Market value of solar PV exports

A FINAL REPORT PREPARED FOR IPART

June 2014

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1 Introduction

The Independent Pricing and Regulatory Tribunal (IPART) has been asked by the New South Wales Government to undertake annual investigations into solar feed-in tariffs for compliant generators in New South Wales. IPART is currently reviewing solar feed-in tariffs for 2014/15.

1.1 IPART's terms of reference

The Terms of Reference asks IPART to undertake an annual investigation and determination of:

- the retailer benefit component payable by a retailer to a customer for electricity produced by a complying generator and supplied to the distribution network by a customer under the Solar Bonus Scheme; and
- the benchmark range for solar feed-in tariffs paid by retailers for electricity produced by complying generators and supplied to the distribution network.

In making its determination on the retailer contribution and benchmark range, IPART should take into account the wholesale market value of the photovoltaic exports at the time of day of export.

1.2 Frontier Economics' engagement

Frontier Economics (Frontier) has been engaged by IPART to provide advice on the forecast wholesale market value of the electricity that solar PV systems are expected to export to the grid in New South Wales for 2014/15.

For this 2014/15 review, our engagement with IPART requires that we forecast the wholesale market value using as much historical data as possible, rather than using a single historical year. Specifically, IPART's Terms of Reference suggests the use of a simulation methodology to provide an estimate of the possible **range** of wholesale market value of solar PV exports for 2014/15.

For this 2014/15 review, IPART is also interested in understanding how the market value of solar PV exports might change depending on the time of day.

1.3 This final report

Frontier has previously released a draft report on the forecast wholesale market value of the electricity that solar PV systems are expected to export to the grid in

New South Wales for 2014/15.[1] This final report is largely unchanged from the draft report, with the following exceptions:

- we have updated the ASX Energy price to account for more recent data;
- we have included NEM fees and ancillary services costs faced by retailers in the forecast wholesale market value of solar PV exports, as requested by IPART;
- we have estimated the forecast wholesale market value of solar PV exports using a time of use tariff with a peak period from 2pm to 8pm, and included these results in Appendix A.

This report is structured as follows:

- Section 2 provides a brief overview of the data available to estimate the wholesale market value of solar PV exports and our methodology to complete the task.
- Section 3 outlines the results of our analysis of the wholesale market value of solar PV exports based on analysis of historical outcomes, including estimation of the potential range and distribution of the value of solar PV.
- Section 4 outlines the results of our analysis of the forecast wholesale market value of solar PV exports for 2014/15.
- Section 5 outlines the methodology and results of our time of use analysis.

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1 Frontier Economics, *Market value of solar PV exports, A Draft Report Prepared for IPART*, April 2014. Available here.

2 Data on solar PV exports

This section outlines the data available to estimate the wholesale market value of solar PV exports for 2014/15 and our approach to the task.

2.1 Overview of solar PV export data available for the task

In undertaking this task IPART has provided Frontier Economics with the following datasets for solar PV exports:

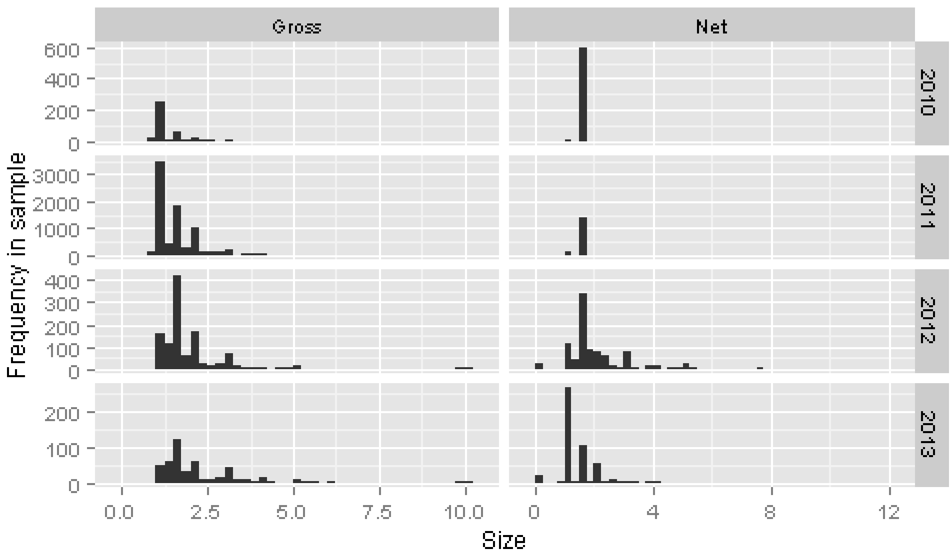
- Data on gross and net metered customers from Ausgrid's distribution area covering the period 2009/10 to 2011/12, which was provided to IPART and Frontier Economics for the purpose of previous reviews of solar feed-in tariffs.
- For this 2014/15 review, IPART has provided analogous data for the 2012/13 financial year. This data reflects a sample of both gross and net metered customers from Ausgrid's distribution area.

These data sets contain half-hourly data on solar PV exports.

Figure 1 shows the frequency of PV unit sizes represented in the data we have from Ausgrid. We see that, across each year and both meter types, these samples are quite similar in the unit sizes they represent:[2] the most common unit size is around 1.5kW.

