Market value of solar PV exports

A DRAFT REPORT PREPARED FOR IPART

November 2011

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Figures

1 Introduction

The Independent Pricing and Regulatory Tribunal (IPART) has been asked by the Premier of New South Wales to undertaken an investigation into solar feed-in tariffs. The investigation will establish a fair and reasonable value for electricity generated by small scale solar photovoltaic (solar PV) systems and exported to the grid.

1.1 IPART's terms of reference

The terms of reference ask IPART to complete two tasks. The first is to establish a future feed-in tariff that is for customers who are not participants in the Solar Bonus Scheme and are not subsidised by the Government or other customers. IPART is to review and recommend:

- a 'fair and reasonable value' for the electricity generated by small-scale solar PV units and exported to the grid, which is consistent with the Council of Australia Government (CoAG) principles for feed-in tariffs
- how this value should be implemented in NSW – for example, whether it should be used to set a minimum feed-in tariff that all retailers must pay for the solar-generated electricity their customers export to the grid, or a benchmark price that retailers and customers can use as a guide in negotiating a price for this electricity
- whether comprehensive network system modelling is required to value the impact of small-scale solar PV on network costs.

1.2 IPART's Issues Paper

IPART have released an Issues Paper on its review of solar feed-in tariffs.[1] IPART's Issues Paper proposes to calculate the value of electricity produced by small-scale solar PV units using two methods:

- By estimating the **financial gain** to retailers if they were to pay no feed-in tariff to customers for the electricity these units export to the grid. For those retailers whose customers export electricity, this financial gain occurs due to the difference between the revenues the retailers collect from their customers and the costs that they face in supplying their customers.
- By estimating the **wholesale market value** of the electricity these units export to the grid (including energy losses).

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1 IPART, *Solar feed-in tariffs, Setting a fair and reasonable value for electricity generated by small-scale solar PV units in NSW*, August 2011.

IPART propose to consider the results of these calculations in determining the most appropriate 'fair and reasonable value' for a future feed-in tariff.

1.3 Frontier Economics' engagement

Frontier Economics has been engaged by IPART to provide advice on the wholesale market value of the electricity that solar PV systems export to the grid, for 2011/12 and 2012/13. In particular, we have been asked to forecast the wholesale market value of the electricity that solar PV systems will export to the grid.

This draft report sets out Frontier Economics' advice to IPART on the wholesale market value of solar PV exports for 2011/12 and 2012/13. This report is structured as follows:

- Section 2 provides an overview of our approach to estimating the wholesale market value of solar PV exports
- Section 3 discusses the data on solar PV exports we have used in our analysis and provides a summary of that data
- Section 4 provides an overview of the modelling framework and assumptions we have used to estimate wholesale market prices in 2012/13
- Section 5 sets out the results of our modelling of wholesale market prices in 2012/13
- Section 6 sets out the results of our assessment of the market value of solar PV exports.

2 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. 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 provides an overview of the methodology for forecasting the wholesale market value of solar PV exports for 2012/13.

2.1 Half-hourly solar PV exports

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.

Given that we are forecasting the market value of solar PV exports for 2012/13, it is necessary to develop a forecast of half-hourly solar PV exports for 2012/13.

As discussed in Section 3, we have been provided with historical data to enable us to calculate half-hourly exports for a large number of customers, including customers with different panel sizes. We have not been provided with a forecast of solar PV exports. Indeed, given that actual half-hourly exports for 2012/13 will depend, among other things, on the weather conditions that occur in 2012/13, it is impossible to forecast the pattern of half-hourly exports with any certainty.

For this reason, we propose to adopt the half-hourly pattern of solar PV exports for an historic year as the half-hourly forecast for 2012/13. Adopting this approach will ensure we have a realistic representation of solar PV exports. Moreover, as long as the correlation between half-hourly solar PV exports and half-hourly prices is preserved, this approach will ensure that the forecast market value of solar PV exports appropriately captures the effect of the timing of exports.

2.2 Half-hourly spot prices

All generators in NSW, and all retailers, face the same spot electricity price. This spot electricity price is referenced to the NSW regional reference node (RRN).

Given that we are forecasting the market value of solar PV exports for 2012/13, it is necessary to develop a forecast of half-hourly spot prices for 2012/13.

Half-hourly electricity spot prices for the NSW RRN are publicly released by AEMO. These prices are available historically since the commencement of the NEM but, clearly, are not available on a forecast basis.

In order to forecast half-hourly spot prices for 2012/13 we use our market modelling framework, as discussed in detail in Section 4.

2.3 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 the 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.

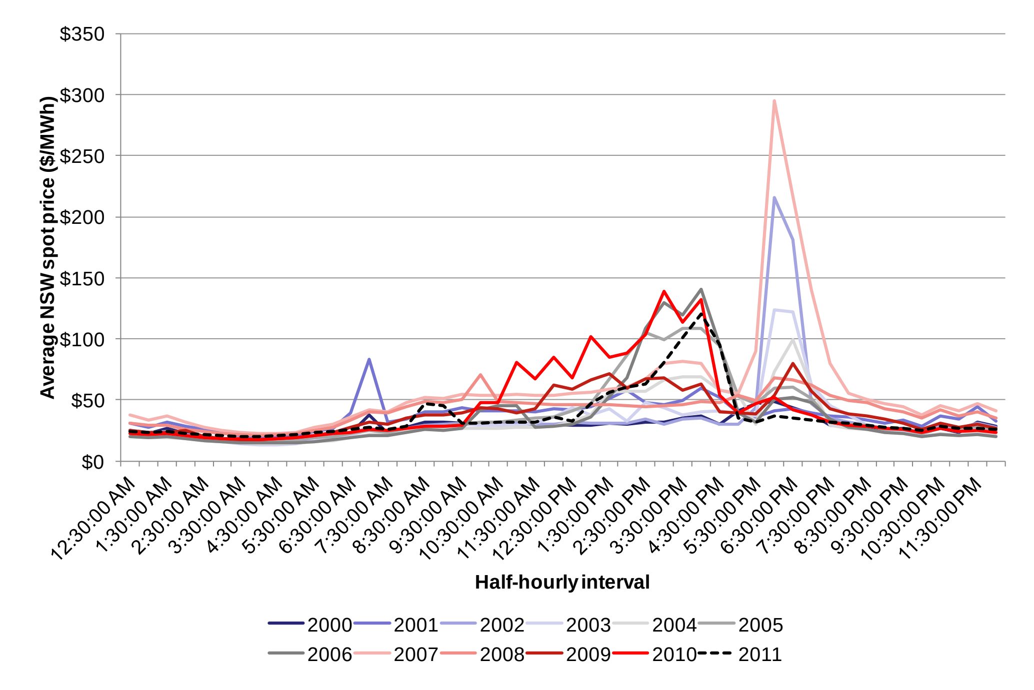
The best data available to describe the relationship between half-hourly solar PV exports and half-hourly spot prices is historical data. This data will capture the relationship between solar radiation (and hence solar PV exports) and electricity spot prices.

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 2012/13 by shaping both forecast solar PV exports and forecast spot prices to the corresponding half-hourly shape for the same year. We propose to use financial year 2010/11 as the basis for establishing the relationship between half-hourly solar PV exports and half-hourly spot prices. There are two reasons for preferring financial year 2010/11:

- Because more customers have connected solar PV over recent years, the significantly more data available on solar PV exports for 2010/11 than there is for earlier years
- The shape of average half-hourly spot prices throughout the day for 2010/11 is not an outlier.

The shape of average half-hourly spot prices throughout the day is shown in Figure 1 for each financial year from 1999/2000. It can be seen from Figure 1 that a number of financial years were characterised by relatively low average prices during the middle of the day (in some cases accompanied by a price spike in the evening). The market value of solar PV during these years would be relatively low. Other financial years were characterised relatively high average prices during the middle of the day, in particular during the afternoon. The market value of solar PV during these years would be relatively high. Financial year 2010/11 falls somewhere in the middle: average prices were relatively low until the early afternoon, at which point they began to increase steadily to a late afternoon peak.

