV investments increasingly financially viable for multiple sectors. Additionally businesses which once installed (or considered installing) smaller systems are increasingly replacing them with (or installing new) mid-scale installations. Utilities have gone through a large recent growth in solar installations and installations in this sector are set to peak in 2021. New construction of utility is not forecast to resume until 2023.

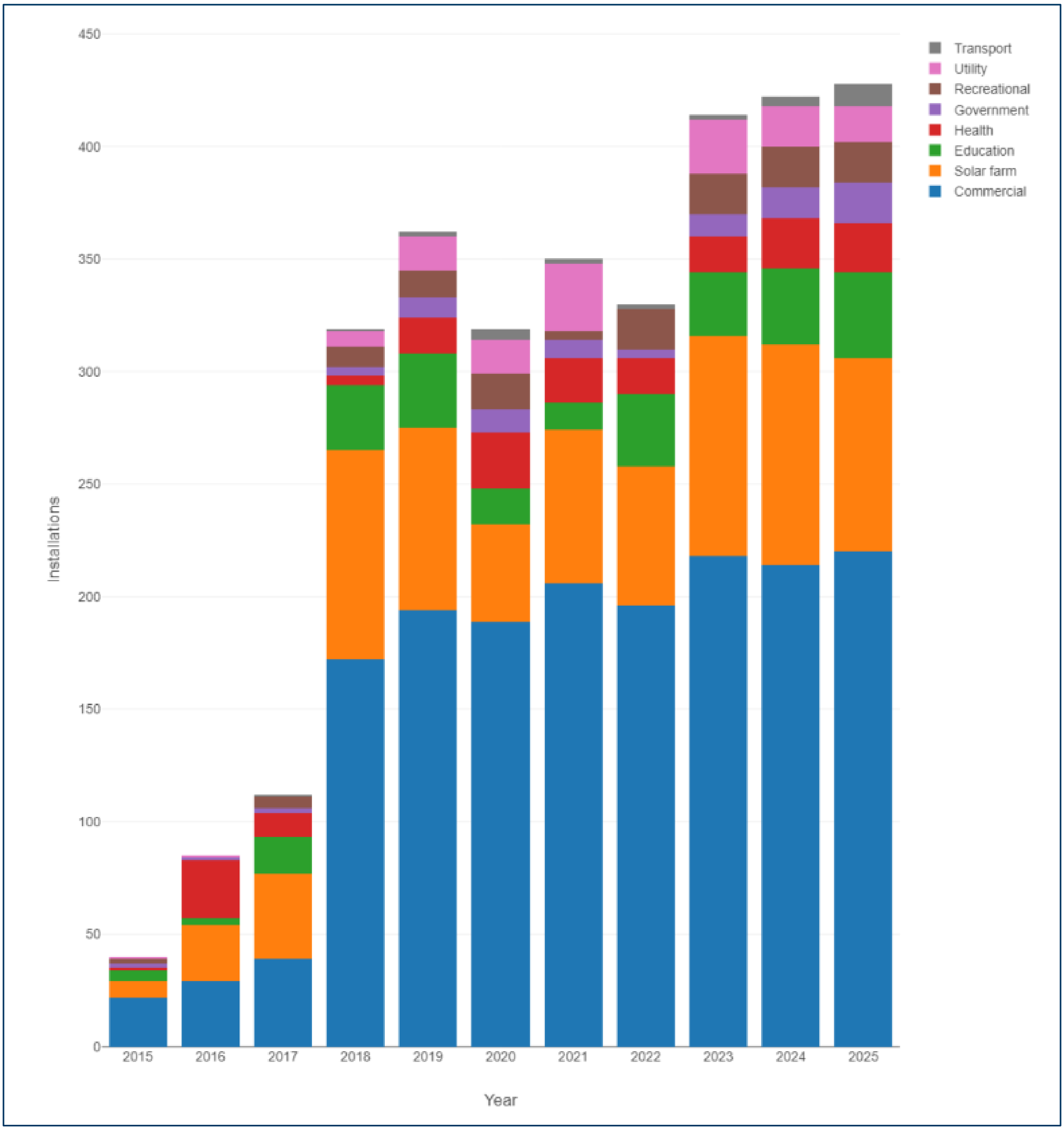

Figure 2 Installations by industry type

3.2.2 Capacity

Our key capacity installed forecasts for the 5 MW category are summarised in Table 9. Although installations fall in 2022, we observe that total installed capacity increases. This indicates the average system size in the 100 kW to 5 MW range is increasing. In fact, over the 2021 to 2025 period, the average size grows from 0.47 MW to 0.57 MW.