2 An 'outlier' in the sample, a unit size of 19.98 in 2012, was removed to show more detail in the chart

Figure 1: PV unit sizes represented in the sample



Source: Frontier analysis

Outlined in Figure 2 are the diurnal PV export profiles for a subset of the data available for the 2014/15 review. Each panel outlines the daily shape of solar PV exports in a given quarter for both gross (blue) and net (red) metered customers. In the chart, each line represents a day, and the y-axis represents aggregate kW exports[3] across the sample of customers supplied by Ausgrid. As expected, the metered exports of gross metered customers is larger than that of net metered customers, since consumption for the latter is netted from total generation while for the former it is not.

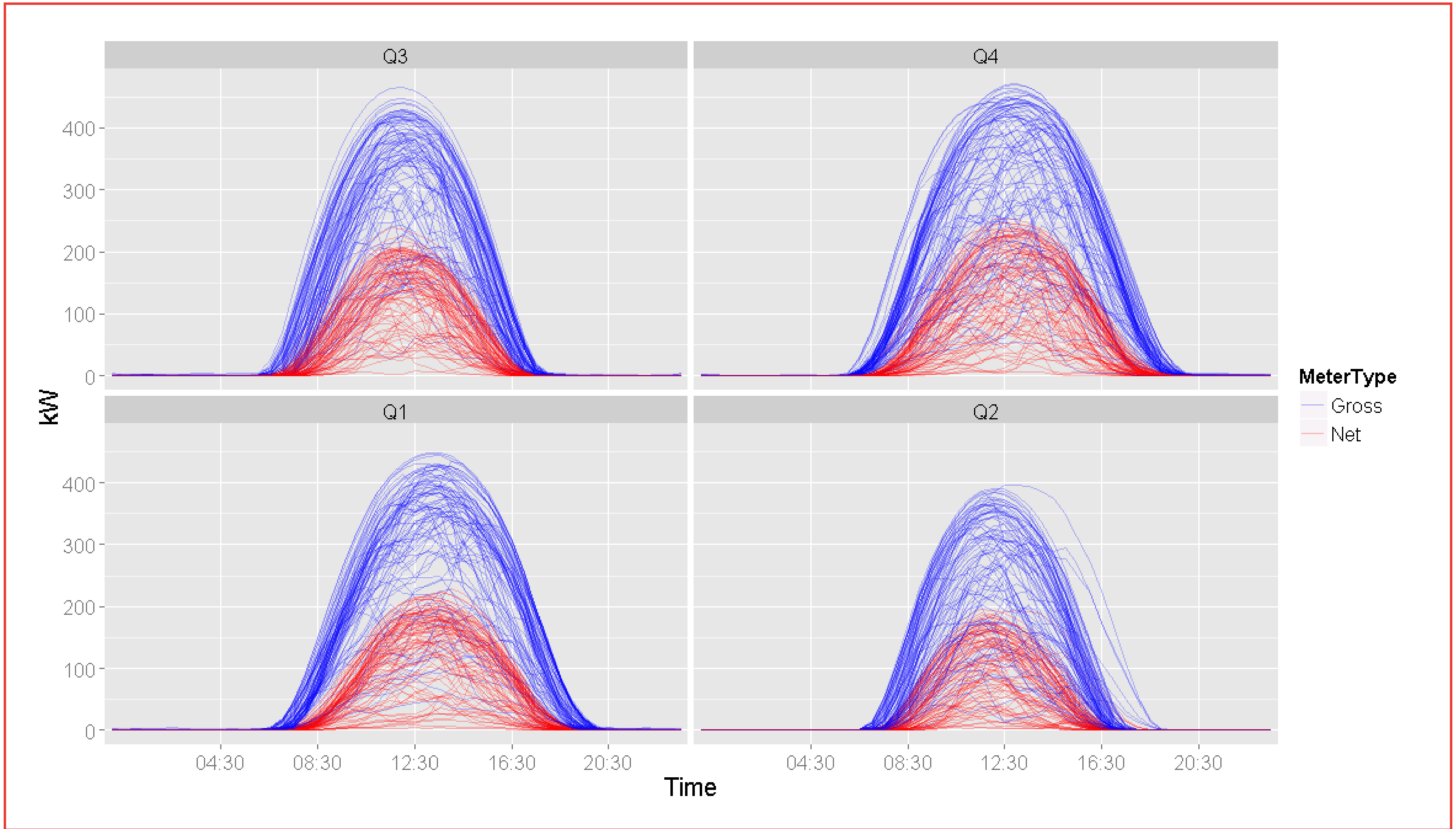
While for a given panel size a gross metered customer would be expected to export more in a given year than an equivalently-sized net metered customer, it is the timing of these exports – and the correlation of exports with spot prices – that ultimately drives the market value of solar PV exports.

To more clearly compare the shape of PV exports between gross and net metered customers, outlined in Figure 3 are **normalised average** export shapes for each meter class. To aid comparison of the timing of PV exports between each customer class, these average shapes have been transformed (or normalised) to represent an equivalent annual amount of metered exports. What this means is

3 Normalised for total Net/Gross capacity in the sample

that the area under each shape is equivalent (this is equivalent to saying that the sum of the green area equals the sum of the orange area). Differences between the shapes reflect relative differences in the timing of average PV exports across the course of the day.