Figure 1: Average daily shape of NSW spot electricity prices



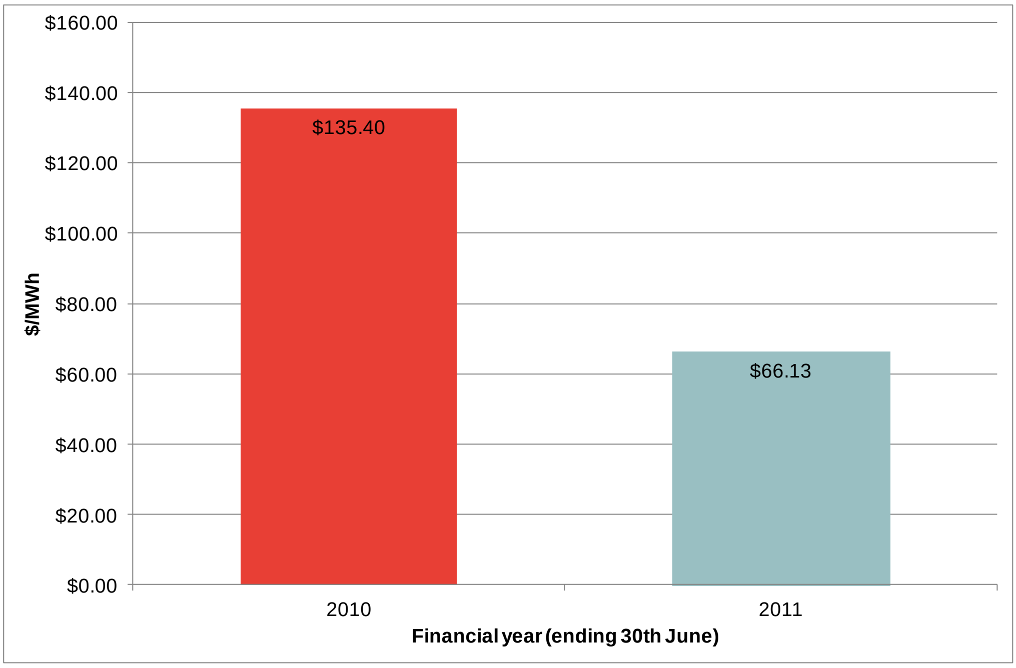
Source: AEMO

The importance to the market value of solar PV exports of the shape of half-hourly spot prices throughout the day can be seen by comparing the market value of solar PV exports in 2009/10 and 2010/11.

Financial year 2009/10 represents something of an outlier, with average prices being consistently high throughout the middle of the day. Even during the morning average prices were consistently above $50/MWh; significantly higher than any other year. Based on half-hourly spot prices during 2009/10 and average half-hourly exports during 2009/10, the market value of exports for solar PV panels rated at 1 kW in Ausgrid's distribution area was around $135/MWh during 2009/10, as shown in Figure 2.

Financial year 2010/11, however, had average prices that were moderate throughout the middle of the day. Based on half-hourly spot prices during 2010/11 and average half-hourly exports during 2010/11, the market value of exports for solar PV panels rated at 1 kW in Ausgrid's distribution area was around $65/MWh during 2010/11, as shown in Figure 2.

Figure 2: Historic market value of solar PV exports ($2011/12)



Source: Frontier Economics

Importantly, this significant difference in the market value of solar PV exports cannot simply be attributed to a difference in annual average prices. Certainly, annual average prices were higher in 2009/10 than in 2010/11 ($47.29/MWh and $38.06/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. This clearly illustrates the importance of accurately capture the relationship between half-hourly solar PV exports and the half-hourly market prices.

2.4 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.

3 Data on solar PV exports

As part of this review of solar feed-in tariffs IPART has requested data on solar PV exports from each of the NSW electricity distribution businesses. This section describes the data on solar PV exports that is available from the distribution businesses and summarises observed patterns of solar PV exports.

3.1 Data available from distribution businesses

Depending on their metering arrangements, each of the NSW electricity distribution businesses has been able to provide different data on solar PV exports.

Ausgrid

Ausgrid record half-hourly data, by customer, for both solar PV generation and for customer load. Ausgrid provided this data for each of their customers with solar PV generation.

For each of these customers, Ausgrid also provided the panel size (in kW) and whether the customer is a business customer or a residential customer. Ausgrid did not provide any information that would enable individual customers to be identified.

Ausgrid provided this data for both 2009/10 and 2010/11.

Endeavour Energy

Endeavour Energy do not routinely record half-hourly data for all customers with solar PV. However, Endeavour Energy have provided IPART with half-hourly solar PV generation for a sample of around 300 of their customers with solar PV.

For each customer of these customers, Endeavour Energy also provided the panel size (in kW), within certain ranges.

Endeavour Energy provided this data for both 2009/10 and 2010/11.

Essential Energy

Essential Energy does not routinely record half-hourly data for customers with solar PV. However, Essential Energy was able to provide meter readings for a sample of around 100 of their customers with solar PV. For each customer, Essential Energy provided half-hourly data for solar PV exports.

For each of these customers, Essential Energy also provided the panel size (in kW) and whether the customer is a business customer or a residential customer.

Essential Energy was not able to provide half-hourly data for a complete year. For most customers, the data series was for the second half of financial year 2010/11.

3.2 Summary of solar PV export data

By far the most comprehensive data on solar PV generation and exports is available for the Ausgrid distribution area. For this reason, the remainder of this report estimates the market value of solar PV exports on the basis of the Ausgrid data.

The data from Endeavour Energy was for a much smaller sample of customers. Nevertheless, we have estimated the market value of solar PV exports based on this data and found that it is comparable with the market value of solar PV exports based on Ausgrid's data.

The data from Essential Energy was both for a much smaller sample of customers and was not available for a full financial year. Ultimately, we found that we were unable to draw firm conclusions about the market value of solar PV exports based on this data.

Ausgrid provided half-hourly data for all solar PV customers that had solar PV connected for a full year:

- For 2009/10, Ausgrid provided half-hourly data for approximately 1,100 customers that were connected for all of 2009/10. This included around 1,100 residential customers and around 30 business customers.
- For 2010/11, Ausgrid provided half-hourly data for approximately 10,000 customers that were connected for all of 2010/11. This included around 9,900 residential customers and around 100 business customers.

While Ausgrid have provided equivalent half-hourly data for both residential and business customers, the remainder of this report focuses only on residential customers. The reason is that the consumption of business customers tends to be sufficiently high during the day that it remains greater than solar PV generation. As a result, business customers tend not to export electricity: the benefit business customers gain from their solar PV generation is that it enables them to avoid buying electricity from their retailer, not that it enables then to export electricity.

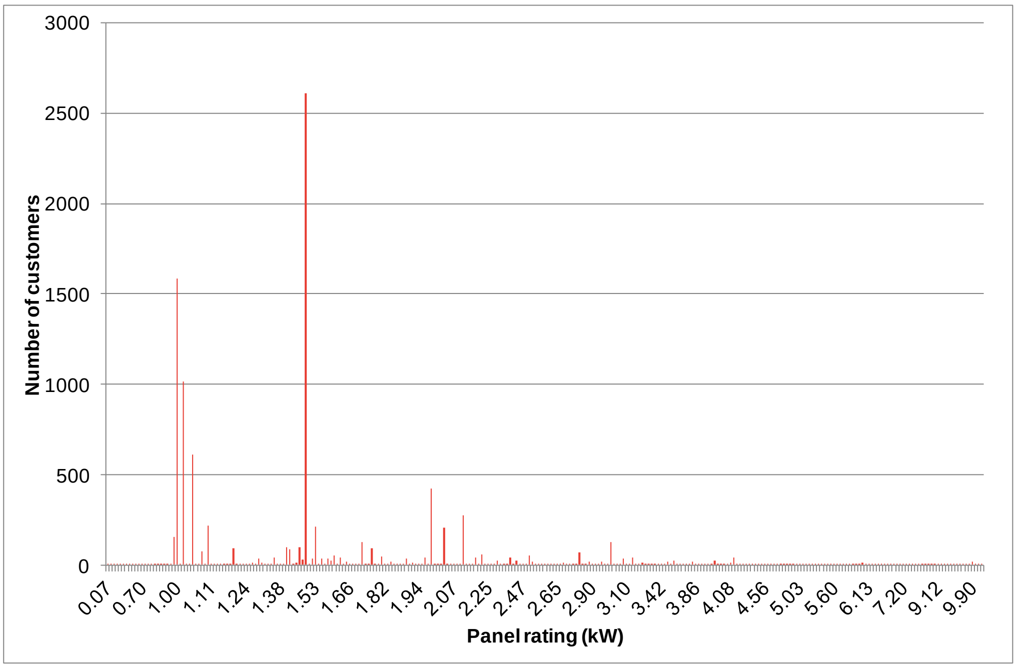
Also, while Ausgrid have provided data for residential customers on both net meters and gross meters, the remainder of this report focuses only on residential customers with gross meters. The reason is that greater information is available for customers on gross meters. For customers on gross meters, data is available for both total consumption and total generation. From this is it possible to calculate total exports. For customers on net meters, data is available for total imports and total exports. However, it is not possible to calculate total consumption or total generation from this data. The majority of customers in Ausgrid's distribution area have gross meters.

Typical panel size

The solar PV customers in Ausgrid's distribution area have a range of different panel sizes.

Figure 3 shows the panel rating (in kW) for residential customers in Ausgrid's distribution area who were connected for all of 2010/11. Figure 3 shows that panels of around 1 kW or around 1.5 kW have been the most popular size for residential customers, with smaller numbers of residential customers installing panels of around 2 kW. While some residential customers have much larger panels, including up to 10 kW, this is much less common.