Table 9 Forecast total capacity installed for 5 MW installations

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	2.4	4.3	2.3	2.3	2.3	2.4

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
NSW	53.1	33.9	39.0	53.5	54.5	60.6
NT	2.1	5.8	7.6	10.3	9.2	4.4
QLD	25.5	28.9	33.9	42.1	39.5	44.3
SA	19.8	21.4	27.1	27.8	43.8	37.7
TAS	0.2	2.2	0.9	4.6	1.4	1.4
VIC	35.3	34.8	37.3	40.3	45.9	51.0
WA	10.7	19.9	6.6	15.9	20.8	25.3
Australia	**149.0**	**151.2**	**154.8**	**196.7**	**217.4**	**227.0**

Our key capacity installed forecasts for the 30 MW category are summarised in Table 10. The trend mirrors that of the installation numbers for this category.

Table 10 Forecast total capacity installed for 30 MW installations

State/Territory	2020 (actual)	2021	2022	2023	2024	2025
ACT	0	0	0	0	0	0
NSW	13.4	25.9	0	63.0	31.2	57.2
NT	0	0	0	0	0	0
QLD	0	22.0	165.5	118.2	53.0	0
SA	20.7	104.3	0	53.2	88.8	53.2
TAS	0	0	0	0	0	0
VIC	71.5	49.8	0	89.9	49.8	76.7
WA	6.1	0	0	0	57.1	19.1
Australia	**111.6**	**202.0**	**165.5**	**324.3**	**279.8**	**206.3**

We also forecast capacity installed by industry type (see Figure 3), covering both the 5 MW and 30 MW categories. Industry type is defined by the nature of the business based on the registered name for business activity in CER provided data (using keywords) and is listed in Appendix A-1-1.

The growth in capacity generally exceeds growth in installations. This is particularly apparent for commercial installations and solar farms, although new mid-scale solar farm capacity is forecast to peak in 2024. Utilities capacity growth has historically been concentrated in water treatment and this appears to be temporarily saturated, with forecast growth paused during 2022. Rather than growing, a steady take-up is forecast in mid-scale solar capacity in the health and recreational sectors.

