# ROOFTOP PV INFORMATION PAPER

National Electricity Forecasting

2012

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Published by

AEMO
**Australian Energy Market Operator**
ABN 94 072 010 327
ISSN: 1836-7593

# EXECUTIVE SUMMARY

## Key observations

The key observations for rooftop PV forecasts detailed in this report are:

- The NEM has experienced a rapid uptake of rooftop PV over the last four years, with total estimated installed capacity rising from 23 MW in 2008 to an estimated 1,450 MW by the end of February 2012.
- PV energy produced in 2011 is estimated at 1,200 GWh, or 0.6% of annual energy. This means it is already at an 'observable' level in the NEM, and while there has been no significant operational impact on the wholesale market, this has the potential to occur if capacity starts to impact investments in the network and/or large scale generation.
- Forecast increases in system installations are expected to offset a large amount of energy that would have otherwise been provided by the NEM.
- Installed capacity is forecast to reach 5,100 MW by 2020 and almost 12,000 MW by 2031 (based on a moderate growth scenario).
  - Rooftop PV uptake is expected to be relatively restrained to 2017 (averaging 320 MW per year for the moderate scenario), due mainly to a reduction or withdrawal in feed-in tariffs, and decreased demand from installations.
  - From 2018 to 2025 uptake is expected to accelerate, with growth forecast to average 620 MW per year (moderate scenario) and 1,130 MW per year (rapid scenario).
  - From 2026 to 2031 uptake continues to increase further as incentives continue to increase, growth for new dwellings continues, and installations on existing dwellings start to slow.
- In the mainland regions, summer maximum demand typically occurs in the late afternoon, when rooftop PV generation is declining from its midday peak and is operating at an estimated 28%– 38% of capacity. Maximum demand in Tasmania typically occurs on a winter evening, when rooftop PV generation is negligible.

## AEMO to include rooftop PV generation in annual forecasting reports

Given its current and forecast growth, AEMO will now publish its analysis of existing and forecast levels of rooftop PV (installed capacity, annual energy generation and the impact on maximum demand) in its annual forecasting reports.

This will comprise one input of the improved forecasting process which will see AEMO publish annual energy and maximum demand electricity forecasts for each NEM region by 30 June 2012, with the aim of making the overall process more transparent and of even more value to stakeholders.

This rooftop PV report provides a NEM-wide summary of rooftop PV growth to date and possible capacity growth over the next 20 years, but it is clear that robust estimates require consistent, detailed, national data. To achieve this, AEMO is seeking increased collaboration with industry and has set up a new six-monthly process to gather the requisite data.

In this report, forecast growth to 2031 is considered under three uptake scenarios: slow (driven by small electricity price increases and PV price reductions, and no government incentives); moderate (moderate electricity price increases and PV price reductions, and moderate government incentives); and rapid (large electricity price increases and PV price reductions, and significant government incentives).

Implications including the effect that increased rooftop PV penetration and any cross-subsidy arrangements might have on retail electricity prices have not been analysed.

**[This page is left blank intentionally]**

# CONTENTS

# TABLES



# FIGURES

**[This page is left blank intentionally]**

# CHAPTER 1 - INTRODUCTION

## 1.1 National Electricity Forecasting

AEMO has changed the way it develops and publishes demand forecasts for the electricity industry. AEMO is for the first time developing an independent set of electricity demand forecasts for each of the five NEM regions. AEMO is ideally positioned to undertake this project and to lead collaboration with industry to ensure that representative and reliable forecasts are produced on a consistent basis across all NEM regions.

These forecasts are used for both operational purposes, including the calculation of marginal loss factors, and as a key input into AEMO's national transmission planning role. It is therefore necessary for AEMO to know how these forecasts are developed, and to ensure forecasting processes and assumptions are consistent across regions, to make certain they are suitable for purpose.

This contrasts with in the past, AEMO published demand forecasts in a series of AEMO publications, namely the Electricity Statement of Opportunities (ESOO), the Victorian Annual Planning Report (VAPR), and the South Australian Supply and Demand Outlook (SASDO).

AEMO developed demand forecasts for South Australia and Victoria, whilst the regional transmission network service providers (TNSPs) developed demand forecasts for the remaining three regions in the National Electricity Market (NEM), namely Queensland, New South Wales (including the Australian Capital Territory), and Tasmania.

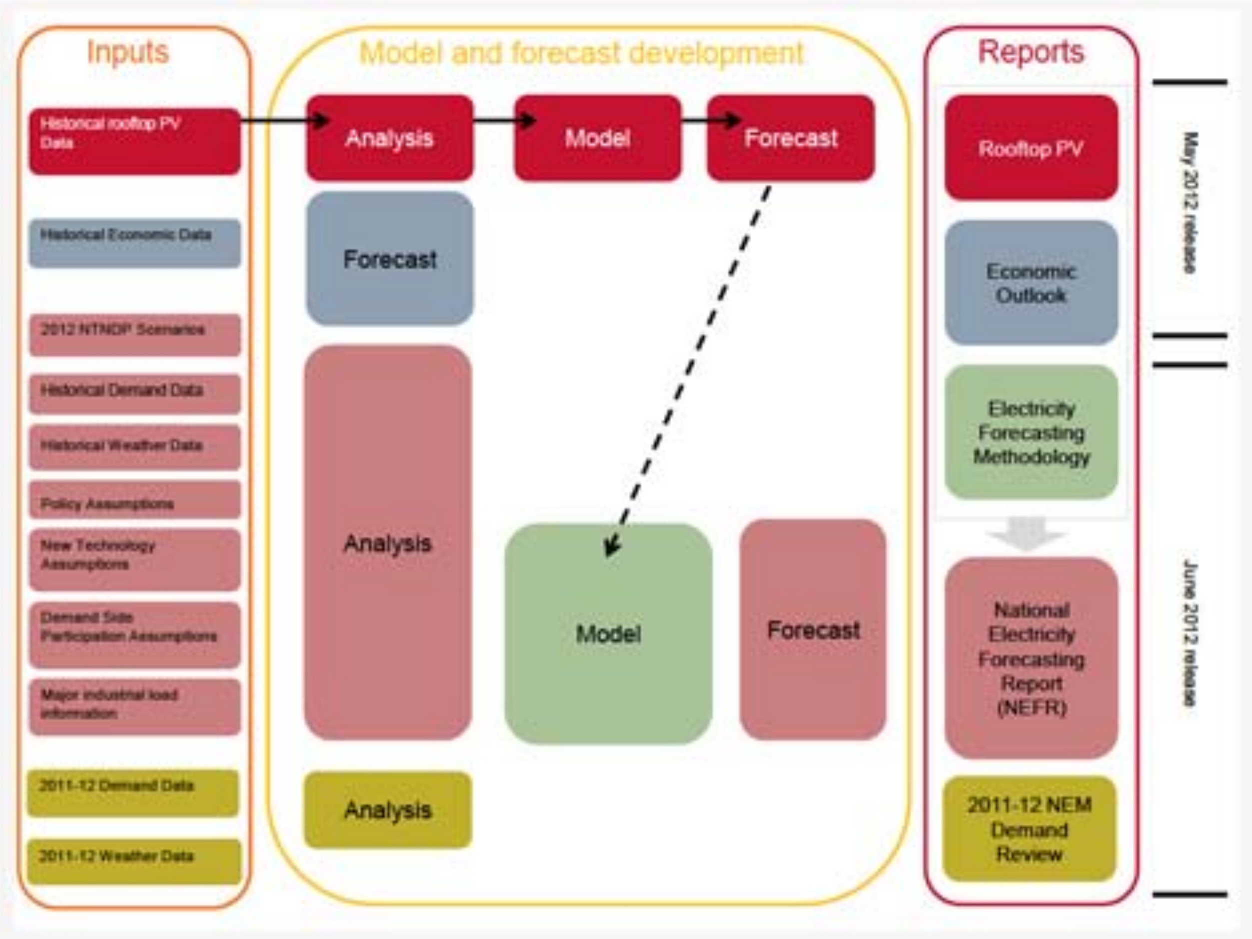
Through this new approach to increase the transparency of the forecasting process and to stimulate discussion with members of the electricity industry, AEMO intends to publish five information papers and reports:

- **Economic Outlook Information Paper** – AEMO's assessment of the work undertaken by the National Institute of Economic and Industry Research (NIEIR).
- **Rooftop PV Information Paper** – Quantifying the impact of rooftop photovoltaic (PV) on the electricity market.
- **2011-12 NEM Demand Review Information Paper** – A review of 2011–12 NEM demand.
- **Forecasting Methodology Information Paper** – A description of the AEMO modelling process used to develop demand forecasts.
- **2012 National Electricity Forecasting Report (NEFR)** – The main forecasting report presenting new electricity demand forecasts for the five NEM regions.

Figure 1-1 shows how all the work behind the forecasts comes together and how we publish it this year.

As this is the first time that AEMO has developed these electricity forecasts across the NEM, there is still work to be done to improve the way AEMO forecasts. Over the next couple of years, AEMO will continue to improve the data, modelling, and interpretation that underpin these forecasts, and engage with industry on an ongoing basis to ensure an open and transparent process.

Figure 1-1 — AEMO's National Electricity Forecasting




## 1.2 Definition of rooftop PV

Rooftop photovoltaics (PV) are behind-the-meter PV generation systems offsetting consumption in the residential and business sectors, and connected to the NEM.[1] It is the first widespread technology used by households and small businesses to generate electricity independently of retailers. For the purposes of this report rooftop PV excludes:

- Dedicated PV generation facilities such as solar farms.
- Off-grid systems and systems connected to electricity grids other than the NEM.[2]
- Solar hot water systems, as they do not generate electricity.

## 1.3 Impact on demand forecasting

AEMO's electricity forecasts are based on modelling demand from the residential and business sectors. When the sun is shining, rooftop PV systems supply a proportion of this demand on-site, which offsets electricity supplied

[1] The small number of systems installed in places other than rooftops are included.

[2] For example systems in Western Australia and the Northern Territory, or connected to a separate grid such as Mount Isa.

from alternative generation. When estimating historical demand or forecasting future demand, it is important to account for the contribution made by rooftop PV systems.

There has been a strong uptake of rooftop PV systems in the past few years to meet growing demand for electricity generated by renewable resources. AEMO has found that by not accounting for the contribution rooftop PV makes to historical demand data, consumer demand may be underestimated. In comparison, by not accounting for the contribution rooftop PV makes to demand forecasts, the future requirements of off-site electricity generation may be overestimated.

This paper forecasts the uptake of rooftop PV and its impact on electricity demand for the 20-year outlook period from 2012 to 2031. The forecasts do not differentiate PV generation by the tariff received.

The analysis presented in this paper will form part of the of the electricity forecasts which will be published in the June 2012 forecasting report, and this is explained further in the next section.

### 1.3.1 Modelling electricity demand

AEMO's demand forecasts are dependent in the long-run on economic variables and short run seasonal variations in the weather. For each of the five NEM regions, the modelling process involves:

- Developing models based on historical relationships between electricity usage and demographic, economic and weather input variables.
- Using models to predict the future path of electricity usage based on input variables defined according to various scenarios.
- Adjusting the projected electricity usage trends to account for expected changes in large spot loads, energy efficiency measures, rooftop PV generation, electric vehicle charging, network losses and generator auxiliary loads to produce the published annual energy forecasts and understand how much of this demand will be served by the NEM.
- Determining the frequency distribution of maximum demand by using the annual energy forecasts as a key input into the half-hourly models that represent time and weather-based variation.

A detailed explanation of this modelling process will be provided alongside the forecasting report due for release in June 2012.

## 1.4 Content of paper

**Chapter 1, 'Introduction',** provides background information and summarises the impact of rooftop PV forecasts on demand.

**Chapter 2, 'Definitions, processes and methodology',** provides a description of drivers, scenarios and a short overview of the approach used to develop rooftop PV estimates discussed in subsequent chapters.

**Chapter 3, 'Rooftop PV in the NEM',** presents estimates for installed capacity and annual energy generation for the NEM.

**Chapter 4, 'Regional rooftop PV',** presents estimates for installed capacity, annual energy generation and maximum demand for each of the five NEM regions.

**Appendix A, 'Data sources',** outlines the data sources used to undertake the analysis discussed in this information paper.

**Appendix B, 'Methodology',** provides further discussion of the methodology used to undertake the analysis discussed in this information paper.

**Appendix C, 'Regional rooftop PV generation curves'**, presents average summer/winter rooftop PV daily generation curves for each of the five NEM regions.

**Appendix D, 'Non-AEMO rooftop PV capacity forecasts',** presents recent non-AEMO rooftop PV forecasts and compares them to the AEMO forecasts presented in this information paper.

## 1.5 Future work

Rooftop PV installed capacity and energy forecasts will be updated annually, forming inputs into AEMO's National Electricity Forecasting Report.

This is the first time AEMO has undertaken a study of this type of a form of technology that influences the NEM. To improve the historical and forecast estimates, future work could be done in the following areas:

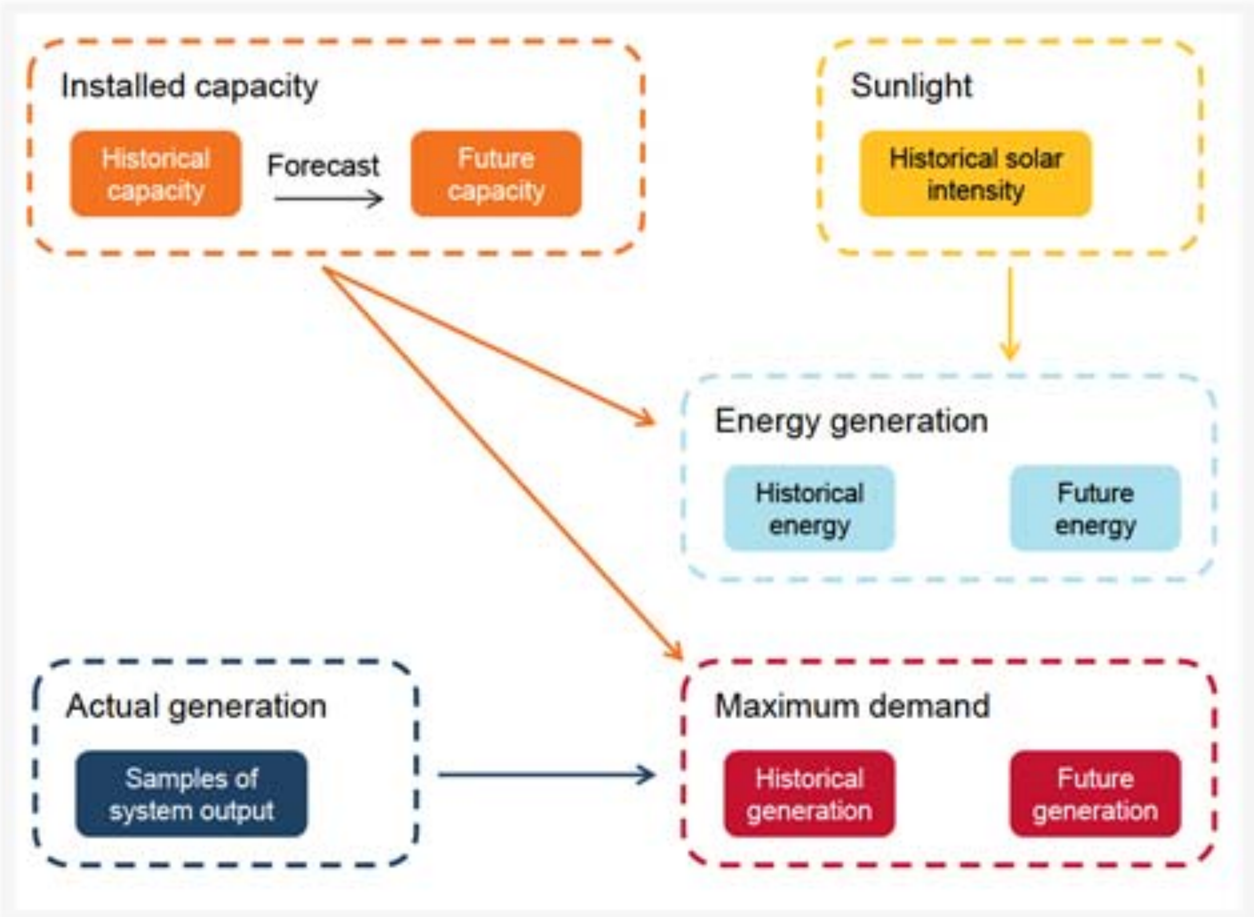
- Gaining access to more consistent data nationwide to calculate more robust estimates of rooftop PV.
- Increased collaboration with the solar industry.
- Analysis of alternative rooftop PV studies in the public domain and comparison to AEMO's research.
- A more in-depth analysis of several assumptions underpinning the installed capacity forecasts:
  - Saturation.
  - Economic payback.
  - Barriers to uptake.
- Validation and comparison with metering data from AEMO data systems, in particular for New South Wales (including the Australian Capital Territory).
- A more detailed study of rooftop PV generation at times of regional maximum electricity demand.
- The development of a continuous series of 30-minute data representing generation estimates and forecasts.
- An analysis of the achievable benefits of aligning rooftop PV generation at times of high demand.

# CHAPTER 2 - DEFINITIONS, PROCESS AND METHODOLOGY

Figure 2-1 shows the inter-relationships between the three types of forecasts this analysis presents:

- Installed Capacity – rooftop PV system capacity based on solar panel rating, in megawatts (MW).
- Energy Generation – energy produced by rooftop PV systems, in gigawatt hours (GWh).
- Maximum Demand – rooftop PV generation at times of peak regional electricity demand, in MW.

**Figure 2-1 — Rooftop PV forecast inputs**




Three main stages were used to develop the forecasts:

- Stage 1: Forecasting future installed capacity based on actual growth in installed capacity over the last three years.
- Stage 2: Estimating historical total energy generated on a monthly basis using historical installed capacity and solar intensity data. Forecast energy generation was calculated using the same approach.
- Stage 3: Forecasting the rooftop PV contribution to maximum demand based on analysing the output of a sample of solar systems during the 2010–11 summer and 2011 winter maximum demands. This contribution was then extrapolated using the installed capacity forecast.

For more information about the data sources used to make the historical data series, see Appendix A. For more information about the adopted approach used in this information paper (briefly discussed in this chapter), see Appendix B.

## 2.1 Drivers of rooftop PV uptake

Economic payback, through reduced electricity bills and income obtained by feeding excess energy into the power system, is the primary factor influencing whether a residential household or business will install a rooftop PV system.

Three main drivers determine economic payback:

- Retail electricity prices.
- The cost of the rooftop PV system.
- Government incentives, including the price obtained for excess energy fed into the power system.

These three drivers were considered when defining the rooftop PV forecast scenarios (see Section 2.2).

Several other factors also influence new installations:

- Reduced greenhouse gas emissions.
- Improved energy efficiency ratings of commercial buildings, for mandatory disclosure requirements.
- Image enhancement, especially for businesses.

## 2.2 Rooftop PV scenarios

Table 2-1 outlines the three drivers used to define the three scenarios used in this information paper:

- The slow uptake scenario, which is a combination of drivers that does not encourage new installations.
- The moderate uptake scenario, which is considered the most likely of the three scenarios.
- The rapid uptake scenario, which is a combination of drivers that encourages new installations.

All three scenarios assume the Australian Government's national Renewable Energy Target (RET) scheme remains unchanged, including the scheduled reduction in the Small-scale Technology Certificate (STC) multiplier.

**Table 2-1 — Drivers and mapping of rooftop PV scenarios**

| Driver | Slow uptake scenario | Moderate uptake scenario | Rapid uptake scenario |
|---|---|---|---|
| Retail electricity prices | Retail electricity prices change little from current levels, in real terms. | Moderate price increases. | Relatively large increases. |
| Rooftop PV system costs | Slow system cost reductions. | Moderate system cost reductions. | Rapid system cost reductions. |
| Government incentives[3] | Incentives are largely removed. Energy may be fed into the grid at prices equivalent to average wholesale generation cost, plus avoided losses. | A moderate level of support. This may take many forms, but the overall effect falls between the other two scenarios. | A clear incentive. The incentive may take many forms, but the overall level of support is equivalent to a feed-in tariff[a] similar to residential retail prices. |

a. Feed-in tariff is the dollar amount per kWh that a retailer pays for rooftop PV electricity fed into the power system.