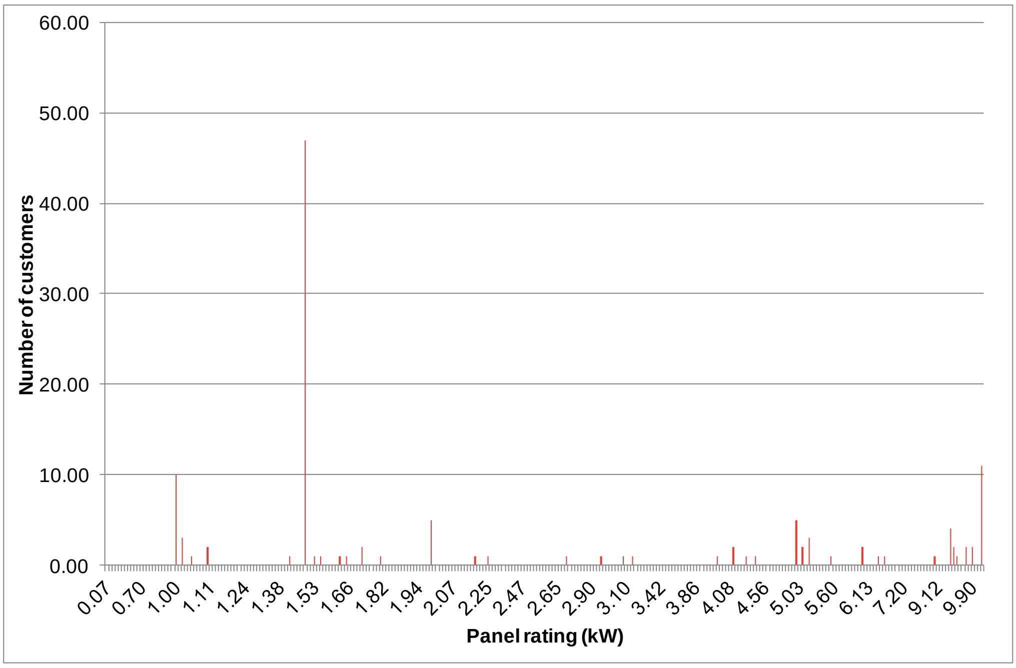
Figure 3: Ausgrid – residential solar PV customers connected for all of 2010/11



Source: Ausgrid data

For the purposes of comparison, Figure 4 shows the panel rating (in kW) for business customers in Ausgrid's distribution area who were connected for all of 2010/11. Figure 4 shows that panels of around 1 kW or around 1.5 kW have been popular with business customers, just as they are with residential customers. However, business customers are more likely than residential customers to have large systems installed, including systems larger than 5 kW.

Figure 4: Ausgrid – business solar PV customers connected for all of 2010/11



Source: Ausgrid data

In order to determine the effect of panel size, we have undertaken our assessment of the market value of solar PV on the following residential panel sizes:

- **1 kW systems** – this includes all systems with panels rated between 0.9 kW and 1.1 kW
- **1.5 kW systems** – this includes all systems with panels rated between 1.4 kW and 1.6 kW
- **2 kW systems** – this includes all systems with panels rated between 1.9 kW and 2.1 kW
- **3 kW systems** – this includes all systems with panels rated between 2.9 kW and 3.1 kW
- **4 kW systems** – this only includes systems rated at 4 kW
- **5 kW systems** – this only includes systems rated at 5 kW
- **6 kW systems** – this only includes systems rated at 6 kW
- **7 kW systems** – this only includes systems rated at 7 kW
- **8 kW systems** – this only includes systems rated at 8 kW

- **9 kW systems** – this only includes systems rated at 9 kW
- **10 kW systems** – this only includes systems rated at 10 kW

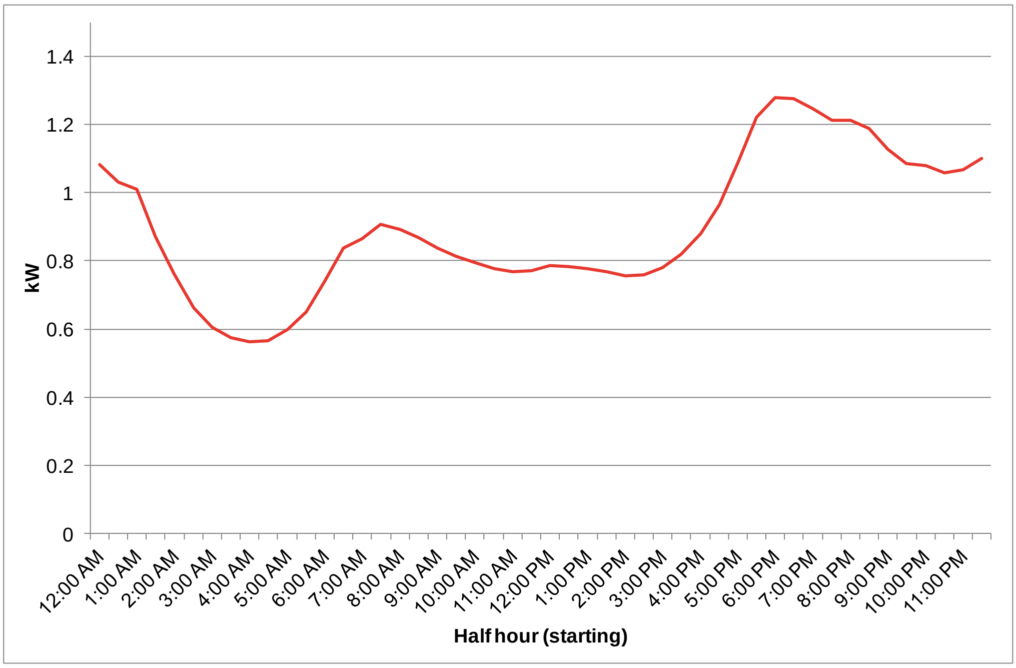
Average consumption, average generation and average exports

In order to assess the market value of solar PV generation for residential customers, it is necessary to determine the solar PV exports of an average residential customer.

The approach that we have adopted is to assume that a residential customer will have a half-hourly load shape that reflects the average across all customers and a half-hourly generation shape that reflects the average across all customers with the same panel rating.

Considering the half-hourly load shape, we have calculated a residential half-hourly load shape for 2010/11 that is the average of the actual half-hourly load shapes for 2010/11 for all of the approximately 10,000 residential solar PV customers in Ausgrid's distribution area that were connected for all of 2010/11. This half-hourly load shape, for an average day, is shown in Figure 5.

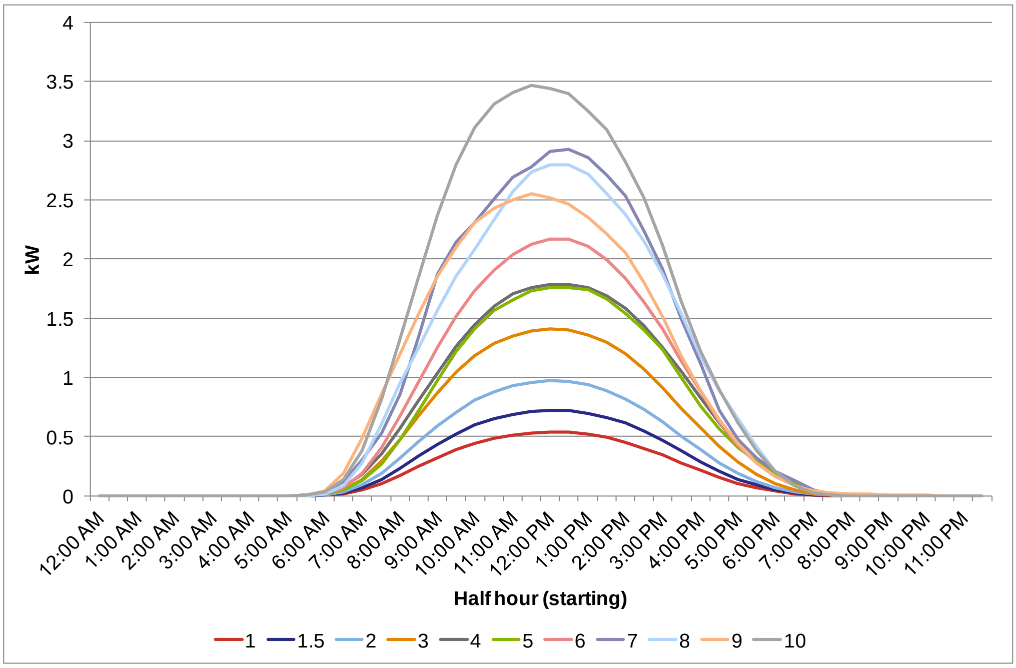
Figure 5: Ausgrid – Residential half-hourly load shape for customers with solar PV for 2010/11



Source: Ausgrid data

Considering the half-hourly generation shape, we have calculated a half-hourly generation shape for 2010/11 for each panel rating that is the average of the actual half-hourly generation shapes for 2010/11 for all of the residential customers in Ausgrid's distribution area that had a panel of that size connected for all of 2010/11. The half-hourly generation shape for each panel rating, for an average day, is shown in Figure 6.

Figure 6: Ausgrid – Residential half-hourly generation shape, by panel rating, for 2010/11



Source: Ausgrid data

Based on the average half-hourly residential load shape (represented for an average day in Figure 5) and the average half-hourly generation shape for each panel rating (represented for an average day in Figure 6), we have calculated an average half-hourly rate of solar PV exports for each panel rating.

4 Modelling framework and assumptions

As discussed in Section 2, estimating the market value of solar PV exports relies on two sets of inputs: an estimate of solar PV exports and an estimate of the spot price of electricity.

This section provides a brief overview of the modelling approach and the key input assumptions that we have used to estimate the spot price of electricity.