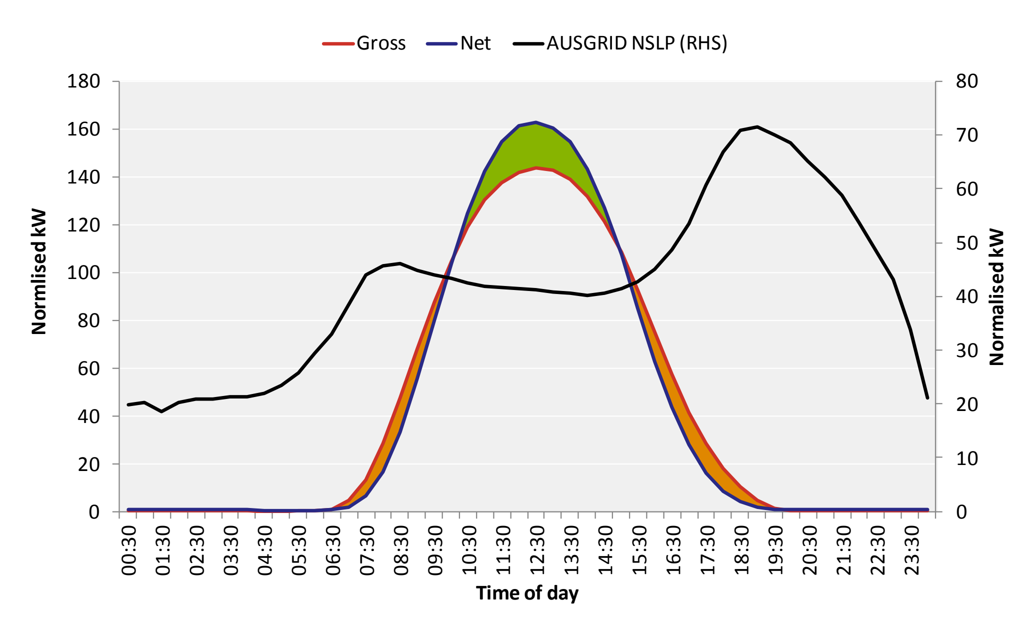
Figure 2: Diurnal PV export profiles – net and gross metered customers



Source: Ausgrid data; Frontier analysis

Data on solar PV exports

Figure 3: Normalised PV exports by interval



Source: Ausgrid data; Frontier analysis

The analysis illustrates that gross metered PV exports are relatively less focused during peak production hours (roughly 10am to 3pm), with relatively more export occurring both earlier in the day (around 6:30am-10am) and later in the day (around 3pm-7:30pm). This makes intuitive sense: since the consumption of gross metered customers is not netted from PV generation, gross metered customers would be expected to export **relatively** more at times when residential consumption is high (i.e. first thing in the morning and mid-late afternoon).

This observation is confirmed by examining the aggregate shape of Net System Load for Ausgrid's distribution area, and comparing the timing of this load with PV exports: since residential and small business customers tend to consume relatively more during the mid morning and mid-late afternoon, at these times net metered PV customers will be exporting to the grid relatively less energy than gross metered customers.

2.2 Methodology to estimate market value of solar PV exports

In order to provide an estimate of the potential range of the market value of solar PV exports – and a distribution around the likely market value of solar PV exports – we have employed a Monte Carlo simulation process. The Monte Carlo process involves bootstrapping historical observations regarding half-hourly solar PV exports and New South Wales spot prices. This is explained in detail below.

2.2.1 Aggregate solar PV profiles and half-hourly price data

The first step in the simulation process is to generate an aggregate annual solar PV export profile for both gross and net metered customers based on the sample of PV data available.

An aggregate half-hourly export profile for each meter class and year of data is created by summing the half-hourly exports recorded for each sampled customer in a given half hour. The resulting half-hourly PV export profile is then normalised to 1 GWh per annum. This normalisation allows the shape of each year of solar PV data and meter class to be easily compared. The normalisation process has no bearing on the market value of solar PV exports, since the correlation between solar PV exports and spot prices is preserved.

The output of this first step is eight annual half-hourly solar PV export and spot price traces:

- Four years of half-hourly solar PV exports for **net** metered customers, and corresponding New South Wales spot prices, for 2009/10, 2010/11, 2011/12 and 2012/13
- Four years of half-hourly solar PV exports for **gross** metered customers, and corresponding New South Wales spot prices, for 2009/10, 2010/11, 2011/12 and 2012/13.

2.2.2 Creating synthetic annual PV profiles

The Monte Carlo process requires the generation of 'synthetic' years from historical data from which a solar premium (discussed below) can be calculated. A synthetic year consists of 365 days of half-hourly price and PV export data sampled from a pool of comparable historical days.

We sample days as a whole to preserve intra-day PV export and price relationships. The assumption here is that each half-hour of PV export and price data is autocorrelated. In other words, each half hour of PV export and price data is related to *n* previous half hours, so mixing and matching half hours between days doesn't make sense.

We adopt the definition of comparable historic days as a combination of 'day name' and quarter. This means, for example, that the first Monday in January is comparable to any other Monday in Q1.[4] Employing this definition means we

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4 Ideally, we would compare the first Monday in January with all previous first Mondays in January, but we cannot do so and maintain a statistically appropriate sample size.

achieve an appropriate sample size (around 48 observations in each pool) while preserving day likeness.

The process of generating a synthetic year is as follows:

1. Pool all comparable historic price and PV export data, which is grouped by day

2. For each day in the synthetic year, randomly draw with uniform probability and replacement from the relevant pool of comparable days. For example, for a synthetic Thursday in July, we would draw a random day of price and PV export data from the pool of Q3 Thursdays.

