Market value of solar PV exports

A FINAL REPORT PREPARED FOR IPART

June 2013

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1 Introduction

The Independent Pricing and Regulatory Tribunal (IPART) has been asked by the New South Wales Government to undertake an annual investigation and determination of the retailer benefit component under the Solar Bonus Scheme and the benchmark range for feed-in tariffs for compliant generators in New South Wales. It is currently undertaking this task for 2013/14.

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 benchmark range for solar feed-in tariffs IPART is to use the methodology adopted in its 2012/13 determination.

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 2013/14.

1.3 Structure of report

This report is structured as follows:

- Section 2 provides a brief overview of the data available to complete the task.
- Section 3 outlines the results of our analysis of the historical wholesale market value of solar PV exports.
- Section 4 outlines the results of our analysis of the forecast wholesale market value of solar PV exports for 2013/14.

2 Data on solar PV exports

This section outlines the solar PV export data available to Frontier to undertake our assessment of the forecast wholesale market value of solar PV exports for 2013/14.

2.1 Data available on solar PV exports

In undertaking this task IPART has provided Frontier with two sets of solar PV export data:

- The first dataset is that provided by IPART during the 2012/13 solar PV determination. For the reasons outlined in our Final report to IPART under that review, the most applicable data from this dataset reflected a net generation profile calculated from gross metered customers covering the period 2009/10 to 2010/11 for customers in Ausgrid's distribution area. A representative net generation profile for customers with different solar panel sizes was calculated from this dataset, for both residential and business customers.
- The second dataset is that provided by IPART during this 2013/14 review. This dataset contains a separate sample of net and gross metered customers covering the period 1 July 2011 to 30 June 2012 (i.e. 2011/12) from Ausgrid's distribution area. Frontier understands that the sample reflects a random drawing of net and gross meter customers, and thus statistically represents the underlying population distribution of panel sizes among net and gross metered customers in Ausgrid's distribution area.

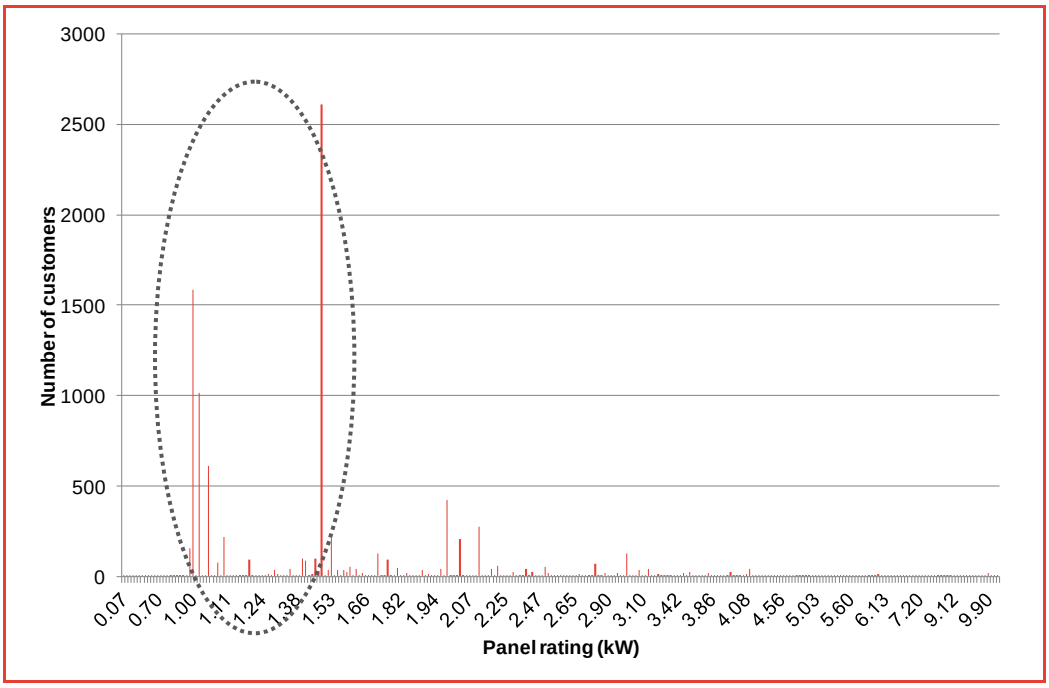
Frontier understands that the penetration of net metered customers within Ausgrid's distribution area has increased substantially in recent years. While the dataset provided by Ausgrid for the 2012/13 review was dominated by gross metered customers, Frontier understands there has been considerable growth in net metered customers since this time. As such, for the dataset available for the 2013/14 review there is now a large sample of both net and gross metered customers available.