4.1 Frontier Economics' energy market models

For the purposes of estimating the spot price of electricity, we adopt a two-staged modelling approach, which makes use of two inter-related electricity market models: *WHIRLYGIG* and *SPARK*. These models are also used in Frontier Economics' advice to IPART on regulated retail tariffs for the standard retailers. The key features of these models are as follows:

- *WHIRLYGIG* optimises total generation cost in the electricity market, calculating the least cost mix of existing plant and new plant options to meet load. *WHIRLYGIG* provides an estimate of LRMC, including the cost of any plant required to meet modelled regulatory obligations.
- *SPARK* uses game theoretic techniques to identify optimal and sustainable bidding behaviour by generators in the electricity market. *SPARK* determines the optimal pattern of bidding by having regard to the reactions by generators to discrete changes in bidding behaviour by other generators. The model determines profit outcomes from all possible actions (and reactions to these actions) and finds equilibrium bidding outcomes based on game theoretic techniques. An equilibrium is a point at which no generator has any incentive to deviate. The output of *SPARK* is a set of equilibrium dispatch and associated spot price outcomes.

WHIRLYGIG provides a least cost investment path for the electricity sector. This least cost investment is an important input for *SPARK*: as electricity demand grows there will be a need for new investment simply to meet reserve constraints.

Both *WHIRLYGIG* and *SPARK* incorporate a representation of the physical infrastructure in the NEM that includes demand forecasts for each region in the NEM, all existing generation plant in the NEM (including technical and cost information for those existing plant), all existing inter-regional interconnectors in the NEM and options for new generation plant.

4.2 Modelling assumptions

In developing the modelling assumptions required for estimating spot electricity prices, we have used the same approach, and the same basic sources of input assumptions, as was used in our advice to IPART on regulated retail tariffs for the standard retailers. Upon instruction from IPART, we have relied, to a large extent, on the following sources:

- AEMO, *Electricity Statement of Opportunities for the National Electricity Market*, 2011 (**AEMO 2011 ESOO**). This is the source for system demand forecasts used in our modelling. This is the most recent available data from AEMO, and updates the 2010 ESOO that was used in our advice to IPART on regulated retail tariffs.
- ACIL Tasman, *Calculation of energy costs for 2011-12 BRCI*, Draft Report, Prepared for the Queensland Competition Authority, December 2010 (**ACIL Report for the QCA**).[2] As well as relying on the report itself, Frontier Economics has, in some cases, used input assumptions from spreadsheets accompanying the ACIL Report for the QCA that were provided to IPART by ACIL Tasman.
- Australian Government, *Securing a clean energy future*, 2011 and Commonwealth Treasury, *Strong Growth, Low Pollution*. These are the sources for fixed carbon price during the initial three years and the forecast carbon price thereafter.

We have not used input assumptions from the AEMO's National Transmission Network Development Plan (NTNDP) for the same reasons that we did not use the NTNDP in our advice to IPART on regulated retail tariffs: the NTNDP provides input assumptions for five different scenarios, but none of these scenarios is a base case that reflects most likely future outcomes.

The sections that follow sets out the key modelling assumptions that we have used in our modelling of spot electricity prices.

Inflation rate

Our advice to IPART in this draft report is provided in 2011/12 dollars. Where it has been necessary to convert costs or prices into 2011/12 dollars, we have used the following inflation rates, as advised by IPART:

- 3.6% from 2010/11 to 2011/12
- 2.9% for each year thereafter

2 At the time of writing, ACIL Tasman's final report to the QCA is not publicly available.

Discount rate

WHIRLYGIG optimises the total system costs of meeting demand over the entire modelling period. Total system costs are calculated as a net present cost in a specified base year using an assumed discount rate. The objective to be minimised by the model is the net present cost.

We have used a pre-tax, real discount rate of 7.8% to discount future values for the optimisation process. This is based on IPART's determination of the appropriate discount rate for the purposes of electricity generation assets.

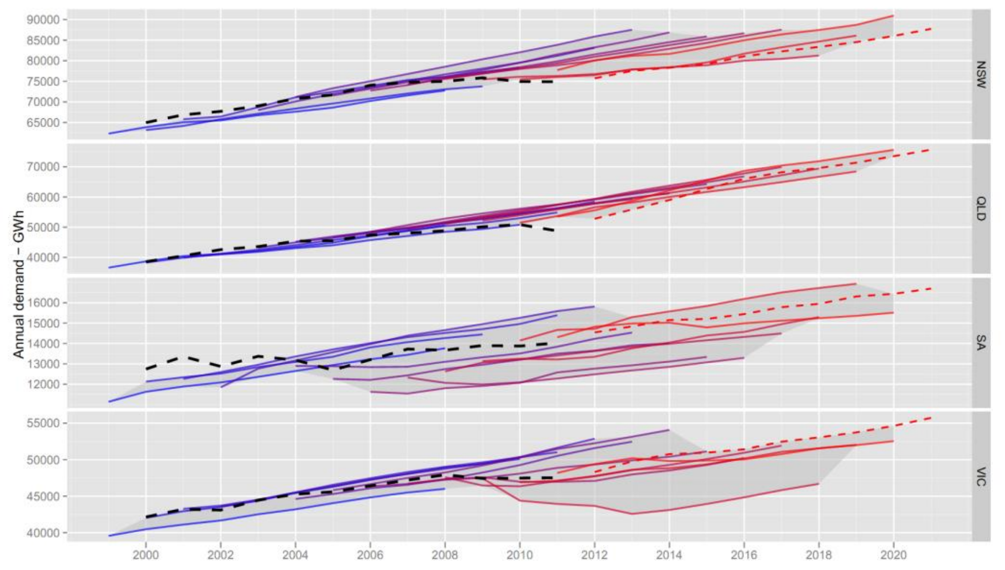
System demand forecasts

System demand forecasts are used as an input to *WHIRLYGIG* and *SPARK*.

We have used energy and maximum demand projections for each NEM region based on the AEMO 2011 ESOO. We have separately modelled the medium growth, 50% POE projections from the AEMO 2011 ESOO and the low growth, 50% POE projections from the AEMO 2011 ESOO.

The reason we have modelled two demand scenarios is that there is increasing uncertainty about demand forecasts from the ESOO. Over recent years, medium growth forecasts from the ESOO have tended to imply growth rates significantly greater than actual historical growth rates, particularly in Queensland and New South Wales. Figure 7 shows all previous ESOO medium demand forecasts, as well as actual demand. Growth in actual demand in Queensland and New South Wales has been almost flat over the last 3 or 4 years. However, over that time, ESOO demand forecasts have continued to forecast significant growth rates. Comparing actual demand (the dashed black line) with the AEMO 2011 ESOO medium demand forecasts (the dashed red line) shows that there is a substantial difference between actual growth rates and forecast growth rates.

Figure 7: AEMO ESOO demand forecasting – medium growth scenario



Source: AEMO

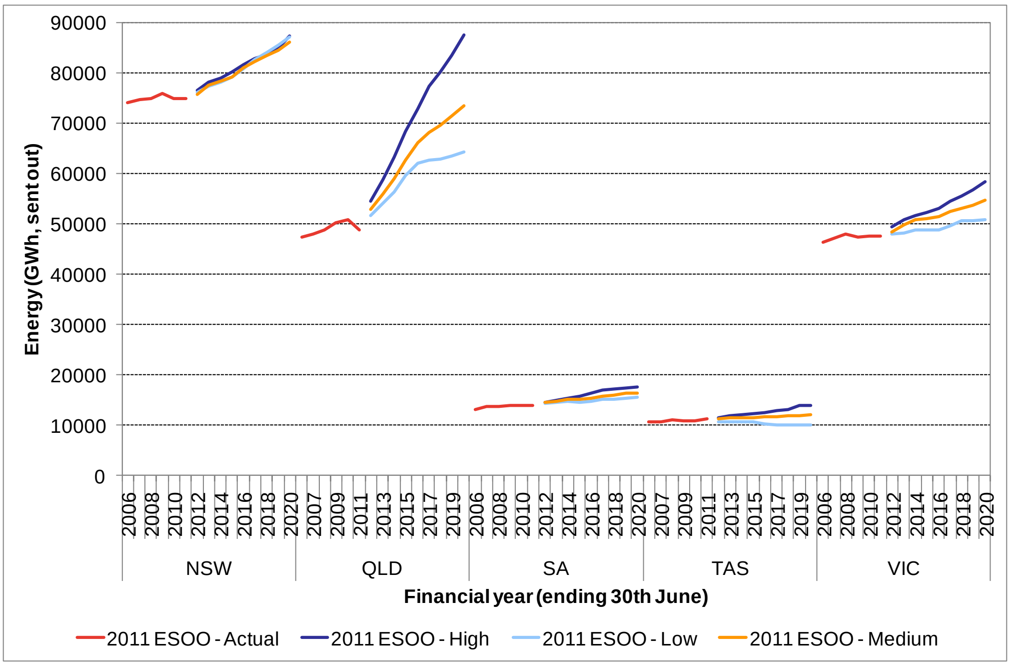
Note: 'Hotter' lines represent more recent ESOO forecasts. Dashed black line is actual historical demand. Dashed red line is 2011 ESOO forecast

Given the uncertainty about whether there will be an increase in the rate of demand growth in NSW and Queensland, we are modelling spot electricity prices in NSW for two scenarios:

- Medium Case – using the medium demand forecasts from the AEMO 2011 ESOO.
- Low Case – using the low demand forecasts from the AEMO 2011 ESOO.