[3] In all scenarios, the Renewable Energy Target (RET) is assumed to remain unchanged.

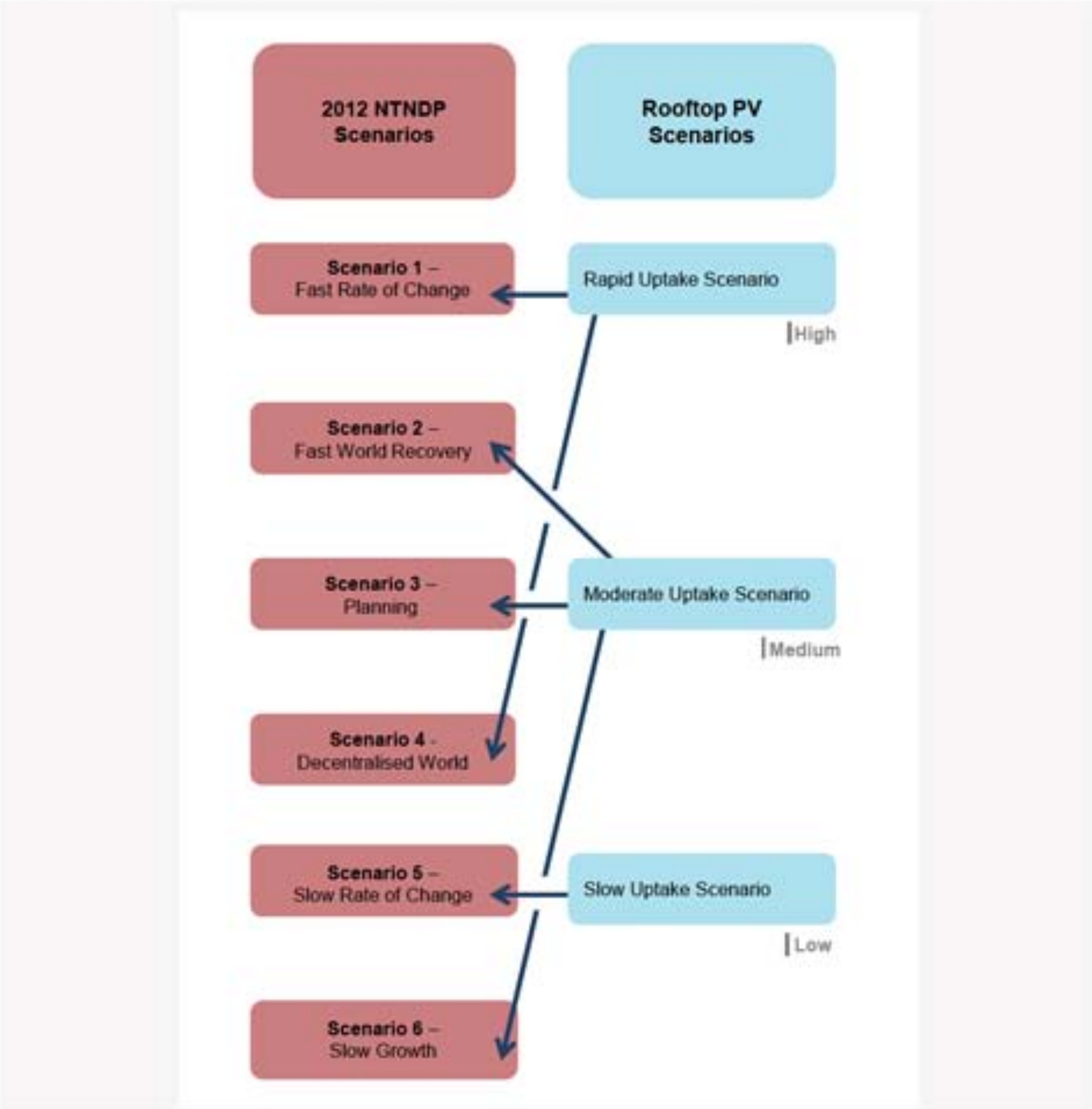
 

### 2.2.1 Mapping rooftop PV scenarios

Six scenarios have been developed for the electricity demand forecasts as part of National Electricity Forecasting.[4] These are equivalent to the scenarios that will also be used in the 2012 National Transmission Network Development Plan (NTNDP) and 2012 Gas Statement of Opportunities (GSOO).

Figure 2-2 shows the rooftop PV scenario (and associated forecast) inputs into the six scenarios underpinning the electricity demand forecasts (to be released in June 2012).

**Figure 2-2 — Mapping scenarios for National Electricity Forecasting**




[4] AEMO "2012 Scenarios Descrip ion", available http://www.aemo.com.au/planning/2418-0005.pdf. Viewed May 2012.

## 2.3 Forecasting installed capacity

Three key factors underpin the development of the forecasts for installed capacity:

- Future economic payback.
- Barriers to uptake.
- Saturation capacity.

### 2.3.1 Future economic payback

Simple regional models have been developed to establish the likely economic viability of future installations, taking into account system costs, rebates via STCs, and retail[5] and wholesale[6] electricity prices.

Factors the models do not account for include the following:

- The impacts and costs of rooftop PV on transmission and distribution networks.
- The costs associated with enhancing the network to support rooftop PV uptake, including voltage control and protection settings.
- The impact of rooftop PV uptake on network tariffs.
- The market impact of rooftop PV increasing total generating capacity in the NEM.

Results varied by region, due to different retail electricity price forecasts and rebates available via STCs. It was found that the payback period in South Australia was shorter than the other regions, with Tasmania the slowest to show a return.

Table 2-2 lists the simple payback period obtained from installing a 3.5 kW system for a household with typical daily electricity consumption. The ranges reflect variation between the NEM regions.

Table 2-2 — Simple payback periods by year of installation

| Installation year | Slow Uptake Scenario | Moderate Uptake Scenario | Rapid Uptake Scenario |
|---|---|---|---|
| 2015 | 8 to 11 years | 6 to 9 years | 4 to 7 years |
| 2020 | 7 to 9 years | 5 to 6 years | 3 to 4 years |
| 2025 | 5 to 7 years | 3 to 4 years | 1.5 to 2 years |
| 2032 | 5 to 6 years | 3 years | 1.5 to 2 years |

From 2012 to 2015, payback periods remain high as scheduled drops in the STC multiplier reduce the rebate available on systems, which tends to counter the drop in system prices.

After the first few years, the economics improve steadily, while the STC rebate remains in place. To avoid strange results towards the end of the analysis period, it was assumed that the STC rebate for rooftop PV will be available until 2025.

[5] AEMO, 2012 Economic Outlook, electronic information, scenarios LCO5, MCO5 and HCO5.

[6] The Australian Government's Treasury and the Department of Climate Change and Energy Efficiency modelled the potential economic impacts of reducing emissions over the medium and long term proposed in the 'Strong Growth, Low Pollution, Modelling a Carbon Price' Report, released on 10 July 2011, available http://archive.treasury.gov.au/carbonpricemodelling/content/default.asp. Viewed May 2012.

The scenarios do not differentiate between current feed-in regimes applicable in each state. Also, the retail electricity price forecasts do not apply the full price rises set by regulators for several states. For these reasons, the simple payback results should be considered indicative only, and may not be accurate for the first few years of the outlook period.

Household and business sensitivity to the payback period is not known. However, it seems likely that payback periods approaching 10 years will be unattractive, as the system's inverter may need to be replaced around this time. On the other hand, payback periods of 3 years or less may even entice households and businesses with short investment horizons, such as renters.

### 2.3.2 Barriers to uptake

Physical constraints within distribution networks can limit uptake volume. For example, to feed excess energy into the distribution network, rooftop PV systems must generate power at a higher voltage than in the street. If several systems do this simultaneously, this raises the street voltage. If the street voltage exceeds the threshold of a rooftop PV system, it will shut down and the system's owner will be deprived of expected revenue.

Anecdotal reports indicate that to prevent this, some distribution businesses are already imposing restrictions on the size of rooftop PV connections. However, alleviating this constraint involves distribution network augmentation. In the future, household electricity storage could also play a role.

Analysis of physical limitations is beyond the scope of this report. For forecasting purposes it is assumed they may delay installations in some localities, but will not affect overall uptake across the NEM.

Another potential barrier is the ability of the solar industry to service the rate of uptake. Given the industry's track record during the rapid expansion of the last two years, this is not expected to be a problem.

### 2.3.3 Saturation capacity

Forecasting installed capacity requires information about the extent of suitable roof space for rooftop PV installation. The AEMO forecast accounts for all systems that offset consumption behind-the-meter, with the majority being rooftop installations.

There are three major assumptions about saturation:[7]

- The average system size per dwelling is 3.5 kW.
- The number of suitable dwellings in NEM regions at the last census (2006) was estimated to be the number of occupied, detached houses, plus 30% of other dwelling types, with an additional allowance for commercial installations.
- The uptake rate (even at saturation) is only 75%.

Saturation capacity was then calculated as the total number of suitable dwellings multiplied by the 75% uptake rate and the 3.5 kW average, resulting in a saturation capacity of 17,841 MW for the NEM in 2006.

AEMO used the forecast number of households to calculate saturation capacity forecasts for the outlook period.[8] The 2006 saturation capacity was multiplied by the household growth ratio since 2006, resulting in capacities of 21,339 MW in 2022 and 22,922 MW in 2031 for the NEM.

These estimates will be revised as more comprehensive rooftop PV saturation studies become available.

[7] Refer to Appendix B.
[8] AEMO. 2012 Economic Outlook, electronic information, MC05 scenario.

## 2.4 Estimating rooftop PV energy generation

The monthly energy forecast for a given region has been calculated based on the following estimation formula:

- Identify the annual generation expected from a 1 kW system.
- Multiply by the percentage contribution for the month.
- Multiply by the forecast installed capacity, in kW.

Historical energy generation was similarly calculated, but was also adjusted for the actual sunlight conditions experienced in a given month. A sunlight factor was calculated by dividing actual average daily sunlight intensity for the month by the average for the same month using historical data from January 2000 to February 2012. The monthly energy result was then multiplied by this factor.

The data sources used to undertake this analysis are explained in Appendix A, and a description of the estimation methodology used is provided in Appendix B.

## 2.5 Rooftop PV generation at times of maximum demand

A preliminary analysis of maximum demand was undertaken for each of the five NEM regions based on sample data. This analysis was completed for the 2010–11 summer for all regions except Tasmania, where the winter 2011 maximum demand was analysed.

Generation at a particular point in time will generally be lower than rated system capacity for several reasons:

- The angle of the sun in the sky.
- Cloud conditions.
- Shading caused by trees, buildings and other structures.
- Reduced panel performance due to high temperatures.
- Electrical losses in the inverter and other parts of the system.

To calculate generation forecasts of rooftop PV systems in a particular region, the average generation as a percentage of the rated system capacity was multiplied by the installed capacity forecast.

For more information about the data sources used to undertake this analysis, see Appendix A. For more information about the estimation methodology, see Appendix B.

At this stage these forecasts are only preliminary, as the size of the sample data was small. Once more comprehensive data becomes available, this analysis will be repeated.

# CHAPTER 3 - ROOFTOP PV IN THE NEM

This chapter presents information about estimates of rooftop PV uptake. This is the first time AEMO has undertaken a study of this type, and the methodology will continue to develop. However, this first step has provided insight into the current setting of rooftop PV and its impact on the NEM.

The historical and forecast estimates for the NEM are an aggregation of each of the five NEM regions. A discussion at the region level is provided in the next chapter.

## 3.1 Installed capacity

AEMO independently studied rooftop PV to understand the current and forecast impact of rooftop PV on the NEM. Other organisations have also estimated the future uptake of rooftop PV, producing a diverse range of views.

For information about these alternative forecasts for rooftop PV and a comparison with AEMO's forecasts see Appendix D.

The analysis discussed in this section forms the basis for AEMO's energy forecast calculations.

### 3.1.1 Historical analysis

The historical data used in the analysis of installed capacity was collected from the distribution businesses and the Clean Energy Regulator (CER).[9] There are discrepancies between these two data sources, in particular an inherent lag in the CER data, which can take up to 12 months to be published.

Until the start of 2010, the level of rooftop PV uptake in the NEM was too small to make a material impact on overall electricity demand. The number of installations rose dramatically in 2010 and 2011, reaching an estimated capacity of 1,450 MW at the end of February 2012.

This increase was largely driven by improved payback of rooftop PV systems, due to incentives such as state government feed-in tariffs, falling system prices, and rising retail electricity tariffs. The estimated average rate of uptake in 2010 and 2011 was 28 MW and 74 MW per month, respectively.

### 3.1.2 AEMO installed capacity forecast

For the NEM as a whole, uptake to 2017 is expected to be relatively restrained, averaging 320 MW per year under the moderate uptake scenario. This rate is slower than the estimated uptake in 2010, and is influenced by two main factors:

- Feed-in tariffs in most states have been withdrawn or reduced, lowering economic payback.
- Demand has been reduced by installations brought forward to 2011 to beat rebate cut-off dates.[10]

From 2018 to 2025, economic payback is expected to improve strongly, with innovative financing reducing the problem of up-front payment, and commercial buildings joining the trend. The moderate uptake scenario sees this accelerate, averaging 620 MW per year, while the rapid uptake scenario forecasts new installations to average 1,130 MW per year. The slow uptake scenario misses out on this phase, suppressed by relatively poor payback.

From 2026 to 2031, payback is expected to improve. Uptake is forecast to continue strongly for newly-built dwellings, and for upgrades or replacements of existing systems. Fresh installations on existing dwellings may start to slow, as the most suitable dwellings have already been taken by earlier installations. Growth may slow in

[9] The Office of the Renewable Energy Regulator (ORER) was amalgamated into the Clean Energy Regulator on April 2, 2012.

[10] The STC solar multiplier is due to fall from 3 to 2 on 1 July 2012, and from 2 to 1 on 1 July 2013.

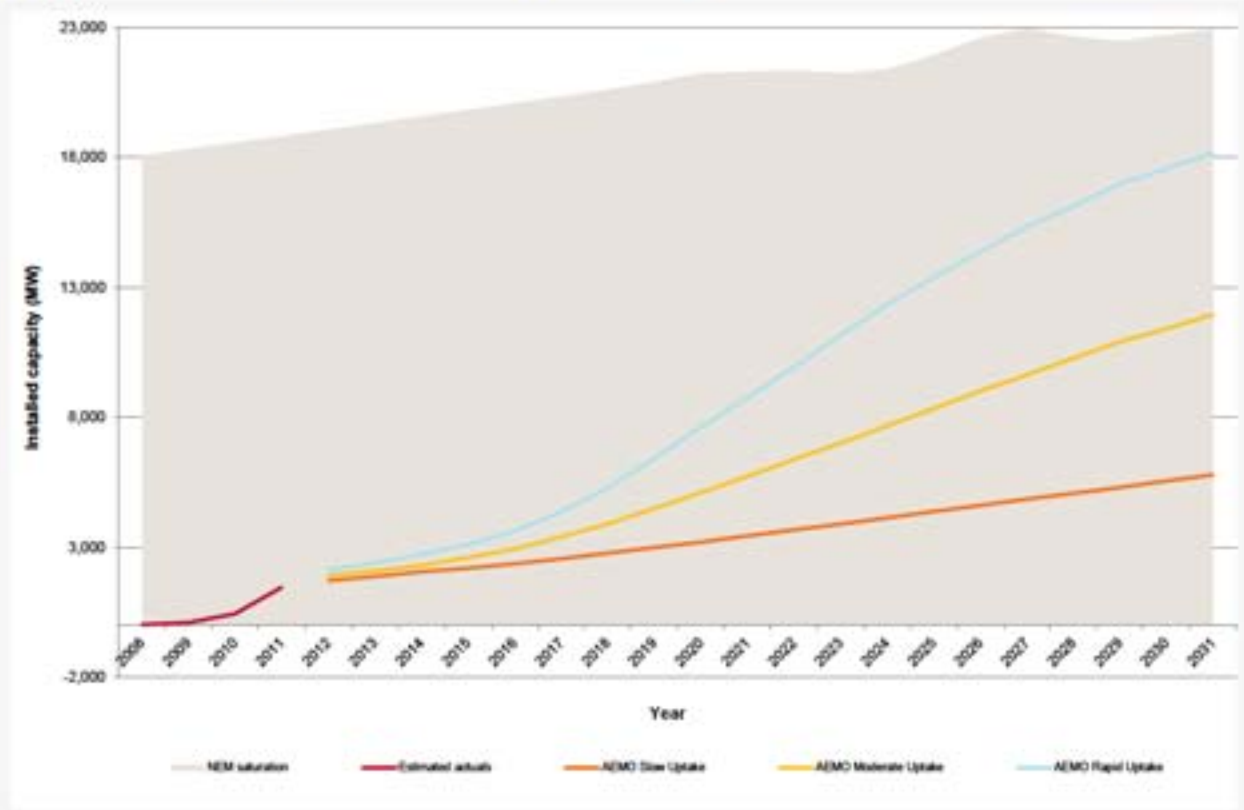
Queensland, New South Wales (including the Australian Capital Territory) and South Australia, as the estimated saturation level is approached.

By 2031, uptake may exceed 50% of estimated saturation in the moderate uptake scenario, and almost 80% in the rapid uptake scenario. The slow uptake scenario continues to follow its previous trend.

Figure 3-1 shows the AEMO rooftop PV installed capacity forecasts. Estimated actual data for 2011 includes installations in January and February 2012. The estimated saturation capacity is shown as the grey background area.

For the moderate uptake scenario, installed capacity is forecast to reach 5,100 MW by 2020 and almost 12,000 MW by 2031.

**Figure 3-1 — Rooftop PV installed capacity forecasts for the NEM**



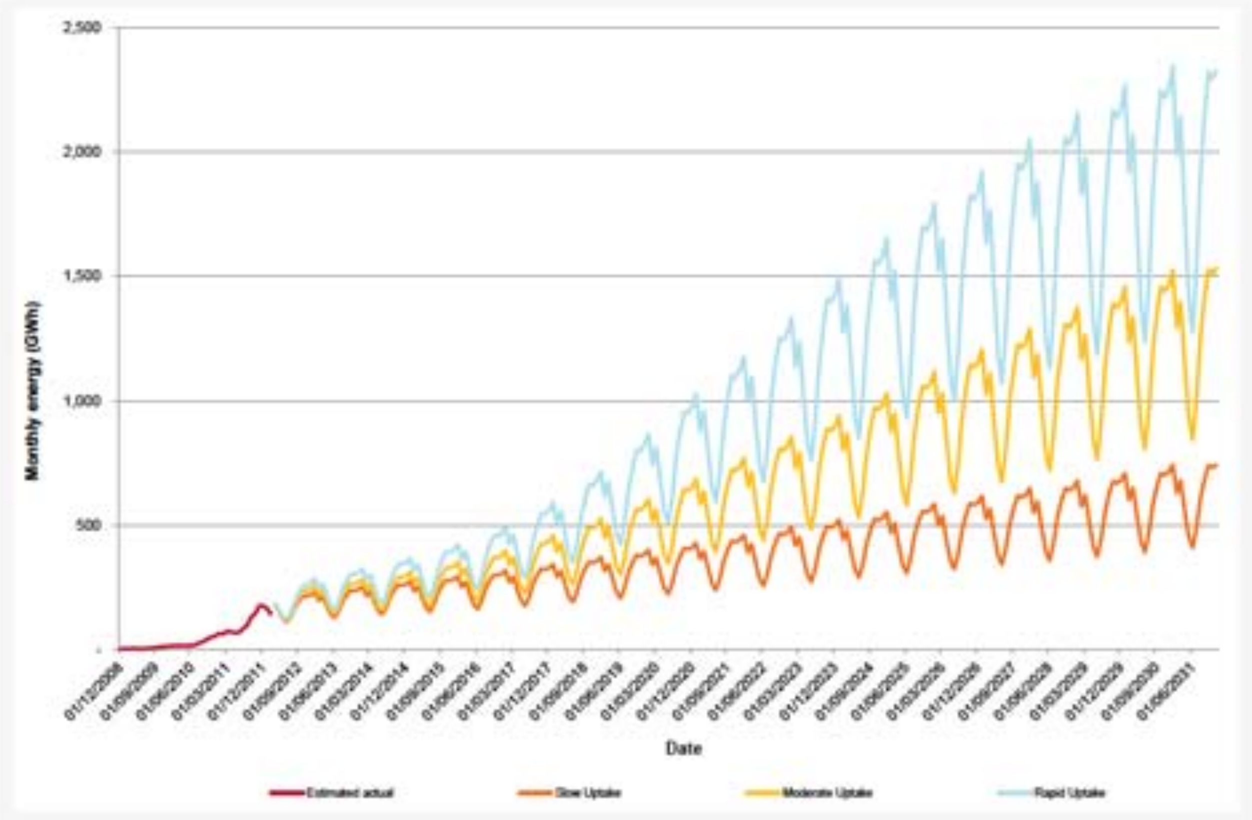

## 3.2 Energy

Figure 3-2 shows the forecast energy for the three scenarios and a historical energy estimate. Monthly energy estimates were calculated as described in Appendix B.

