Assessing the Impact of Household PV Systems on the Profits of All Electricity Industry Participants

S. J. Oliva, *Student Member, IEEE*, and I. F. MacGill, *Member, IEEE*

***Abstract*—The recent rapid growth in distributed PV deployment within countries including Australia is now raising important and challenging questions regarding the societal value of PV and the most appropriate policy options to drive appropriate deployment. A key issue is how the costs and benefits of PV systems are currently shared between different industry participants including of course customers who deploy PV, but also their retailers and network service providers and, more broadly again, other energy customers and large centralized generation. The interaction of different PV support policies such as feed-in tariffs is a further complication. This paper presents a study attempting to estimate the operational revenue and costs associated with household PV systems for these industry participants within the Australian State of NSW under current market arrangements and PV support policies. Our results suggest that customer deployment of PV seems likely to have most impacts on the operating profits of their retailers but potentially significant adverse impacts on their distribution network service providers. The methodology and results has potentially important implications for retail market arrangements and PV policy support.**

***Index Terms*— Australia, Commercial analysis, Feed-in tariffs, PV systems.**

I. Introduction

PHotovoltaics (PV) has experienced remarkable growth in deployment over the past decade [1]. Whilst system costs have fallen significantly over this time, this deployment has been largely driven by supportive government policies in a number of key countries. Some 96 countries have implemented policies to support renewable power generation as of 2010 and many of these have been targeted at PV. Feed-in tariffs (FiTs) which provide a premium 'tariff' for eligible renewable generation are the most widely implemented policy mechanism, and were in place in more than 61 countries and 26 states/provinces worldwide in 2010 [1].

FiTs have demonstrated their effectiveness in promoting PV deployment in a growing number of countries [1], however, the success of PV has raised growing concerns about the expense of these FiT policies on other energy users who pay the program costs [2]. PV offers a wide range of potential benefits as a clean generating source with no operational emissions or resource requirements other than sunshine that can be easily located in the built environment at the premises of energy consumers. Nevertheless, the technology still has high capital costs and hence levelised costs by comparison with some existing large centralised generation options. The overall economics of distributed PV generation are actually highly complex given the variable and uncertain nature of PV generation, its location within the distribution network and environmental benefits that are still externalities in many industries.

Another key issue is how these costs and benefits are distributed amongst electricity industry participants from households to retailers, network businesses and other generators. At present, the commercial arrangements for small energy uses in most industries do not effectively reflect the time and location varying value of energy and associated environmental costs [3].

PV may well add considerable complexity and inefficiency into these existing arrangements and financial transfers between industry participants. And PV support policies bring yet further financial flows between participants. In some cases these policies have involved very significant financial transfers to households installing home PV systems which, together with the large price reductions in solar PV over recent years, have led to an unexpected and overwhelming rate of installations in some countries [1]. As a consequence, many existing FiTs are under review around the world. For example, in late 2010, the Czech Republic passed new legislation to slow the rate of PV installation in part because of the impact of FiTs on rising electricity prices. In 2011, Italy has reduced the rate of their solar PV FiT by around 20-50% for 2013 (ranges apply to different scales of installation) and in 2010 Spain capped the annual hours rewarded by their solar PV FiT [1]. Other more critical cases have led to the sudden reduction or cancelation of FiTs raising concerns for the long term value of such policies. For example, the UK government has recently proposed to halve their PV FiTs as quickly as possible for all new solar PV installations, arguing that the policy is not sustainable since returns available to new generators are higher than envisaged. [4]. In the Australian context, the FiTs Solar Bonus Scheme (SBS) implemented in the state of New South Wales (NSW) provided a significant payment on all (gross) PV generation and led, in conjunction

S. J. Oliva and I. F. MacGill are with the Centre for Energy and Environmental Markets and School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney, Australia (email: s.olivahenriquez@student.unsw.edu.au).

with Federal Government support and falling PV prices, to the deployment of over 150,000 PV systems in little more than a year [5]. This has involved very significant financial transfers from all energy customers to those households who installed PV systems [6]. This situation led to the sudden cancelation of the scheme for new participants little more than a year after the scheme commenced. This unfortunate outcome has also focussed attention on how the costs and benefits are distributed across electricity industry participants including retailers and network providers as well as other electricity customers than those who have PV. For example, the Independent Pricing and Regulatory Tribunal (IPART) of NSW has been tasked with determining a fair and reasonable value of PV sourced electricity (PVelec) exported to the grid and its impacts on Distribution Network Service Providers (DNSPs) and electricity retailers [7].

