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The Potential Value of Peer-to-Peer Energy Trading in the Australian National Electricity Market

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Abstract
The existing retail market arrangements for investment in distributed energy technologies, including household solar PV systems, are not well aligned with the economic value that these technologies can provide within the electricity industry. In particular, these commercial arrangements fail to account for temporal and spatial variations in costs and benefits across market participants. The study presented here considers peer-to-peer (PTP) energy trading as one potential solution to this misalignment, as it can provide a price signal for better coordination of local generation and consumption. This work assesses the impacts of consumer participation in PTP energy trading when an aggregator facilitates energy trading between residential participants, according to their energy surpluses and deficits at different times. The potential operational financial impacts on solar PV customers, non-PV customers, their retailers, the distribution network service provider (DNSP) and aggregators are modeled under such trading arrangements. Based on these operational cash flows, the potential impacts on investment decisions of consumers - whether or not to participate in PTP trading and perhaps to invest in solar PV systems - are explored, to understand the potential longer-term implications of peer-to-peer energy trading.

This modelling finds that PTP trading via customer 'pools' set up by an aggregator has considerable promise to generate benefits for both customers with solar PV systems and customers without them. Conversely, retailers and DNSPs are significantly disadvantaged by the participation of their customers in PTP energy trading under current retail tariff arrangements. The main influences on these impacts are the solar PV penetration rate within the pool of customers, the number of PTP participants and the margin charged by the pool aggregator. In contrast, factors such as the existing feed-in-tariff rates received by participants with solar PV systems have a very limited influence on their trading behavior at PV penetration rates close to existing levels.

1. Introduction
The Australian National Electricity Market (NEM) has undergone rapid change in recent years. In particular, the widespread uptake of distributed energy technologies, such as solar photovoltaic (PV) technology, has had a surprising and profound impact on many stakeholders in the NEM. The long-held assumption of ever continuing growth in the demand for electricity is no longer assured as this and other distributed technologies such as energy efficiency and storage continue to reduce the net load profiles of customers across the NEM. What now look to be unnecessary sunk investments in network infrastructure by distribution

network businesses over the past decade are being recovered from customers through higher retail electricity prices for households and businesses.

The uptake of distributed energy is likely to continue as more engaged consumers act to reduce their energy bills, and because they are likely to play an important role in low carbon energy system transition. However, existing mechanisms for incentivising distributed energy technologies are not well aligned with the costs and benefits, hence net value, that they can provide to the electricity industry. Distributed energy provides value through energy (or consumption reduction), depending on the volume, time and location of the energy provision. It also provides potential network value through avoided losses and deferral of network augmentation, and broader environmental values and energy security. In Australia, at present, retail market arrangements for small energy users are generally based around simple flat or time-of-use volumetric retail and network tariffs. Three main incentives exist to invest in technologies such as solar PV: feed-in tariffs (IPART, 2015) paid by retailers for exported PV generation by their customers, avoided retail electricity costs (IPART, 2015) through PV self consumption, and the Small-scale Renewable Energy Scheme (SRES) (CER, 2015). However these fail to adequately reflect the potential energy, network and broader values. In particular, the locational and temporal variation in the value of energy exports and the potential avoided network augmentation are not reflected by the existing incentive mechanisms.

A number of proposed incentive mechanisms for distributed energy, such as Local Network Credits (Langham, Rutovitz & McIntosh, 2015) and cost-reflective tariffs (AEMC, 2015) could offer better alignment to the value these technologies provide to society. This paper will consider the novel and promising opportunity offered by peer-to-peer energy (PTP) trading, as an incentive that could align with both the time-based and location-based values of household solar PV and other distributed energy technologies.

PTP energy trading, also referred to as virtual net metering (VNM), wheeling and most recently local energy trading (Rutovitz et al., 2016) is an incentive mechanism under which the exported generation of distributed customers are traded on a time-of-use basis with other local customers. While PTP trading can take different forms (e.g. whether or not the full network charges are paid, and by whom), the version of PTP trading considered in this study is shown in Figure 1. Here, PTP trading would result in an energy value payment by the distributed consumer to the distributed generator via an aggregator. Stringer (2014) suggests the two ‘peers’ could share the ‘local use of network service’ charge (LUOS) based on the network infrastructure required for the trade. She puts forward that this would encourage both buyers and sellers to participate in local trading.