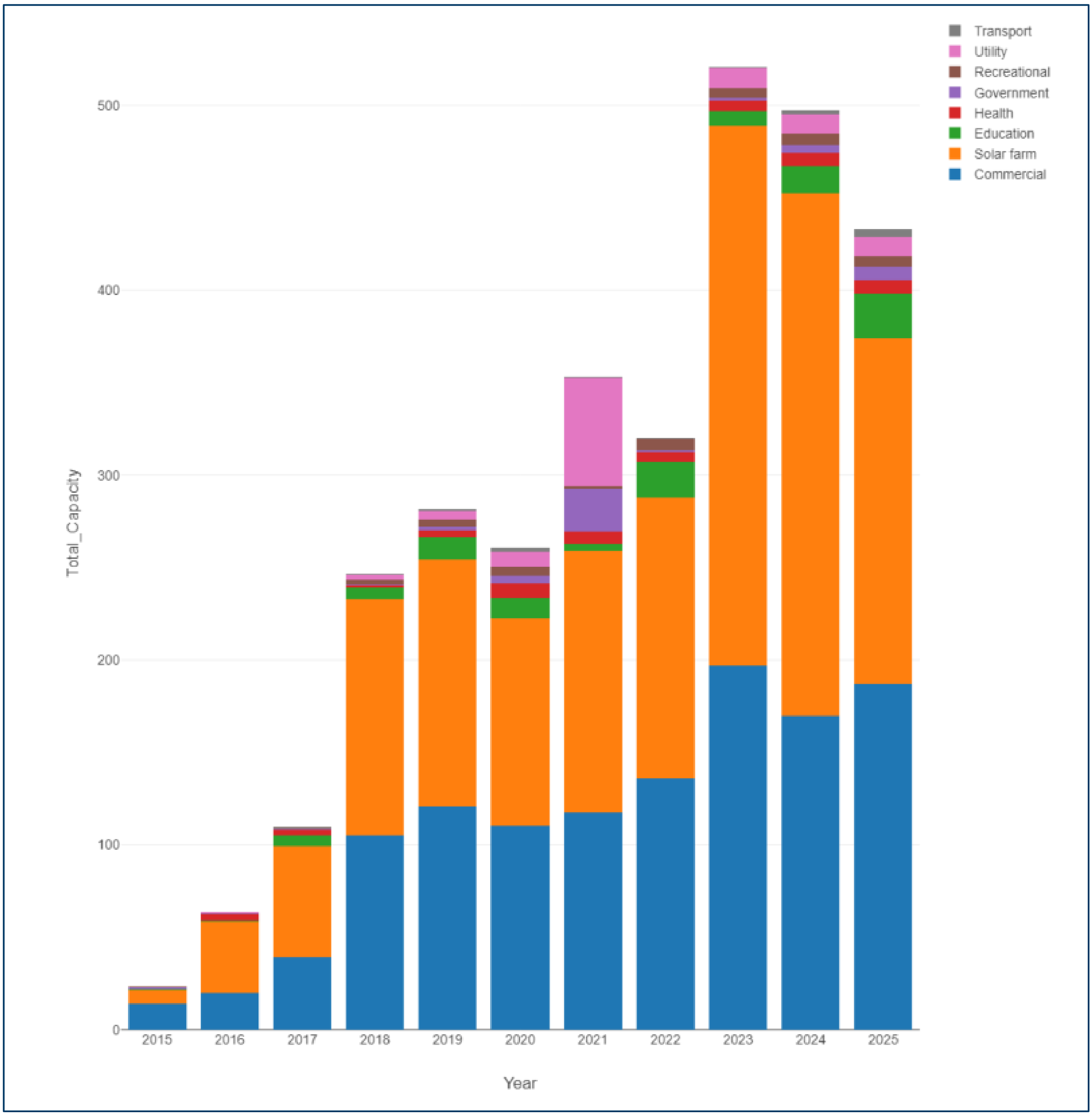

Figure 3 ***Capacity installed by industry type***

Glossary

Acronym	Meaning
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AEMC	Australian Energy Market Commission
AER	Australian Bureau of Statistics
AI	Artificial Intelligence
ASGC	Australian Standard Geographical Classification
ARIMA	Auto-regressive integrated moving average
ASHP	Air Source Heat Pump
CER	Clean Energy Regulator
CoD	Coefficient of Determination
DISER	Department of Industry, Science, Energy and Resources
ERP	Estimated Resident Population
ETS	Error, Trend & Seasonal
kWh	Kilowatt hour
LGC	Large-scale Generation Certificates
LRET	Large-scale Renewable Energy Target
MW	Megawatts
NSW	New South Wales
NT	Northern Territory
PV	Photo-voltaic
SA	South Australia / South Australian
SEIFA	Socio-economic Indexes for Areas
W	Watt
WA	Western Australia / Western Australian

Appendix A

A-1 Detailed model description

A-1-1 Data collation

Industry types were identified in the data and noted as one of:

– Commercial (food: supermarkets, shopping centres, meat and flowers; textile, warehouse and Australia Post)
– Education (schools, TAFE, universities / colleges)
– Solar Farm (as named, sometimes by capacity as solar / solar farm / solar power station)
– Health (hospital, aged care, nursing home, medical, clinical services, health space)
– Government (municipal or shire centre, town square, civic or town hall, library, depot, prison)
– Recreation (aquatic centre, sports club, stadium, zoo, exhibition centre, art gallery)
– Utility (waste and water treatment plants, energy or power services)
– Transport (airports, interchange and carpark)

Source: Australian Energy Update 2020 **|** *energy.gov.au Table K*

https://www.energy.gov.au/publications/australian-energy-update-2020

A-1-2 Modelling nuances

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

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

Forecasting utilises these learnt coefficients of including macro-economic coefficients to forecast installation and capacity.