2.2 Overview of solar PV export data

As noted above, both datasets available for this review comprise a range of solar PV customers of differing panel size.

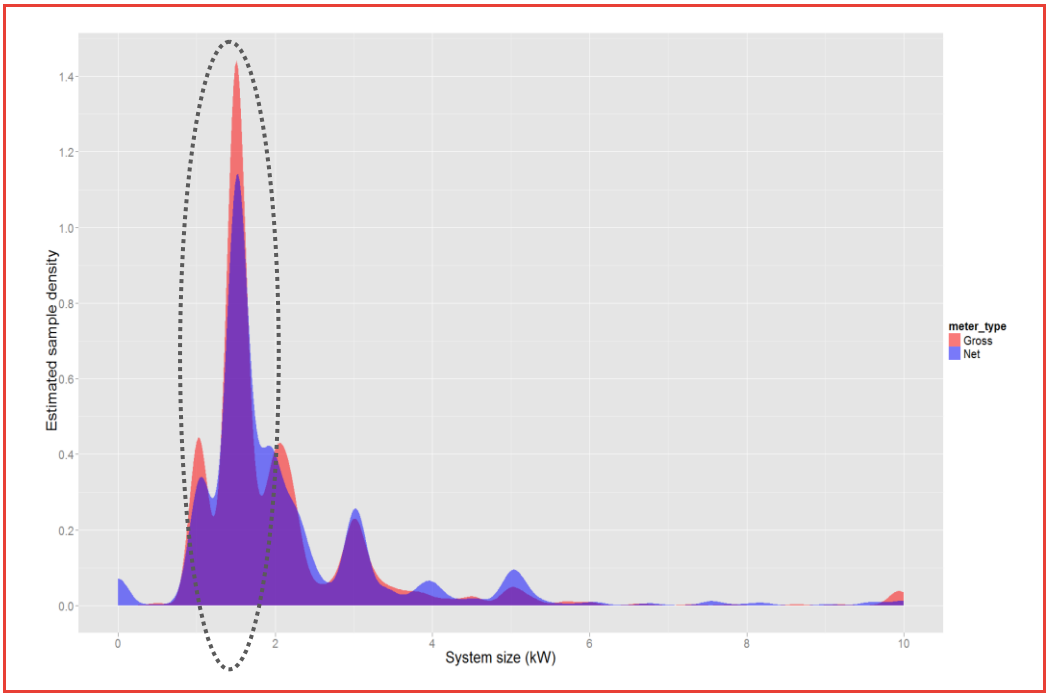
Outlined in Figure 1 is a distribution of panel sizes for residential, gross metered customers from the dataset provided for the 2012/13 review. The dataset provided for the 2012/13 review is bi-modal around two distinct panel sizes: 1 kW and 1.5 kW systems.

Figure 1: Distribution of panel sizes: residential customers, 2012/13 review dataset



Source: Frontier

Figure 2: Distribution of panel sizes: residential customers, 2013/14 review dataset



Source: Frontier

Outlined in Figure 2 is a distribution of panel sizes for residential customers from the dataset provided for the 2013/14 review, across both gross and net metered customers.

As expected, the datasets provided for the 2012/13 and 2013/14 reviews exhibit a very similar distribution of panel sizes: both datasets are dominated by systems that are 1-1.5 kW in size. There is mildly more variation in panel sizes for net metered customers than gross metered customers based on the dataset provided for the 2013/14 review (reflected by less distribution mass around 1.5 kW and slightly more mass at larger system sizes), however the bulk of systems for both net and gross metered customers are in the above 1-1.5kW range, with 1.5kW being the modal system size.

Outlined in Figure 3 are the diurnal PV generation profiles from the data provided for the 2013/14 review. Each panel outlines the daily shape of solar PV generation in a given quarter for both gross (blue) and net (red) metered customers. In the chart, the y-axis represents aggregate kW output across the sample of customers supplied by Ausgrid. As expected, the metered generation of gross metered customers is larger than that of net metered customers, since consumption for the latter is netted from generation while for the former it is not.

