Submission
No 4

INQUIRY INTO ELECTRICITY SUPPLY, DEMAND AND PRICES IN NEW SOUTH WALES

Organisation: Climate Change Balmain-Rozelle

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To:

Legislative Council Select Committee
on Electricity Supply, Demand and Prices in New South Wales

Please note that this submission was originally provided to the IPART enquiry earlier in 2017.

As this present enquiry covers a similar field, we are submitting it as it stands. We stand by the calculations and the arguments in this document.

Derek Bolton
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Submission from

Climate Change Balmain-Rozelle[1]

on IPART's Draft Recommendation for

Solar feed-in tariffs in 2017-18[2]

Derek Bolton, 18/5/17

Abstract

The fair value for the NSW grid of small scale PV is analysed based on data for January 2015 and 2016. The analysis includes estimates of the spot prices and poles-and-wires costs had there been no PV.

Different definitions of "fair value" are considered.

Summary of Conclusions

For the month of January 2016, depending on how a fair value per kWh is defined, it may argued to be, at the extremes:

- *6.7c for each kWh fed in, or,*
- *23c/kWh generated,* ***plus*** *6.7c/kWh for that portion fed in*

In addition, shaving peak network capacity requirement by existing small scale PV is worth

- *$50 per nominal kW of panel per year.*

On average, that equates to 3.5c/kWh generated, or 7c/kWh fed in.

For 2017/18, 6.3c/kWh can be added to the above figures.

Recommendations

1. *That IPART adopt one of the fairer valuation principles developed below.*
2. *That IPART desist from down-rating the future value of PV feed-in on the basis that it will have lowered peak demand yet further.*
3. *That IPART recommend a mandatory minimum feed-in tariff of at least*
   - *13.5c/kWh off-peak, 16.5c/kWh peak, or*
   - *15c/kWh flat*
4. *That IPART recommend a discretionary feed-in tariff range of*
   - *13.5c-18.5/kWh off-peak, 16.5-21.5c/kWh peak, or*
   - *15c-20c/kWh flat*

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1 http://www.climatechangebr.org/

2 https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/pricing-reviews-energy-services-publications-review-of-solar-feed-in-tariffs-201718/fact-sheet-review-of-solar-feed-in-tariffs-2017-18-may-2017.pdf

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1 Historic Undervaluation

"Our terms of reference require that there should be no increase in retail electricity prices to provide subsidised feed-in tariffs."

Every IPART assessment has undervalued fed in PV power as a result of the way this requirement has been interpreted.

No increase compared with what? Compared with what customers are paying now, or compared with what they would be paying without the benefit of the power generated by grid-connected PV?

IPART has always taken the former view, using the ***current marginal*** value of each additional kWh fed in today. This completely ignores the benefit that all grid customers enjoy from the way that the existing PV has reduced peak demand.

Were PV households united as a negotiating entity, like a union, they could demand, and get, a price based on the totality of the current feed in, not the marginal value of further feed in.

In between thes two extremes, the current marginal rate and the "***unionised***" price, a ***fair free market*** view would be:

- start with a spot price model based on current electricity consumption but no PV generation;
- incrementally add PV generation and feed-in at the spot price, that price diminishing as more is added;
- continue until the present level of PV generation and feed-in is reached.

Since PV generation is still a relatively small portion of the total, the price decline during that process would be roughly linear over that range. The resulting average price for the feed in would therefore be about the mid point between the initial marginal rate (i.e. with no feed in) and the current marginal rate.

Thus, a truly free market would provide a fairer and higher price than calculated by IPART.

Interpreting the requirement in respect of what customers are paying now, in the context of existing PV feed in, perpetuates the unfairness. It is exacerbated by the way IPART determines the solar premium[3]:

"we have used the 25th percentile solar premium, rather than the median. This is because we consider that the pattern of high prices in the middle of the day during 2009-10 and 2010-11 may not be representative of future years"

In other words, IPART anticipates that increasing PV feed-in will further erode the marginal value. As an analogy, this is like an employee with a company car declaring its value as a fringe benefit based on how useful she would find a *second* company car. The ATO may demur.