A-2 Detailed data sources

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

A-2-1 Average Large-scale Generation Certificate spot prices

LGCs arise when a power station has produced electricity generated from renewable sources, known as 'eligible electricity'. One LGC can be created per MWh of eligible electricity generated by a power station.[7]

We observe that LGC spot prices are forecast to drop sharply over the next five years (see Figure 4).

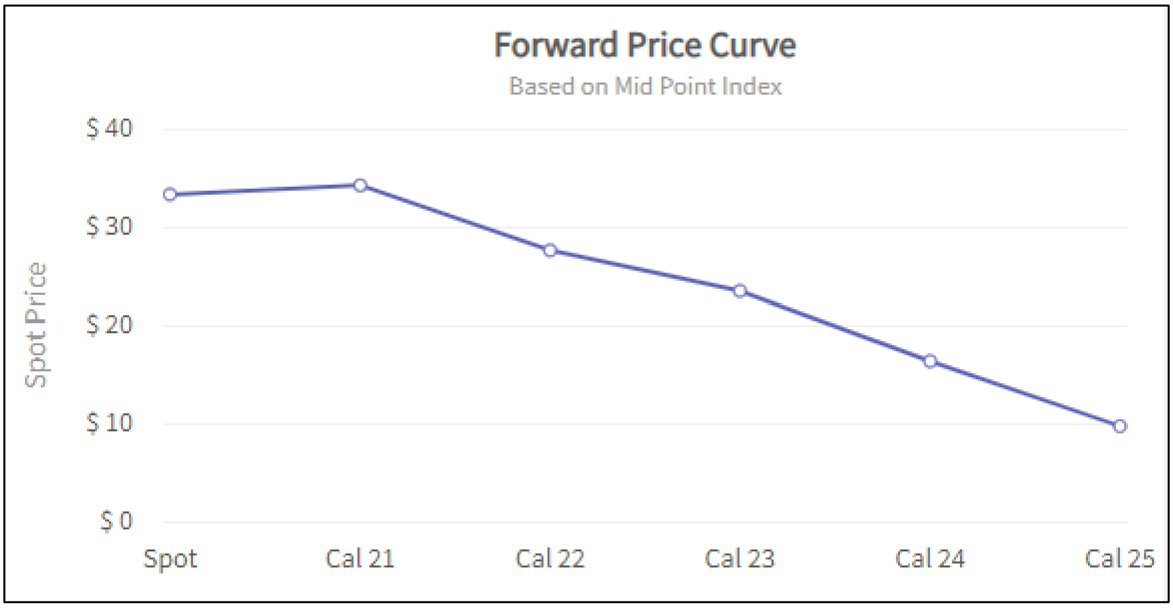

Figure 4 ***Forward price curve for LGCs (source (as of 8 July 2021): http://lgc.mercari.com.au/)***

A-2-2 Data sources

Data sources that we referred to during our analysis include:

- System costs value of STCs – Solar Choice https://www.solarchoice.net.au/blog/solar-power-system-prices
- Total Net Energy Consumption in Australia (PJ) - Australian Energy Update 2020 | energy.gov.au Table F; https://www.energy.gov.au/publications/australian-energy-update-2020

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

A-3 Model construction

A-3-1 Installation Cost ($ / W)

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1.6	1.5	1.3	1.2	1.1	1.1	1.16	1.09	1.01	0.94	0.89	0.84

A-3-2 Average LGC Spot Price ($ / MWh)

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
28	43	80	93	83	45	35	34	28	24	16	10

A-3-3 Total Net Energy Consumption in Australia (PJ)

2013[8]	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
5,915	5,891	5,897	6,041	6,115	6,159	6,196	6,259	6,322	6,386	6,451	6,516	6,582

[8] We have used financial year 2012-13 as the basis for calendar year 2013. We also adopt this convention for future years.

ghd.com

→ The Power of Commitment