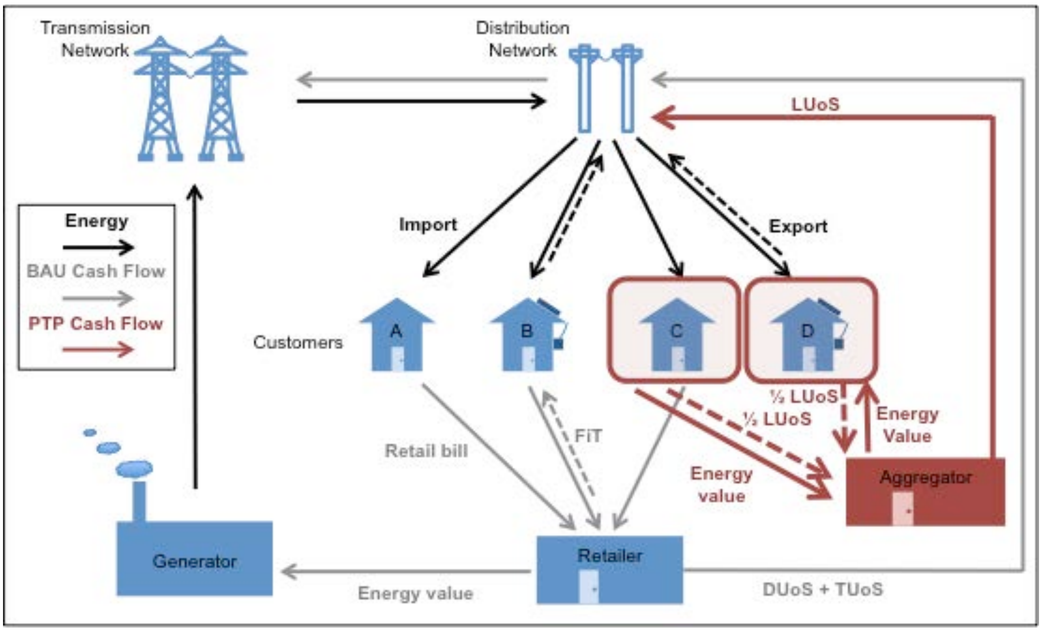


Figure 1. Energy and cash flows under PTP energy trading, adapted from Langham, Rutovitz and McIntosh (2015) and Stringer (2014)

There is a growing body of research on PTP energy trading. Most notably Stringer (2014) explored the impacts of two households trading energy at a variety of locations in the same distribution network and the Institute of Sustainable Futures (Rutovitz et al., 2016) has conducted virtual trials of trading between two commercial-scale participants. This paper addresses a gap in existing research on the impacts of peer-to-peer energy trading when many peers are pooled together by an aggregator. It does so by assessing short-term impacts on cash flows and medium-term impacts on investment decisions of each PTP participant at different rates of PTP participation and solar PV technology deployment.

The rest of the paper is structured as follows. Section 2 explains the modeling in detail, and this is followed by the results and analysis in Section 3. Section 4 summarises the findings and discusses their implications before concluding the report with an evaluation of the significance of the findings and area of further research.

2. Methodology

A model, based on real residential customer load profiles, has been built to estimate short-term cash flow implications of PTP trading on the following electricity industry stakeholders: residential customers with solar PV systems, residential customers without solar PV systems, the local distribution network service provider (DNSP), retailer and PTP aggregator. The results are then used to assess the impact of PTP arrangements on two investment decisions faced by potential participants: investing in a smart meter to participate in PTP trading and investing in a residential solar PV system. (Roy, 2016), provides a detailed explanation of the model, calculations and assumptions.

2.1. Data acquisition

Interval metered gross consumption and gross generation data from 300 residential customers in the Ausgrid (2015b) is used to model the net electricity imports of a set of customers with solar PV systems, and set of customers without such systems, from 1 July 2010 to 30 June

2013. The Hunter and Central Coast region was selected as it had by far the most customers (150 out of 300 in the data set). Note that the solar PV generation has been scaled up to reflect the current average residential PV system capacity, according to growth in average PV system capacity from 1.73kWp in 2010-11 (Ausgrid, 2015b) to 2.43kWp in March 2016 (APVI, 2016). Additional model parameters are detailed in Table 1.

This model assumes that gross consumption behavior is not influenced by the presence of a solar PV system. Further research should incorporate actual consumption data of households without solar PV systems.