A third interpretation of "no net price increase for other consumers" can be justified. Suppose that all the rooftop PV generated today were self-consumed, so no feed-in to the grid. Both the current marginal rate view and the fair free market view would calculate zero value. Yet the lowering of peak demand on the grid reduces the peak spot prices, benefiting all grid customers. Remunerating PV households for the totality of benefits to other customers we will call the ***cost neutral*** view.

In terms of the values that would be calculated on these various interpretations:

current marginal < fair free market < unionised < cost neutral

It is stressed that all of these are valid interpretations of IPART's "no increased cost" principle.

2 A case study: January 2015/2016

This analysis attempts to place a fair value on small scale PV power in the NSW grid in the periods of January 2015 and 2016. It considers:

1. The value to the grid of the kWh fed in.
2. The savings on network cost by reduced peak load.

3 IPART's "solar premium" reflects the positive correlation between PV feed-in and high spot prices

2.1 Notation

Symbol	Meaning
kWp	The peak power output (kW) of a set of PV panels
kWe / kWhe	The actual power (kW)/energy (kWh) from the PV panels
kWf / kWhf	The power/energy fed into the grid from the PV panels

Fig 1 Power and energy units

3 Method

3.1 Time base

All times are AEST. The month of January is selected as the one with the greatest likelihood of extreme spot prices and network peaks.

3.2 Total Demand and Spot Price Response – A Model

For the value of existing PV, we need a way to estimate what the spot prices would have been without any. This requires constructing a general model of how the price depended on demand over the sample years. The price is subject to sudden and violent peaks, with demand not being the sole cause, as illustrated in Fig 2, Fig 3 and Fig 4.