We generate 5000 synthetic years of data, meaning we consider around 87.6 million half-hour observations in our analysis.

2.2.3 Calculating the solar premium

A solar premium is a measure of the relative value of solar PV output compared to a flat output profile. It is the ratio of **output-weighted price** to **time-weighted price:**

- Output weighted price is the average price across the year weighted by how much solar is exported at the time
- Time weighted price is the arithmetic average price across the year

Simply put, the solar premium captures how much solar PV export occurs at high or low price times. A flat output profile results in the output-weighted price being equal to the time-weighted price. Higher PV exports at higher-price times will increase the output-weighted price, but not the time weighted price. This will be reflected in an increase in the solar premium.

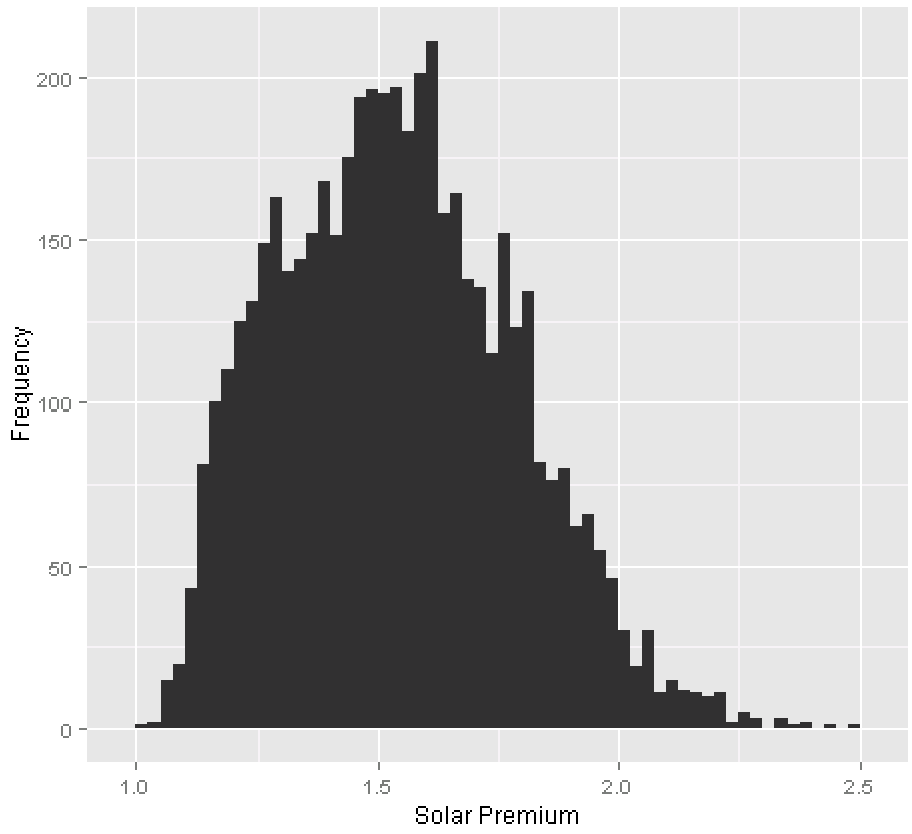
There is a high likelihood that the solar premium of any given year will be greater than one. Spot prices tend to be positively correlated with daylight hours and demand, which is coincident with when solar PV exports occur. Solar PV exports are generally zero overnight, when spot prices tend to be at their lowest.

For each of the 5,000 synthetic years we generate, we calculate a solar premium for each meter class, resulting in the calculation of 10,000 premiums in total.

2.2.4 Generating a distribution of solar premiums

These solar premiums represent a range of possible outcomes based on the synthetic years generated from the past four years of historical price and PV export data. A higher frequency of a given solar premium suggests an increased likelihood of it occurring. The minimum and maximum solar premiums suggest a range that values may take. Figure 4 presents this visually as a histogram of calculated solar premiums for gross metered customers. The top end of the distribution (the right hand side) reflects synthetic years with a large number of sampled high-price days with coincident solar PV exports. Likewise, the bottom end reflects synthetic years with few sampled high price days with coincident solar PV exports.

Figure 4: Sampled solar premium distribution



Source: Frontier analysis

From this distribution, we can calculate a number of useful summary statistics. The mean value represents an expected solar premium given price and PV export patterns from the previous four years. The median value can be used similarly, but is unaffected by the range of the generated solar premiums. We can use percentiles, such as the 25th and 75th and the 5th and 95th, to form a range of expected solar premiums and their likelihoods.

Data on solar PV exports

3 Wholesale market value of solar PV exports

The wholesale market value of solar PV exports is essentially the value that customers with small-scale solar PV would receive if they sold their exported energy into the wholesale spot market in the same way that large scheduled generators do.[5] This is a hypothetical concept, and does not directly reflect what customers are able to do in the market: customers with small-scale solar PV cannot sell their exported energy into the wholesale spot market.

This section outlines the analysis we have undertaken to determine the historical range and distribution of the wholesale market value of solar PV exports. The results of this analysis are combined in Section 4 with a forecast of future wholesale spot prices for the 2014/15 year to arrive at a forecast of the wholesale market value of solar PV exports for the coming 2014/15 year.

3.1 Correlation between historical solar PV exports and spot prices

In forecasting the market value of solar PV exports it is essential to accurately capture the relationship between half-hourly solar PV exports and half-hourly market prices. This relationship will significantly affect the value of solar PV exports: for instance, if it is the case that spot electricity prices tend to be high when solar PV exports occur, then the market value will be high; if spot electricity prices tend to be low, then the market value will be low.