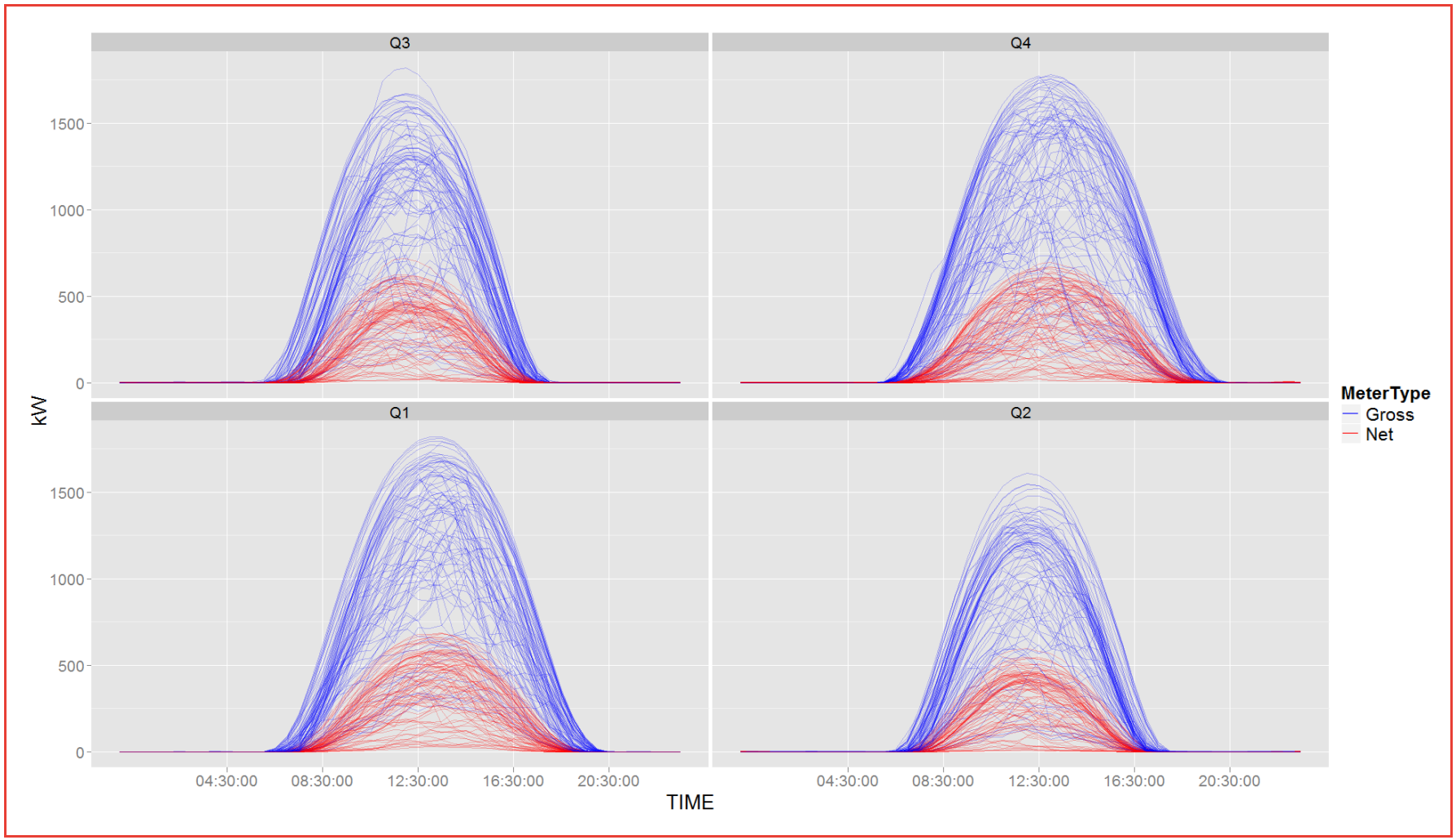
While for a given panel size a gross metered customer would be expected to produce more metered generation in a given year than an equivalently-sized net metered customer, it is the **timing** of this production – and its correlation with spot prices – that ultimately drives the market value of solar PV (discussed more in later sections). To more clearly compare the shape of PV output between gross and net metered customers, outlined in Figure 4 are normalised average generation shapes for each meter class. These shapes are the average half-hourly PV profile for each meter class underlying the data outlined in Figure 3.

To aid comparison of the **timing** of PV output between each customer class, the average shapes have been transformed (or normalised) to represent an equivalent annual amount of metered generation. What this means is that the area under each shape is equivalent (or that the sum of the dark green areas equals the light green area), and differences between the shapes reflect relative differences in the timing of average PV output across the course of the day.

The analysis illustrates that gross metered PV generation is relatively less focused during peak production hours (roughly 10am to 3pm), with relatively more generation 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 generate **relatively** more at times when residential consumption is high (i.e. first thing in the morning and late afternoon / early evening).