Figure 8 compares the three demand forecasts from the AEMO 2011 ESOO for each NEM region. This shows that the low demand forecasts typically have a lower growth rate, and one that is more consistent with historical growth rates. The exception is NSW, which has similar demand forecasts for the low, medium and high growth scenarios.

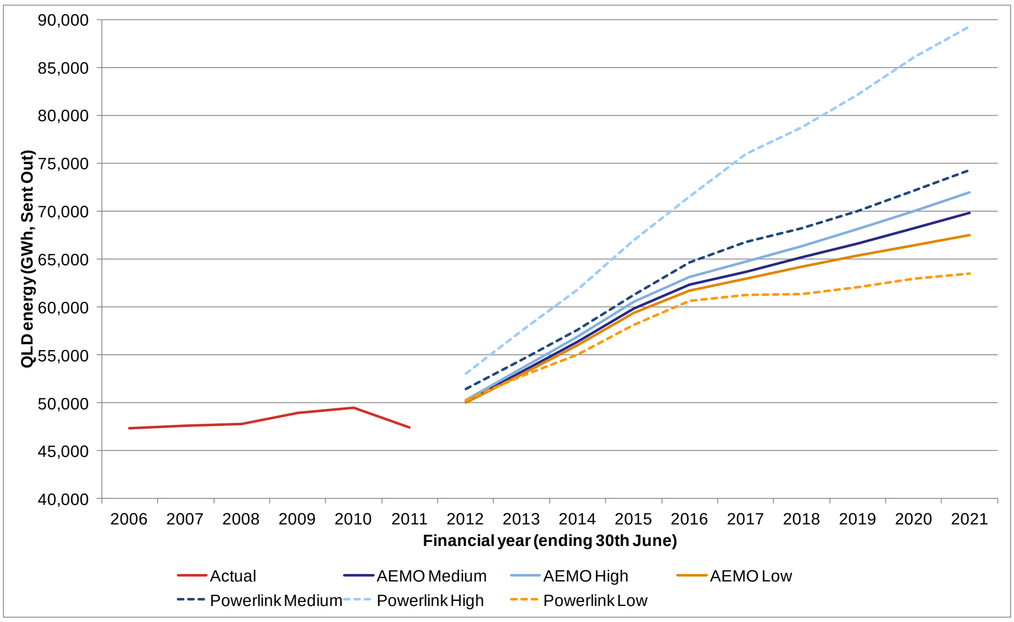
Figure 8: AEMO 2011 ESOO demand forecasts – all regions



Source: AEMO

The growth rates for Queensland shown in Figure 8 are particularly high. These forecasts are based on work by Powerlink, the TNSP in Queensland. In light of Powerlink's forecast showing energy growth significantly greater than historical outcomes even in the low energy scenario, AEMO has released their own forecast. The two sources are compared in Figure 9, which shows the AEMO data as solid lines and the Powerlink data as dashed lines. The AEMO forecast, whilst still aggressive, is more consistent with both historical outcomes and the forecasts in the other NEM regions. We have used the AEMO forecasts for both energy and peak demand in this analysis.

Figure 9: AEMO 2011 ESOO demand forecasts – Queensland, AEMO vs. Powerlink



Source: AEMO

For each scenario, we have also used 10% POE projections for summer and winter for the purpose of modelling reserve constraints. These 10% POE projections are assumed to be 100% co-incident, implying that maximum demand occurs in each NEM region at the same time. This assumption of co-incidence is made to ensure consistency with AEMO's reported regional reserve margins in the reserve constraints.

Existing NEM generation plant

We have used the latest information available from AEMO's website[3] on existing and committed scheduled and semi scheduled generation plant in each region of the NEM. This provides both the identity of existing and committed generation plant and the summer and winter capacity of these generation plant.

In addition, our models require key technical and cost information for existing generation plant.

The required technical information for existing generation plant includes the following:

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3 AEMO, Tables of Existing and Committed Scheduled and Semi Scheduled Generation – by Region. Available from:

http://www.aemo.com.au/data/gendata.shtml

- Expected outage rates – we have used the same information on outage rates as was used for our advice to IPART on regulated retail tariffs[4]
- Heat rate – we have used the information on the heat rate for existing generators that is set out in the ACIL Report for the QCA
- Emissions intensity – we have used the information on emissions intensity for existing generators that is set out in the spreadsheets accompanying the ACIL Report for the QCA that were provided to IPART by ACIL Tasman
- Auxiliary power – we have used the information on use of auxiliary power for existing generators that is set out in the ACIL Report for the QCA

The required cost information for existing generation plant is the following:

- Variable operating and maintenance costs – we have used the information on variable operating and maintenance costs for existing generators that is set out the ACIL Report for the QCA. We have assumed that variable operating and maintenance costs remain flat in real terms at these levels over time (which is consistent with the assumption in the spreadsheet provided to IPART by ACIL Tasman)
- Fuel costs – we have used the information on fuel costs for existing generators that is set out the ACIL Report for the QCA. Where the fuel costs for existing generators are not stated in the ACIL Report for the QCA, we have used the information on fuel costs for existing generators that is set out in the more detailed accompanying spreadsheet that was provided to IPART by ACIL Tasman

In addition to these assumptions on cost and technical information, our modelling also requires information on ownership of existing generation plant. This information is based on the latest available information.

New generation plant

We have used the ACIL Report for the QCA as the basis for input assumptions for our assumptions on new entrant generation plant.

The technologies that will be available as options over the modelling period are, therefore, black coal, brown coal, CCGT, OCGT, wind, hydro and biomass. We have not included geothermal as an option over the modelling period because we consider it unrealistic that geothermal will be available to any significant degree over the modelling period at the capital cost in the ACIL Report for the QCA (which is around $5,000/kW). At this capital cost, and taking account of the other geothermal assumptions in the ACIL Report for the QCA (particularly availability), geothermal will be lower cost than any other generation technology

4 AEMO, *2009 NTS Consultation: Final report*, 2009, Tables 20 and 21

in the NEM once a carbon price is introduced, and will be built in preference to coal-fired generation, gas-fired generation and all other renewable technologies. It is our view that the cost and availability of geothermal over the modelling period make it unlikely that investment in geothermal over this period will dominate investment in all other generation technologies.

As with the existing generation technologies, for each of the new entrant generation technologies our models require key technical and cost information.

The required technical information for new entrant generation plant includes the following:

- Expected outage rates – we have used the same information on outage rates as was used for our advice to IPART on regulated retail tariffs
- Heat rate – we have used the information on the heat rate for new entrant generators that is set out in the ACIL Report for the QCA
- Emissions intensity – information on emissions intensity for new entrant generators is not set out in the ACIL Report for the QCA. Therefore, we have assumed that the emissions intensity for a new plant will be the same as the emissions intensity of the most recently built plant of the same technology
- Auxiliary power – we have used the information on use of auxiliary power for new entrant generators that is set out in the ACIL Report for the QCA

The required cost information for new entrant generation plant is the following:

- Capital costs – we have used the information on capital costs for new entrant generations that is set out in the ACIL Report for the QCA. However, rather than using the learning curve for capital costs implied by the ACIL Report for the QCA, we have applied the same information on learning curves as was used for our advice to IPART on regulated retail tariffs, and applied these learning curves to the capital cost for 2010/11 from the ACIL Report for the QCA
- Fixed operating and maintenance costs – we have used the information on fixed operating and maintenance costs for new entrant generators that is set out in the ACIL Report for the QCA. We have assumed that fixed operating and maintenance costs remain flat in real terms at these levels over time (which is consistent with the assumption in the spreadsheet provided to IPART by ACIL Tasman)
- Variable operating and maintenance costs – we have used the information on variable operating and maintenance costs for new entrant generators that is set out in the ACIL Report for the QCA. We have assumed that variable operating and maintenance costs remain flat in real terms at these levels over time (which is consistent with the assumption in the spreadsheet provided to IPART by ACIL Tasman)

- Gas costs – we have used the information on new entrant gas costs that is set out in the ACIL Report for the QCA
- Biomass costs – we have used the information on new entrant biomass costs that is set out in the ACIL Report for the QCA
- Coal costs – as discussed in our most recent report to IPART on regulated retail tariffs for the standard retailers, neither the ACIL Report for the QCA nor the spreadsheet provided to IPART by ACIL Tasman provide new entrant coal costs. The ACIL Report for the QCA does contain a set of coal prices that ACIL uses in its LRMC modelling. However, these coal prices are simply an average of the coal prices to the existing coal-fired generators in the relevant region.