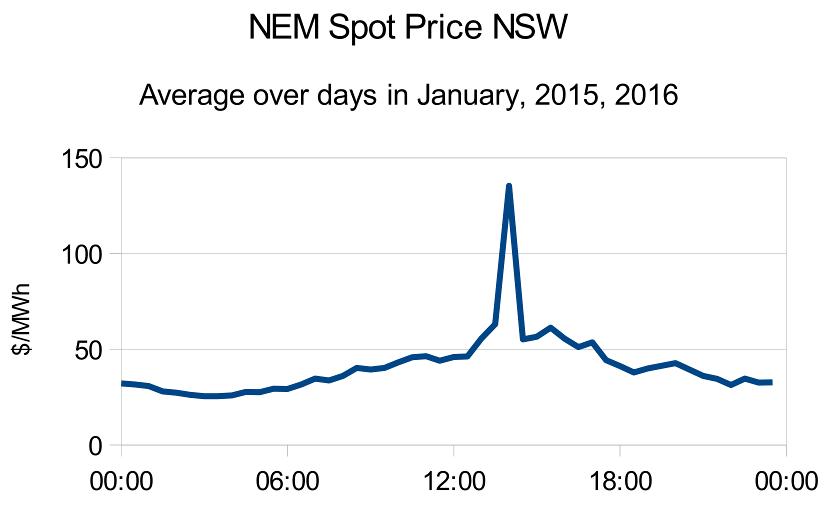


Fig 2: Spot price by time of day averaged over month

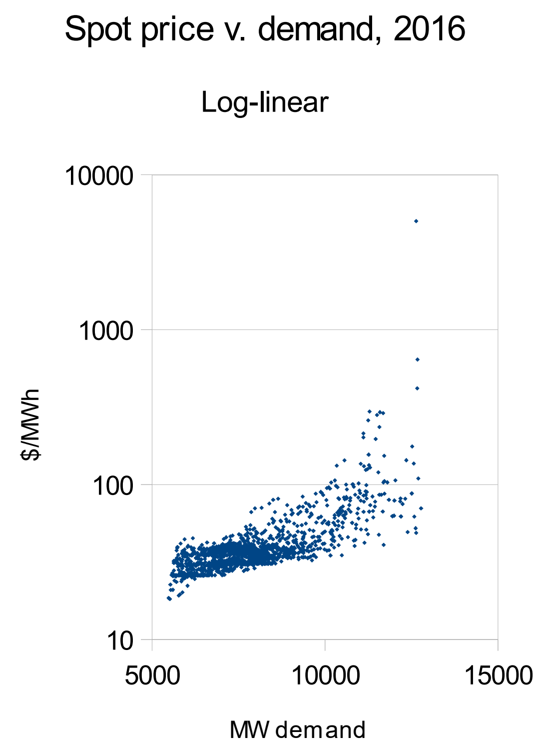


Fig 3

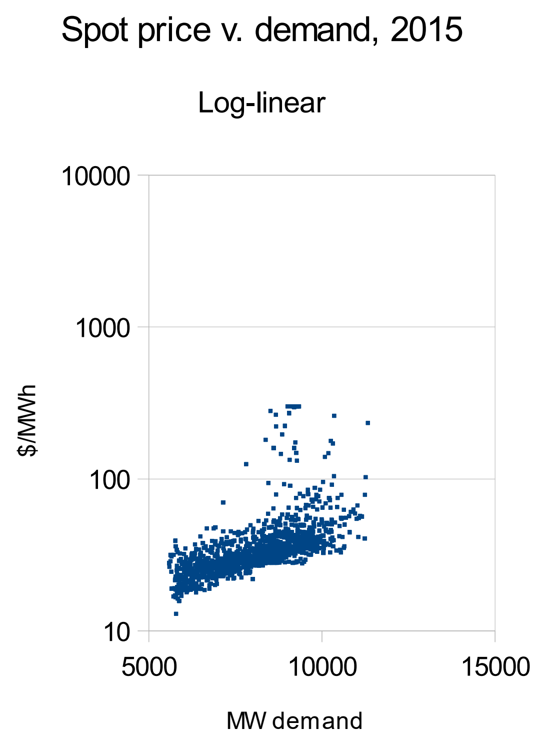


Fig 4

Fig 3&4: Erratic relationship between demand and spot price

The relationship appears roughly linear on a log-linear scale. Accordingly, the price is modelled as an exponential function of demand.

$$\text{price} = \alpha\, e^{\beta\,(\text{demand})}$$

For present purposes, the model accuracy is most critical when PV production is high. To compare the model with reality, the theoretical earnings of feeding the PV in is calculated for both the modelled price and the actual price. The model is tuned such that it does not overestimate the total earnings.

Year	α	β	Error in total $
2015	$3.13	0.3/GW	-0.3%
2016	$1.54	0.4/GW	-0.11%

Fig 5: Parameters for price model vary by year

The validity of the model can be assessed in several ways. Since we mainly require accuracy in respect of PV earnings, we can compare (Fig 6) the total over all PV fed in that would have been earnt at the actual spot price with what would have been earnt at the price predicted from demand. This calculation takes into account the pattern of PV generation across the day.

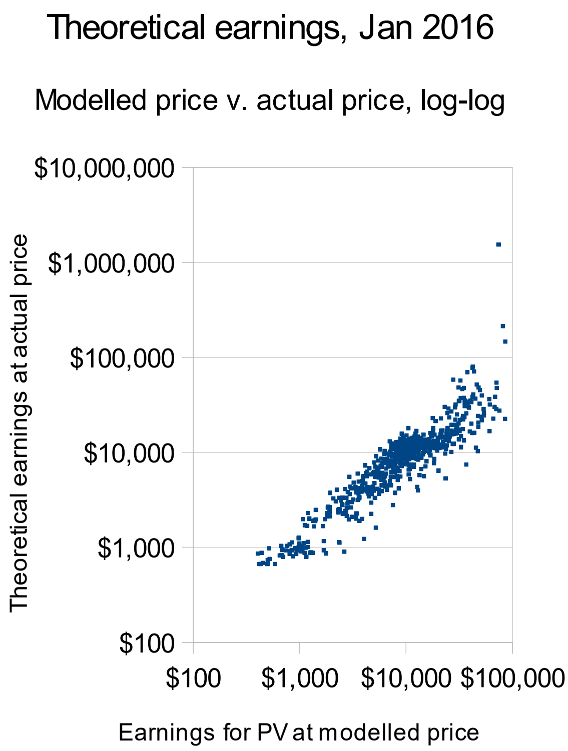


Fig 6: Total PV earnings, modelled v. actual price

The same comparison, but per day across the month, is shown in Fig 7 and Fig 8. The gaps in the charts are the hours when there is no PV generation:

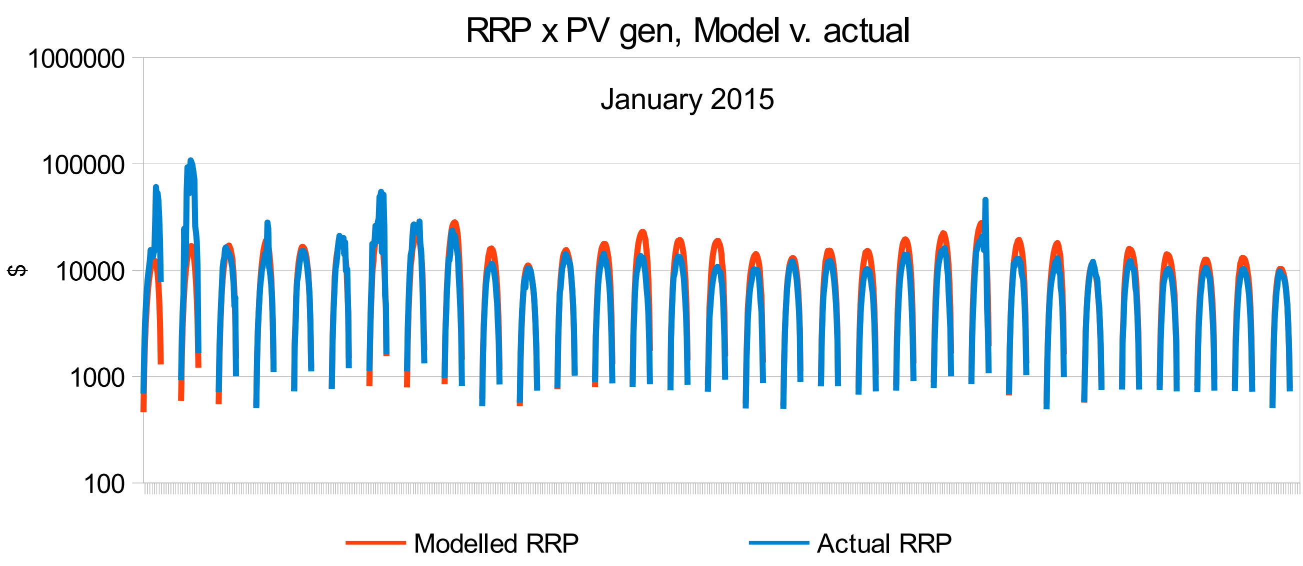


Fig 7: Predicted spot price from demand, Jan 2015

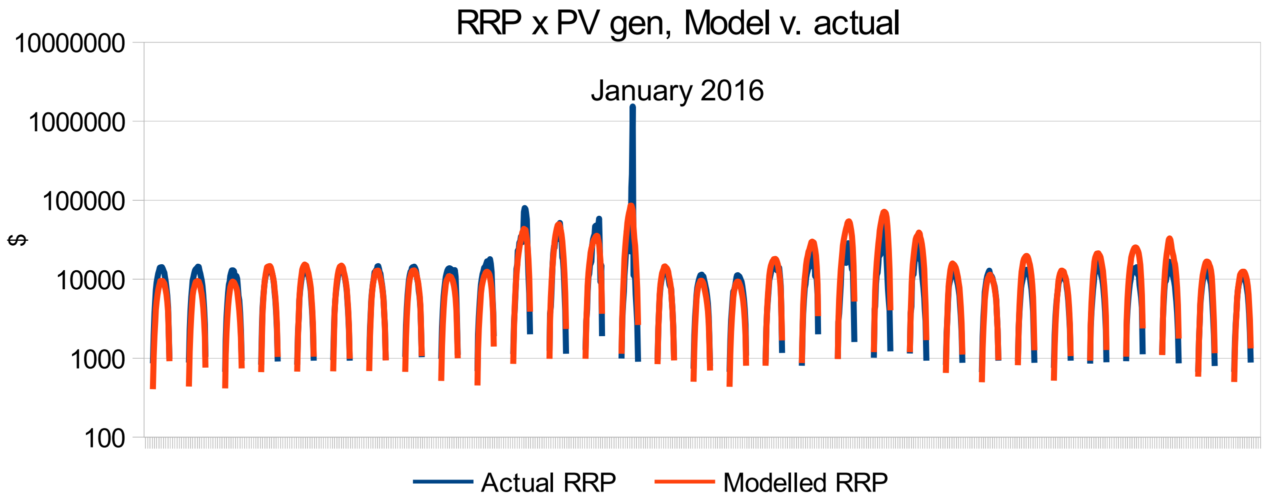


Fig 8: Predicted spot price from demand, Jan 2016

3.3 Total Demand without PV

The actual demand reported by the NEM treats small scale PV power, whether self-consumed or fed into the grid, as a reduction in demand. To arrive at the true demand, the estimated PV output is added back in in Fig 9.

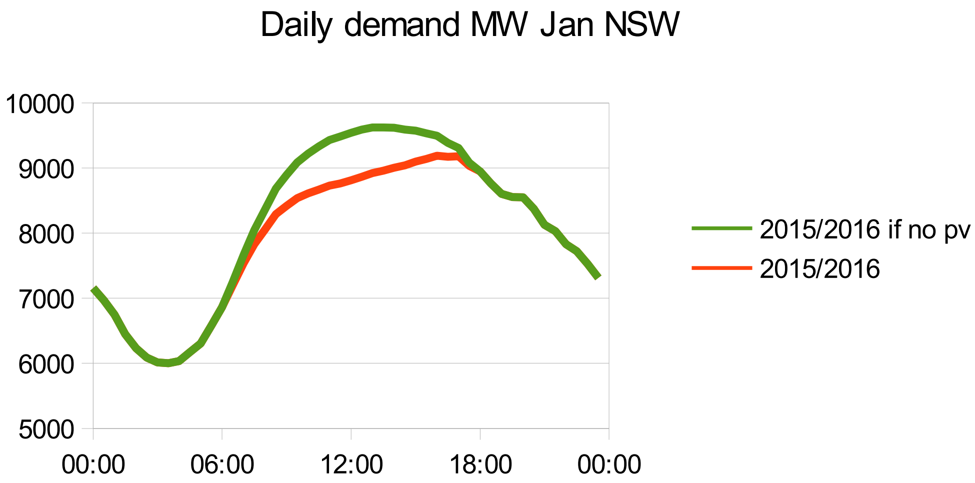


Fig 9: Daily demand with and without PV generation, 2015 and 2016 January average

3.4 Actual feed in

Self-consumption by PV households is taken to average 60%. That is a relatively high figure, typical only of systems up to 1.5kW. It is chosen here as an opposite extreme to the "all fed in" case.

The demand pattern of a PV household is assumed to be as is typical of domestic demand. The Summer daily profile is shown in Fig 10.

Thus, feed-in per kW of panel at a given time of day, *t*, is given by:

fed_in_power(t) = max{power_output(t) – demand_profile(t) x scale_factor, 0}

where *scale_factor* is adjusted to make the total feed-in over the day equal 40% of the power generated.