Table 1. Additional model inputs

Data type:	Description:
Solar PV penetration rate	Varied to create a sample of customers with a proportion of PV installations representative of the region currently, and in the future. Currently 15% (ABS, 2015), but rate is modelled up to 85% PV penetration
Retail tariffs	Current market offers obtained from EnergyMadeEasy (2016) for the region have been used based on the average distribution of tariff type (inclining block or TOU) for consumers in the Ausgrid network (Ausgrid, 2015a), and retailer market share data (AER, 2016). This paper excludes the daily supply charge when calculating retail bills, as it must be paid in all scenarios.
Feed-in tariffs	Feed-in tariffs were selected based on the IPART (2015) analysis of the 15 best-priced offers for PV customers from each retailer, which range between 0 and 10 c/kWh. The model assumes that an equal number of PV consumers have taken up each of these offerings.
Network Use of Service (NUOS) and Local Use of Service (LUOS)	NUOS charges for both the inclining block and TOU tariff classes are based on Ausgrid (2016). The model considers the scenario where all customers are trading within the LV system, and adopts the approach proposed by Stringer (2014) that the LUOS charge be shared amongst the buyer and seller to encourage trading to occur locally. However, it is important to note that this design is significantly different to the current practice, as NUOS charges are only imposed on customers importing electricity rather than exporting, although exported PV is assigned to the customer retailer who effectively on-sells it.
Solar PV Installation Costs	The scaled generator capacity for each customer has been used to determine the solar PV installation costs and examine the impact of PTP trading on investment in distributed solar PV systems. System costs have been based on data from SolarChoice (2016). The model considers a lifetime for solar PV installations of 20 years.
Smart Meter Installation Costs	Customers must have a smart meter installed in order to participate in PTP energy trading. The smart meter's remote on-demand meter read service (AEMC, 2015b) is required to provide the aggregator with real-time energy demand and supply data. Most customers will need to purchase a smart meter to participate in PTP energy trading. However, considering the recent mandatory rollout of smart meters in Victoria (AER, 2011), the proposed opt-out smart meter roll out in NSW and the numerous benefits of smart meters, it appears that smart meter adoption is inevitable. Thus, it could be argued that customers will eventually adopt smart-meters anyway regardless of their participation in PTP energy trading. Given past meter costs and the uncertainty around both the cost of smart meters and the likelihood of customers having smart meters anyway in the future, the model will consider three scenarios for smart meter costs: a \$0, \$250 and a \$500 smart meter upfront capital cost. A 20-year lifetime for smart meters has been used in the model.

2.2. Business As Usual (BAU) scenario

The model will compare the results of PTP trading with the BAU scenario where all imports are purchased from the retailer and all exports are sold to the retailer. The cash and energy flows in this scenario are calculated for each customer in each time period, according to whether they are importing or exporting electricity after PV generation is accounted for.

2.3. PTP pricing mechanism

A pricing mechanism has been developed that uses the revealed preferences of PTP participants to determine the quantity traded, and the PTP market price, which is based on the reservation price at which the marginal buyers and sellers are willing to trade, and applied to all trades for any given 30-minute time interval. This approach closely matches the revealed preference approach used by AEMO in the wholesale market to determine a market clearing price and quantity (MacGill, 2013). The approach is useful as it can deliver efficient dispatch and it limits market distortion. Furthermore, it ensures that all trading participants are either better off or no different than they would have been if they did not participate. The following steps were taken for each 30-minute time period in the years modeled.

Step 1: Calculate the amount of electricity imported or exported by each customer. This is the same calculation as the BAU scenario. This model assumes that electricity net import quantities are not affected by PTP trading in the short term. Only cash flows are different. In the medium to longer term, the incentive is likely to change customer behavior and hence electricity volumes.

Step 2: Calculate the reservation purchase price for each electricity importer and the reservation sale price for each electricity exporter as follows:

a. The reservation purchase price for customer, i, at time point, t, is:

$$Reservation\ Purchase\ Price_{i,t} = Retail\ Tariff_{i,t} - \frac{1}{2}(LUOS_{i,t}) - \frac{1}{2}(margin)$$

b. The reservation sale price for customer, i, at time point, t:

$$Reservation\ Sale\ Price_{i,t} = (Feed-in\ Tariff)_{i,t} + \frac{1}{2}(LUOS_{i,t}) + \frac{1}{2}(margin)$$

Step 3: Build effective demand and supply curves by prioritising PTP participants with the largest potential to benefit from trade. This step is crucial to ensuring the maximum benefits of trade across the pool of PTP participants. Importers are sorted in descending order of reservation price so that those with the highest reserve prices are given priority access to opportunities to purchase energy on the PTP market. Similarly, exporters are sorted in ascending order of reservation price. The cumulative demand for electricity imports and supply of electricity exports is used to produce the supply curve shown in Figure 2.

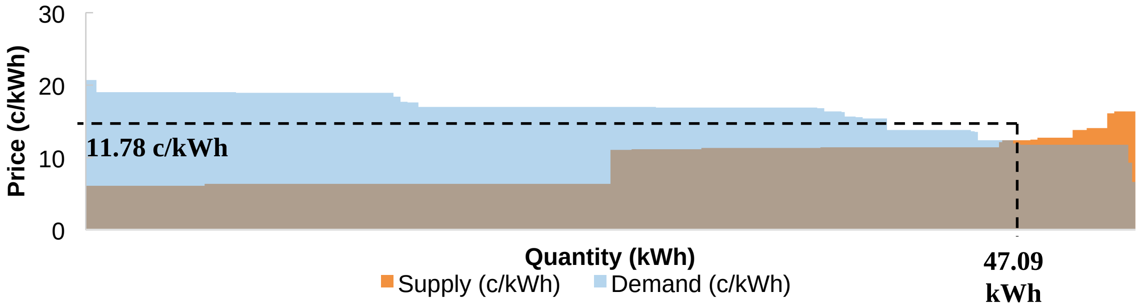


Figure 2. PTP Pricing Mechanism for 9:30am on 9th September 2011 [300 Participants, 50% PV Participants, 40% Total Margin]

Step 4: Find the quantity at which the curves intersect, if at all, and determine the PTP price and quantity accordingly. In the example shown in Figure 2, the price is set by the marginal buyer (PTP importer) but the quantity is set by the marginal seller (PTP exporter). However, the opposite could also occur.