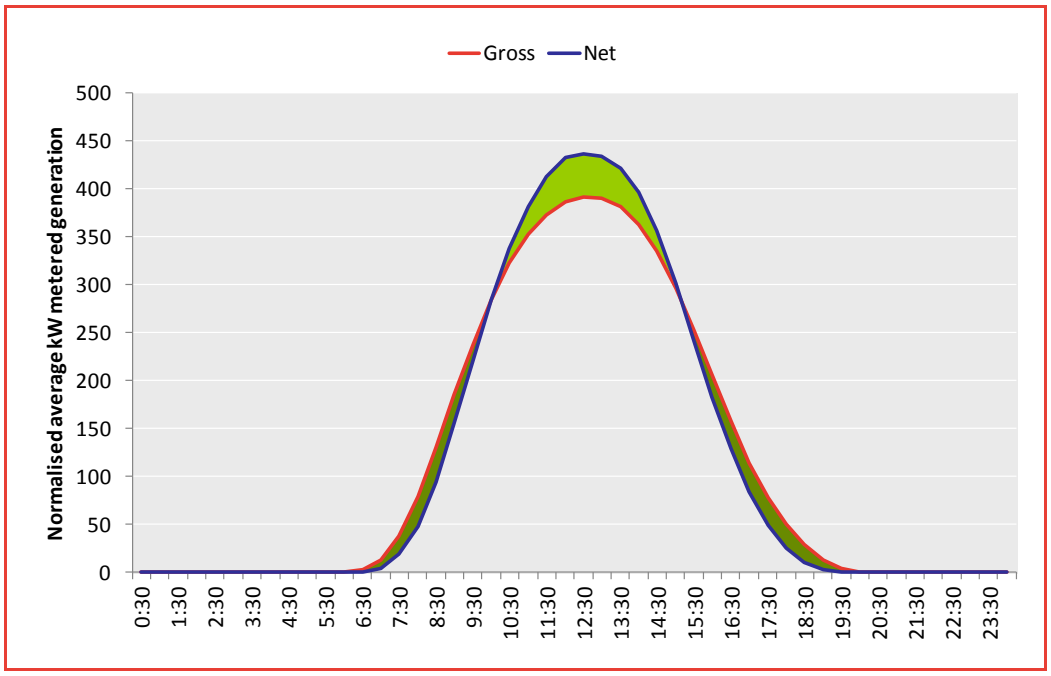
Data on solar PV exports

Figure 3: Diurnal PV generation profiles (2011/12) – net and gross metered customers



Source: Ausgrid data; Frontier analysis

Figure 4: Normalised metered generation by interval



Source: Ausgrid data; Frontier analysis

The above analysis suggests that the market value of solar PV across gross and net metered customers is unlikely to vary significantly unless significant spot prices occur at times when the relative output of net metered customers differs from that of gross metered customers. Typically this is not the case, since spot prices tend to peak during the mid-late afternoon (not early in the morning or mid evening) when the output profile of gross and net metered customers are quite similar.

2.3 Summary of solar PV export data available for this review

Frontier has at its disposal two historical solar PV generation datasets for the current review:

- The data provided for both the 2012/13 review and the 2013/14 review reflect a consistent distribution of panel sizes across solar PV customers. In both cases the distribution of panel sizes is bimodal around the 1-1.5 kW size range, with the dominant panel size being 1.5 kW.
- Based on the data supplied for the 2013/14 review, there is a noticeable difference between the average diurnal generation profiles for net and gross metered customers when viewed on an **energy-normalised** basis.
- This difference results in relatively more solar PV exports occurring during midday hours for net metered customers, since the consumption for net

metered customers at times of peak residential consumption (morning and evening) is netted from PV generation at these times. This means that relatively more exports occur at times when residential consumption is low (during midday hours).

- Other things being equal, the aggregate metered exports of gross metered customers would be expected to be larger than that for net metered customers, since the latter's consumption is netted from generation.
- The aggregate level of solar PV exports is not relevant to the determination of the unit (i.e. $/MWh) market value of solar PV exports: what is relevant is the timing / correlation of these exports to NSW pool prices.
- The difference in generation profiles for net and gross metered customers is not expected to result in a material difference in the market value of solar PV exports based on the 2011/12 data supplied. This is since NSW pool prices tend to peak in the mid-late afternoon when the generation profiles for each class of customer are quite similar.

3 Historical 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.[1] 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 Frontier has undertaken to determine the historical 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 2013/14 year to arrive at a forecast of the wholesale market value of solar PV exports for the coming 2013/14 year.