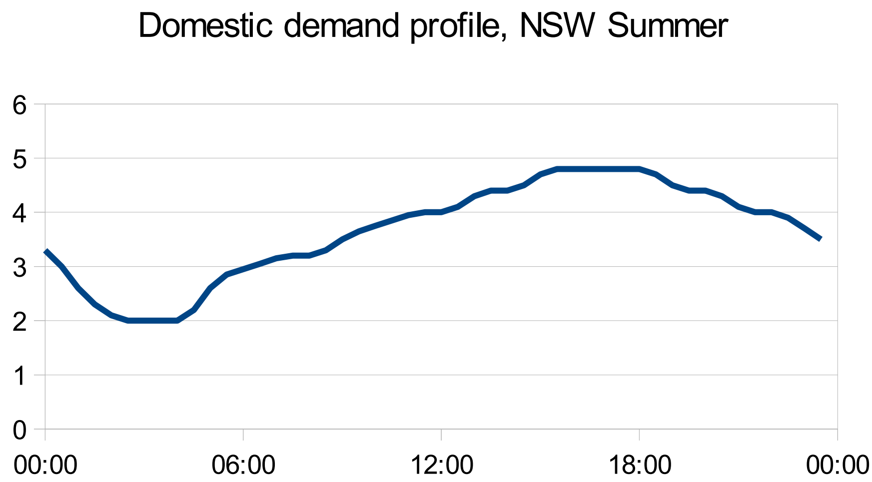


Fig 10: Domestic demand profile, NSW Summer

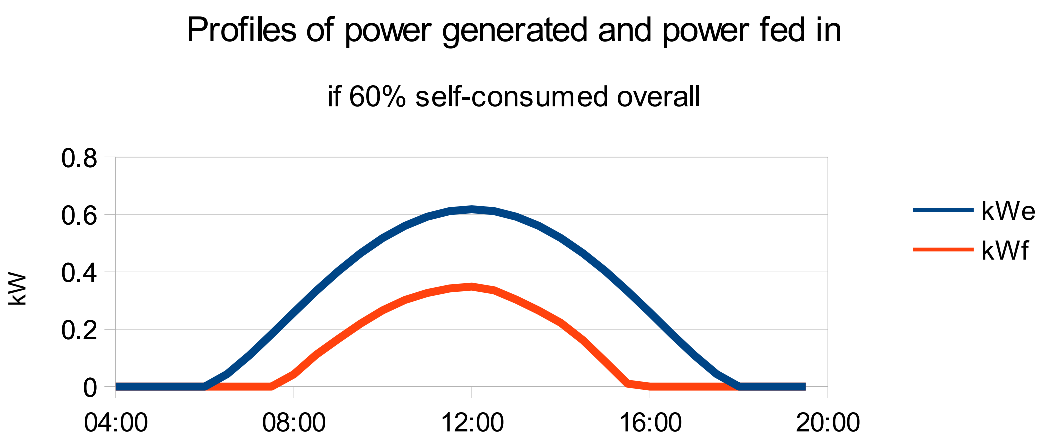


Fig 11: PV generation and feed in profiles

3.5 Network Cost

In addition to the savings on cost of power generation, distributed PV reduces the capacity needed by the poles and wires.

Retailers charge business customers a cost-reflective fee of 33c/kW per day, excluding GST, based on the peak kW drawn by the customer in the calendar month. Allowing for overhead and profit, this suggests a network cost of $300 per day per MW of grid capacity. But not all businesses will draw their peak demand at the same time, so if this is truly cost-reflective the grid capacity must cost more, say $400/MW-day. Further, this charge applies each month, even though the peak demand on the grid occurs mostly in summer months. Thus, we take the cost of providing and maintaining the poles and wires to be $140,000 per MW of peak per annum.

The network savings from PV generation can be computed from the estimated reduction in peak demand. Note that these savings come from all PV generated power, not just that fed in to the network. That which is fed in will mostly be consumed within the same few streets.

4 Results

4.1 Value, all fed in

January	2015	2016
c/kWh value of PV, free market basis only	5.04	6.80
Additional c/kWh value of PV, cost neutral basis	9.1	20.0

Fig 12: Two valuations of PV, assuming all fed in

4.2 Value, 40% fed in

On the cost neutral basis, both self-consumed power and fed in power have value to other network customers because of the price depression.

It is to be expected that excess domestic generation would be low when demand is high, but it turns out to have only modest overall consequence on the free market value.

January	2015	2016
c/kWh value of PV fed in, free market basis only	4.96	6.63
Additional c/kWh value of PV generated, cost neutral basis	9.1	20.0

Fig 13: Valuations of energy and power, 40% fed in on average

4.3 Network Savings

Year	Case	Peak MW	$/MW-year	$/year
	Actual	11325	140000	$1,585,553,200
	if no PV	11719	140000	$1,640,612,362
2015	Saved by PV	393	140000	$55,059,162
	Actual	9101	140000	$1,274,155,716
	if no PV	9525	140000	$1,333,524,054
2016	Saved by PV	424	140000	$59,368,337

Fig 14: Network capacity savings by reduced peak

Expressing the average savings in terms of kW of PV installed and kWhe of electricity generated:

Savings as per kW panel installed	$50.47 /year
Savings as per kWh generated	3.55 c

4.4 Net value of small scale PV in January 2015/2016

Combining the spot price savings (free market basis) with the network savings is problematic since one depends on energy fed in while the other depends on power generated. However, if forced to express all in terms of energy fed in, the total for January 2016 is 6.63+5.92 = ***12.5c/kWhf***. The figure is lower if a higher feed-in fraction is used.