The best data available to describe the relationship between half-hourly solar PV exports and half-hourly spot prices is historical data. This data will capture the relationship between solar radiation (and hence solar PV exports) and electricity spot prices.

As discussed in Section 2.2, our methodology for estimating the range and distribution of the market value of solar PV exports explicitly relies on historical half-hourly PV export and spot price outcomes, and carefully preserves the correlation between solar PV exports and spot prices. This correlation is a critical driver of the market value of solar PV exports, since high spot prices in New South Wales tend to be reasonably well correlated with solar PV exports.

It can be seen from Figure 5 that in New South Wales a number of historical financial years have been characterised by relatively low average prices during the middle of the day (e.g. 2011/12 and 2012/13). The market value of solar PV exports during these years would be relatively low. Other financial years were characterised by relatively high average prices during the middle of the day, in

5 Including adjusting the value of the generation to account for it being close to where it will be used.

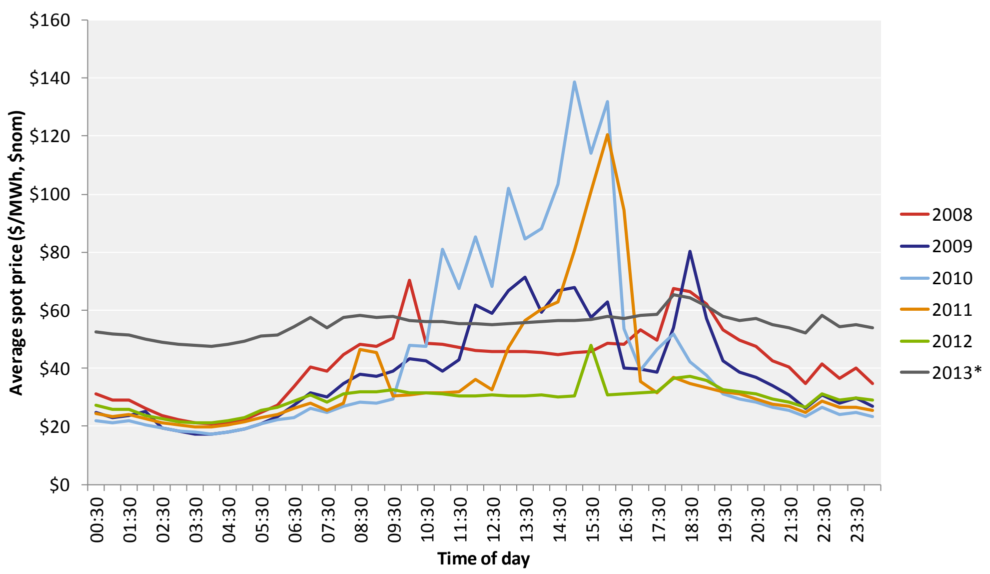
particular during the afternoon (e.g. 2009/10 and 2010/11). The market value of solar PV exports during these years would be relatively high.

Over the four years of historical data for which solar PV export data is available for this review (2009/10 to 2012/13) it can be said that:

- 2009/10 experienced significantly higher prices through the middle of the day than other financial years.
- 2010/11 experienced a somewhat representative level of average pool prices during the middle of the day as compared to the last decade of New South Wales pool prices, and a higher degree of average pool prices during the middle of the day than more recent financial years.
- 2011/12 experienced a significantly low level of average pool prices during the middle of the day.
- 2012/13 also experienced a significantly low level of average pool prices during the middle of the day.

The lower level of average spot prices during the middle of the day experienced in New South Wales in recent years is a consequence of falling demand and a widening demand-supply balance in the market, which has resulted in a reduction in the average level and volatility of spot prices in recent years.

Figure 5: Historical NSW spot prices by time of day



** Reflects a $23./t carbon price introduced on 1 July 2012*

Source: AEMO, Frontier analysis

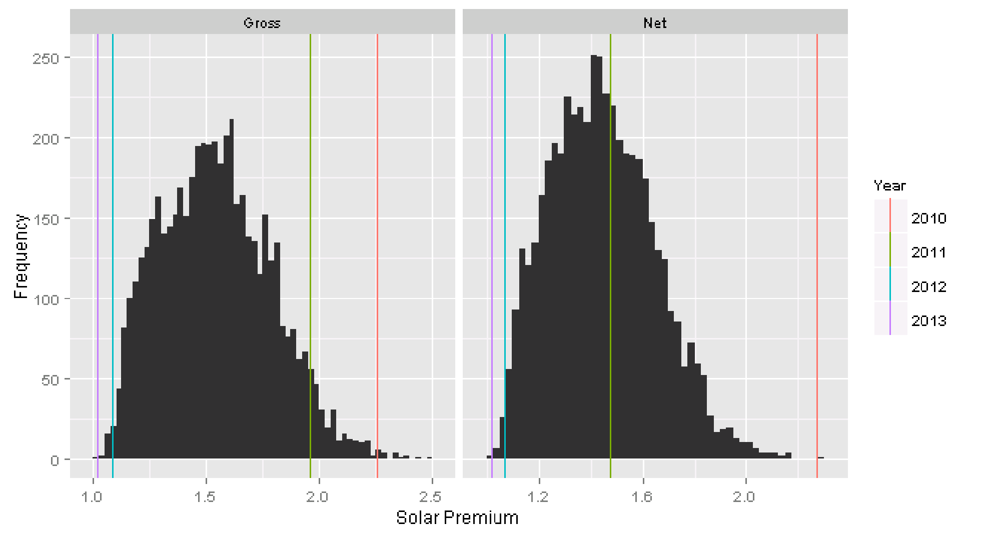
3.2 Distribution of solar premiums

Outlined below are the results of the Monte Carlo process described in Section 2.2. As discussed, the Monte Carlo process was used to generate a distribution of potential solar premiums for gross and net metered customers using the historical relationship between solar PV exports and New South Wales spot prices over the period 2009/10 to 2012/13.