These four steps are repeated for every half-hour interval over the three years analysed to determine the short-term cash flow implications and hence, longer term impacts on investment decisions.

3. Results and Analysis

3.1. Preliminary Model Output

When the pricing mechanism defined in Section 2.3, and using an aggregator margin of 40%, was applied across all 300 PTP participants, half of which had PV systems, the supply and demand curves for each half hour of each year were compiled and then compared to determine the market clearing price and quantity. Figure 2 shows one such instance for 9:30am on 9th September 2011.

Figure 3 provides an indication of how the PTP prices and quantities of energy trade change across the day and year. The higher reservation price of importing customers on TOU tariffs clearly pushes up prices during the peak periods, from 2pm to 8pm. However, from 2-5pm the average PTP price is significantly less than the peak TOU tariffs outlined in Table 6.3:5. This can be attributed to solar PV export generation in the late afternoon putting downward pressure on PTP prices.

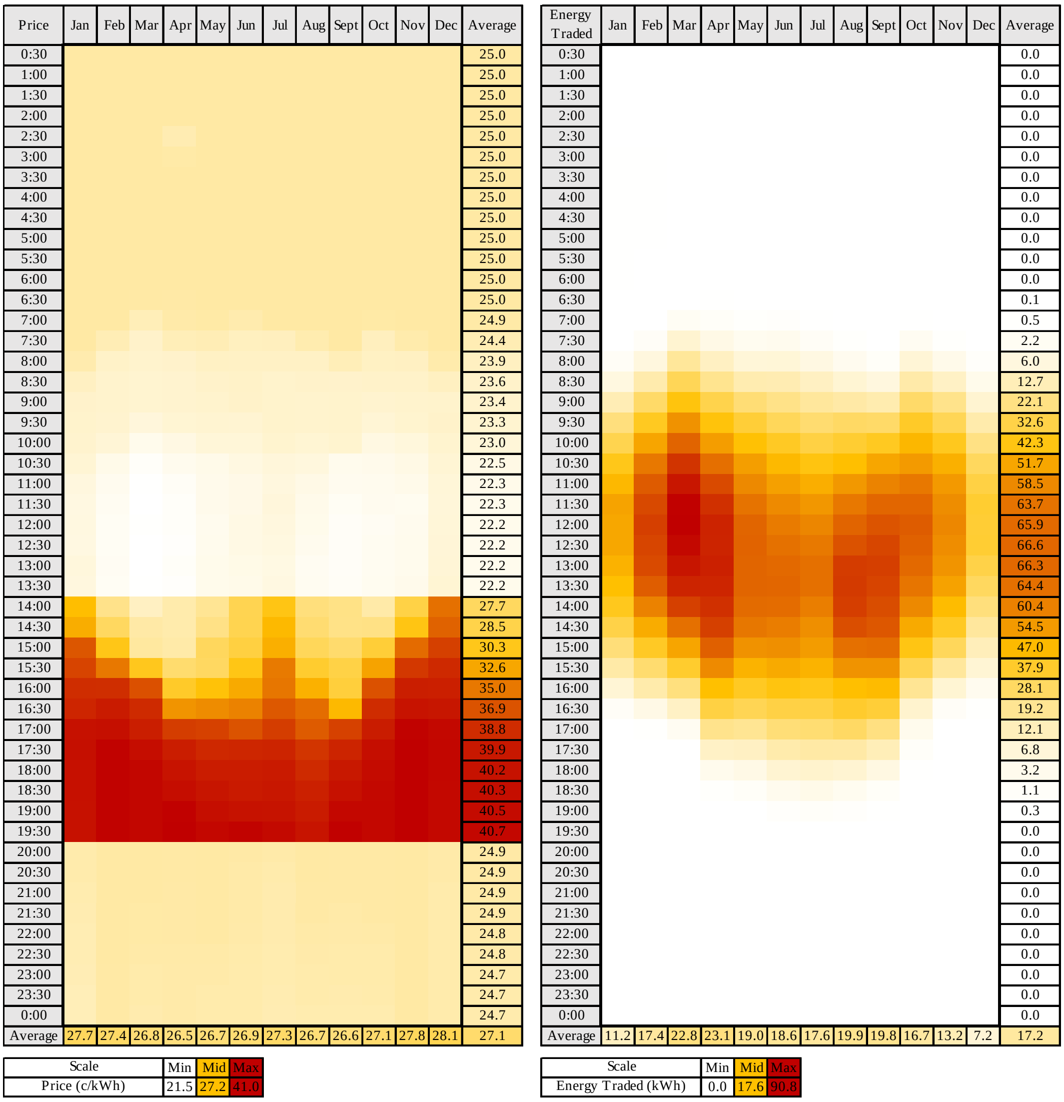


Figure 3. Average price (left) and energy trade quantities (right) for 2012-13 [300 Participants, 15% PV Participants, 40% Total Margin, LV System Trade Only]