4.5 Incremental Value of further small scale PV

We evaluate an additional kW of PV by performing the same calculations, but now using the actual demand and price values. Note that while this reflects the value of *further* PV feed-in, it does not affect the fair value of existing feed-in.

Because the existing PV has shifted peak demand to later in the day, an extra 1kW panel only trims an average of 0.1kW from peak demand.

January	1kWp
Value to grid of PV fed in, free market basis	5.65c/kWhf
Additional Value of PV generated, cost neutral basis	25c/kWhe
Savings in reduced network capacity need	$15.78/year

Fig 15: Valuation of 1 kW of panel added now

4.6 Adjustment for 2017/18

For 2017/18, IPART has determined a draft benchmark 6-7c/kWh above its 2016/17 estimate. Since this is almost entirely driven by anticipated increase in wholesale prices, it is reasonable to extrapolate the conclusions above by adding the same delta to PV feed-in.

Analysis[4] of three days of the February 2017 NSW heatwave has shown that solar PV slashed the cost to the grid of purchasing power by $888m. This amply illustrates that the benefit of solar PV generation to all customers continues unabated.

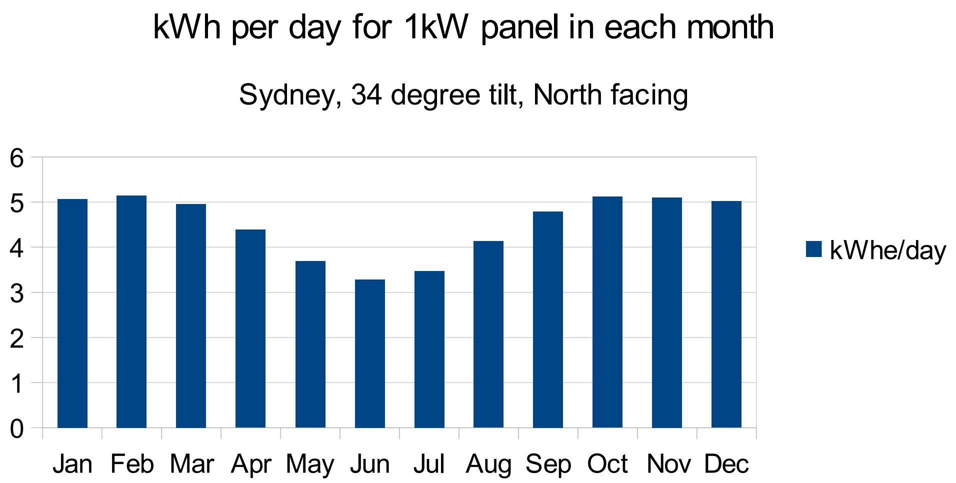
4 http://www.wattclarity.com.au/2017/02/small-solar-owners-saved-the-nsw-electricity-market-888-million-during-heatwave/

5 Data Sources

5.1 PV output profile

The pattern of PV output from a panel is modelled using standard equations for the sun's position as a function of time of day and day of year at Sydney. All existing panels are presumed to be oriented N and at 34 degrees to the horizontal.

Note that this profile is only used to model the *pattern* of power generated across a January day and across the months of the year.



The overall amplitude is adjusted to fit the generally agreed average power over a year in Sydney, namely, 3.9kWh/day for each kWp.

5.2 Network Demand and Prices

Half hourly demand and price data are from AEMO, http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Data-dashboard#aggregated-data

5.3 Total small scale PV in NSW in 2016

According to the Clean Energy Regulator, the total small scale PV operational in NSW in 2016 was1,182,300kW[5].

5.4 Summer Domestic Demand Profile

From AEMO data, via http://www.solarchoice.net.au/blog/home-energy-consumption-versus-solar-pv-generation/

5.5 Fraction fed in

The relationship between system size and fraction self-consumed is illustrated in Figure 6 at https://www.energycouncil.com.au/media/6016/2016-06-10_australian-energy-council-solar-report_sep-2016.pdf.