3.1 Historical half-hourly solar PV exports and pool prices

As with any generator, the market value of solar PV exports will depend on when the exports occur: with prices varying in the NEM on each half-hour, the average price received for a given annual output will depend on when that output occurs. For this reason, in order to assess accurately the market value of solar PV it is important to use half-hourly data.

As discussed in Section 2, we have been provided with historical data to enable us to calculate an average half-hourly export profile for both gross (2011/12) and net (2009/10, 2010/11, 2011/12) metered customers.

3.2 Correlation between solar PV exports and spot prices

As discussed, 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: for instance, if it is the case the 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.

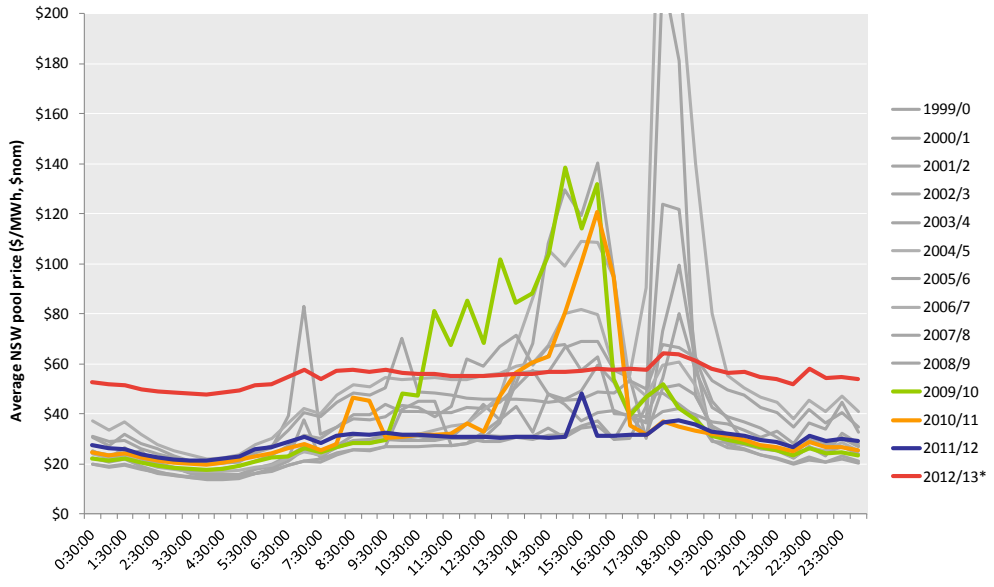
[1] Including adjusting the value of the generation to account for it being close to where it will be used.

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.

The historical data on half-hourly solar PV exports and half-hourly spot prices can be used as the basis for forecasting the market value of solar PV exports for 2013/14 by examining the historical 'shape premium' that solar PV generation has earned over the 'flat' or time-weighted annual pool price. This premium is expected to be positive, given that solar PV generation outputs at times when pool prices are greater than average (i.e. during day-light hours). The extent of this premium (for a given solar PV generation profile) will be a function of both:

- The average **level** of spot prices
- The **volatility** of spot prices, and how this volatility is **correlated** to solar PV generation.

Figure 5: Historical NSW spot prices by time of day



** Year-to-date as of end of May 2013*

Source: AEMO, Frontier analysis

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 during these years would be relatively low. Other financial years were characterised by relatively high average prices during the middle of the day, in particular during the afternoon (e.g. 2009/10). The market value of solar PV during these years would be relatively high.

Over the three years of historical data for which solar PV generation data is available (2009/10, 2010/11 and 2011/12) it can be said that:

- 2009/10 experienced a large level of average pool prices during midday hours
- 2010/11 experienced a somewhat representative level of average pool prices during midday hours.
- 2011/12 experienced a significantly low level of average pool prices during midday hours.

3.3 Energy losses

As discussed, the wholesale market value of solar PV exports can be thought of as 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.

In order to be consistent with this approach it is necessary to adjust the NSW spot electricity price (which is measured at the NSW RRN) for the network losses that would be faced by customers exporting solar PV into the market. To make this adjustment for losses, we have used the transmission and distribution losses applicable to each distribution area. The effect of this is to **increase** the market value of solar PV exports into the distribution networks, reflecting the benefit of being located where load is located (i.e. avoiding these losses).

When calculating the historical wholesale market value of solar PV exports we have assumed the following loss factors, to convert the value of solar generation at the customer premise to a value at the NSW node:

- **1.0657** for 2009/10 and 2010/11
- **1.0647** for 2011/12.