For the moderate uptake scenario, rooftop PV annual energy generation is forecast to reach approximately 6,350 GWh by 2020 and over 15,400 GWh by 2031.

The similarity to the installed capacity forecast (Figure 3-1) is evident, although the scale and unit of measure differs. The figure also shows the seasonal nature of the energy forecasts.

**Figure 3-2 — Rooftop PV energy forecasts for the NEM**




### Comparison with NEM energy

As reported in the 2011 ESOO, annual energy in 2010–11 for the NEM was 196,440 GWh. By comparison, rooftop PV energy is currently small, equivalent to 0.6% in 2011.

It is expected that this proportion will increase substantially over the outlook period, and will be investigated in the main forecasting report released in June 2012.

**[This page is left blank intentionally]**

# CHAPTER 4 - REGIONAL ROOFTOP PV

This chapter provides information about historical and forecast installed capacity estimates for rooftop PV in each region. Providing an initial overall picture of rooftop PV, additional data mining work is required to develop the results. Installed capacity is defined as the installed rooftop PV's rated panel capacity.

## 4.1 New South Wales (and the Australian Capital Territory)

### 4.1.1 Installed capacity

The forecasts use historical estimates of installed capacity growth in New South Wales (including the Australian Capital Territory).

At the end of February 2012, the estimated total rooftop PV installed capacity in New South Wales (including the Australian Capital Territory) was 461 MW. Uptake was significant in early 2011, but slowed after the gross feed-in-tariff was closed to new customers in April 2011.

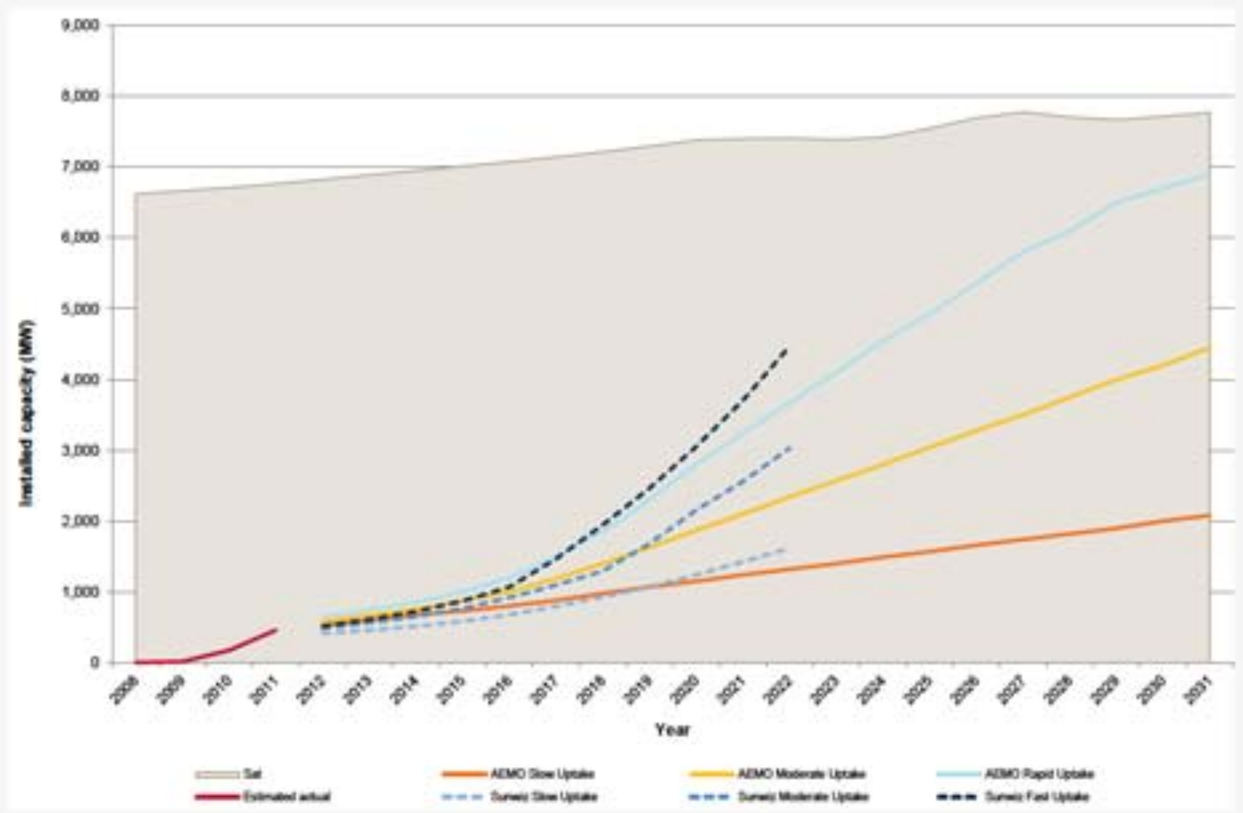
Figure 4-1 shows the installed capacity forecast for each of the three scenarios. It also plots estimated historical data, estimated saturation capacity, and a set of independent forecasts developed by SunWiz[11], which were commissioned by AEMO for comparison.

Forecast uptake in the short term is expected to be low, relative to 2011. This is a continuation of the slowdown observed since mid-2011. In the medium term, uptake diverges depending on the scenario. In the long term, the rate of uptake under the rapid uptake scenario begins to slow, as the installed capacity approaches the estimated saturation capacity.

For the moderate uptake scenario, the installed capacity reaches 1,870 MW in 2020 and 4,450 MW in 2031.

[11] **http://www.sunwiz.com.au/index.php/resources/download-free-reports.html** Viewed May 2012.

**Figure 4-1 — Rooftop PV installed capacity forecasts for New South Wales (and the Australian Capital Territory)**




### 4.1.2 Energy

Figure 4-2 shows forecast energy for the three scenarios, and estimated actual monthly energy from 2008 to 2011 for New South Wales (including the Australian Capital Territory).

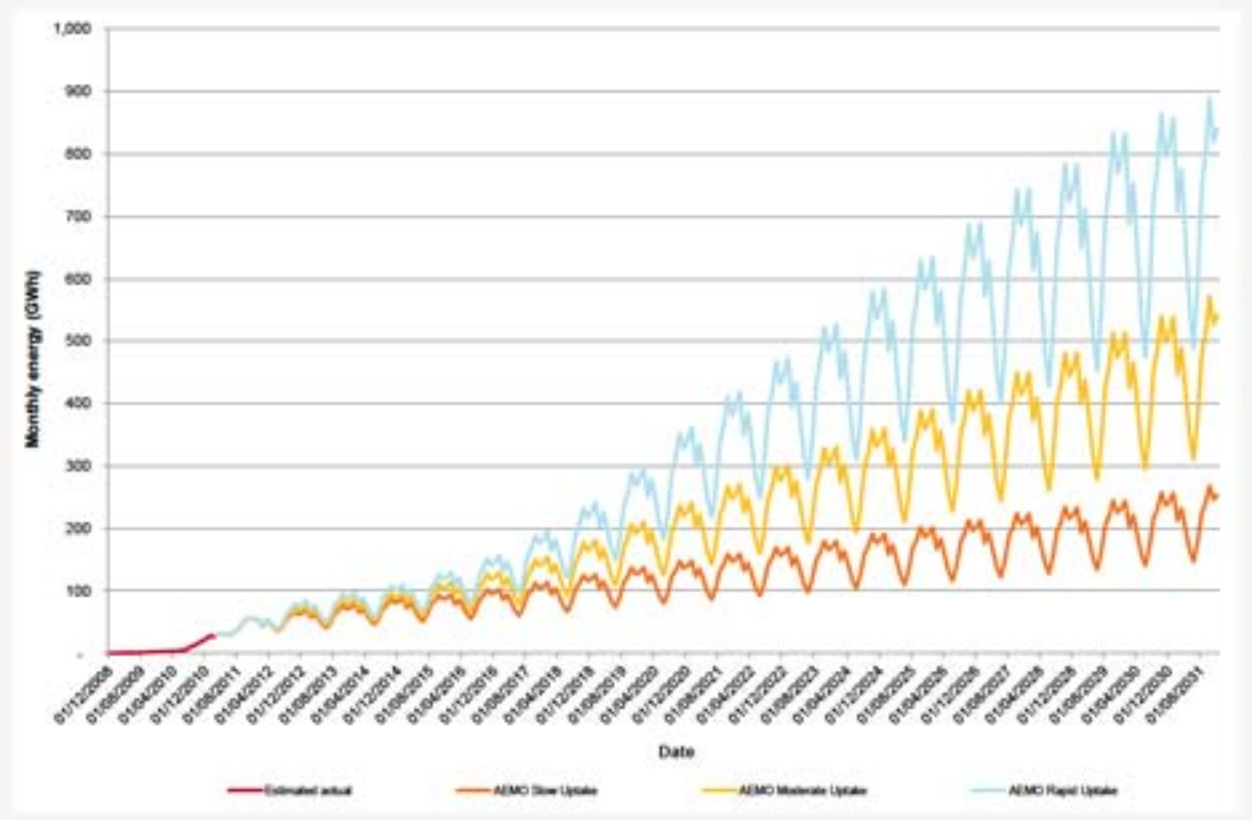
The similarity to the installed capacity forecast (Figure 4-1) is evident, although the scale and unit of measure differs. The figure also shows the seasonal nature of the energy forecasts.

Over 2011 and the first two months of 2012, rooftop PV systems are estimated to have generated 550 GWh, compared to annual energy in 2010–11, which was 74,902 GWh[12], implying that in 2011, rooftop PV energy is approximately 0.7% of recent demand.

For the moderate uptake scenario, annual energy is forecast to reach 2,260 GWh in 2020 and 5,560 GWh in 2031.

[12] AEMO, available http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportuni ies. Viewed May 2012.

## Figure 4-2 — Rooftop PV energy forecasts for New South Wales (and the Australian Capital Territory)




### 4.1.3 Maximum demand

Historically, maximum demand in New South Wales may occur in summer or winter. Summer maximum demand on the day ranges from 15:30 to 16:30.[13] At the time of peak demand, average rooftop PV generation as a percentage of installed capacity ranged from 20% to 34%. At a typical peak demand time of 16:00 AEST (Australian Eastern Standard Time), systems averaged 29% of their installed capacity.

For information about the average summer rooftop PV daily generation curve for New South Wales (and the Australian Capital Territory) based on sample historical data, see Appendix C.

The historical daily profile of summer rooftop PV generation was also analysed in the 2011 NTNDP[14], which derived profiles for both a sunny and a cloudy day using a theoretical approach. The profile in Figure C-1 (Appendix C) falls between these two profiles.

To forecast rooftop PV generation at times of maximum demand (based on sample data), the average percentage derived (29%) was multiplied by the installed capacity estimates.

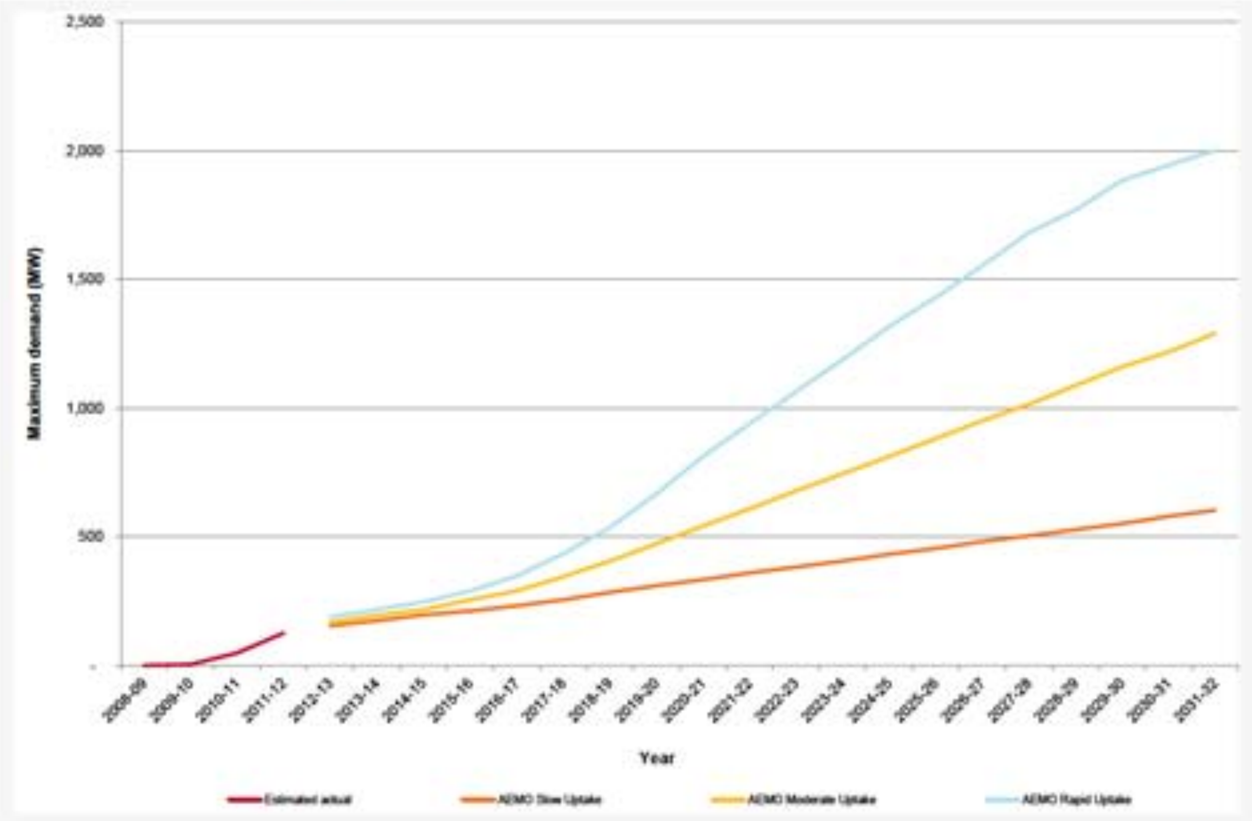
Figure 4-3 shows forecasts of rooftop PV generation at the time of maximum demand. This is based on system performance during the 2010–11 summer and so has no probability of exceedence.

For the moderate uptake scenario, rooftop PV generation at the time of maximum demand reaches 540 MW in 2020-21 and 1,300 MW in 2031-32.

13 AEMO, WARE database, Operational Demand, as per the HistDemand table.

14 AEMO, available http://www.aemo.com.au/planning/NTNDP2011_CD/ntndp.html , Chapter 9. Viewed May 2012.

**Figure 4-3 — Summer maximum demand forecasts for New South Wales (and the Australian Capital Territory)**




### Seasonal peak demand (winter)

Peak demand in winter occurs in the evening, when rooftop PV generation is generally negligible. As a result, rooftop PV during the winter peak was not analysed and was beyond the scope of this project. For information about daily profiles for both a sunny and a cloudy day (derived on a theoretical basis), see the 2011 NTNDP.[15]

## 4.2 Queensland

### 4.2.1 Installed capacity

The forecasts use historical estimates of installed capacity growth in Queensland.

At the end of February 2012, the estimated total installed rooftop PV capacity in Queensland was 427 MW. Uptake has slowed slightly since late 2011, but is still quite strong and driven by the continuing 0.44 $/kWh net feed-in-tariff.

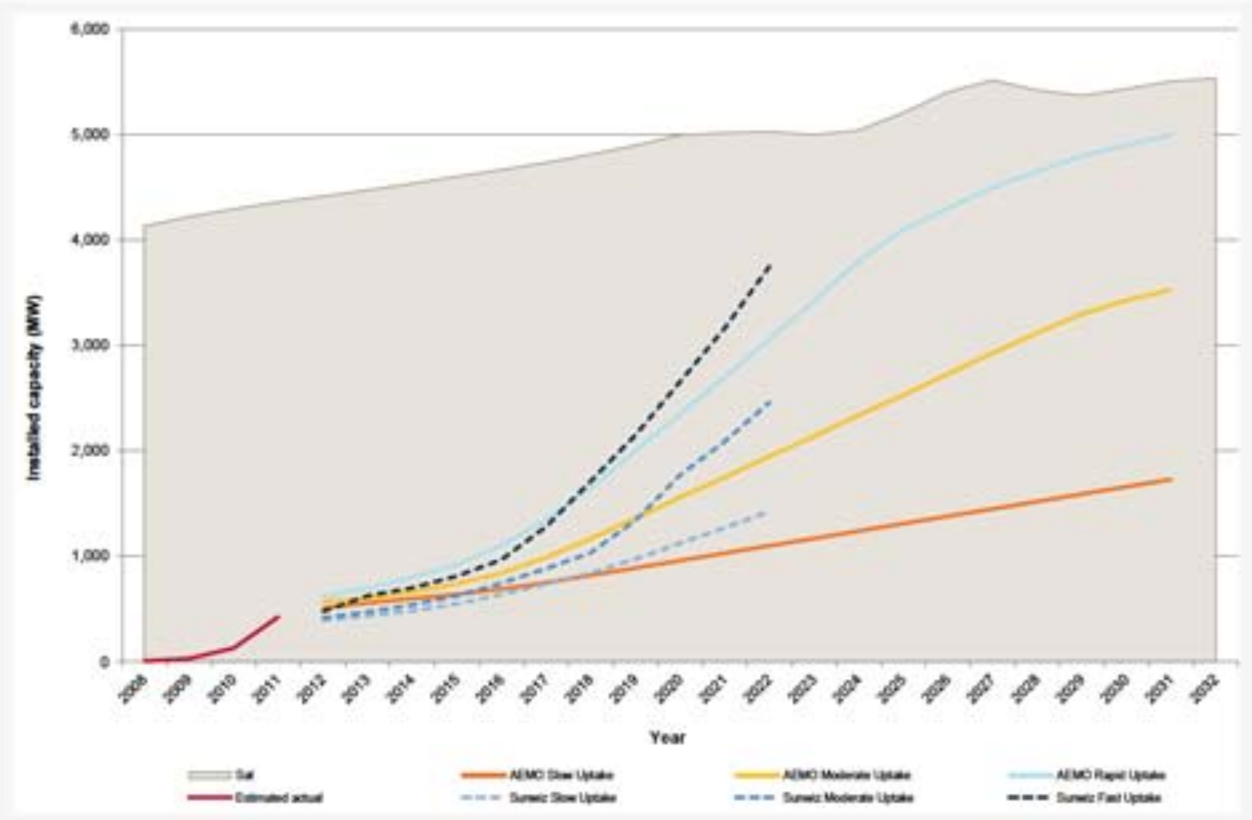
Figure 4-4 shows the installed capacity forecast for each of the three scenarios. It also plots estimated historical data, estimated saturation capacity, and a set of independent forecasts developed by SunWiz, which were commissioned by AEMO for comparison.