5http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations#Small-generation-unit-SGU-installations

6 Caveats

6.1 Less loss from distributed generation

The IPART analysis allows that distributed generation is more valuable since less is lost in transmission to the user, but only allows a 1% gain in value. It has been omitted from the analysis in this submission.

6.2 Temperature-based demand/production correlation

The temperature pattern over the month is not considered. In practice, there would be a positive correlation between the temperature and demand, and likewise between temperature, insolation and PV output, beyond that which follows merely from time of day. In this respect, the method underestimates the value of the PV power fed in.

6.3 Panel Location

All panels are assumed to be in Sydney. Panels located further West would align better with peak demand, while those further North would enjoy stronger insolation.

6.4 Limited reference data

The frequency and amplitude of extreme spot prices vary wildly from year to year. The demand-price model is necessarily just an educated guess.

In particular, the model uses a cap of $1000/MWh in order to get a reasonable-looking fit to the data. The actual cap was ten times that in 2016. Thus, without small scale PV, eye-watering prices might have been reached rather more often.

6.5 Degradation

The temperature-based output degradation varies between panel models and is ignored.

6.6 Estimate of poles-and-wires cost

From 2009 to 2014, the East coast networks spent $45bn on poles-and-wires maintenance and upgrades.[6] That averages $9bn/year, of which we might assume around $3bn was in NSW. That is about double the estimate made in this document. Since it has been argued that half of the spend was unnecessary, the $1.5bn figure used herein is reasonable.

6 https://www.themonthly.com.au/issue/2014/july/1404136800/jess-hill/power-corrupts

7 Angle and Power Calculations

All angles shown in radians unless otherwise noted[7].

7.1 Declination

Declination describes the sun's angle to the equatorial plane over the course of the year. It is defined to be positive to the North. For the Nth day of the year:

$$\sin(\delta)=-\sin(0.409)\cos(0.0172(N+10)+0.0334\sin(0.0172(N-2)))$$

7.2 The Hour Angle

The hour angle is the Sun's latitude, by time of day, relative to the observer. It is defined as positive to the East of the observer's position.

$$\omega = \pi(1-h/12)$$

where h is the hour from midnight.

7.3 The Altitude Angle

The altitude angle (α) is the Sun's elevation above the horizon as seen by the observer.

$$\sin(\alpha) = \sin(\delta)\sin(\varphi)+\cos(\delta)\cos(\omega)\cos(\varphi)$$

where φ is the observer's latitude, positive North.

7.4 Angle of Incidence

The angle of incidence, θ, to the panel is the angle which the sun's rays make to the normal at the panel surface. If the panel is tilted at angle β to the horizontal and oriented at angle γ E of N,

$$\cos(\theta) = \sin(\delta)\sin(\varphi)\cos(\beta)+\sin(\delta)\cos(\varphi)\sin(\beta)\cos(\gamma)+\cos(\delta)\cos(\varphi)\cos(\beta)\cos(\omega)$$

$$-\cos(\delta)\sin(\varphi)\sin(\beta)\cos(\gamma)\cos(\omega) - \cos(\delta)\sin(\beta)\sin(\gamma)\sin(\omega)$$

7.5 Air 'Mass'

Light is attenuated as it passes through the atmosphere. Ignoring Earth's curvature, the path length is inversely proportional to the cosine of the altitude angle. The consequent received power varies as the negative exponential of this:

$$\exp(-\lambda \sec(\alpha))$$

where λ ≈ 0.261.

The power received by the panel per unit area is then proportional to:

$$\exp(-\lambda \sec(\alpha)) \cos(\theta)$$

7.6 Examples

The following chart shows the power output by time of day, in January, for a 1kW panel. The red line shows the standard installation, viz., oriented N and tilted at 34 degrees to the horizontal.

The kW scale is normalised to an annual average daily production of 3.9kWh for the standard installation.

Note that the standard installation is optimised for total annual production. If the Summer production is the

7The angle equations are from http://www.itacanet.org/the-sun-as-a-source-of-energy/part-3-calculating-solar-angles/, except for a refinement to the declination equation to correct for Earth's elliptical orbit.

most valuable, the tilt angle should be lowered. If late afternoon Summer production is the most desirable of all, a more Westerly orientation is appropriate.

The peak outputs fall well short of the nominal 1kW because the graphs represent averages over all weather conditions.