These loss factors represent the losses estimated by AEMO as being applicable to Ausgrid's distribution network and used by IPART in its previous retail price determinations. They are comprised of both the distribution and transmission loss factors associated with delivering energy from the NSW node to the customer premises in Ausgrid's supply area.

3.4 Historical wholesale market value of solar PV exports

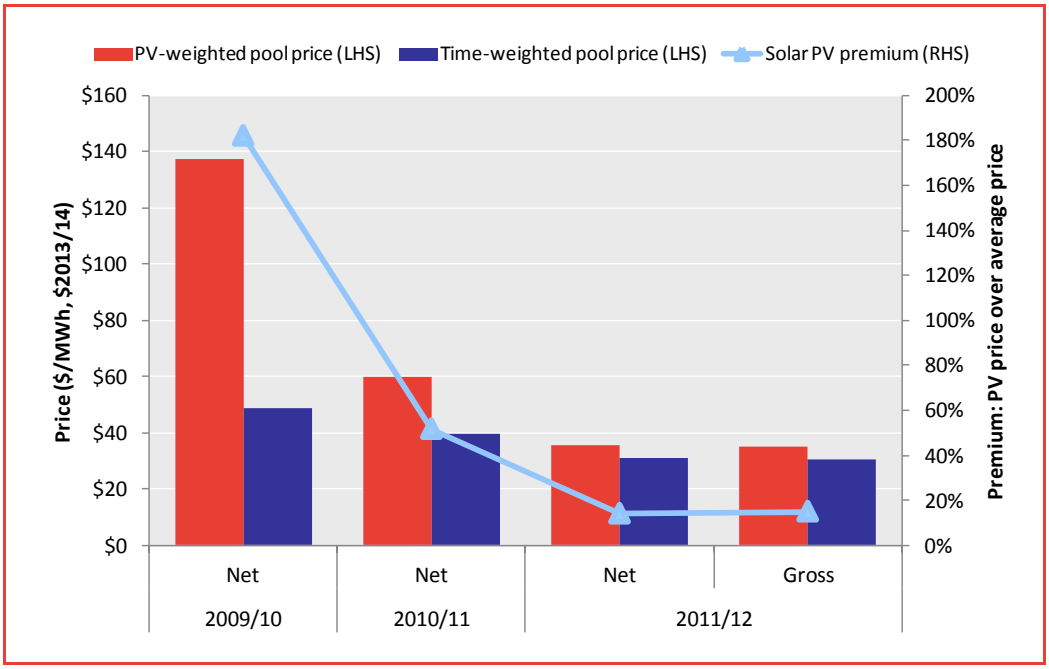
The historical wholesale market value of solar PV exports is calculated by taking a generation-weighted average NSW pool price using half-hourly solar PV export and NSW pool price data. In order to reflect the value of solar PV exports at the NSW node, an appropriate loss factor is used to 'gross' up the level of generation at the customer premise to the NSW node (which is where pool prices are

reported). In order to present results on a comparable price basis, all values are reported in $2013/14 using an assumed 2.5% annual inflation rate.

Outlined in Figure 6 is the estimated historical wholesale market value of solar PV exports for the following years and solar PV generation profiles:

- **2009/10 for net metered customers** (as calculated by Frontier for the 2012/13 review. We have reported the result for 1.5 kW systems, given this is the modal system and thus best represents the weighted-average wholesale market value of PV exports across all system sizes).
- **2010/11 for net metered customers** (also as calculated by Frontier for the 2012/13 review and also for 1.5 kW systems).
- **2011/12 for gross metered customers** (calculated across all system sizes from the data supplied by Ausgrid for the 2013/14 review).
- **2011/12 for net metered customers** (calculated across all system sizes from the data supplied by Ausgrid for the 2013/14 review).

Figure 6: Historical wholesale market value of PV exports ($2013/14)



Source: Frontier analysis

The importance of the shape of half-hourly spot prices throughout the day to the market value of solar PV exports can be seen by comparing the market value of solar PV exports across the three financial years of data available.

Given the significant number of high-priced events that occurred during midday hours in 2009/10, the market value of solar PV generation in 2009/10 was considerably larger than in any of the other years for which data is available. The

PV-weighted pool price (including losses) in this year was roughly 180% greater than the time-weighted average price.

Midday prices in 2010/11 were more moderate than in 2009/10, and the result is reflected in the market value of solar PV in that year: the solar PV premium was roughly 50%.