In the short-term uptake is forecast to slow, as rebates from STCs diminish. In the medium term, uptake diverges by scenario. In the long term, the rate of uptake under the moderate uptake and rapid uptake scenarios starts to slow as installed capacity approaches the estimated saturation capacity.

[15] AEMO, available http://www.aemo.com.au/planning/NTNDP2011_CD/ntndp.html, chapter 9. Viewed May 2012.

For the moderate uptake scenario, the installed capacity reaches 1,560 MW in 2020 and 3,530 in 2031.

**Figure 4-4 — Rooftop PV installed capacity forecasts for Queensland**




## 4.2.2 Energy

Figure 4-5shows forecast energy for the three scenarios, as well as estimated actual monthly energy from 2008 to 2011 for Queensland.

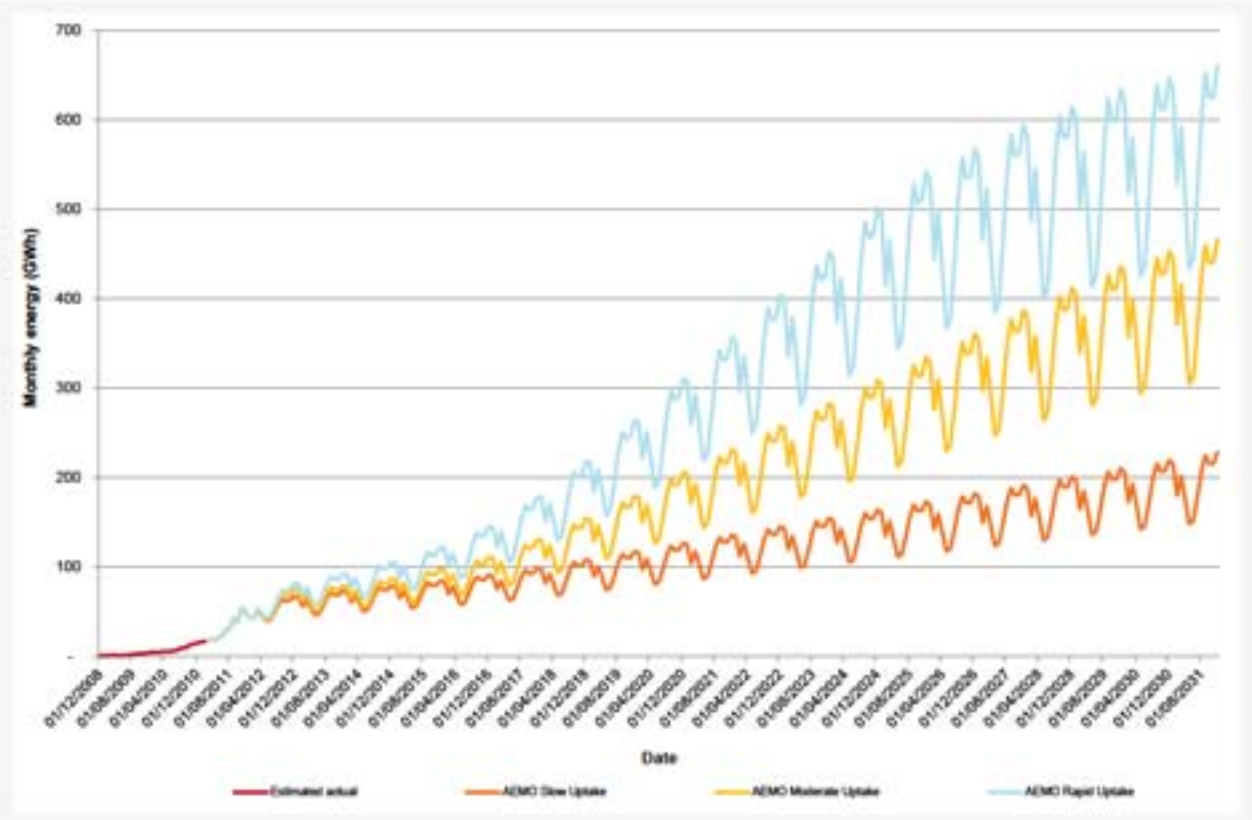
The similarity to the installed capacity forecast (Figure 4-1) is evident, although the scale and unit of measure differs. The figure also shows the seasonal nature of the energy forecasts.

Over 2011 and the first two months of 2012, rooftop PV systems are estimated to have generated 440 GWh, compared to annual energy in 2010–11, which was 48,786 GWh[16], implying that in 2011, rooftop PV energy represents approximately 0.9% of recent demand.

For the moderate uptake scenario, annual energy is forecast to reach 2,030 GWh in 2020 and 4,800 GWh in 2031.

[16] AEMO, available http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportuni ies. Viewed May 2012.

Figure 4-5 — Rooftop PV energy forecasts for Queensland




### 4.2.3 Maximum demand

Historically, maximum demand occurs in summer and on the day ranges from 12:30 to 17:30.[17] At the time of maximum demand, average rooftop PV generation as a percentage of installed capacity ranged from 3% to 62%. At a typical maximum demand time of 16:00 AEST, systems averaged 28% of their installed capacity.

For information about the average summer rooftop PV daily generation curve for Queensland based on historical data, see Appendix C.

To forecast rooftop PV generation at times of maximum demand (based on sample data), the average percentage derived (28%) was multiplied by the installed capacity estimates.

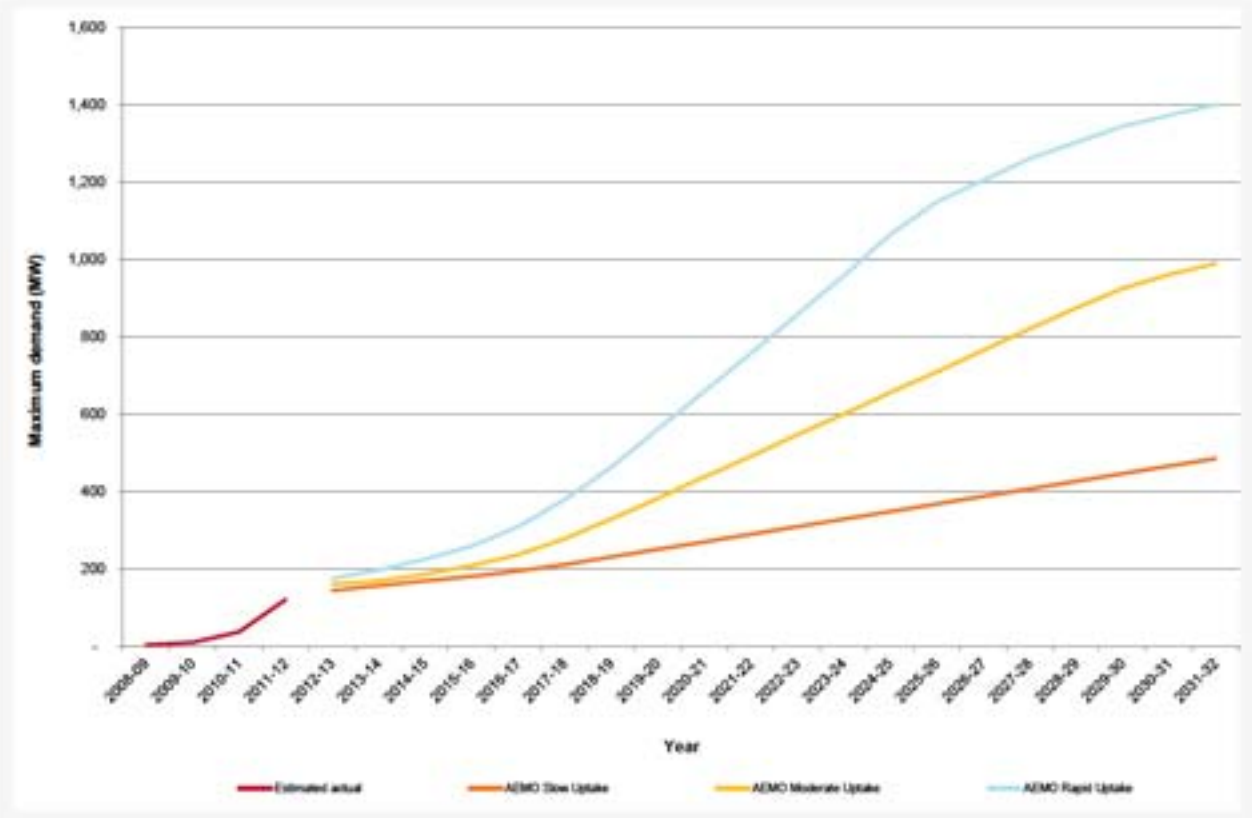
Figure 4-6 shows forecasts of rooftop PV generation at the time of maximum demand. This is based on system performance during the 2010–11 summer and so has no probability of exceedence.

For the moderate uptake scenario, rooftop PV generation at the time of maximum demand reaches 440 MW in 2020-21 and 990 MW in 2031-32.

[17] AEMO, WARE database, Operational Demand, as per the HistDemand table.

Figure 4-6 — Summer maximum demand forecasts for Queensland




# 4.3 South Australia

## 4.3.1 Installed capacity

The forecasts use historical estimates of installed capacity growth in South Australia.

At the end of February 2012, the estimated total rooftop PV installed capacity in South Australia was 267 MW.

The feed-in tariff legislation in South Australia was amended in July 2011. Current applicants will receive approximately 0.22 $/kWh net, compared to 0.50 $/kWh prior to the amendment. After September 2013, the feed-in tariff is scheduled to drop further.

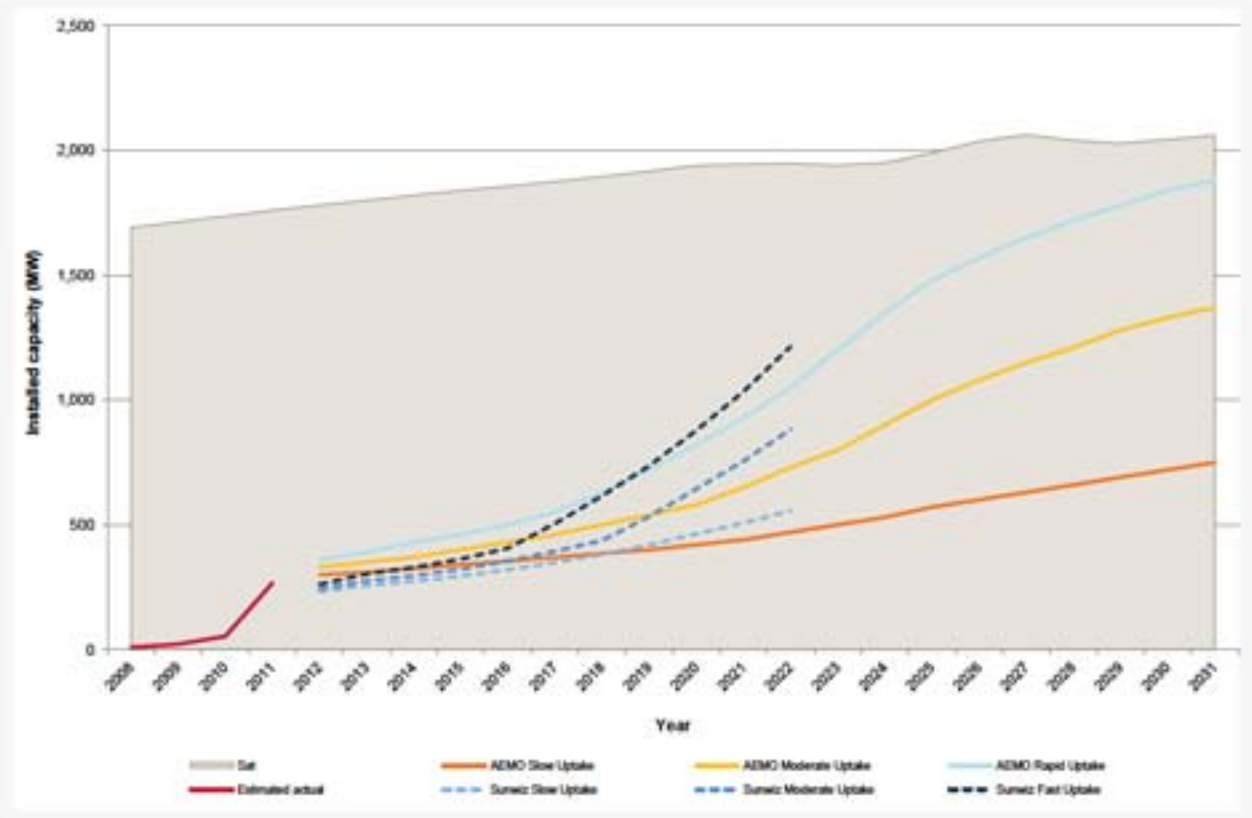
Uptake has slowed slightly since mid-2011, but is still quite strong, and is supported by high average sunlight intensity compared to other capital cities. For the same reason rebates via STCs are also relatively high.

Figure 4-7 shows the installed capacity forecast for each of the three scenarios. It also plots estimated historical data, estimated saturation capacity, and a set of independent forecasts developed by SunWiz, which were commissioned by AEMO for comparison.

Uptake in the first few forecast years is expected to slow down, as changes to the feed-in-tariff flow through, and rebates due to STCs diminish. In the medium term, uptake diverges by scenario. In the long term, the rate of uptake under the moderate uptake and rapid uptake scenarios starts to slow, as the installed capacity approaches the estimated saturation capacity.

For the moderate uptake scenario, the installed capacity reaches 580 MW in 2020 and 1,370 in 2031.

Figure 4-7 — Rooftop PV installed capacity forecasts for South Australia




### 4.3.2 Energy

Figure 4-8 shows forecast energy for the three scenarios, as well as estimated actual monthly energy from 2008 to 2011 for South Australia.

The similarity to the installed capacity forecast (Figure 4-7) is evident, although the scale and unit of measure differs. The figure also shows the seasonal nature of the energy forecasts.

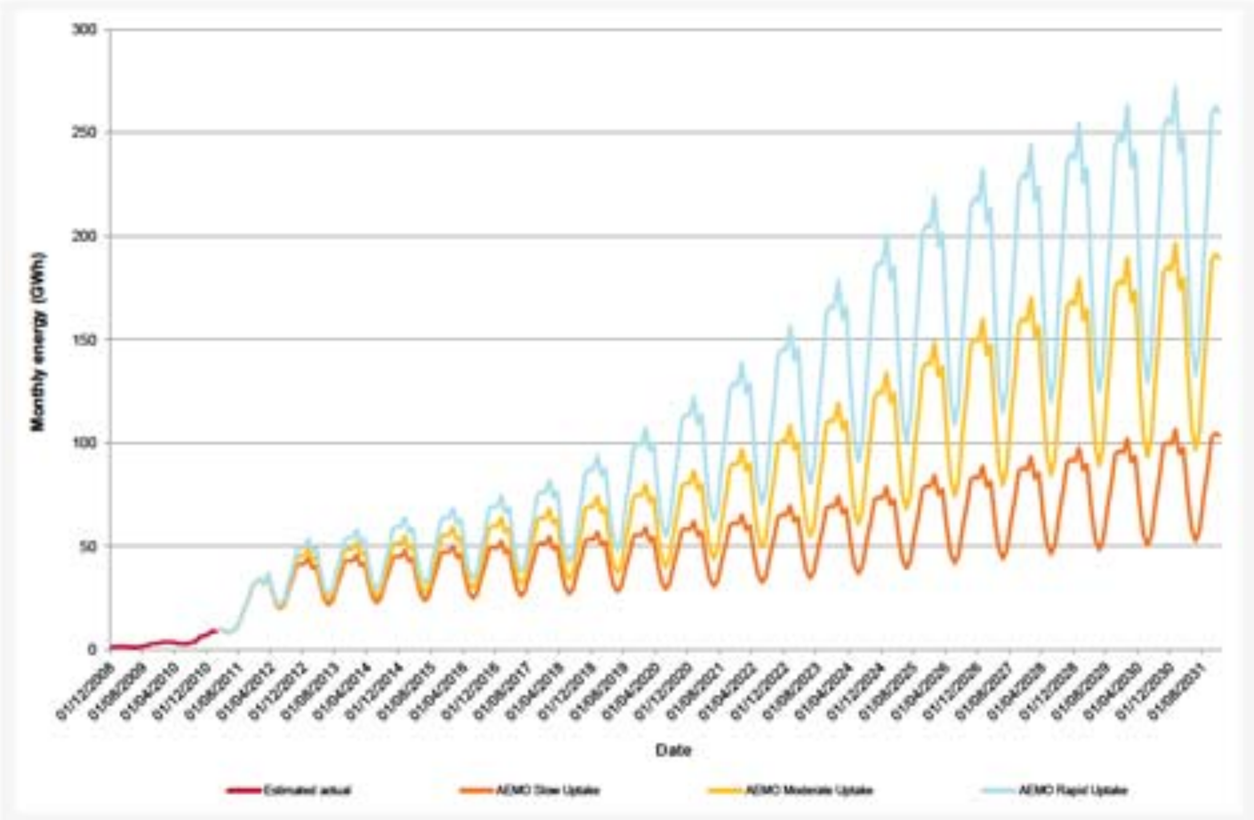
Over 2011 and the first two months of 2012, rooftop PV systems in South Australia are estimated to have generated 250 GWh, compared to annual energy in 2010–11, which was 14,030[18], implying that in 2011, rooftop PV energy represents approximately 1.8% of recent demand.

For the moderate uptake scenario, the annual energy is forecast to reach 774 GWh in 2020 and 1,860 GWh in 2031.

[18] AEMO, available http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportuni ies. Viewed May 2012.

Figure 4-8 — Rooftop PV energy generation forecasts for South Australia




### 4.3.3 Maximum demand

Historically, maximum demand occurs in summer and on the day ranges from 14:00 to 18:00.[19] At the time of maximum demand, average rooftop PV generation as a percentage of installed capacity ranged from 19% to 60%. At a typical maximum demand time of 16:00 AEST, systems averaged 38% of their installed capacity.

For information about the average summer rooftop PV daily generation curve for South Australia based on historical data, see Appendix C.