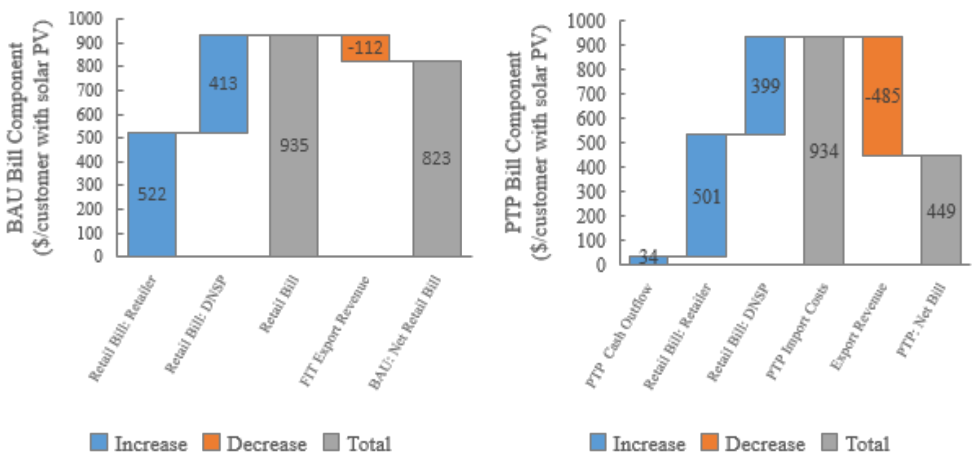
Interestingly, there appears to be little evidence of the inclining block tariffs having a significant impact on PTP prices as there is no trend of increasing prices across the day. This result can be attributed to the fact that the difference between the rates of each block in an inclining block tariff is low compared to the differences between the peak and off-peak rates of a TOU tariff. It would thus be expected that a trend towards TOU pricing will result in greater price variability in PTP markets.

Interestingly, even though summer months are characterised by more hours of sunshine each day than other months, they exhibit less energy trade in both mid-morning and late afternoon periods. This may be result of higher self-consumption of solar PV generation by participants due to high cooling loads in the Hunter & Central Coast region.

3.2. Test 1 – Impact of PTP Energy Trading

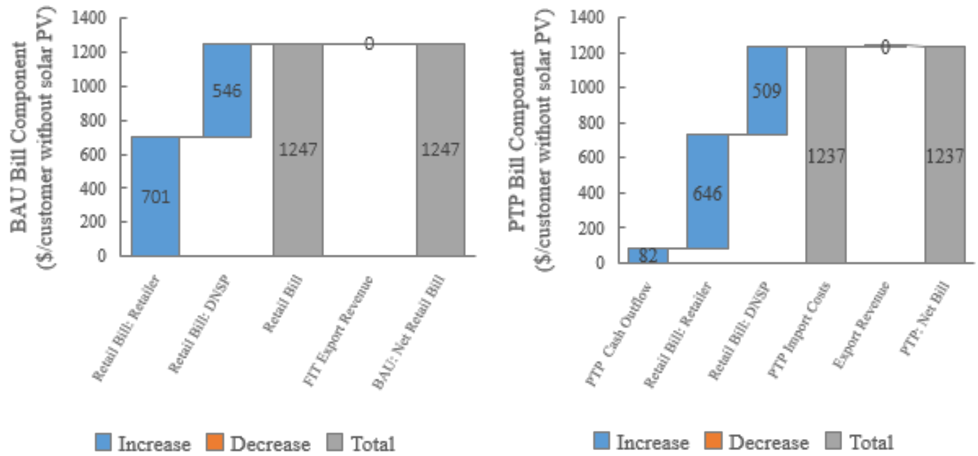
Figures 4a (BAU) and 4b (PTP) show the impact of 1000 residential customers participating in PTP trading, including 150 customers with solar PV systems. The scenario incorporates a 0.46% aggregator margin, based on the current margins charged by the ASX. Comparing the net bills of the two figures, indicates that participation in PTP trading reduces the average retail bill of solar PV customers from $823 per year to just $449 per year. Recall from Table 1 that this retail bill, and all others in this study, excludes the daily supply charge as this fixed component of the bill is independent of participation in PTP trading in the short term. The main cause of reduction in the bill is higher export revenue. In fact, the volume-weighted average PTP price received by sellers (and paid by buyers) was 24.85c/kWh, significantly higher than the FiTs that range from 5c/kWh to 10 c/kWh in the ‘likely FiT distribution’. This high price reflects the fact that under a 15% PV penetration rate, demand of both the 150 PV and 850 non-PV customers, far outweighs the supply of the 150 PV customers.