The solar premium is the ratio of the output-weighted spot price that solar PV exports earn to the time-weighted annual average spot price. The solar premium is a statistic that summarises the relative value – as compared to the annual average spot price – that solar PV exports earn due to a positive correlation between solar PV exports and above-average midday spot prices.

Figure 6 presents a distribution of generated solar premiums for gross metered and net metered customers. These plots show the frequency of solar premium values as generated by the Monte Carlo process for each meter type. Overlayed are the historical premiums from the data used to generate the synthetic years.

Figure 6: Distribution of solar premiums with historical premiums overlayed



Source: Frontier analysis

The properties of the distributions in Figure 6 reflect historical solar PV export and pricing patterns. The generated solar premiums can be viewed as synthesised versions of these historical values. Both distributions are positively skewed, largely because the unusually large number of high prices during the middle of the day during 2010 provides the possibility of a synthetic year with a similarly high solar premium. Additionally, the range of solar premiums for the gross metered customer is greater (at the top end) than that of net metered customers. Net metered customers tend to consume while prices are higher, and so export less in high price times. Reductions in solar PV exports at high-price times are reflected in a lower output-weighted price, and hence a tighter distribution of solar premiums.

From these distributions we can compute a number of summary statistics. The median solar premium for gross metered customers is 1.52, and the median for net metered customers is 1.43. The interpretation of these values is that solar PV exports by gross metered customers are 1.52 times more valuable than the average annual spot price (due to it being produced at higher priced times) and solar PV exports by net metered customers are 1.43 times more valuable than the average annual spot price.

4 Forecast wholesale market value of solar PV exports

This section outlines the results of our analysis to forecast the wholesale market value of solar PV exports for the 2014/15 year. Our approach to forecasting the market value of solar PV exports involves combining information from the distribution of solar premiums, outlined in Section 3.2, with forecasts of 2014/15 average annual pool prices for New South Wales.

4.1 Spot price forecasts

For the purposes of this report, we base our forecast of average annual pool prices for New South Wales in 2014/15 on observed contract prices. In particular, we infer spot prices for 2014/15 from the price of baseload swap electricity contracts traded on the ASX. To calculate the inferred spot price based on ASX Energy contract prices, we have:

- Taken a 40 trading day average of base strip prices for 2014/15 covering the period 26 March 2014 to 23 May 2014
- Removed an assumed contracting premium of 5 per cent from these contract prices, to arrive at an inferred underlying spot price for 2014/15.

The resulting inferred spot price for 2014/15 is $36.32 (in 2014/15 dollars).

4.2 Energy losses

In forecasting the market value of solar PV exports in 2014/15 Frontier has applied a loss factor of 1.0647 to ‘gross up’ solar PV generation at the customer premises to the NSW node. This loss factor was used by IPART in its 2013/14 electricity determination, and it reflects the estimated 2014/15 distribution and transmission loss factors applicable to Ausgrid’s distribution area.

4.3 NEM fees and ancillary services costs

For this Final Report, IPART have asked that we incorporate the NEM fees and ancillary services costs that retailers would face into the forecast wholesale market value of solar PV exports.

Market fees are charged to participants in the NEM in order to recover the cost of operating the market. Market fees for the coming financial year are set out in budget documents on AEMO’s website. The latest document provides markets fees for 2014/15 and forecasts of certain elements of fees for the period to 2018/19. Based on this information, our estimate of the market fees that retailers would face in 2014/15 are $0.35/MWh.

Ancillary services are those services used by AEMO to manage the power system safely, securely and reliably. To estimate the future cost of ancillary services, we have examined the past 11 years of ancillary service cost data published by AEMO for the New South Wales region of the NEM and used the average of annual ancillary services costs as the basis for future ancillary services costs. Based on this information and approach, our estimate of the ancillary services costs that retailers would face in 2014/15 is $0.74/MWh.

4.4 Forecast range of wholesale market value of solar PV exports

To provide a forecast of the wholesale market value of solar PV exports in 2014/15 we combine information on the range of solar premiums (outlined in Section 3.2) with the forecasts of NSW annual average spot prices for 2014/15 (outlined in 4.1), and an estimate of the distribution and transmission losses applicable to Ausgrid's distribution area, NEM fees and ancillary services costs.

We do this by applying an estimate of the solar premium (say 1.20) to a forecast of the time-weighted average annual NSW pool price (say $50/MWh) to yield a forecast market value of solar PV exports at the NSW node. This value is then 'grossed up' by distribution and transmission losses (say 5%), and NEM fees and ancillary services costs (say $1/MWh) are added, to yield an estimate of the market value of solar PV exports at the customer premises:

Market value = $50/MWh x (1.20) x (1.05) + $1/MWh= $64/MWh

(or divide by 10 to convert to c/kWh)

The solar premium captures the value that solar PV exports are expected to earn – over and above the time-weighted annual average price – due to the production and export of solar PV generation being positively correlated with above-average spot prices during the day.