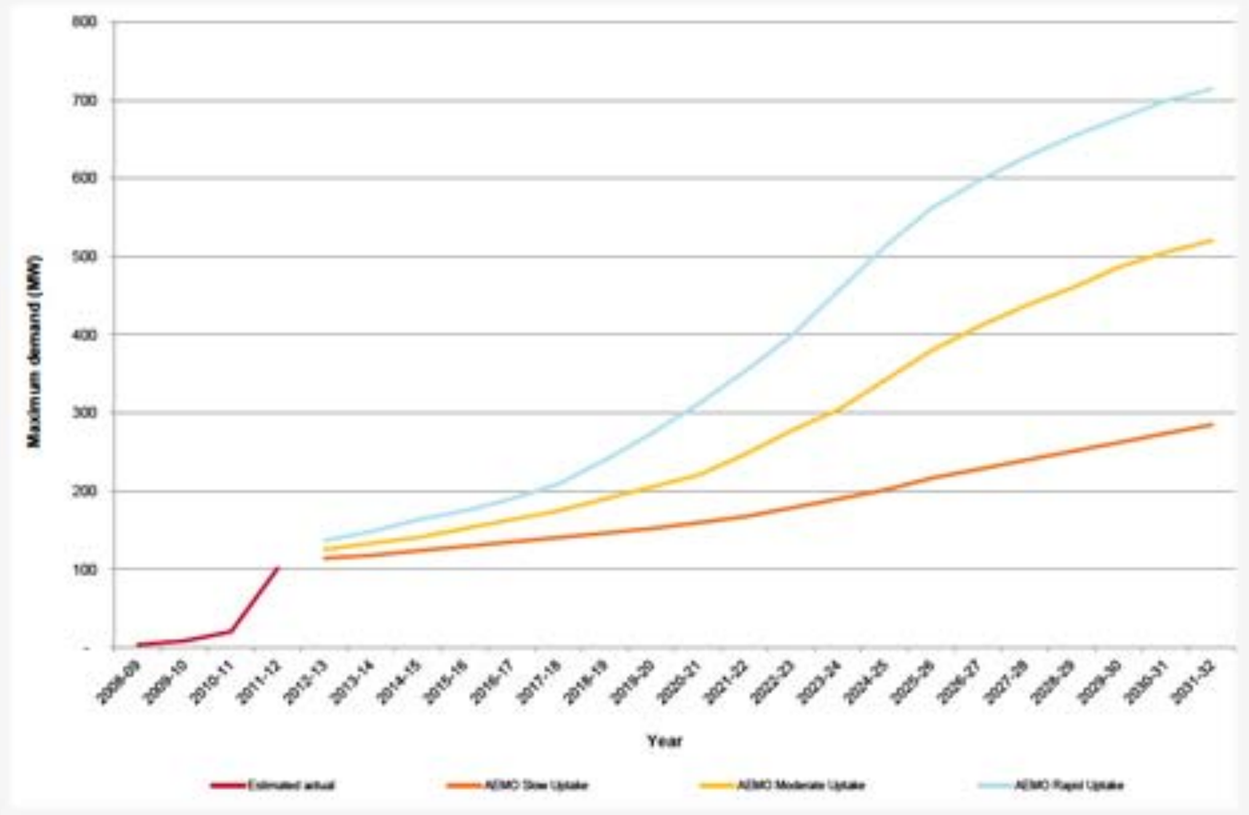
To forecast rooftop PV generation at times of maximum demand (based on sample data), the average percentage 38% was multiplied by the installed capacity estimates.

Figure 4-9 shows forecasts of rooftop PV generation at the time of maximum demand. This is based on system performance during the 2010–11 summer and so has no probability of exceedence.

For the moderate uptake scenario, rooftop PV generation at the time of maximum demand reaches 220 MW in 2020-21 and 520 MW in 2031-32.

[19] AEMO, WARE database, Operational Demand, as per the HistDemand table.

Figure 4-9 — Summer maximum demand forecasts for South Australia




# 4.4 Tasmania

## 4.4.1 Installed Capacity

The forecasts use historical estimates of installed capacity growth in Tasmania.

At the end of February 2012, the estimated total rooftop PV installed capacity in Tasmania was 12 MW. Uptake in Tasmania has been slower than in other regions, which has been influenced by longer times to achieve economic payback, due to average sunlight intensity being lower than other regions. Feed-in tariffs have not changed recently, with participants receiving 0.20 $/kWh on a net basis.

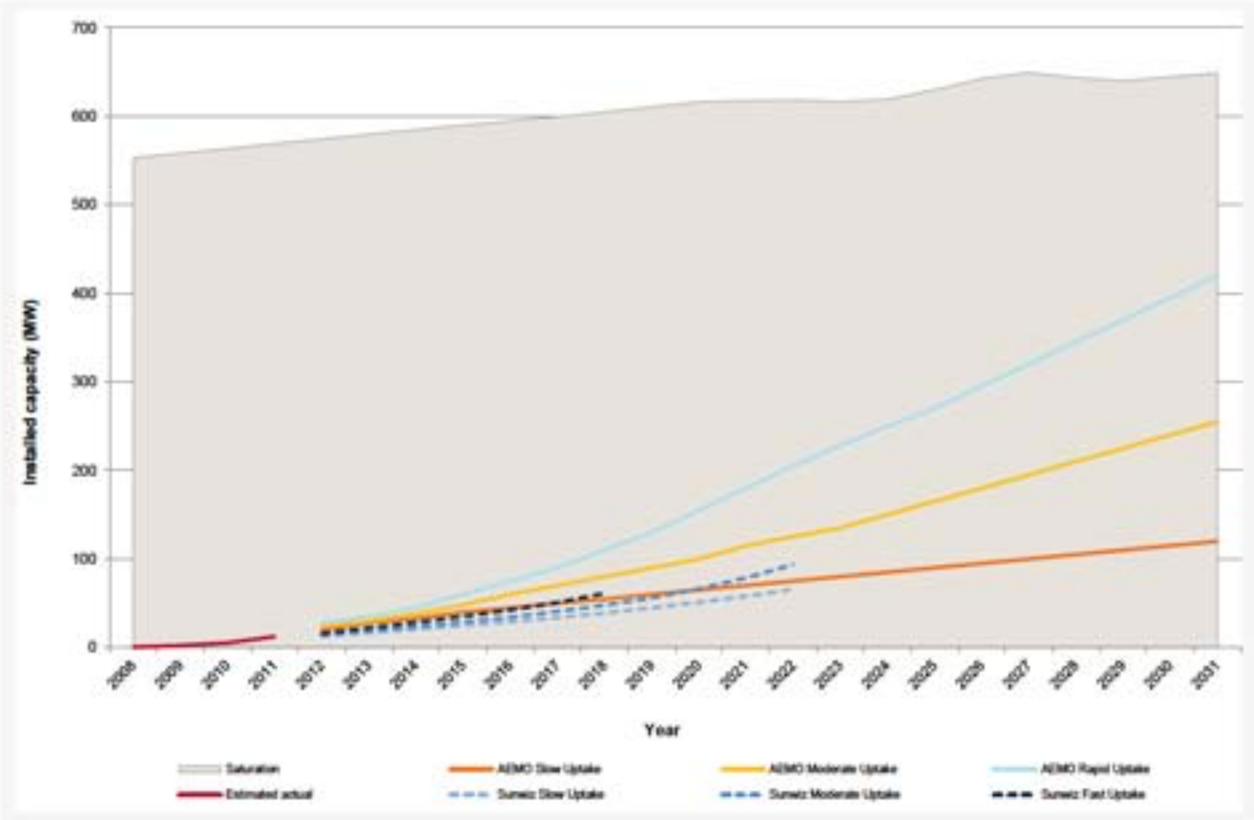
Figure 4-10 shows the installed capacity forecast for each of the three scenarios. It also plots estimated historical data, estimated saturation capacity, and a set of independent forecasts developed by SunWiz, which were commissioned by AEMO for comparison.

Uptake in the first few forecast years is expected to continue with a similar trend to 2011. In the medium term, uptake diverges by scenario. Even in the long term, Tasmania has plenty of headroom before reaching the estimated saturation capacity.

For the moderate uptake scenario, the installed capacity reaches 100 MW in 2020 and 250 MW in 2031.

Figure 4-10 — Rooftop PV installed capacity forecasts for Tasmania




## 4.4.2 Energy

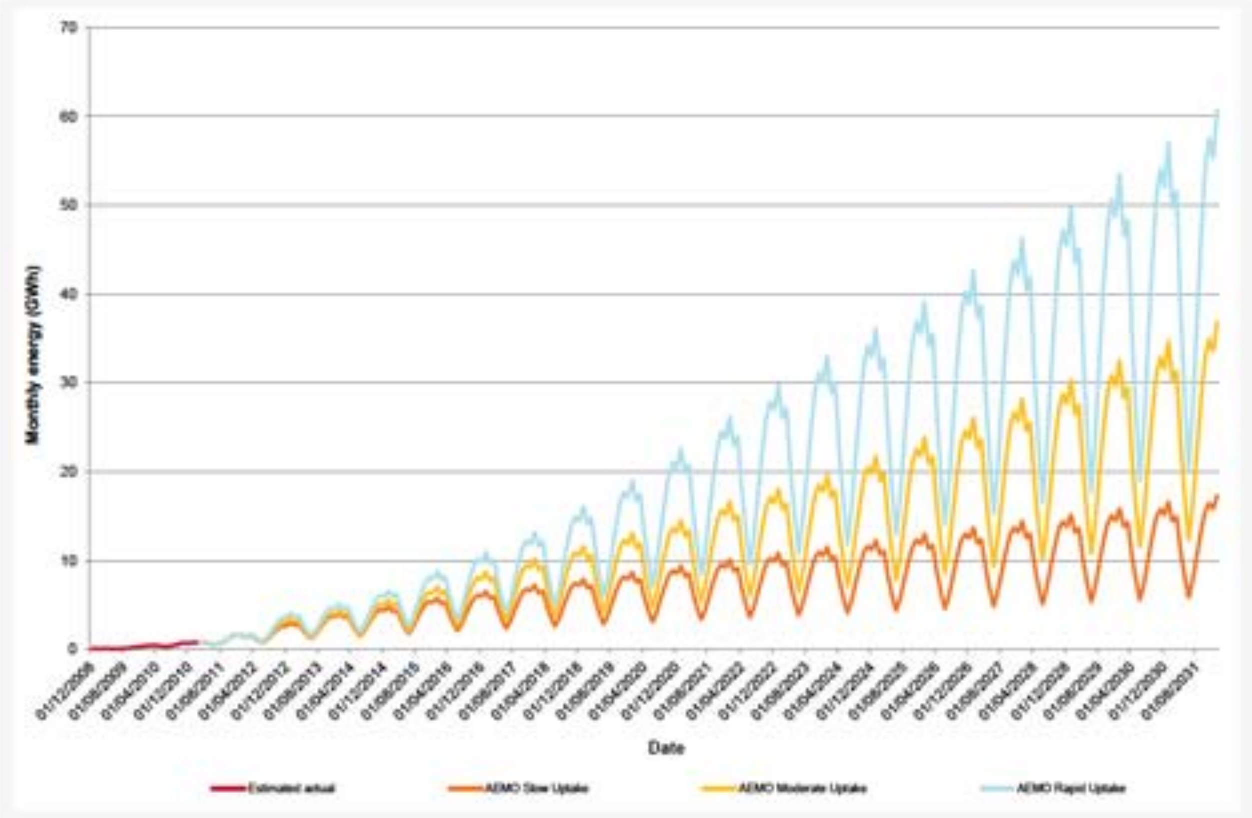
Figure 4-11 shows forecast energy for the three scenarios, as well as estimated actual monthly energy from 2008 to 2011 for Tasmania. The similarity to the installed capacity forecast (Figure 4-10) is evident, although the scale and unit of measure differs. The figure also shows the seasonal nature of the energy forecasts.

Over 2011 and the first two months of 2012, rooftop PV systems in Tasmania are estimated to have generated 14 GWh, compared to annual energy in 2010–11, which was 11,196[20], implying that in 2011, rooftop PV energy represents approximately 0.1% of recent demand. This proportion is low as industry accounts for a large proportion of Tasmanian electricity demand.

For the moderate uptake scenario, the annual energy generation is forecast to reach 120 GWh in 2020 and 320 GWh in 2031.

[20] AEMO, available http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportunities. Viewed May 2012.

Figure 4-11 — Rooftop PV energy generation forecasts for Tasmania




### 4.4.3 Maximum demand

Historically, maximum demand occurs in winter and on the day can occur at any time, ranging from 08:30 to18:30.[21] At the time of maximum demand, average rooftop PV generation was negligible, and as a percentage of installed capacity ranged from 0% to 6%, with an average of 2%. At a typical maximum demand time of 18:00 AEST system output was negligible, and as a result forecasts for winter maximum demand are zero.

For information about the average summer rooftop PV daily generation curve for Tasmania based on historical data, see Appendix C.

## 4.5 Victoria

### 4.5.1 Installed capacity

The forecasts use historical estimates of installed capacity growth in Victoria.

At the end of February 2012, the estimated total rooftop PV installed capacity in Victoria was 288 MW. Uptake in Victoria has been slower than in other mainland regions, which has been influenced by longer times to achieve economic payback, due to average sunlight intensity in Melbourne being lower than other capital cities. The feed-in tariff legislation in Victoria was amended for new applicants in September 2011. Current applicants will receive approximately 0.25 $/kWh on a net basis, compared to a typical 0.66 $/kWh prior to the amendment.

Despite the change in feed-in tariff, uptake has not slowed greatly.

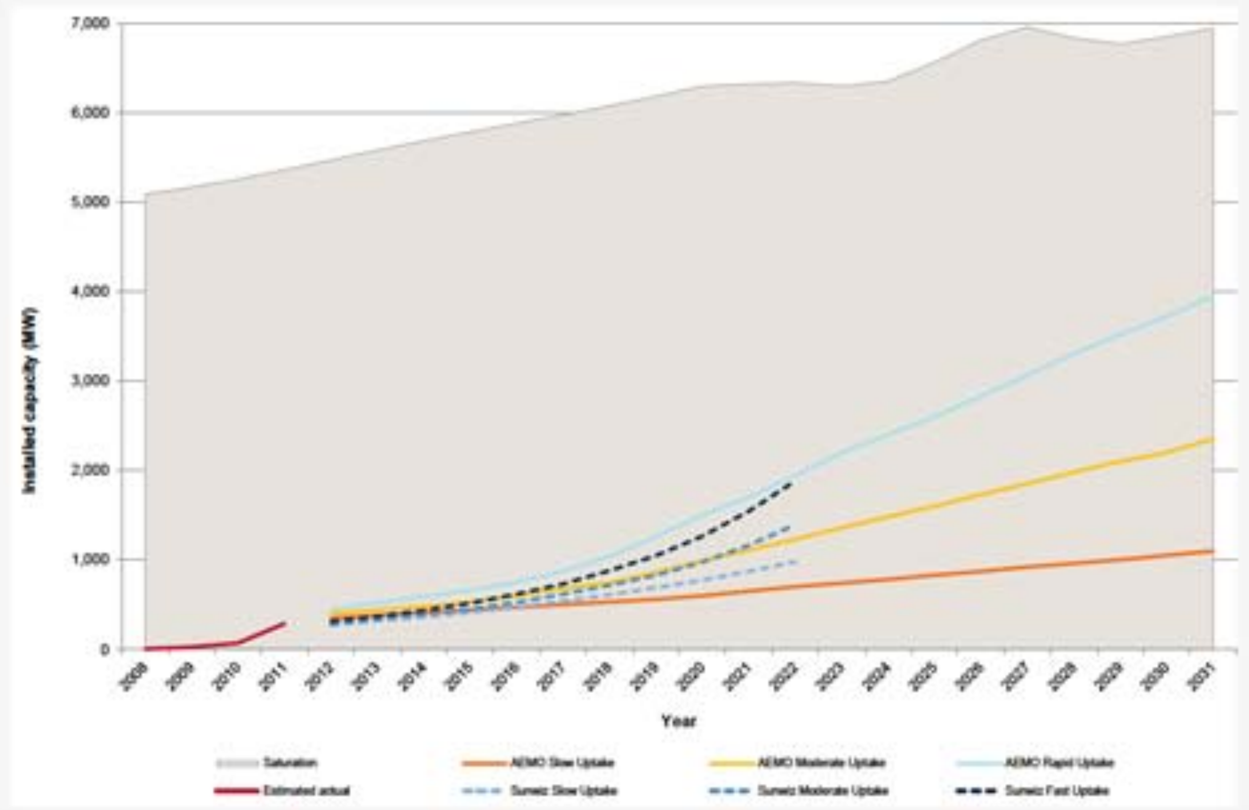
[21] AEMO, WARE database, Operational Demand, as per the HistDemand table.

Figure 4-12 shows the installed capacity forecast for each of the three scenarios. It also plots estimated historical data, estimated saturation capacity, and a set of independent forecasts developed by SunWiz, which were commissioned by AEMO for comparison.

Uptake in the first few forecast years is expected to slow down relative to 2011, as changes to the feed-in-tariff flow through, and rebates due to STCs diminish. In the medium term, uptake diverges by scenario. Even in the long term, Victoria has significant headroom before reaching the estimated saturation capacity. This is partly due to relatively strong forecast growth in the total number of dwellings compared to other regions, providing more space for rooftop PV.

For the moderate uptake scenario, the installed capacity reaches 990 MW in 2020 and 2,350 MW in 2031.

**Figure 4-12 — Rooftop PV installed capacity forecasts for Victoria**




## 4.5.2 Energy

Figure 4-13 shows forecast energy for the three scenarios, as well as estimated actual monthly energy from 2008 to 2011 for Victoria.

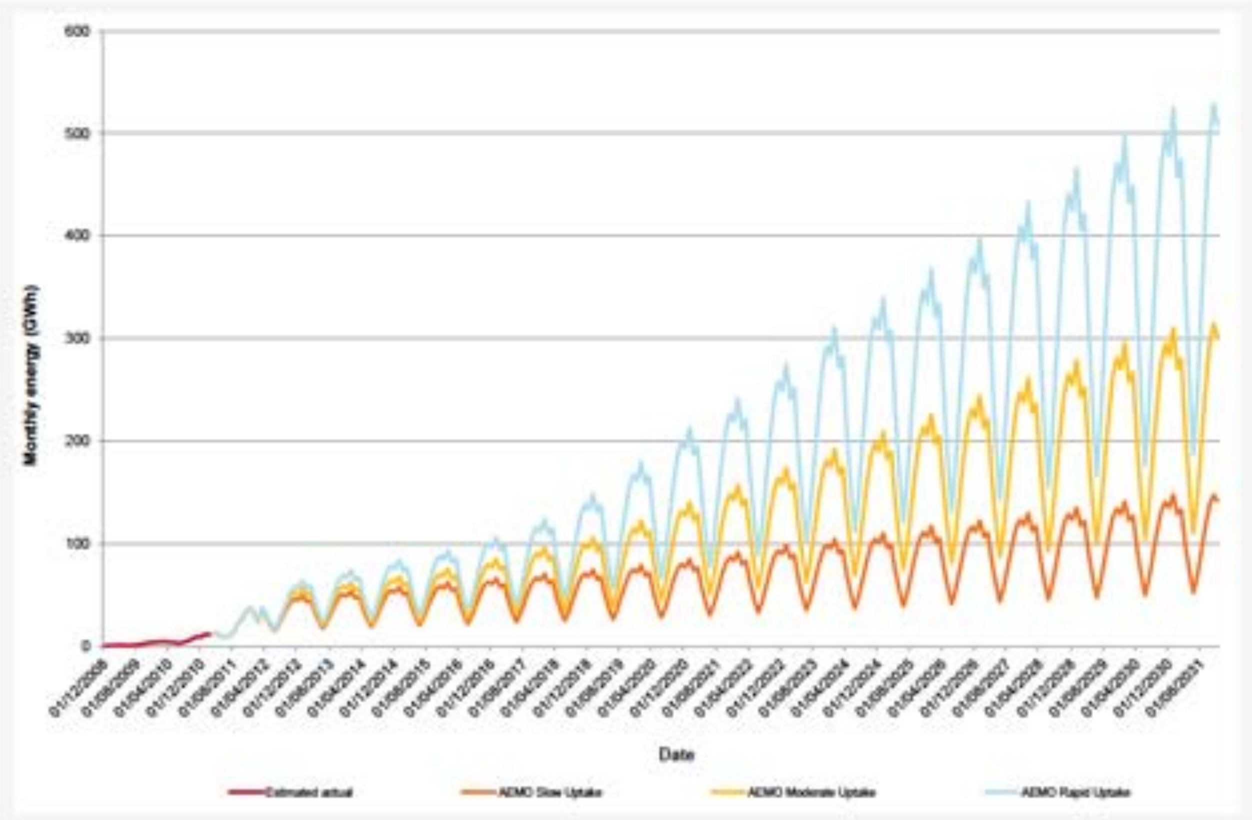
The similarity to the installed capacity forecast (Figure 4-1) is evident, although the scale and unit of measure differs. The figure also shows the seasonal nature of the energy forecasts.

Over 2011 and the first two months of 2012, rooftop PV systems in Victoria are estimated to have generated 260 GWh, compared to annual energy in 2010–11, which was 47,527[22], implying that in 2011, rooftop PV energy represents approximately 0.6% of recent demand.

[22] AEMO, available http://www.aemo.com.au/Electricity/Planning/Electricity-Statement-of-Opportunities. Viewed May 2012.

For the moderate uptake scenario, the annual energy generation is forecast to reach 1,160 GWh in 2020 and 2,840 GWh in 2031.