The very benign prices of 2011/12 resulted in PV-weighted prices for both net and gross solar PV generation only slightly above the time-weighted average: once accounting for losses, the solar PV premium for both meter classes was roughly 15%. While we do not have solar PV export data for 2012/13, based on the volatility of midday pool prices year-to-date it is likely that the solar PV premium for 2012/13 will also be relatively low.

Importantly, differences in the market value of solar PV exports across years cannot simply be attributed to a difference in annual average prices. Certainly, annual average prices were higher in 2009/10 than in 2010/11, and higher in 2010/11 than in 2011/12 ($47.29/MWh, $38.06/MWh and $29.67/MWh respectively), but the difference does not explain the difference in the market value of solar PV exports during these years. Rather, the difference is also driven by the timing of higher prices throughout the year, the extent of solar PV exports during those high price periods.

Historical wholesale market value of solar PV exports

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 2013/14 year. Our approach to forecasting the market value of solar PV involves combining the historical solar PV price premiums outlined in Section 3.4 with a forecast of 2013/14 average annual pool prices for NSW.

4.1 Frontier's modelling approach

The modelling approach and framework utilised by Frontier in forecasting average annual NSW pool prices is extensively outlined in our recent Final report[2] to IPART as part of its 2013 determination of regulated retail electricity prices in New South Wales. This report formed the basis of the energy purchase cost allowance used in determining regulated retail prices. Frontier has adopted the same spot price forecasts as determined in our Final report for this review.

4.2 Spot price forecasts

Outlined in Table 1 are the time-weighted average annual spot price forecasts for 2013/14 contained in Frontier's Final report to IPART and prepared for the 2013 regulated retail price determination. As explained in that report, two spot price forecasts were provided: a "Hybrid" price forecast, which relied on d-cyphaTrade contract prices, and a "Modelled" price, which was based purely on Frontier's spot price modelling. The spot price forecasts provided are an arithmetic average of the POE10, POE50 and POE90 spot price forecasts outlined in our Final report.

In its Final determination on regulated retail prices for the period 2013/14 to 2015/16 IPART ultimately adopted the Hybrid approach to forecasting spot prices for the purposes of determining the market-based energy purchase cost associated with serving an incremental regulated customer in New South Wales.

2 http://www.ipart.nsw.gov.au/files/7aa6293d-9f89-4762-8006-a1dd00e25729/Consultant_Report_-_Frontier_Economics_-_Energy_purchase_costs_-_June_2013.pdf

Table 1: Forecast annual average NSW spot prices for 2013/14

Forecasting approach	Time-weighted average annual NSW spot price ($/MWh, $2013/14)
Hybrid approach	$54.89
Modelled approach	$61.50

Source: Frontier modelling

4.3 Energy losses

In forecasting the market value of solar PV exports in 2013/14 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 2013/14 distribution and transmission loss factors applicable to Ausgrid's distribution area.

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 2013/14 we combine the various historical estimates of solar PV generation premiums (outlined in Section 3.4) with the various forecasts of NSW annual average spot prices for 2013/14 (outlined in Table 1). We do this by applying a historical estimate of the solar PV premium (say 20%) to a forecast of the time-weighted average annual NSW pool price (say $60) to yield a forecast market value of solar PV:

$60/MWh x (1+20%) = $72/MWh.

As noted in Section 3, the historical solar PV premium captures:

- The historical correlation between solar PV exports and NSW spot prices for a given year. Each year will exhibit a different pattern of NSW spot prices (in terms of timing and volatility during midday hours) and hence a different solar PV premium.
- An estimate of the 'value' of solar PV generation being located close to load, and thus 'avoiding' the network losses associated with transmitting energy from the NSW node to the customer premises.

By combining the above solar PV premiums with a forecast of average NSW spot prices, we account for the third factor which drives the market value of solar PV exports: the average level of spot prices.

In utilising this approach we consider that the best estimate for the relationship between the timing of solar PV exports and NSW pool prices is that embedded

within the historical data we have available. By applying a historical solar PV premium to a revised forecast of the annual average NSW pool price, we are implicitly assuming that the pattern, volatility and correlation of NSW pool prices to solar PV exports exhibited in a given historical year (say 2010/11) would repeat itself in 2013/14. We assume the only difference between the historical year (say 2010/11) and the forecast year is the average **level** of spot prices (that is, differences in the time-weighted annual average spot price).

Based on our analysis of historical NSW spot prices during midday intervals, we exclude 2009/10 as a candidate historical year with which to estimate a forecast market value of solar PV exports in 2013/14. We exclude 2009/10 on the basis that the pattern and volatility of midday spot prices in this year were something of an outlier when compared to both all historical years available, but in particular when compared to more recent historical years (2010/11, 2011/12 and 2012/13).