The value of solar PV exports varies considerably depending on the volatility of spot prices during the day. To account for this variation, we have estimated a distribution of solar premiums that ranges from relatively low value years (when spot prices during the day are benign) to relative high value years (when spot prices during the day are high).

Our results our outlined in Table 1. We present a range of results for both net and gross metered customers for 2014/15 based on differing values of solar PV premiums – these values reflect the 5th, 25th, 50th, 75th and 95th percentiles of the estimated distribution of solar premiums, as well as the mean.

Table 1: Estimated market value of solar PV exports for 2014/15 – flat (c/kWh, $2014/15, customer premise)

Solar premium metric	Gross metered customers	Net metered customers
5th Percentile	4.62	4.50
25th Percentile	5.33	5.10
50th Percentile	6.00	5.63
Mean	6.06	5.69
75th Percentile	6.72	6.21
95th Percentile	7.70	7.03

Source: Frontier modelling and analysis

5 Time of use market value of solar PV exports

This section outlines the methodology and results of our analysis to forecast the wholesale market value of solar PV exports by time of use (TOU). Our approach to forecasting the market value of solar PV exports by TOU is broadly similar to the methodology described in Section 2.2. However, here we analyse the value of solar PV exports at different times of the day, and suggest a two-part tariff designed to incentivise customers to align their solar panels to produce at peak times.

5.1 Methodology overview

Our methodology for calculating a TOU tariff is similar to that of a calculating a flat annual tariff, as described in Section 2.2. The key difference is that the TOU tariff requires the calculation of solar premiums and market values of solar PV exports for two separate periods during the year, which we will call the peak period and the off-peak period. Following discussions with IPART, we have decided to define a TOU tariff such that the peak period is defined as a two-hour block that occurs at the same time for each day of the year. The off-peak period is defined as all other hours of each day of the year.

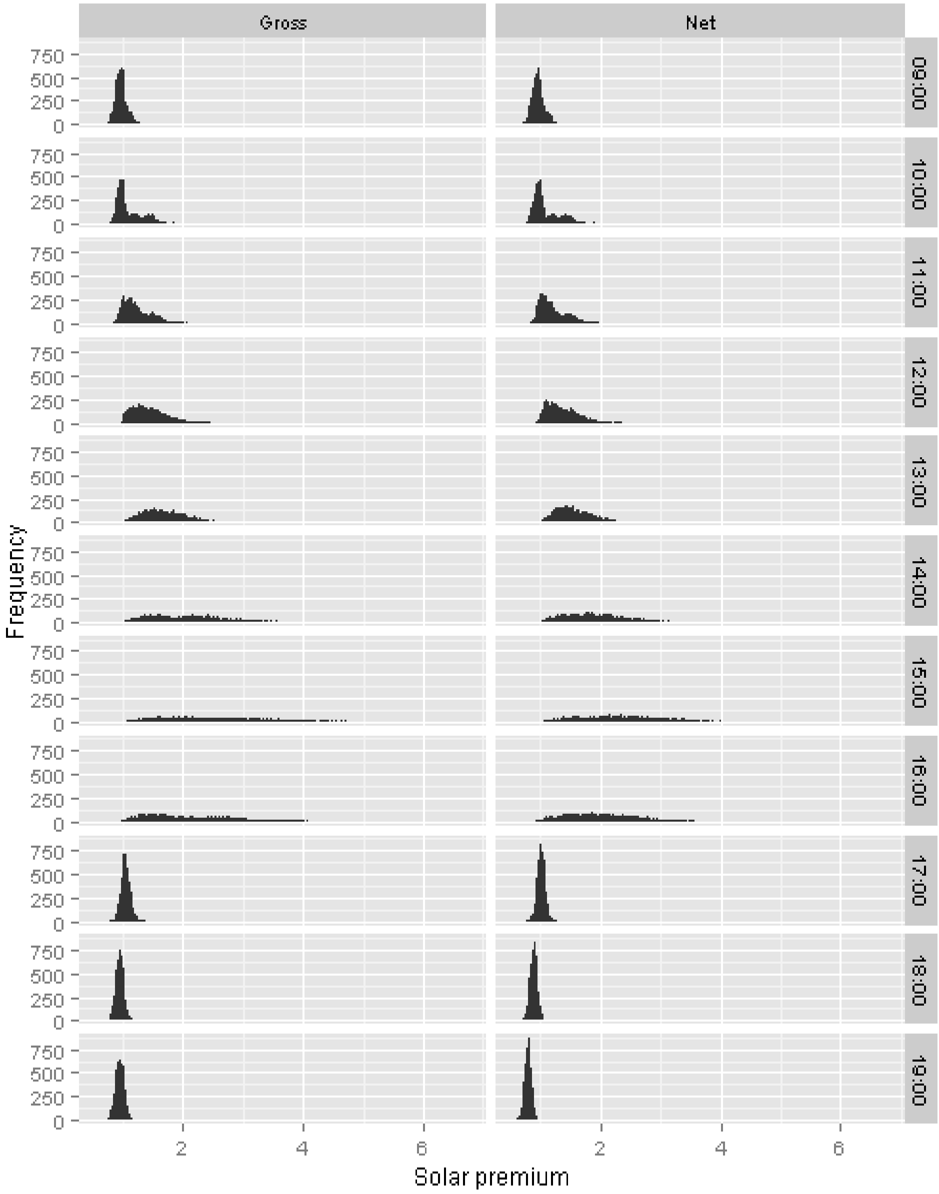
The first step of determining the TOU tariff is to determine the two-hour block to apply each day that is expected to provide the greatest market value of solar PV exports. We do this by calculating the solar premium for each two-hour block of the day, and defining the peak period as that two-hour block that provides the highest solar premium.