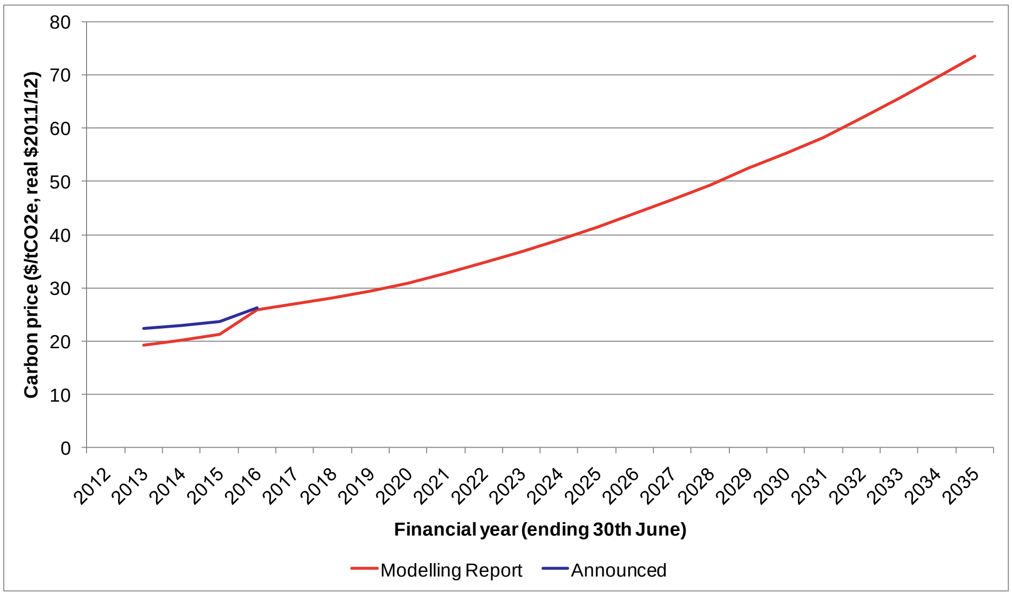
  For the purposes of this review, IPART have decided to continue with the same approach for new entrant coal price as was used in the most recent annual review: the new entrant coal price is determined by escalating the new entrant coal prices from the ACIL 2009 Report in line with average increases in mining cost indices over the previous ten years.[5] This implies an annual increase in coal prices of 4.1% in nominal terms.
- Maximum capacity factors – we have used the information on maximum capacity factors that is set out in the ACIL Report for the QCA.

Carbon price

Consistent with current policy, our modelling was undertaken on the basis that there will be a carbon price introduced from the beginning of 2012/13. The carbon price we modelled was the announced price for the fixed price period (2012/13 to 2014/15) followed by the carbon price path from the modelling report released by Commonwealth Treasury. The carbon price path is shown in Figure 10.

5 The index for open cut mining and the index for underground mining, both from the ABS' Producer Price Index, have been used to determine an average increase in mining costs over the previous ten years. The two indices have been given an equal weight.

Figure 10: Carbon price



Source: Commonwealth Treasury

LRET target

From 1 January 2011, the RET scheme has been split into the Large-scale Renewable Energy Target (LRET) and the Small-Scale Renewable Energy Scheme (SRES). As part of this process, the RET target was amended to include the LRET target and the adjusted LRET target (which accounts for the surplus of RECs available at the end of 2010). We used the adjusted LRET target in our modelling.

5 Spot price forecasts

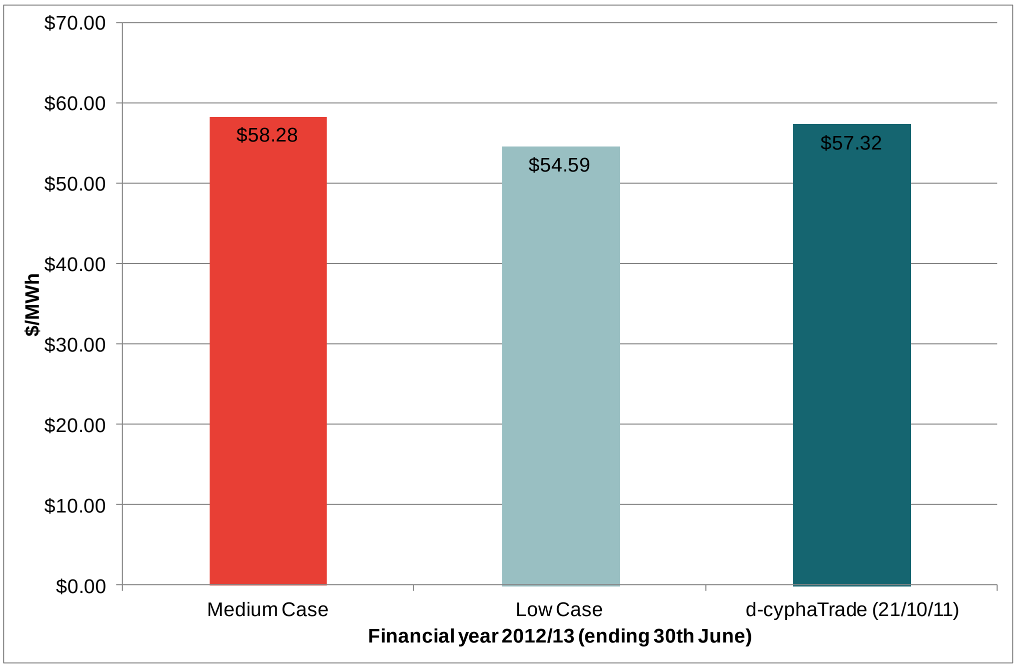
This sections sets out our forecasts of spot electricity prices for 2012/13, and discusses the affect that the introduction of a carbon price will have on spot electricity prices.

5.1 Spot price forecasts

As discussed in Section 4.1, we use *SPARK* to forecast spot electricity prices. Price forecast results for the NSW region from *SPARK* are presented in Figure 11. Price forecasts are shown for two scenarios:

- Medium Case – using the medium demand forecasts from the AEMO 2011 ESOO
- Low Case – using the low demand forecasts from the AEMO 2011 ESOO

Figure 11: NSW annual average spot price forecast ($2011/12)



Source: Frontier Economics

For the purpose of comparison, Figure 11 also shows the d-cyphaTrade forward prices for flat annual swaps in NSW as of 21 October 2011. The d-cyphaTrade prices provide an indication of the market view on future contract prices (and, by association, pool prices).

It can be seen in Figure 11 that our forecasts under the Medium Case are around $4/MWh higher than our forecasts under the Low Case. This is to be expected: with lower demand, there is a greater likelihood that demand can be met by low cost generation and less opportunity for strategic bidding by generators to increase prices. A large part of the difference in prices between Medium Case and the Low Case is driven by demand forecasts for Queensland: as discussed in Section 4.2, demand forecasts for Queensland are significantly lower in the Low Case, while demand forecasts for NSW are not.

It can also be seen in Figure 11 that Frontier Economics' spot price forecasts are close to the current d-cyphaTrade prices. Adjusting for the fact that Frontier Economics' forecasts are spot price forecasts (by applying Frontier Economics' assumption of a 5% contract premium) Frontier Economics' spot price forecasts for the Medium Case are around $4/MWh higher than the equivalent d-cyphaTrade price. However, Frontier Economics' spot price forecasts for the Low Case are almost exactly equal to the equivalent d-cyphaTrade price.

5.2 Effects of the carbon price

Since the spot electricity forecasts for 2012/13 account for the introduction of a carbon price, it is worth discussing the effects of a carbon price on spot price of electricity.

5.2.1 Effects of carbon price in the short-run

With the introduction of a carbon price generators will experience different increases in costs, according to their relative emissions intensity. This will result in a change in operation, with a general trend towards reduced output from coal generators and an increase in output from gas generators in the short to medium term.

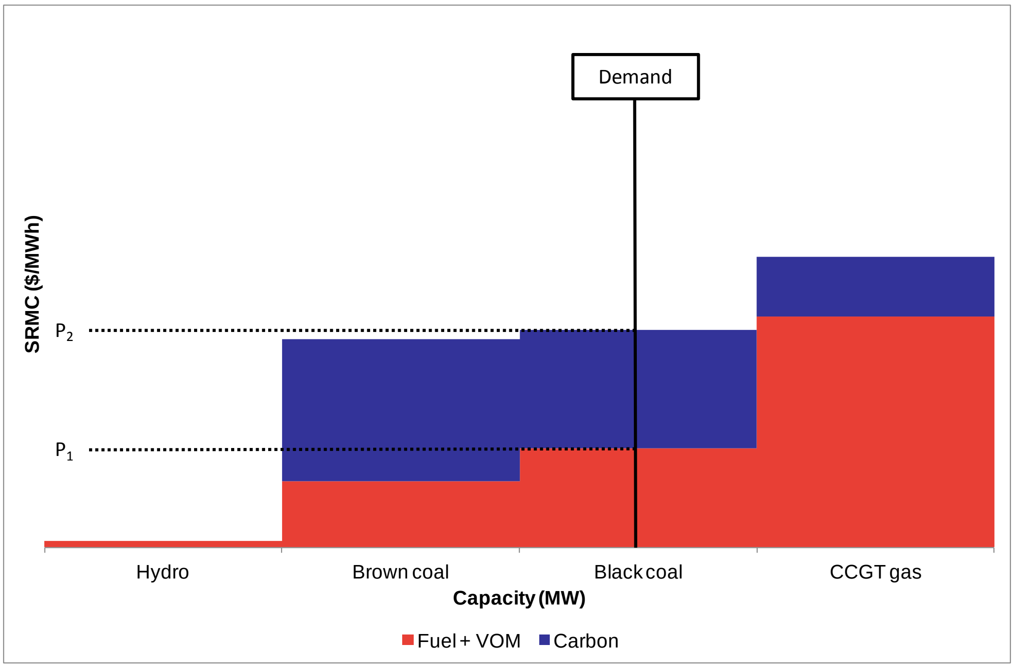
In the short-run, the mix of generation capacity in the electricity sector is relatively inflexible. As a result, the opportunities for abatement are limited to changing the operations of existing plant, such as running existing gas generators more often and coal generators less often. In the long run, as demand grows and existing plant is retired, more opportunities arise to reduce emissions through investment in new lower emissions generators.