**Figure 4-13 — Rooftop PV energy generation forecasts for Victoria**




### 4.5.3 Maximum demand

Historically, maximum demand occurs in summer and on the day ranges from 12:30 to 16:30.[23] At the time of maximum demand, average rooftop PV generation as a percentage of installed capacity ranged from 36% to 76%, with an average of 51%. At a typical maximum demand time of 16:00 AEST, systems averaged 35% of their installed capacity.

For information about the average summer rooftop PV daily generation curve for Victoria based on historical data, see Appendix C.

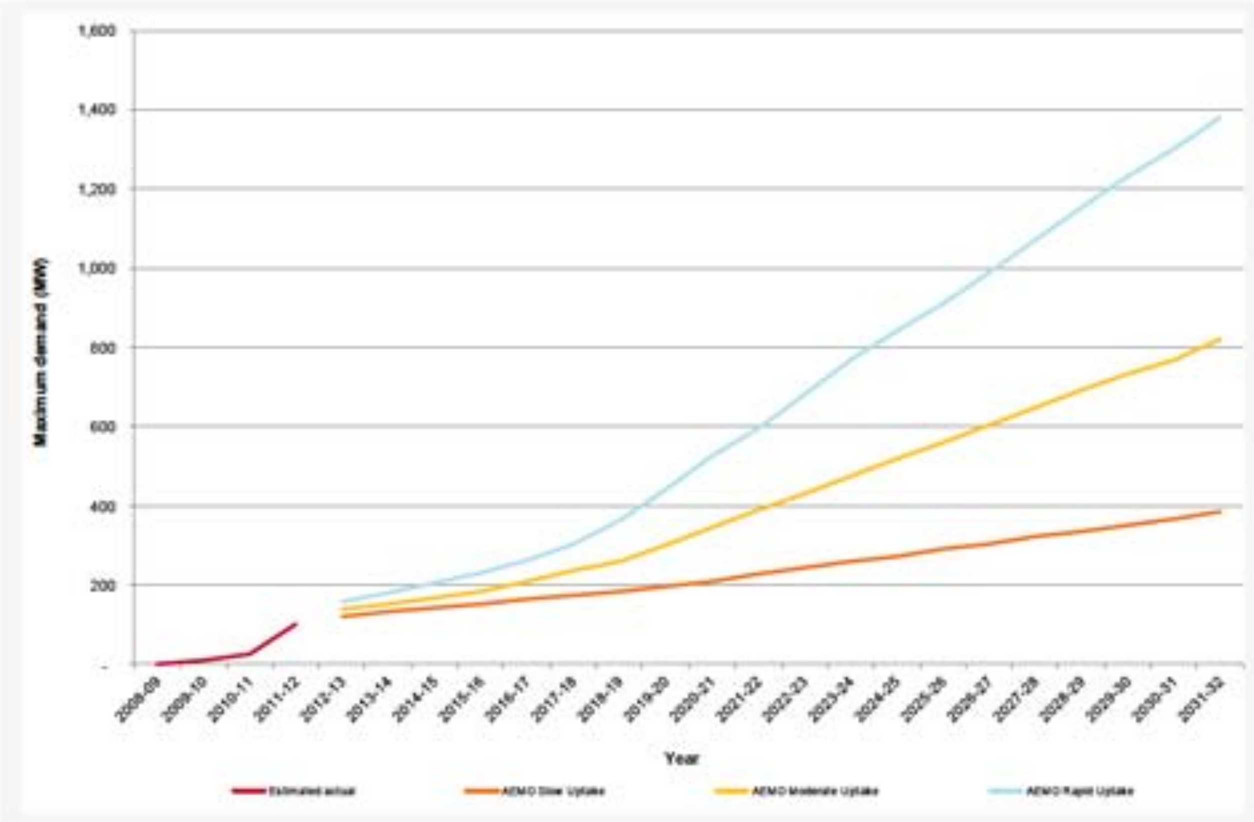
To forecast rooftop PV generation at times of maximum demand (based on sample data), the average percentage derived (35%) was multiplied by the installed capacity estimates.

Figure 4-14 shows forecasts of rooftop PV generation at the time of maximum demand. This is based on system performance during the 2010–11 summer and so has no probability of exceedence.

For the moderate uptake scenario, rooftop PV generation at the time of maximum demand reaches 390 MW in 2020-21 and 820 MW in 2031-32.

[23] AEMO, WARE database, Operational Demand, as per the HistDemand table.

Figure 4-14 — Summer maximum demand forecasts for Victoria



**[This page is left blank intentionally]**

# APPENDIX A - DATA SOURCES

The rooftop PV analysis required historical data for the number of rooftop PV systems, capacity, and output.

Metering data represents the ideal data source, however, most regions only use a net meter, measuring the difference between generation and household or business consumption.

Even in regions where the total PV output is measured, the number of installed systems (over 200,000 in New South Wales and the Australian Capital Territory) makes monitoring the output from all systems problematic. Work has commenced to identify and extract metering data for New South Wales, but was not available in time for this publication.

As an alternative, AEMO used estimated installed capacity, energy, and maximum demand as data sources to undertake this analysis.

## A.1 Installed capacity

### A.1.1 Distribution businesses

Unlike large generating systems, rooftop PV systems do not need to be registered in the NEM. As a result, there is not one central source of information on rooftop PV installations. However, their connection to the power system does need be approved by the local electricity distribution business.

There are thirteen distribution businesses throughout the NEM, with a variety of processes to record information about rooftop PV systems. Distribution businesses may have several reasons to collect this information:

- To track and report the progress of state government incentive schemes.
- Planning for system augmentation.
- Supporting internal commercial analysis.

In November 2011, AEMO approached the distribution businesses for information about installed rooftop PV systems located in their areas. This data provides a snapshot at the end of each month commencing from December 2008, including the number of systems and the total installed capacity, and AEMO has started collecting this data twice a year (September and March).

Due to the diversity of record-keeping, not all distribution businesses were able to supply a full data set for several reasons:

- Missing months.
- Differing definitions (for example, inverter capacity instead of panel capacity).
- Differing scope (for example, including only installations receiving a particular feed-in tariff).

AEMO has made assumptions where necessary to compile a complete data set.

### A.1.2 Comparing data from distribution businesses with the Office of the Renewable Energy Regulator

Another source of information about rooftop PV installations is the Clean Energy Regulator (CER).[1]

For many years, the Australian Government has provided an incentive for rooftop PV systems and other renewable installations, in the form of Renewable Energy Certificates (REC). For small systems, such as rooftop PV, the relevant certificates are now called Small-scale Technology Certificates (STCs).

Because it is uncommon for a rooftop PV owner or installer to not claim this incentive, CER has a comprehensive register of rooftop PV installations, which it publishes on a quarterly basis by postcode.[2] It can take up to 12 months for the STC paperwork to be submitted to CER, and as a result CER's information underestimates the true picture in the more recent months.

When installed capacity information was compared at a regional level, the analysis showed that distribution businesses records showed significantly lower installed capacity than CER. Further investigation revealed several reasons for this discrepancy:

- Timing delays, where some distribution businesses have used a date other than the installation date. For example:
  - The date that an installation was entered into the system.
  - The date when a new meter was installed.[3]
- Different definitions and scope.

The data obtained from the distribution businesses and CER was combined to derive an up-to-date estimate of rooftop PV installed capacity. For each region, a scaling factor was applied to the distribution business data to obtain a match with the CER data over 2010 and into early 2011.

Some grid-connected rooftop PV capacity has not been accounted for by either the distribution businesses or CER:

- Systems where additional panels were installed without notifying the distribution business as required.
- Installations that were not reported to the distribution business as required.
- Systems for which STCs were not claimed.

The number and capacity of these systems has not been estimated, and as a result it is likely that the actual installed capacity is higher than that estimated in this report.

## A.2 Energy

### A.2.1 Average Daily Production

The data used to estimate rooftop PV generation is the average daily generation per kilowatt of installed capacity. This was obtained by capital city from the Clean Energy Council[4], and ranges from 3.5 kWh for Hobart to 4.3 kWh for Adelaide.

[1] The Office of the Renewable Energy Regulator was amalgamated into the Clean Energy Regulator on April 2, 2012.

[2] http://ret.cleanenergyregulator.gov.au/REC-Registry/Data-reports

[3] In some states, PV installations should not be switched on until the dwelling's meter is replaced or re-configured. However, in practice systems are often switched on prior to this date and connected to the existing meter, providing the owner benefit from their system in the interim. In some cases, old accumulation meters have been set to "spin backwards".

[4] http://www.cleanenergycouncil.org.au/cec/resourcecentre/Consumer-Info/solarPV-guide.html, page 4.

### A.2.2 Historical solar intensity

The average daily exposure was obtained from the Australian Government Bureau of Meteorology, aggregated on a monthly basis for each capital city. The unit of measure for this data is megajoules (MJ) per square meter. Gaps in the data were filled by substituting the value from the previous year.

### A.2.3 Actual generation from a sample of systems

Rooftop PV energy data was obtained from PVOutput.org. This website records actual historical generation for individual systems, collected and released by system owners.

## A.3 Maximum demand

Maximum demand is measured at half-hourly intervals in megawatts (MW). To estimate the output of rooftop PV systems at the time of the maximum demand, sample data for maximum system days was obtained on a regional basis from the website PVOutput.org for the last summer (or winter in the case of Tasmania).

**[This page is left blank intentionally]**

# APPENDIX B - METHODOLOGY

## B.1 Saturation

### B.1.1 City of Port Phillip study

The Victorian Government Department of Sustainability and Environment commissioned Entura – Hydro Tasmania to undertake a study of saturation capacity of rooftop PV systems in the City of Port Phillip in Melbourne.[5] Rooftops were mapped with aerial lasers, analysed by computer and a sample verified manually. Allowing for roof orientation and tilt, solar exposure, shading, irregular geometry and minimum size it was found that at a conservative estimate, the City of Port Phillip could support 220 MW of rooftop PV capacity. This comprised 180 MW on dwellings and 40 MW on large flat roofs, which were taken to be commercial.

### B.1.2 Calculating saturation capacity forecasts

According to the latest census, the City of Port Phillip is very densely populated by Australian standards. Only fourteen percent of its 43,728 occupied private dwellings are separate houses, with the majority being units and apartments. By comparison, the Australian average is 75%.

Dividing the City's estimated residential potential of 180 MW by the number of occupied private dwellings results in an average installed capacity per dwelling of over 4 kW.

In the absence of a more comprehensive study, the City of Port Phillip result was used as the starting point for an assessment of the NEM's installed capacity at saturation. Due to the small size of the study, conservative assumptions were applied.

First, the average system size per household for saturation was reduced from 4 kW to 3.5 kW. This allows for aesthetic considerations and site-specific installation constraints that may not have been apparent in the Entura study. Given the limited roof space of dwellings in the City of Port Phillip, a 3.5 kW average at saturation should be conservative when applied to the entire NEM.

Across the outlook period, the roof space per dwelling is forecast to increase, since the average size of newly-built houses is larger than the current average size of all dwellings. Also, as solar panel efficiency increases, the capacity will increase for a given roof area. These factors are not considered when calculating an estimate for saturation, which is again conservative. As a point of comparison, the average capacity of installations in the six months from September 2011 to February 2012 was estimated to be 3 kW, based on data from distribution businesses.

Second, it was assumed that the uptake rate even at saturation would only be 75%. Some rooftops will remain bare even if a rooftop PV installation makes economic sense for reasons including the following:

- Restrictions by authorities (for example, heritage overlays).
- Aesthetic considerations.
- Lack of interest or awareness.
- Lack of incentive in rental properties.
- Lack of agreement by building management (for example, body corporate).

The number of suitable dwellings in NEM regions at the last census (2006) was estimated as the number of occupied, detached houses, plus 30% of other dwelling types. An additional allowance for commercial installations was added, using the ratio of residential to commercial capacity in the Port Phillip study.

[5] **http://www.enviroehub.com.au/council-policy-strategy/relevant-council-reports** Viewed May 2012

Saturation capacity was then calculated as the total number of suitable dwellings multiplied by the 75% uptake rate and by the 3.5 kW average, resulting in a saturation capacity of 17,841 MW for the whole NEM in 2006.

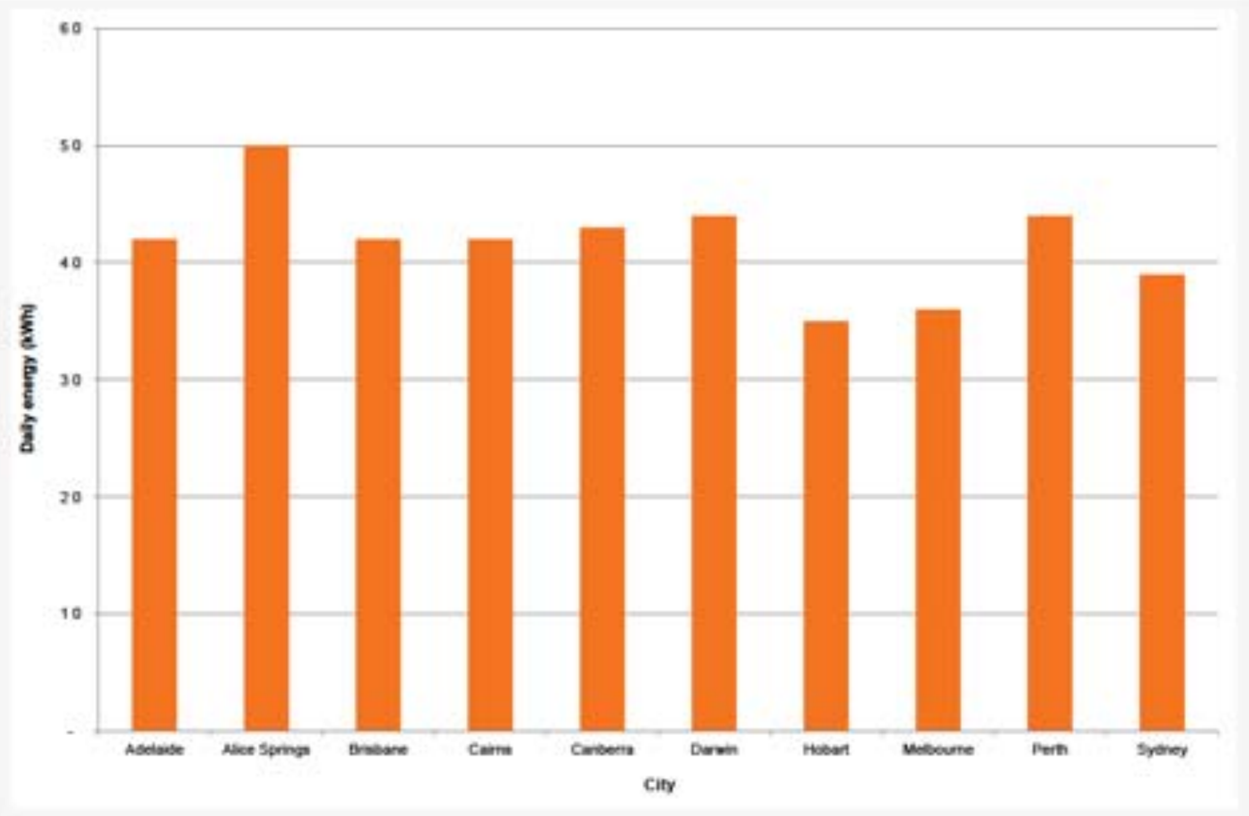
# B.2 Estimating rooftop PV energy generation

## B.2.1 Energy generation

The Clean Energy Council (CEC) consumer guide[6] provides daily generation data for a typical rooftop PV system, including the expected daily energy generation (in kWh) from a 1 kW system, averaged over the entire year.

Figure B-1 shows the daily variation in energy generation for different cities across Australia.

**Figure B-1 — Daily energy generation from a 1 kW system by capital city**




The generation of a rooftop PV system varies monthly with solar intensity. The proportion of the annual generation contribution in each month is determined by several factors:

- Relative solar intensity.
- Location.
- Temperature, as solar panels generate less when they are hot.
- Tilt of the panels relative to the horizontal.

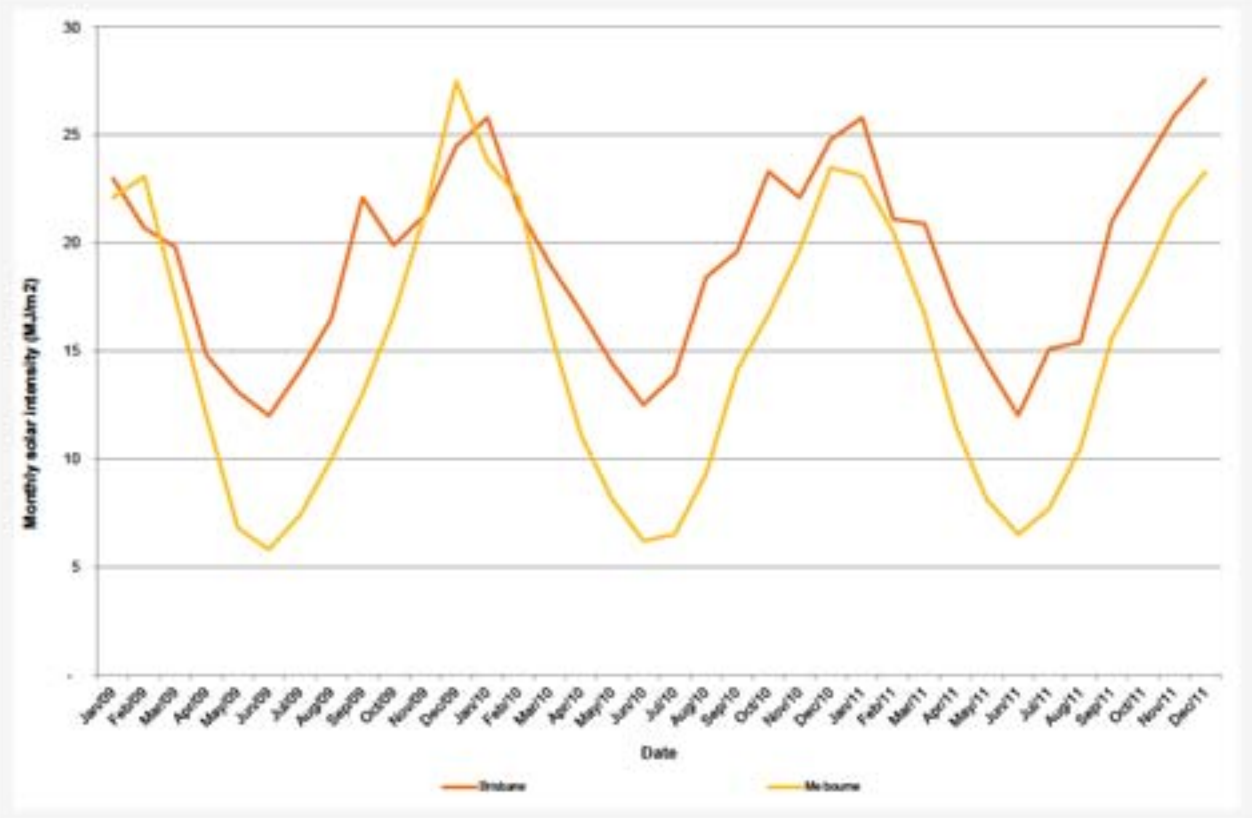
[6] CEC Consumer Guide, available http://www.cleanenergycouncil.org.au/resourcecentre/Consumer-Info/solarPV-guide.html. Viewed May 2012.

### Solar intensity

Solar intensity data was obtained from the Australian Government Bureau of Meteorology (BOM). Solar systems in capital cities are used as reference points to approximate systems within a region.

Figure B-2 shows historical monthly solar intensity for Brisbane and Melbourne, demonstrating the seasonal pattern.