The second step is to determine the appropriate market value of solar PV exports. We apply the same approach as for our flat annual tariff: that is, we use the solar premium for the most valuable two-hour block, a forecast of the time-weighted average annual price for NSW and a value for losses. The difference is that we have two solar premiums for the TOU tariff: one for peak periods and the other for off-peak periods.

5.1.1 Calculating solar premiums by time of day

The methodology for calculating TOU solar premiums is similar to that described in Section 2.2.3. However, rather than calculating annual output-weighted prices as described, we calculate output-weighted prices which are grouped in rolling two hour blocks. That is, for each two hour block in a day, we calculate the output-weighted price for all the hours in the year that fall in that two hour block, and take the ratio of that output-weighted price to the time-weighted price for the year. The result is a solar premium for the two hours in question. Hence, we end up with a distribution of solar premiums for each two-hour block in a day, which are based on the same synthetic years generated earlier. These distributions are shown in Figure 7.

Figure 7: Solar premium distributions for two-hour blocks (labels are two hour starting)



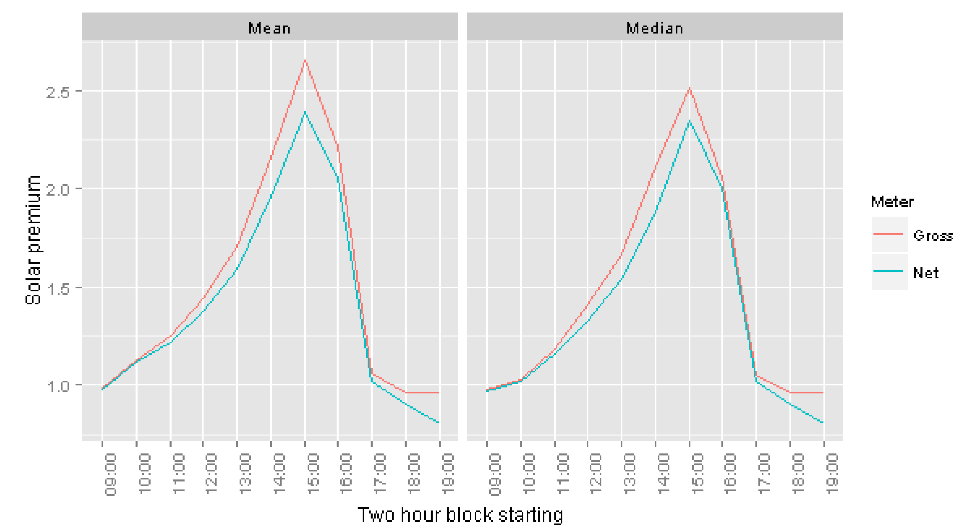
Source: Frontier analysis

From these distributions, we can use a metric (such as the mean or median) to determine the most valuable period and the solar premium for that most valuable period. Once we know this most-valuable period, we determine the off-peak solar premium by removing this most valuable two hour block and calculating the off-peak solar premium.

5.2 Results

Applying the methodology described in Section 5.1, we find the most valuable two-hour period of solar production to be 3-5pm for both gross metered and net metered customers. Recall this measure takes into account both the amount of solar PV exports in the two-hour period and the price that applies in that two-hour period. So, while this two-hour block may not be the time at which solar is producing the most exports, it is the time at which solar exports are most valuable relative to a flat profile. Figure 8 outlines the simulated mean and median solar premium values for each two-hour block of the day.

Figure 8: Solar premium values across the day



Source: Frontier analysis

Removing 3-5pm from the output-weighted price and calculating the off-peak solar premium in the same way, we can calculate distributions for the off-peak solar premiums for gross metered and net metered customers. Using the median of both the peak and off-peak distributions, and applying the same methodology as in Section 4.4, we arrive at the estimated market values of solar PV exports in Table 2.

Table 2: Estimated market value of solar PV exports for 2014/15 – TOU with peak period from 3pm to 5pm (c/kWh, $2014/15, customer premise)

Solar premium metric	Gross metered customers	Net metered customers
Peak period (3-5pm daily)	10.00	9.27
Off-peak period (all other times)	5.06	4.86

Source: Frontier modelling and analysis

Appendix A

As well as estimating the value of solar PV exports during the most valuable two-hour period of solar production, for this Final Report IPART also asked us to estimate the value of solar PV exports using a definition of the peak period that is consistent with the time of the network tariff peak period (that is, between 2pm and 8pm). We have undertaken these estimates using the same methodology as discussed in Section 5.

Table 3 presents the results of this analysis. The estimated market values are lower than with the 3-5pm definition of peak, which reflects the extension of the peak period from two hours to six.

Table 3: Estimated market value of solar PV exports for 2014/15 – TOU with peak period from 2pm to 8pm (c/kWh, $2014/15, customer premise)

Solar premium metric	Gross metered customers	Net metered customers
Peak period (2-8pm daily)	8.20	7.62
Off-peak period (all other times)	4.64	4.52

Source: Frontier modelling and analysis

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