A simple example of the effect of a carbon price on spot electricity prices can illustrate the short-run effects of a carbon price. For the purpose of this example, four types of generating plant are considered, each with constant short run marginal cost (SRMC) over output. In this highly stylised example, the supply curve for electricity can be represented by the "merit order": plant is ordered by SRMC (ie, there is no strategic bidding) from lowest to highest, and the intersection of demand and supply determines the market price. The carbon price will increase the costs of black coal and brown coal generators most, as these are higher emitters. It will also increase the cost of gas generators, but by a lesser amount because gas generators emit less greenhouse gas then coal generators.

The merit order for this hypothetical example is represented in Figure 12, for a moderate carbon price. When a carbon price is introduced, generators will add the carbon cost to their bids. At this carbon price, the change in costs is not sufficient to change the merit order, which means that there will be no reduction in the emissions intensity of supply. At the level of demand shown, the black coal generator will be the marginal generator and will set spot electricity prices with or without a carbon price.

When a carbon price is introduced, the change in the spot electricity price depends on (a) the carbon price and (b) the emissions intensity of the marginal generator before and after the cost of carbon is introduced. In this example in which the merit order is unchanged by the carbon price, the effect of the carbon price on the spot electricity price is a function of the carbon cost faced by the black coal generator (P_2-P_1).

Figure 12: Stylised example of carbon costs – no change in merit order



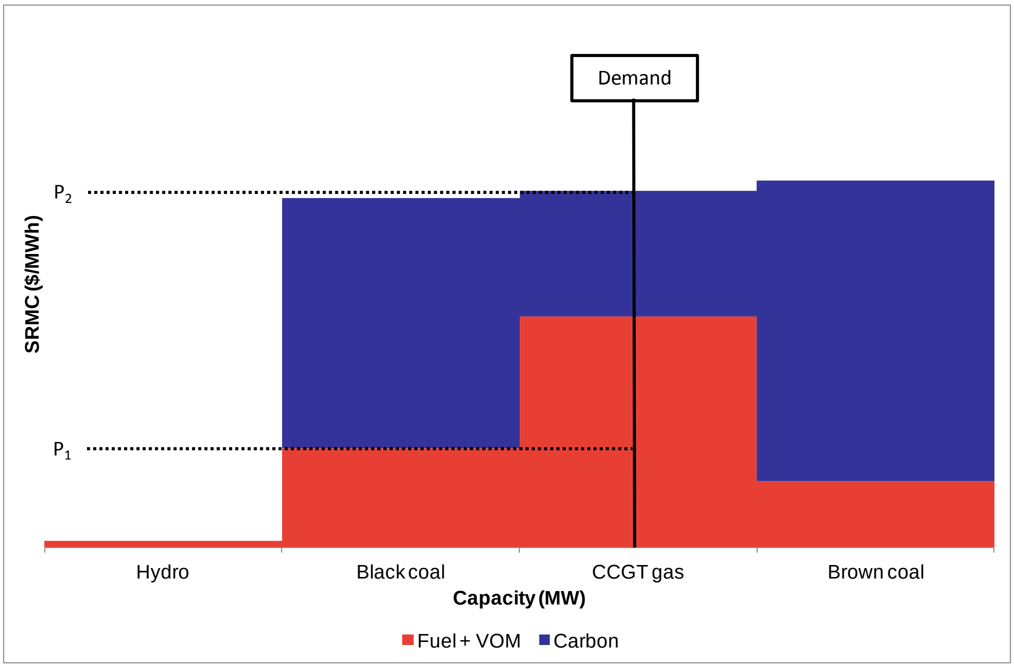
Source: Frontier Economics

In order to achieve abatement from the generation sector, the carbon price must be high enough to change the merit order. The merit order in Figure 13 reflects a higher carbon price. At this higher carbon price, and in this simple example, the

CCGT generator displaces the brown coal generator in the merit order, and becomes the marginal plant. This results in a reduction in emissions.

Estimating the effect of the carbon price on the spot electricity price in this instance is more difficult since the marginal generator changes when the carbon price is introduced. In this instance, the change in price is P_2-P_1, or the difference between the SRMC of a black coal generator *without* a carbon price and the SRMC of a CCGT generator *with* a carbon price.

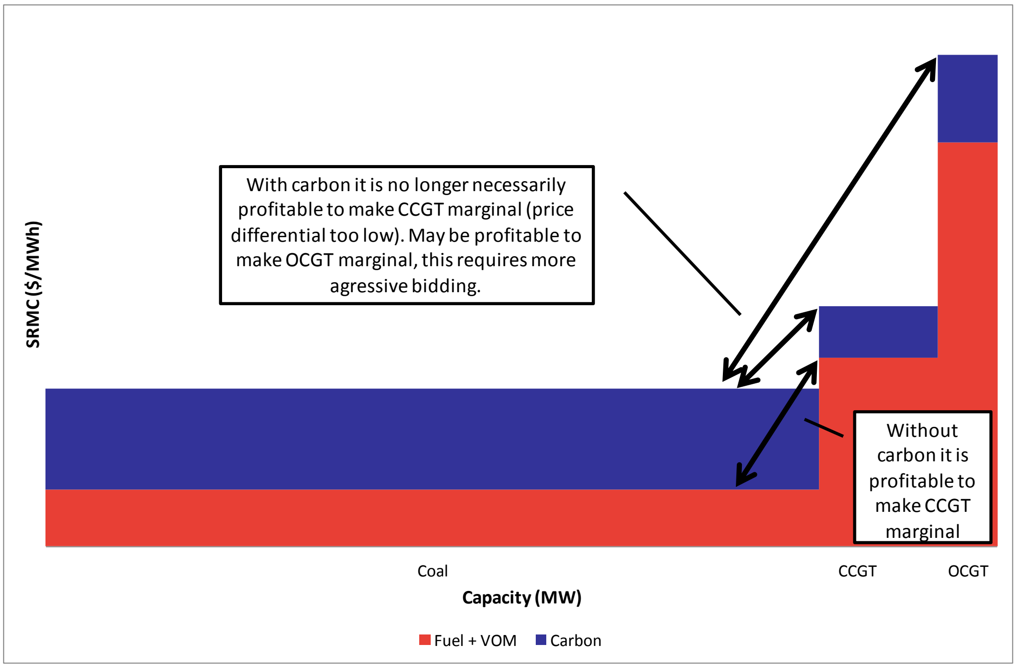
Figure 13: Stylised example of carbon costs – with change in merit order



Source: Frontier Economics

The simple examples highlighted above assume that all plant is bid into the market at SRMC. In practice, some generators may have strategic incentives to bid in other ways at certain times. For instance, generators may withhold some of their capacity from the market to require the operation of high cost plant to meet demand or they may bid their capacity at a price higher than SRMC. The introduction of a carbon price, and the resulting change to the merit order, can change these incentives. For instance, as the relative price differential between coal generators and CCGT generators reduces, it may become less profitable for strategic coal generators to withhold some of their capacity in order to require the operation of a CCGT generator to meet demand. Conversely, the price differential between coal generators and OCGT generators remains high. What this can mean, particularly in the early stages of a carbon price, is that strategic coal generators may be incentivised to engage in even more aggressive withdrawal strategies in order to require the operation of an OCGT generator to meet demand, resulting in higher prices. This concept is illustrated in Figure 14.

Figure 14: Diagrammatic representation of bidding incentives with a carbon price



Source: Frontier Economics

5.2.2 Accounting for the carbon price in Frontier Economics' modelling

As discussed in our report for IPART on the determination of electricity tariffs for 2010/11 to 2012/13,[6] under our modelling approach the pass-through of the carbon price into spot prices is not a modelling input, but is a modelling output. That is, we do not increase a modelled carbon-exclusive spot price by the carbon price adjusted for an assumed rate of carbon pass-through. Rather, our modelling includes input assumptions that define the extent to which the costs of each generator increase as a result of a carbon price (which is determined by the carbon price and each generators' emissions intensity). This increase in each generator's SRMC is incorporated in both *WHIRLYGIG* and *SPARK*. This reflects the way that a carbon price will be reflected in spot electricity prices: the

6 Frontier Economics, *Energy purchase costs*, A Final Report Prepared for IPART, March 2010.

effect is a result of the way that generators bid in response to the carbon costs that they each face, and can only be determined by comparison between a market with a carbon price and the same market without a carbon price (and is therefore not observable in practice).