It is interesting to note that by participating in this PTP trading scenario, solar PV customers do not meaningfully reduce the ‘import’ costs of their bill ($935/year versus $934/year) This is can be attributed to the fact that the average PTP price over the year was well within the range of retail tariffs defined in Section 2 and so gains to be made from importing from the PTP market were low.



Figures 4a and 4b. Average annual net retail bill for customer with solar PV in BAU and PTP scenarios, 2012-13 [1000 Customers, 15% PV Penetration, 0.46% Total Margin]

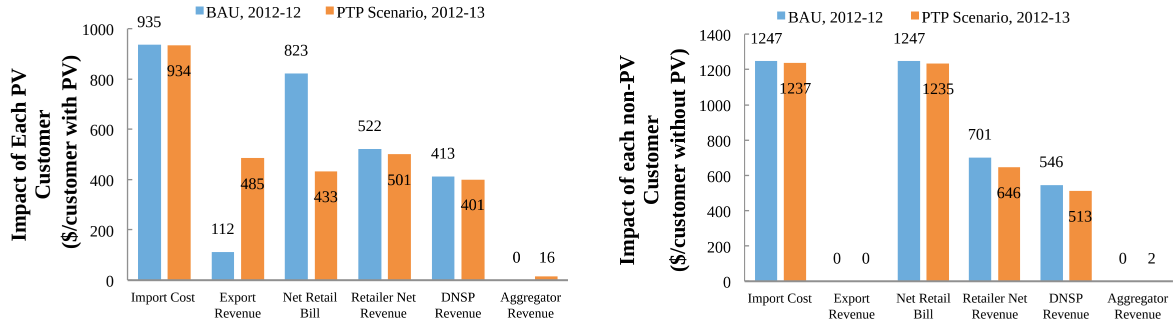
Figures 5a and 5b show the impact of a non-PV customer's participation in PTP trading in a similar fashion. Participation in PTP trading reduces the variable component of the average non-PV customer's annual retail bill by only $10. All of this reduction comes from a reduction in import costs. While still low, this reduction in import costs is higher than the $1 reduced on the bills of solar PV customers, for two reasons. Firstly, non-PV customers import more, on average, than PV customers and so they simply have more opportunities to import from the PTP market if the price is below their reservation price. Secondly, and more importantly, non-PV customers import substantially more during the middle of the day than PV customers do, as they do not have any PV generation. Thus they benefit greatly from PTP trading in the middle of the day from lower PTP prices as shown in Figure 3.2. This is supported by the observation in Section 3.1 that PTP prices are substantially lower than the peak TOU retail tariffs during the first half of the peak TOU period, from 2-5pm.



Figures 5a and 5b. Average net retail bill for customer without solar PV in BAU and PTP scenarios, 2012-13 [1000 Customers, 15% PV Penetration, 0.46% Total Margin]

Given the small value in participation in PTP for non-PV customers in this low (current) PV penetration scenario above, it is worth considering whether they would choose to participate. According to the AEMC, residential customers on average would typically consider switching retailers or retail plans if they could save $190 annually from doing so (AEMC, 2015b). If the same consumer behaviour was true for switching between the BAU retailer and a retailer willing to also act as a PTP aggregator, solar PV customers would certainly consider switching as their annual net retail bill is reduced by $390, as shown in Figure 3.5a, whereas non-PV customers likely would not. Hence this scenario would likely not arise, Instead, a smaller number of non-PV customers would likely sign up.

Figure 6a also shows that under this PTP trading scenario, retailer annual net revenue decreases by $21 per PV customer while DNSP revenue decreases by $12 per PV customer.



Figures 6a and 6b. Impact of each solar PV and non-solar PV customer engaged in PTP trading, 2012-13 [1000 Customers, 15% PV Penetration, 0.46% Total Margin]

At the margin rate of 0.46%, aggregator revenue is only $16 per PV customer and $2 per non-PV customer, as shown in Figures 6a and 6b above. The difference in aggregator margin by type of customer reflects the fact that in this scenario, the 150 PV customers trade on average 125kWh each from the PTP market and sell 2010kWh while the 850 non-PV customers on average buy 333kWh each per year. The next section of the paper (Test 2) explores the potential for aggregator revenue to increase with higher margins.

Table 2. Impact of PTP trading on the investment attractiveness of solar PV installations, 2012-13 [1000 Customers, 15% PV Penetration, 0.46% Total Margin]

Solar PV	Cash Flows ($/customer)	Discounted Payback Period (years)	NPV ($/customer)
Average Capital Cost	3903	N/A	
BAU PV Returns ($/year)	426	12.47	1252
PTP PV Returns ($/year)	791	5.09	4023

Table 2 assesses the impact that PTP returns might have on the PV investment decision. For this PTP scenario, participating in PTP trading greatly improves the investment attractiveness of PV, reducing the DPP from 12.47 years to 5.09 years and providing $2771 extra value in present terms.