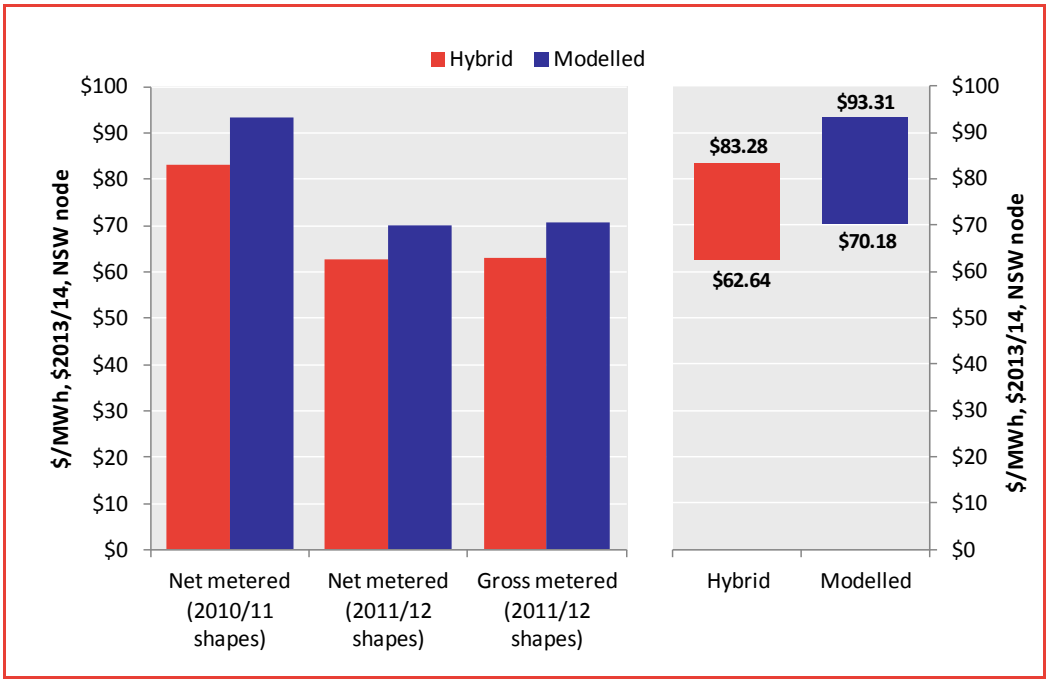
By excluding 2009/10 as a year with which to inform a forecast of the market value of solar PV exports, we are left with three historical annual solar PV export shapes across two annual years of prices:

- net metered customers for 2010/11
- net metered customers for 2011/12
- gross metered customers for 2011/12.

In addition, we have two annual average spot price forecasts for NSW for 2013/14. In combination, the above three generation-price pairs and two spot price forecasts results in six potential estimates of the market value of solar PV exports: each estimate is based on a given generation-price trace and a given NSW spot price forecast.

Outlined in Figure 7 are the results of our analysis. The left-hand panel outlines the 6 discrete estimates of the wholesale market value of solar PV exports in 2013/14 based on various generation-price shapes (x-axis) and forecasts of the NSW average annual spot price for 2013/14 (coloured bars). The right-hand panel summarises these six estimates into a range for each spot price forecast approach. All prices are presented in $2013/14 and are on a $/MWh basis at the NSW node.

Figure 7: Forecast value of solar PV exports ($/MWh, $2013/14, NSW node)



Source: Frontier analysis

Our forecast of the wholesale market value of solar PV exports in 2013/14 range between:

- $62.64/MWh and $83.28/MWh using the Hybrid approach to forecasting NSW average annual spot prices
- $70.18/MWh and $93.31/MWh using the Modelled approach to forecasting NSW average annual spot prices.

The upper end of the range is defined by the 2010/11 spot price and solar PV generation shapes, which exhibit a relatively large number of high-priced midday intervals. The bottom end of the range is defined by the 2011/12 spot price and solar PV generation shapes, which exhibit a much lower level of average midday spot prices. Based on the 2011/12 solar PV export and spot price data there is a negligible difference between the forecast wholesale market value of gross and net metered solar PV generation.

FRONTIER ECONOMICS | MELBOURNE | SYDNEY
Frontier Economics Pty Ltd 395 Collins Street Melbourne Victoria 3000
Tel: +61 (0)3 9620 4488 Fax: +61 (0)3 9620 4499 www.frontier-economics.com
ACN: 087 553 124 ABN: 13 087 553 124