5.2.3 The impact of the carbon price on electricity customers

From the perspective of determining the market value of solar PV exports, it is the impact of the carbon price on spot electricity prices that is relevant.

From the perspective of electricity customers in general, however, it is the impact of the carbon price on retail electricity prices that is relevant.

While the effect of the carbon price on spot electricity prices is an important determination of the impact of the carbon price on retail electricity prices, it is not the only relevant factor. Retailers do not simply purchase electricity from the spot market to supply their customers; rather, in order to manage the risk associated with volatile spot electricity prices, retailers hedge their exposure to spot electricity prices through a range of hedging contracts. The cost to a retailer of supplying a retail customer is, therefore, a function of the cost of hedging that load. Certainly, the cost of hedging a load will be affected by the introduction of a carbon price because the price of hedging contracts reflects expectations about the spot price. However, the cost of hedging a load will also be affected by the volatility of spot electricity prices, the shape of the customer load to be supplied and the relationship between prices and load.

More specifically, in the case of customers on the regulated retail tariff in NSW, the effect of the carbon price on retail electricity prices will be a result of the approach to determining tariffs that IPART is required to adopt under its terms of reference. In particular, regulated retail tariffs are based on the higher of the cost of hedging a load and the LRMC of supplying that load. While the former will be affected by the rate of carbon pass-through in the spot market the latter will not. Rather, the LRMC of supplying the retail load will reflect a much different rate of carbon pass through that would occur in the hypothetical 'greenfields' generation mix that is the basis for calculating that LRMC.

6 Conclusion on 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. It is calculated as the product of half-hourly solar PV exports and half-hourly spot prices.

We have calculated the market value of solar PV exports for four cases:

- **Historical** – in this case, the market value of solar PV exports is based on actual half-hourly exports for residential solar PV installations in Ausgrid's distribution area and actual half-hourly spot electricity prices. We have calculated the historical market value for the two financial years for which data is available: 2009/10 and 2010/11.
- **Annual review** – in this case, the market value of solar PV exports is based on actual half-hourly exports for residential solar PV installations in Ausgrid's distribution area and the forecast spot electricity price for 2011/12 from IPART's most recent annual review. To preserve the correlation between exports and prices, we have used actual exports from 2010/11 and shaped the forecast spot electricity price for 2011/12 to the half-hourly historic prices in 2010/11.
- **Forecast – Medium case** – in this case, the market value of solar PV exports is based on actual half-hourly exports for residential solar PV installations in Ausgrid's distribution area and the forecast spot electricity price for 2012/13 – for the Medium Case – discussed in Section 5. To preserve the correlation between exports and prices, we have used actual exports from 2010/11 and shaped the forecast spot electricity price for 2012/13 to the half-hourly historic prices in 2010/11. This case has been provided to allow IPART to compare outcomes under the financial gain approach and the wholesale market value approach (these two approaches were discussed in Section 1.2).
- **Forecast – Low case** – in this case, the market value of solar PV exports is based on actual half-hourly exports for residential solar PV installations in Ausgrid's distribution area and the forecast spot electricity price for 2012/13 – for the Low Case – discussed in Section 5. To preserve the correlation between exports and prices, we have used actual exports from 2010/11 and shaped the forecast spot electricity price for 2012/13 to the half-hourly historic prices in 2010/11.

The results for each of these cases, and for each panel rating, are shown in Figure 15. A few things stand out from this figure.

First, there was a substantial difference between the market value of solar PV exports in 2009/10 and 2010/11. As discussed in Section 2.3, this is a result of the significant difference in the average shape of half-hourly spot electricity prices during these years, with 2009/10 representing an extreme year.

Second, the forecast market value of solar PV exports for 2012/13 is higher than the forecast market value of solar PV exports for 2011/12. This reflects the increase in spot electricity prices from 2011/12 to 2012/13, largely as a result of the introduction of a carbon price. The difference between the Medium Case and the Low Case also reflects different forecasts of the spot electricity price in 2012/13, due to the different demand conditions.

Third, the difference in the market value of solar PV exports for different panel ratings tends not to be dramatic. This can be seen more clearly in Figure 16, which shows the market value of solar PV exports for the forecast cases only. For the Medium Case, the difference in market value across panel ratings ranges from a low of around $75/MWh (for the 1.5 kW systems) to a high of around $95/MWh (for the 4 kW systems).[7] What this indicates is that even though the volume of exports for different panel ratings may vary significantly, the weighted average spot when export occurs is relatively consistent.

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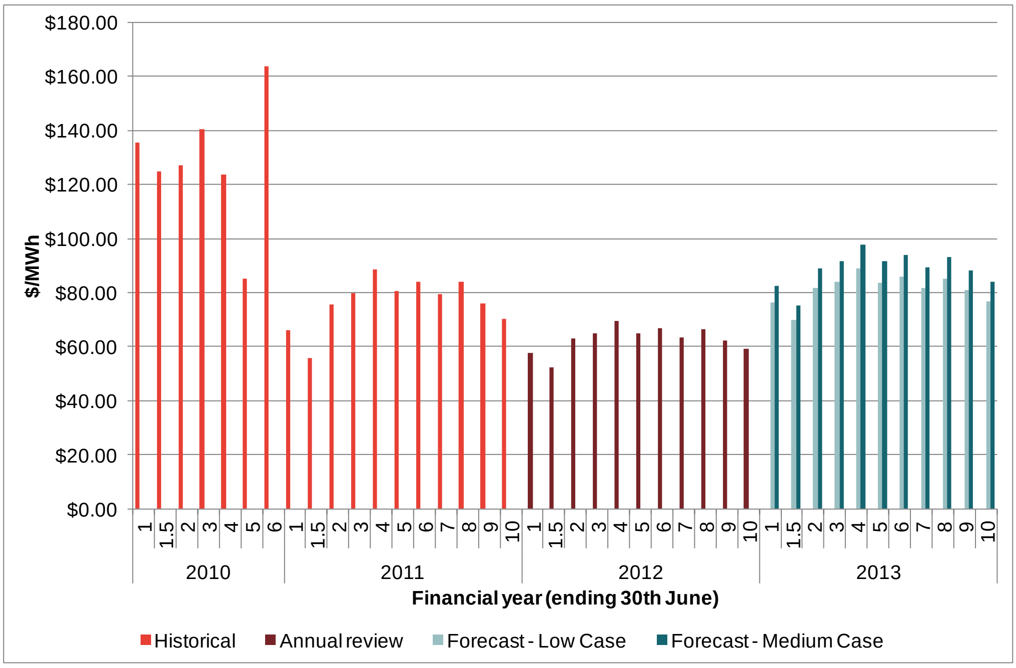
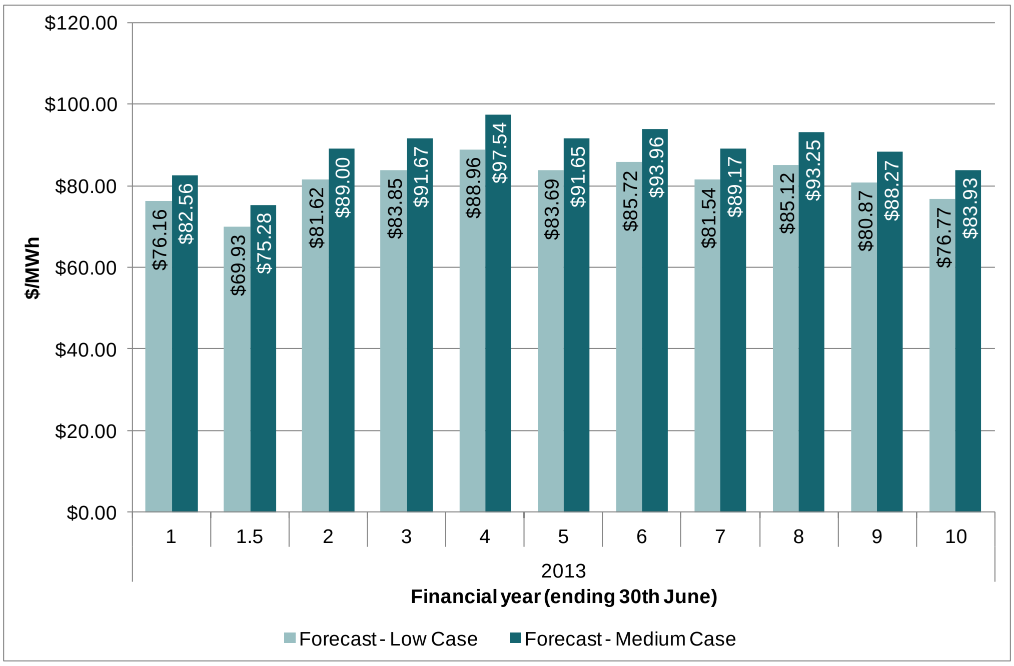
7 It is worth noting that the relative value solar PV exports for different panel ratings will not always be the same, but will vary each year as the half-hourly spot prices vary.

Figure 15: Market value of solar PV exports – All cases ($2011/12)



Source: Frontier Economics

Figure 16: Market value of solar PV exports – Forecast cases ($2011/12)



Source: Frontier Economics

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