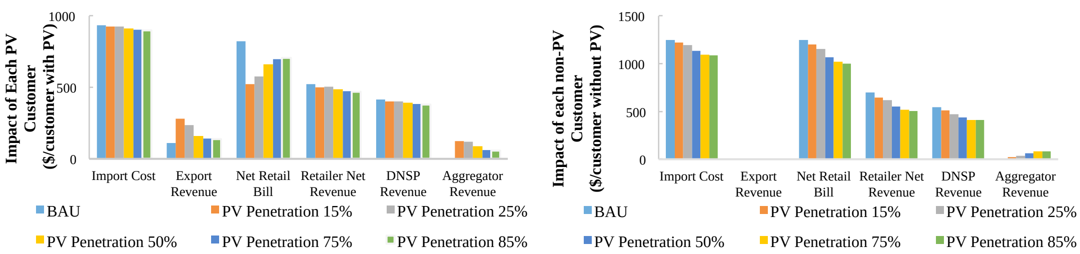
Now considering the investment decision of buying a smart-meter for the sole purpose of engaging in PTP trading, Table 3 shows that it is highly attractive for customers with existing solar PV to engage in PTP trading at all scenarios of smart meter cost. In contrast the investment in a low-cost or high-cost smart meter for non-PV customers does not pay itself back over the lifetime of the meter. Thus non-PV customers would only consider participating in PTP trading in the 'free smart meter' scenario.

Table 3. Investment in smart meter attractiveness for customers with and without solar PV, 2012-13 [1000 Customers, 15% PV Penetration, 0.46% Total Margin]

	Smart Meter Scenario:	**Free Smart Meter**	**Low-Cost Smart Meter**	**High-Cost Smart Meter**
	Capital Cost ($/meter)	0	250	500
Solar PV Customers	PTP Annual Returns	374	374	374
	Discounted Payback Period	0	0.28	1.39
	NPV	$4,525	$4,275	$4,025
Non-Solar PV Customers	PTP Annual Returns	10	10	10
	Discounted Payback Period	0	Not paid back	Not paid back
	NPV	116	-134	-384

3.3. Test 2 – Effect of Solar PV Penetration

This section assesses the influence of the PV penetration rate within the PTP participant pool on the impacts of those participants. Higher PV penetration rates result in greater supply in the PTP market, thereby pushing prices down and significantly reducing the amount of electricity purchased by participants from the retailer. This also led to a significant decrease in export revenue for PV PTP participants as shown in Figure 7a. In fact, at the 85% penetration rate, the volume-weighted PTP price received by sellers was only 13.74 c/kWh, 5.8 c/kWh of which went to the aggregator, while a proportion of the remainder went to the DNSP as LUOS charges. Figure 7b shows that at high PV penetration levels, non-PV participants benefit greatly from lower import costs which reduce their net retail bill substantially.



Figures 7a and 7b. Influence of solar PV penetration on the impact of each solar PV customer and non-PV customer engaged in PTP trading, 2012-13 [150 participants with solar PV, 40% total margin, number of non-PV participants determined by PV penetration rate]

It is interesting to explore whether the benefits of PTP trading would incentivise additional investment in PV systems. Figure 8 shows the annual benefits of PV system ownership in BAU (no PTP) and various cases of PV penetration (15% to 85%) within the PTP pool. PV investment attractiveness improves for PTP trading scenarios with low penetrations of PV, but then deteriorates at higher penetrations such that at a PV penetration rate of 50% or above, PTP trading makes investments in solar PV less attractive than in the BAU (no PTP) scenario. This is because while PTP trading at high levels of PV penetration still results in higher export revenue than the BAU case, the reduction in energy prices due to PTP reduces the self-consumption savings of PV systems. Thus, PTP trading would not always incentivise new investment in solar PV, it only does so for lower cases of solar PV penetration. The discounted payback period increases from 8.42 years at 15% PV penetration to 17.49 years at 85% PV penetration, well beyond the 12.8-year payback in the 2011-12 BAU scenario.

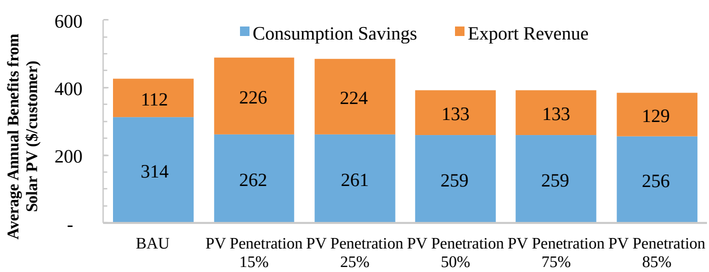


Figure 8. Influence of PV penetration rate on returns of solar PV installations, 2012-13 [150 participants with solar PV, 40% total margin, number of non-PV participants determined by PV penetration rate]