**Figure B-2 — Historical monthly solar intensity**



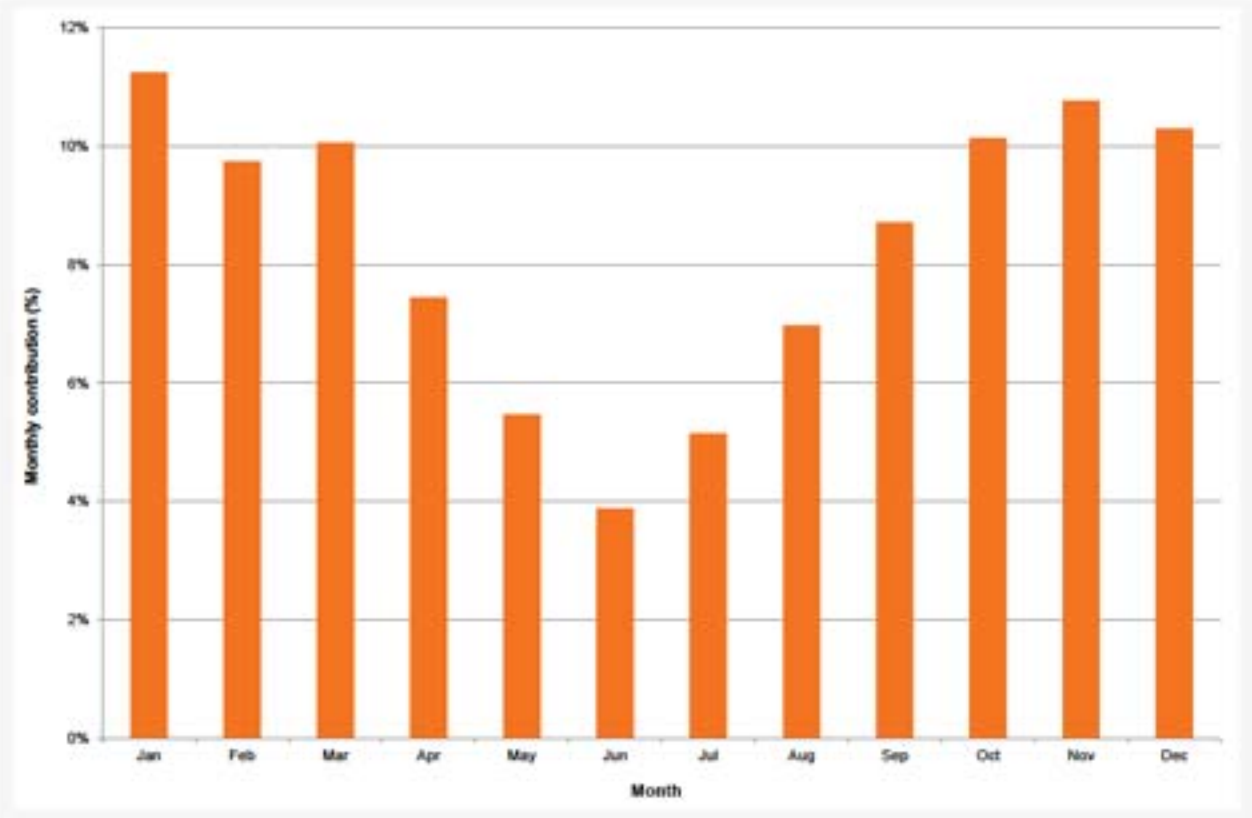

## B.2.2 Monthly contribution

The program Pvwatts[7] was used to estimate the monthly contribution of annual energy generation. A separate analysis was undertaken for each capital city, with the assumption that panels are tilted to an angle equal to the city's latitude.

Figure B-3 shows the monthly contribution for Melbourne. This analysis is influenced by the number of days in the month, so February is lower than either January or March.

7 PVOutput, available http://pvoutput.org/. Viewed May 2012.

**Figure B-3 — Monthly contribution of annual energy in Melbourne**

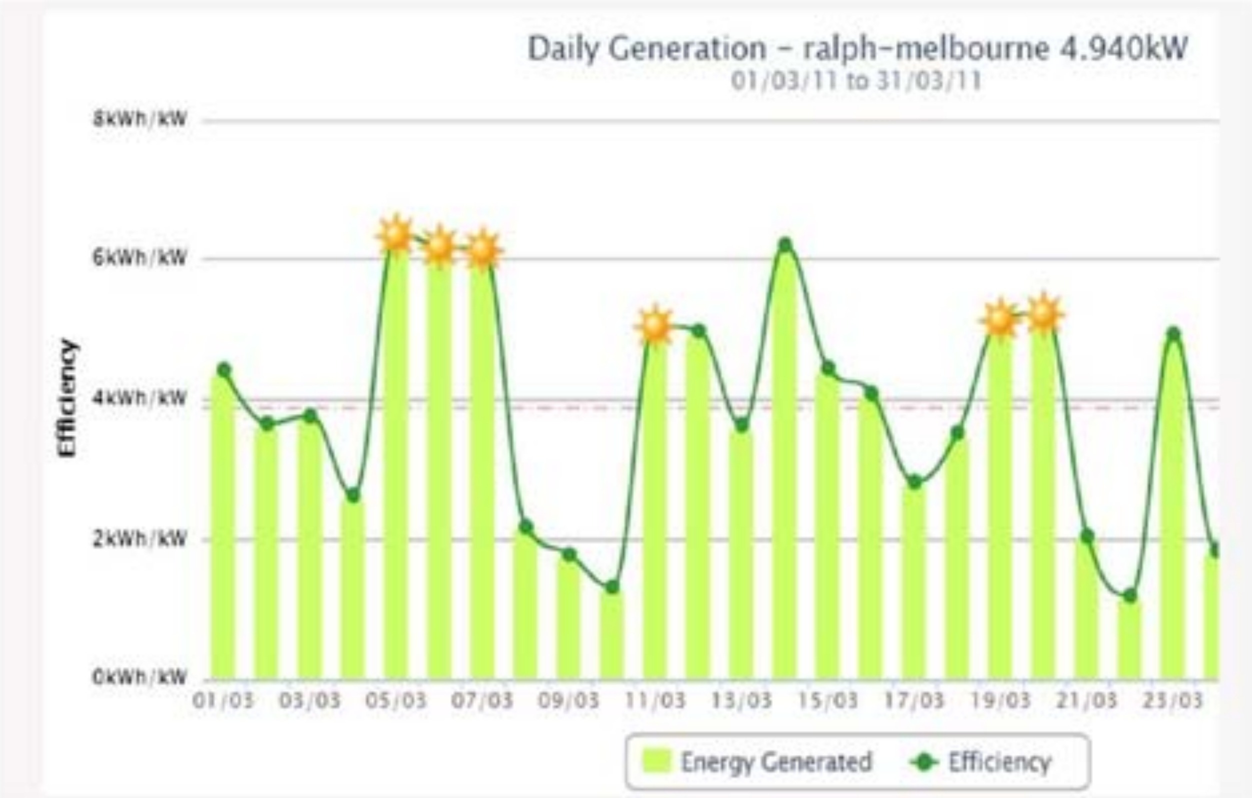



## B.2.3 Adjustment of results against actual data

The results obtained from the estimation process were compared to sample data obtained from PVOutput.org, which publishes actual rooftop PV generation data, as reported by system owners.

Figure B-4 provides an example of the available data.

**Figure B-4 — Sample generation data from PVOutput.org**




For several reported systems, actual monthly energy generation was divided by the system's capacity to normalise the data to the generation of a 1 kW system. This was then averaged across all sample systems in the region.

AEMO's estimates were compared to the reported generation of the sample systems. In comparison, the generation from the sample systems were lower than the AEMO estimates. This is an expected result, as the AEMO estimates assume ideal conditions that in reality may not be representative, as actual systems experience a series of issues:

- Different panel tilt and orientation.
- Shading.
- Overheating.
- Sub-optimal configuration and installation of components.

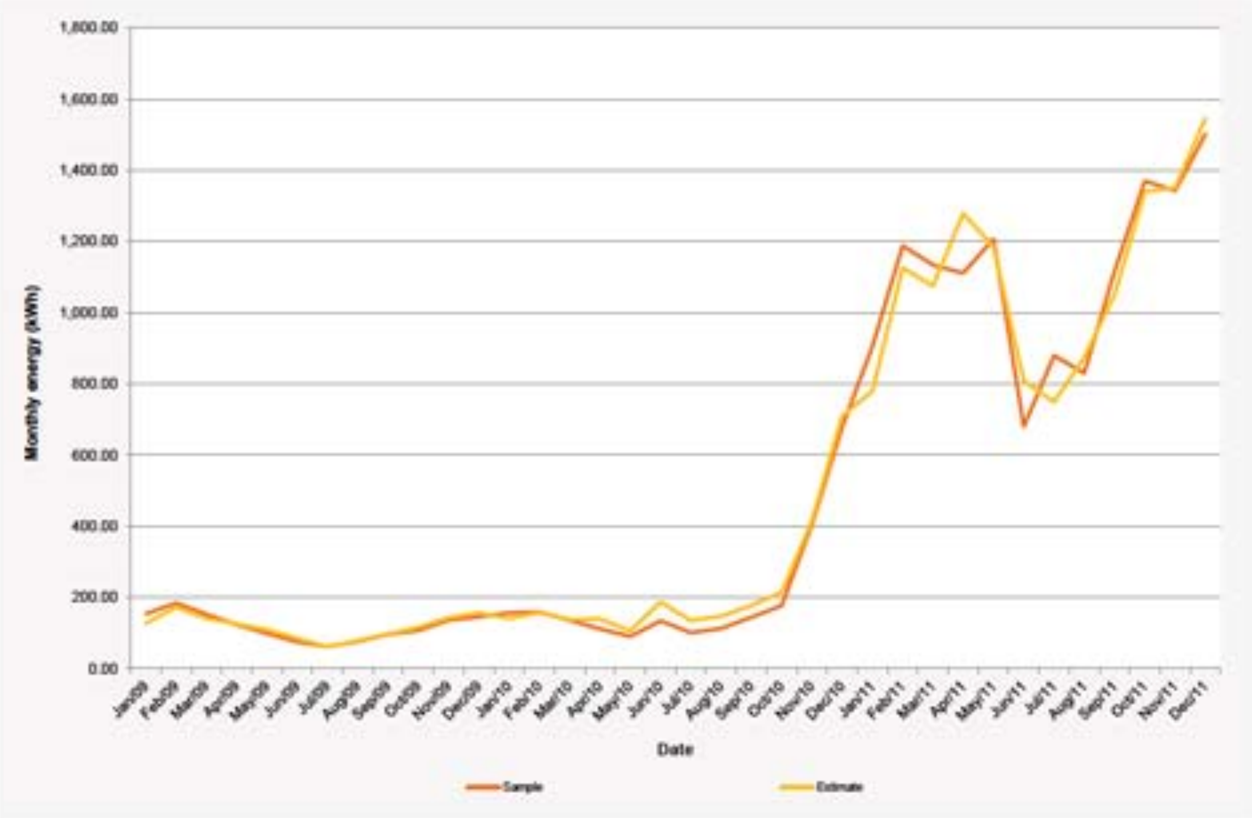
Based on this analysis, AEMO's estimated generation results were lowered to align with the sample generation data from PVOutput.org. This reduction was estimated to be 5% for Victoria, 0% for Tasmania, and 10% for Queensland, South Australia, and New South Wales (including the Australian Capital Territory).

It is possible that the sample systems obtained from PVOutput.org are not representative of rooftop PV systems across the NEM. It seems likely that people who log their system generation and upload it to a website will also ensure that their system is configured, installed and maintained to above-average standards. There is an opportunity for future work to analyse whether these energy generation results are over-estimated.

These adjusted estimates were then used to estimate historical and forecast energy generation.

Figure B-5 compares adjusted AEMO estimates with sample systems for Melbourne, after the 5% reduction factor was applied.

Figure B-5 — Comparison between adjusted AEMO estimates and sample systems in Melbourne




## B.3 Rooftop PV generation at times of maximum demand

Detailed generation data for high-demand days during summer 2010-11 was obtained from PVOutput.org for a range of sample systems in each of the regions. Each system's generation was recorded as a percentage of its rated installed capacity.[8]

Records were filtered according to 30-minute intervals, with a time lag applied in order to align the data to Australian Eastern Standard Time (AEST). Readings were averaged for each 30-minute interval of the day, to derive a generation curve. The value on this curve was noted for a typical time of maximum demand in each region, for example 16:00 AEST. To produce a forecast of rooftop PV generation at the time of maximum demand, this value was multiplied by the region's forecast installed capacity.

At this stage these forecasts are only preliminary, as the size of the sample data was small. This analysis will be repeated when more comprehensive data becomes available.

[8] The output capacity of PV systems is typically quoted in kilowatts peak (kWp) or megawatts peak (MWp). This is the output of the PV modules under standard test conditions of 1,000 watts per metre squared (W/m2) of solar irradiance and ambient temperature of 25 °C.

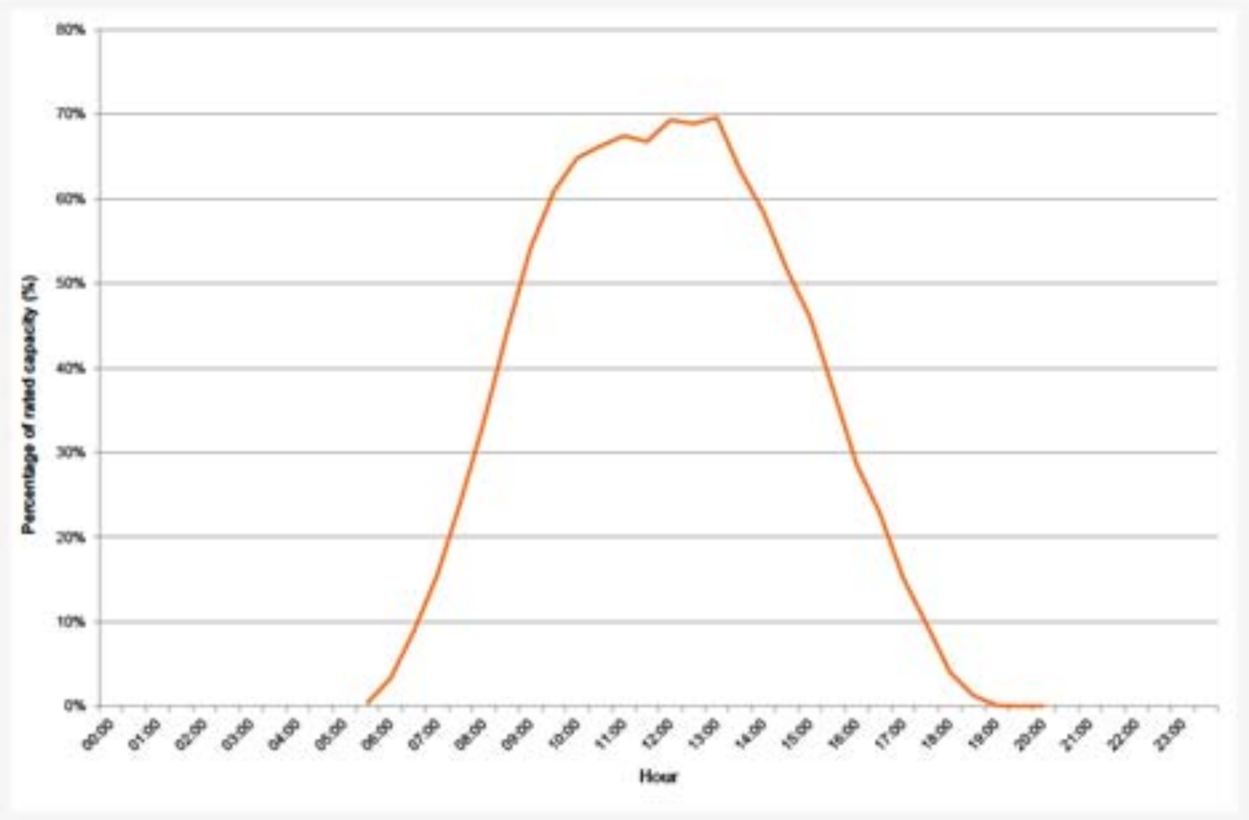
 

# APPENDIX C - REGIONAL ROOFTOP PV DAILY GENERATION CURVES

Figure C-1 to Figure C-5 show average rooftop PV daily generation curves during summer for all regions except Tasmania, which shows the average during winter as this data is used to establish contribution at times of peak demand. These figures represent the average daily generation profile of sample rooftop PV systems as a percentage of their total rated capacity for a given region, and recorded at Australian Eastern Standard Time (AEST).

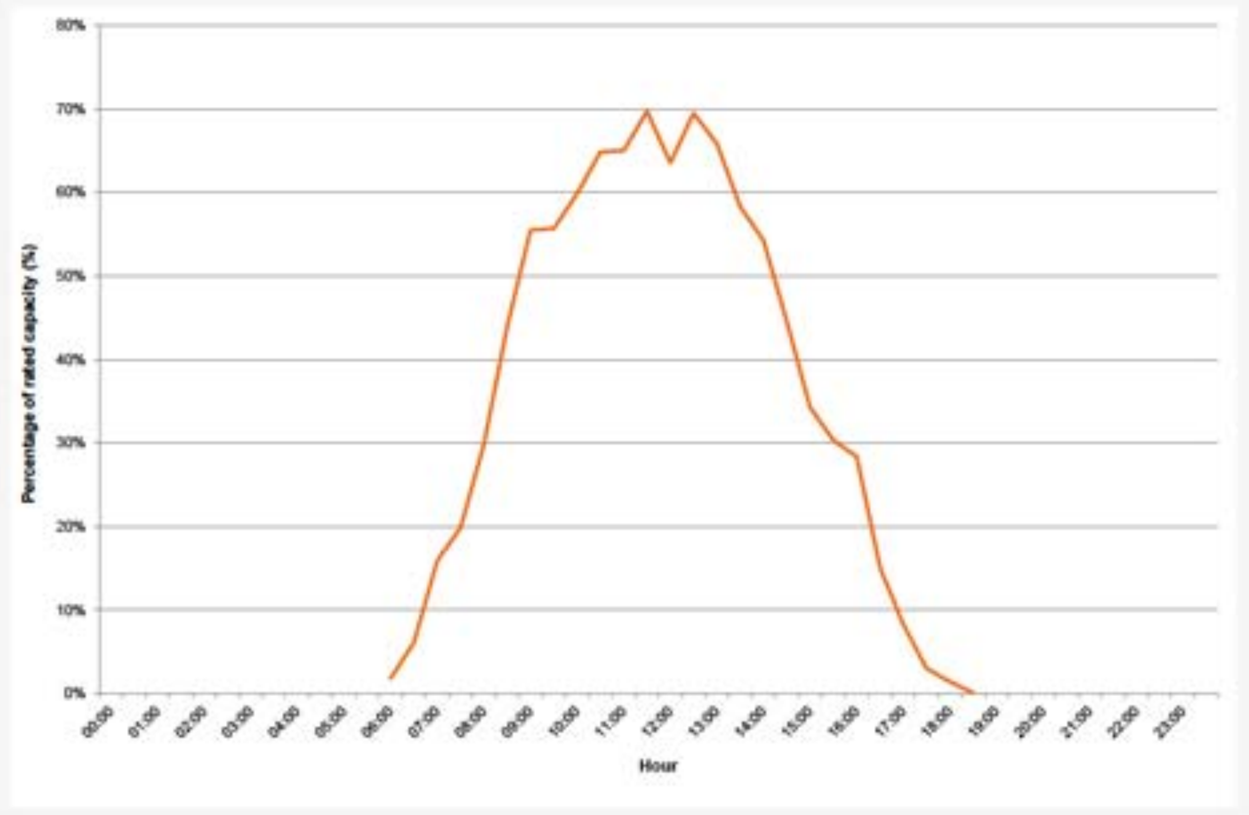
## C.1 New South Wales (and the Australian Capital Territory)

**Figure C-1 — Daily average summer rooftop PV generation curve for New South Wales (and the Australian Capital Territory)**