3.4. Test 3 – Effect of Aggregator Margin

Figure 9 highlights that aggregator margins of up to 40% have almost no impact on the amount of energy traded under PTP settings. This is a reflection of the large difference between the feed-in-tariffs received for net energy exports and the retail tariffs paid for energy imports. Accordingly, revenue per PTP customer increases substantially as margin is increased up to 40%. However, when the margin is increased to 60%, the amount traded per customer starts to drop and thus revenue increases less from 40% to 60% than it does from 20% to 40%. It should be noted that aggregators could potentially earn even more revenue per customer at higher margins. However, without sufficient benefit, few non-PV customers would participate, resulting in high PV penetration in the customer pool, reducing benefits for PV customers, as explored in the next section. In addition, realistically, there would be a psychological limit at which potential PTP customers would start to be deterred from participating due to the perceived unfairness of the aggregator's high margins. Future research could consider the business case for aggregators to determine what level of margins are required to cover both capital and ongoing costs as well as a profit margin.

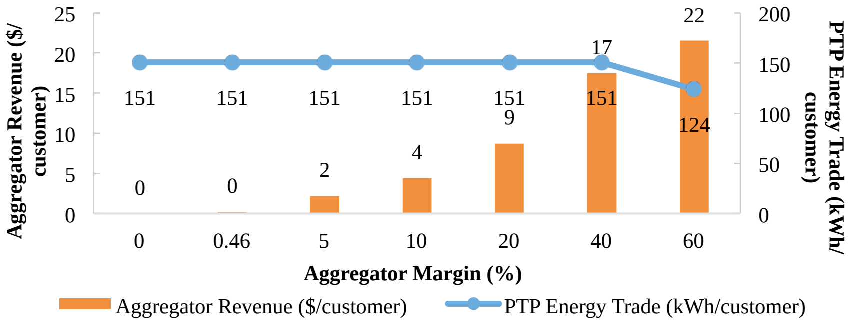


Figure 9. Impact of aggregator's margin setting on PTP energy trade and aggregator revenue, 2012-13 [1000 Customers, 15% PV Penetration]

4. Conclusion

The findings outlined in this paper provide an initial insight into the impacts of peer-to-peer trading through pool aggregation on different stakeholders. In this section, the key findings are summarized in Table 4, and areas of further research are outlined in Table 5 below.

Table 4. Key findings and implications

Test	Key Findings	Implications
1. Impacts of PTP energy trading	If the ratio between PV and non-PV customers participating in PTP trading was equivalent to current PV penetration levels, PTP trading is very profitable for solar PV customers as it significantly increases the export revenue they receive. Non-PV customers receive little benefit and would not buy a smart meter to join the PTP market.	It is likely that good returns would attract a greater proportion of PV customers so that PTP trading becomes more attractive for non-PV customers. Otherwise, aggregators must seek to create additional incentives for non-PV customers to join the PTP market, potentially reducing margins, or perhaps splitting LUOS in favour of non-PV customers.
2. Effect of PV penetration on the impacts of PTP energy trading	At low levels of PV penetration, export revenues for solar PV PTP participants are high while the benefits of PTP trading for non-PV participants is low. At levels of PV penetration of 50% or above the opposite is true, so much so that the investment decision for investing in new solar PV is worse than it is in the BAU scenario. Non-PV customers are substantially better off at high PV levels.	PTP trading arrangements cannot simply be considered to an incentive mechanism for solar PV investment. Rather, preliminary findings suggest PTP arrangements create an additional incentive for solar PV investment when that investment can provide benefits to the pool of peers in the market.

3. Effect of margin on the impacts of PTP energy trading	Margins of 40% or lower have little impact on the amount of energy traded, but higher margins would likely reduce participation rates.	There is considerable scope for aggregators to generate revenue as a result of the significant disparity between FiTs and retail prices. Further work is required to determine appropriate margins that would attract non-PV customers to participate.

Table 5. Areas for Further Research

Area for further research	Description
Influence of cost-reflective tariffs	This study has considered how participants with TOU and inclining block retail tariffs would behave in a PTP pool market. Given the shift towards cost-reflective tariffs, further research should consider how the behaviour of PTP participants may change when they are being charged more cost-reflective retail tariffs.
Influence of load diversity on impacts	The influence of load and generation diversity could be further explored in future research. A potential starting point could be to consider the impacts of residential and commercial customers interacting in the same PTP market.
Influence of LUOS	There is considerable scope for further research into the impact that LUOS has on trading behaviour and the impact of PTP participants. The model in this paper has assumed all trade occurs within the LV system but future work could explore how the impacts of PTP trading change when some participants trade in different LV systems, using a substation. The PTP pool pricing mechanism relies on a LUOS definition based on the proximity of all PTP participants to one specific location. Further research should consider how the definition of LUOS proposed by Stringer (2014), based on the proximity of two peers in the market can be used in a single-price PTP market of multiple peers with different levels of proximity to one another. The impact of allocation of LUOS between buyers and sellers could also be explored.
Distributed energy storage	This study has focused on the impact of customers with solar PV in PTP markets but a natural extension of this research is to examine the impact of PTP customers with energy storage (including EVs) or demand response technologies.

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