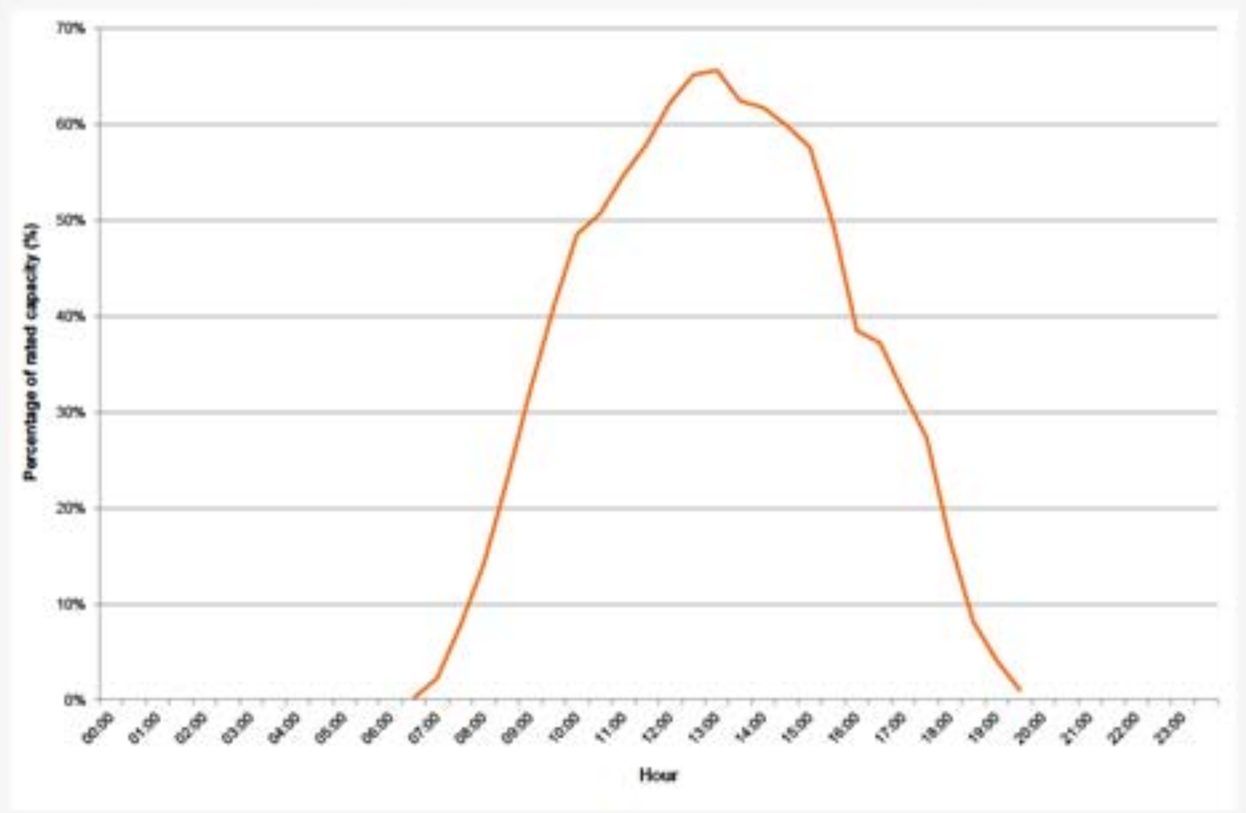
## C.2 Queensland

**Figure C-2 — Daily average summer rooftop PV generation curve for Queensland**



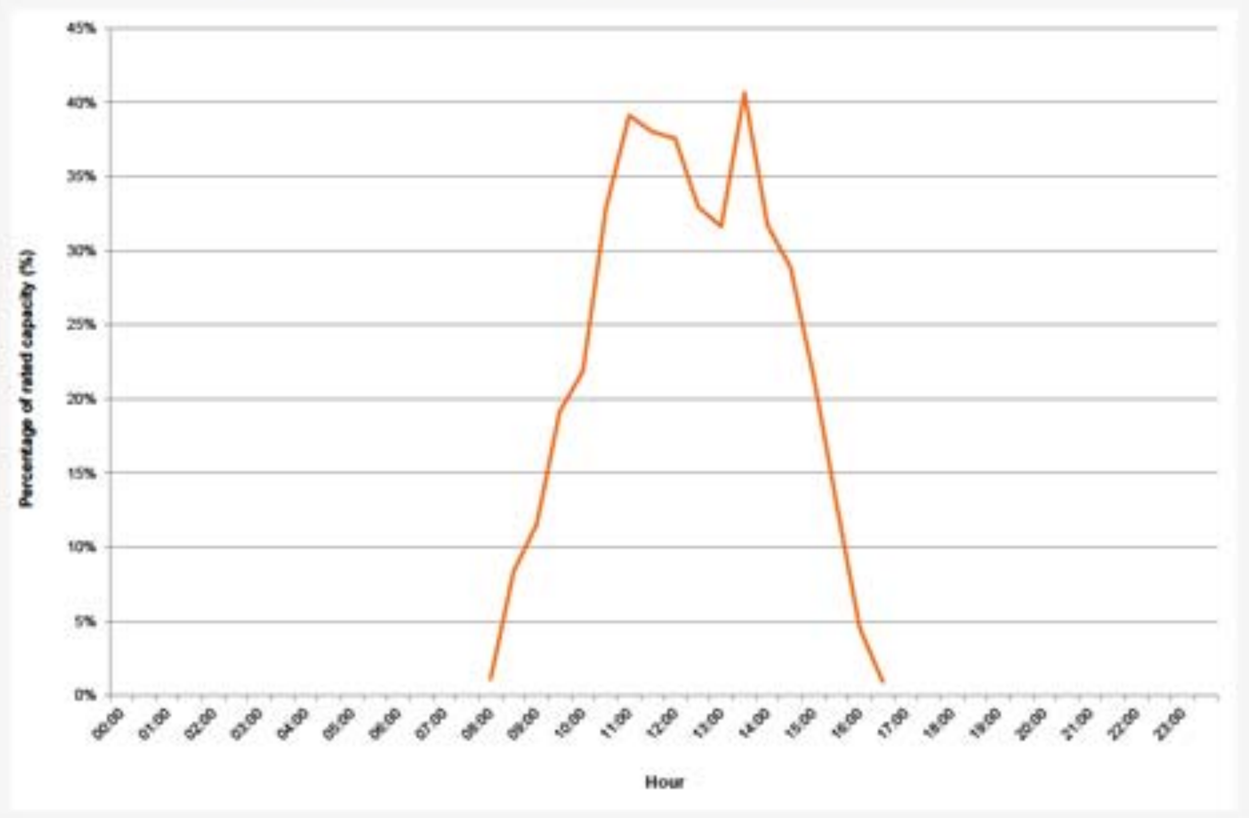
## C.3 South Australia

Figure C-3 — Daily average summer rooftop PV generation curve for South Australia



## C.4 Tasmania

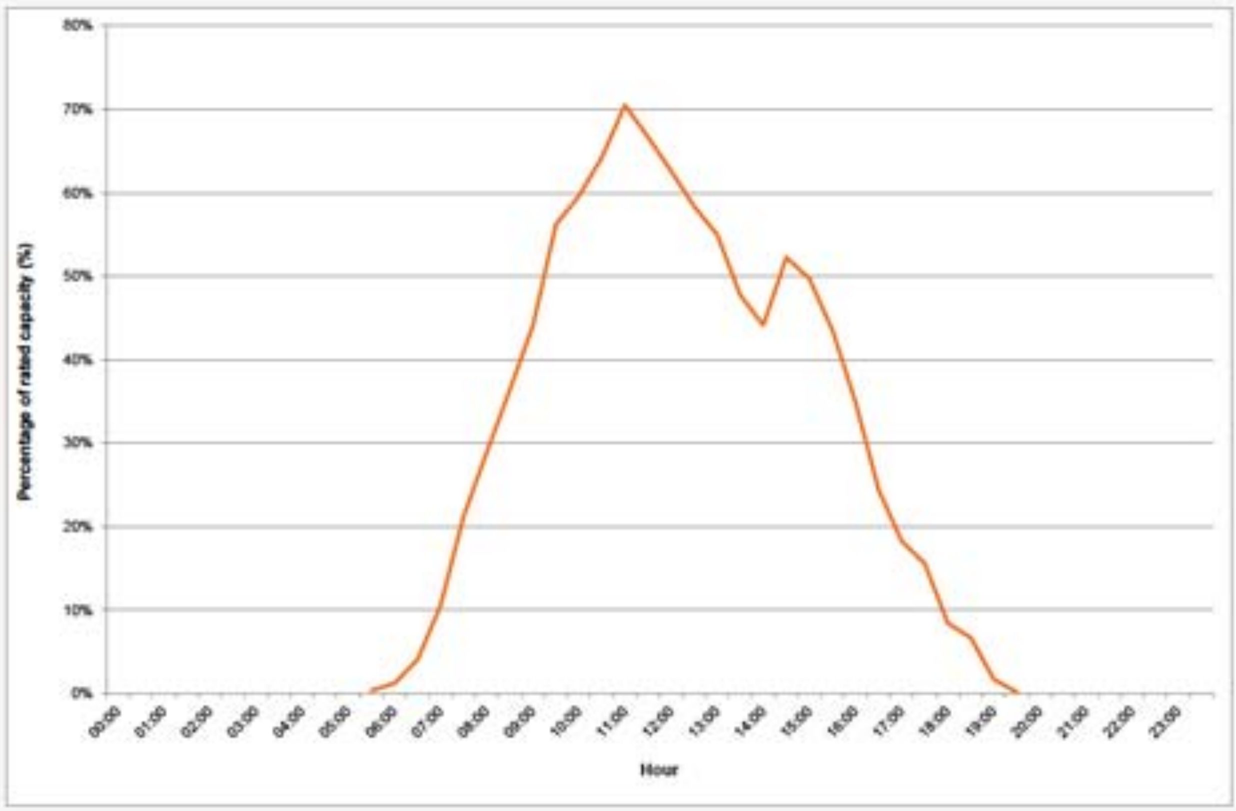
**Figure C-4 — Daily average winter rooftop PV generation curve for Tasmania**



## C.5 Victoria

Figure C-5 — Daily average summer rooftop PV generation curve for Victoria



**[This page is left blank intentionally]**

# APPENDIX D - NON-AEMO ROOFTOP PV CAPACITY FORECASTS

In 2011 and early 2012, several organisations estimated the future uptake of rooftop PV. These forecasts were prepared for a variety of different purposes:

- Forecasting Small-scale Technology Certificates creation.
- Predicting the growth of the PV industry in Australia.
- Informing long-term government energy policy.

The estimates have also been calculated at various different levels:

- For the whole of Australia.
- NEM-wide.
- Behind-the-meter generation only.
- All solar installations, including large solar farms.
- PV only.
- PV and solar thermal jointly.

As a result, the non-AEMO forecasts are not a direct comparison with the AEMO forecasts for the NEM (see Chapter 3), but provide a good indication about whether the AEMO estimates are reasonable.

The lack of certainty surrounding future rooftop PV uptake is demonstrated by the diversity in these forecasts, with two main groupings being apparent:

- Organisations focusing on renewable energy (for example, SunWiz, Suntech Australia, and Beyond Zero).
- Public organisations or consultants engaged by them (for example, the Bureau of Resources and Energy Economics and the Australian Government Department of Resources, Energy and Tourism).

Forecasts developed by the second group are noticeably lower than those by the first group for several reasons:

- The forecasts in general are older so do not account for the acceleration in 2011.
- The documents may have a longer gestation period, making their available data even less fresh.
- A more conservative approach may have been taken.

Figure D-1 shows the AEMO rooftop PV installed capacity forecasts, and compares them to a range of non-AEMO forecasts. Historical data has been included with 2011 data including installations in January and February 2012, and the estimated saturation capacity is shown as the grey background area.

**Figure D-1 — Comparison of AEMO and non-AEMO rooftop PV installed capacity forecasts for the NEM**

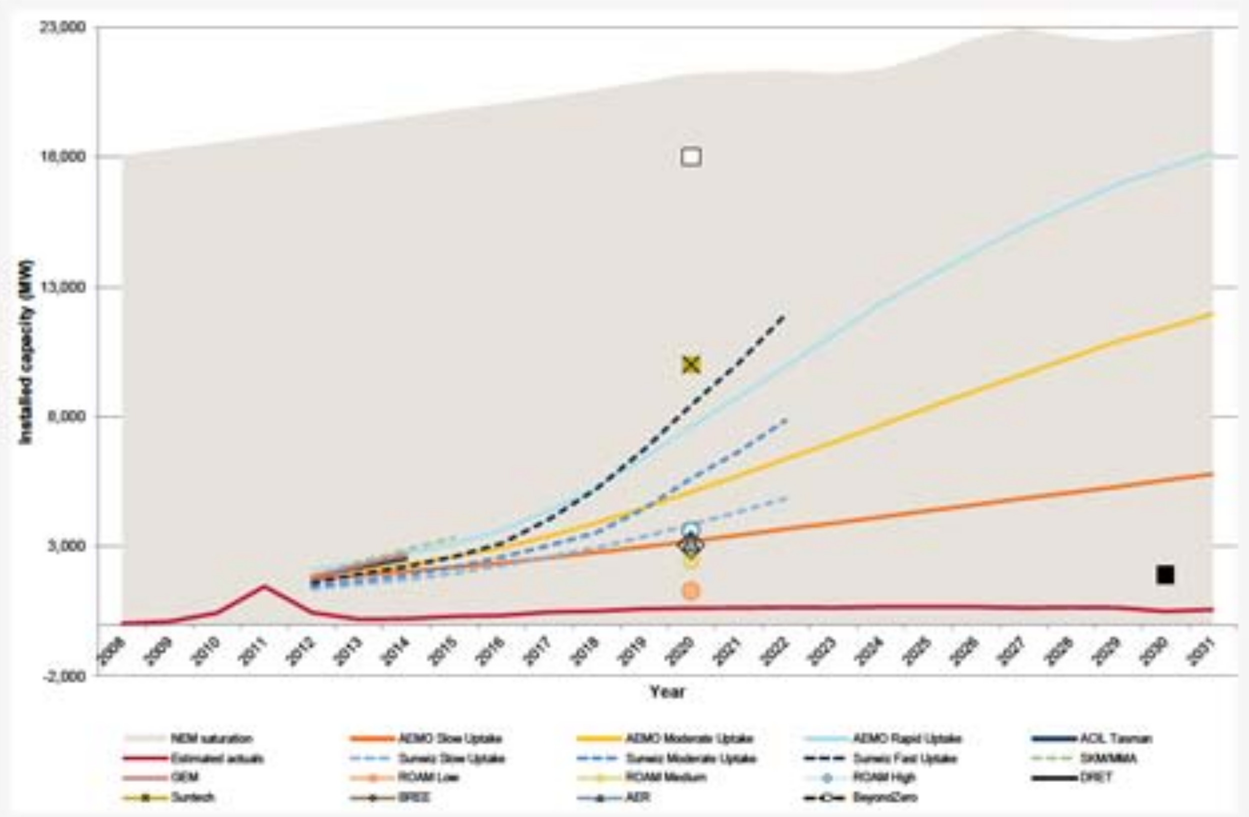



Table D-1 provides additional information, and where the forecast includes more than one scenario (for example, low, medium and high), the results displayed relate to the central scenario.

## Table D-1 — Scope of non-AEMO rooftop PV forecasts for Australia

| Organisation | Geographic scope | Scope | Forecast date | 2020 forecast | 2030 forecast |
|---|---|---|---|---|---|
| SunWiz | NEM only. | Behind-the-meter. | March 2012. | 5,516 | |
| SKM/MMA | NEM only. | PV attracting STCs only. | 13 December 2011. | | |
| Green Energy Markets | Australia. | PV attracting STCs only. | December 2011. | | |
| ACIL Tasman | Australia. | PV attracting STCs only. | December 2011. | | |
| AER | Australia. | PV attracting STCs only. | 25 November 2011. | 3,136 | |
| DRET | Australia. | PV and solar thermal. | 13 December 2011. | | 1,900[a] |
| Suntech Australia | Australia. | PV. | 16 November 2011. | 10,000 | |
| Roam Consulting | Australia. | PV. | 11 March 2011. | 1,260 | |
| BREE | Australia. | PV and solar thermal. | December 2011. | 3,044 | 3,805[b] |
| Beyond Zero | Australia. | PV. | March 2012. | 18,000[c] | 30,000[c] |

a. Capacity in MW is inferred from an energy forecast, assuming a 1 kW system averages 3.6 kWh per day.

b. This forecast is for 2035 rather than 2030.

c. Assessment of capability rather than a forecast.

Table D-2 shows a reference list of the non-AEMO compiled forecasts for Australia.

**Table D-2 — Reference list of non-AEMO rooftop PV forecasts for Australia**

| Organisation | Title | Source | Page |
|---|---|---|---|
| SunWiz | Solar PV Forecast for AEMO 2012 – 2022. | http://www.sunwiz.com.au/index.php/download-free-reports.html | 36 |
| SKM/MMA | Small-scale Technology Certificates Data Modelling for 2012 – 2014 | http://ret.cleanenergyregulator.gov.au/About-the-Schemes/Administration/Reports/reports | 33-37 |
| Green Energy Markets | Small-scale Technology Certificates Data Modelling for 2012 – 2014. | http://ret.cleanenergyregulator.gov.au/About-the-Schemes/Administration/Reports/reports | 26 & 30 |
| ACIL Tasman | Modelling Creation of Small-scale Technology Certificates. | http://ret.cleanenergyregulator.gov.au/About-the-Schemes/Administration/Reports/reports | 49 |
| AER | Impact of the Enhanced Renewable Energy Target on Energy Markets (final report). | http://www.aemc.gov.au/Market-Reviews/Completed/Impact-of-the-enhanced-Renewable-Energy-Target-on-energy-markets.html | 13 |
| DRET | Energy White Paper (draft). | http://www.ret.gov.au/energy/facts/white paper/Pages/energy white p aper.aspx | 273 |
| Suntech Australia | Stefan Jarnason seminar held by the Grattan Institute and the University of Melbourne. | As reported in http://www.climatespectator.com.au/commentary/suntech-calls-australian-solar-boom | N/A |
| Roam Consulting | Impact of Renewable Energy and Carbon Pricing Policies on Retail Electricity Prices. | http://www.cleanenergycouncil.org.au/resourcecentre/reports.html | 28 |
| BREE | Australian Energy Projections to 2034–35. | http://bree.gov.au/publications/energy/index.html | 36 |
| Beyond Zero | Presentation to AEMO. | Preliminary modelling for the Zero Carbon Australia Buildings Plan | N/A |

# DISCLAIMER

This publication has been prepared by the Australian Energy Market Operator Limited (AEMO) as part of a series of information papers about the development of AEMO's demand forecasts for the National Electricity Market for 2012-13 onwards, to be used for AEMO's planning and operational functions under the National Electricity Rules.

This publication may contain data provided by or collected from third parties, and conclusions, opinions, assumptions or forecasts that are based on that data. AEMO does not warrant or represent that the information in this publication (including statements, opinions, forecasts and third party data) is accurate, complete or current, or that it may be relied on for any particular purpose.

Anyone proposing to rely on or use any information in this publication should independently verify and check its accuracy, completeness, reliability and suitability for purpose, and should obtain independent and specific advice from appropriate experts.

To the maximum extent permitted by law, neither AEMO, nor any of AEMO's advisers, consultants or other contributors to this publication (or their respective associated companies, businesses, partners, directors, officers or employees) shall have any liability (however arising) for any information or other matter contained in or derived from, or for any omission from, this publication, or for a person's use of or reliance on that information.



## Acknowledgements

AEMO acknowledges the support, co-operation and contribution of all participants in providing the data and information used in this publication, including SP-Ausnet, Powercor, Jemena, Citipower, United Energy, Aurora Energy, ETSA Utilities, Ausgrid, Essential Energy, Endeavour Energy, ActewAGL, Ergon Energy and Energex.

**[This page is left blank intentionally]**