In [8] we explored the economics aspects of PVelec from a wide societal perspective of costs and benefits concluding that the investment of a representative particular PV system located in Sydney, NSW, could potentially be socially beneficial in some circumstances with total benefits higher than costs. In that estimation we assessed energy, network and environmental benefits. Energy is valued at wholesale price of electricity given that PVelec offset the generation of the marginal unit who bid its production costs when the electricity market is competitive. Avoided losses in the network are estimating using a methodology that consider the non-linear relation between power flow and losses proposed in [9] whereas some potential values of deferral network augmentation are obtained for some locations in Sydney. Finally the environmental value considers the avoided CO_2 emissions using a methodology that uses the emission intensity factor of the power plant that PVelec offsets multiplied by a social carbon cost. Values vary enormously with the value of carbon cost used which can be based on a damage cost or a control cost approach where the first one considers the economic costs of the consequences of the climate change [10][11] while the second one is usually materialized in a carbon price [12]. This is a social non-private valuation of the PV technology. We did not, however, consider how these costs and benefits are currently shared across industry participants.

In this paper we now undertake an analysis of the commercial (private) costs and benefits of such household PV systems under current retail market arrangements in NSW and the Australian National Electricity Market (NEM) within which the State resides.

The intent is that such analysis can help guide commercial arrangements in retail markets, and any associated PV support policies, to align private costs and benefits with the overall economics of PV in this context.

To date, there have only been limited efforts to align such commercial arrangements with the societal economic value of PV systems. Part of the challenge is the estimation of this value itself given the complexity of PV generation and its temporal and locational variability and unpredictability. Furthermore, electricity industry economics are also highly complex with electricity value varying by time and location according to varied and uncertain energy user preferences, the mix of generation and network requirements. There is also the range of environmental and societal externalities associated with the electricity industry to consider. On the other hand the consideration of PV value on current commercial arrangements requires a design compatible with other challenges of the electricity industry like security of supply and environmental and equity goals.

Despite these challenges, this task is essential to tailor support policies such as FiTs to maximise the economic value that PV can provide the electricity industry and society more widely through efficient and equitable deployment.

We first outline the potential impact of household PV systems on the various cost and revenue streams for retailers, DNSPs and PV customers within the current NSW context.

In Section IV we then apply this framework to the case of an average residential PV system in Sydney to estimate actual operating profit impacts (net changes in revenues and costs) for the different electricity industry participants for the year 2009-10. Section V discusses the likely longer-term impacts of these operating profit impacts whilst some tentative conclusions and thoughts on future work are presented in Section VI.

II. Commercial Arrangements for Small-scale PV Systems in NSW

Key electricity industry stakeholders in the Australian context for distributed PV include:

- Retailers (known as suppliers in some other industries such as the UK) who purchase electricity from the wholesale market and sell to energy users through retail tariff contracts;
- Distribution Network Service Providers (known as DISCOs in some industries) who are regulated monopolies within their service region that own and operate the distribution network, and charge regulated network tariffs to the retailers;
- Customers who are potentially interested and able to install a PV system on their premises;
- Large generators selling into the wholesale market; and
- Other electricity consumers that don't have PV systems.

All of these market participants are impacted financially by the decision of an energy customer to install a PV system. The nature of these commercial impacts depends of course on the market arrangements including the particular regulated and competitive tariffs being paid by the customers, other potential factors such as net or gross metering choices or requirements on PV system owners, and any policy measures in place that create additional profit streams for PV generation such as feed-in tariffs or deemed renewable energy credits. Under the NSW SBS PV customers get paid a gross FiT of 60 ¢/kWh which is effectively paid, in the end, by all end-users [6]. Interestingly, retailers can actually experience financial gains under the SBS since they can 'sell' the exported electricity from their customers with PV to other customers. Some but not all retailers do provide a PV premium for their customers PV generation that is also receiving the SBS FiT. With the cancellation of the SBS, customers now installing PV systems generally have net metering arrangements where their PV generation largely offsets their own consumption whilst exports are paid at a retailer set tariff. This tariff can be valued either at the wholesale price of electricity or by estimating the avoided costs of the exports for the retailer [7]. Current financial flows between key electricity industry stakeholders are highlighted in Fig. 1. Such an impact requires a policy framework to align commercial arrangements with the benefits and costs for society as a whole and each stakeholder to lead towards an efficient PV deployment that achieves associated objectives which include a proper uptake of PV system, CO_2 emissions abatement and PV industry development and job creation. Particularly important is the estimation of benefits and costs for each stakeholder and hence the determination of what is the contribution that each of them should make to afford that efficient deployment based on such assessment.

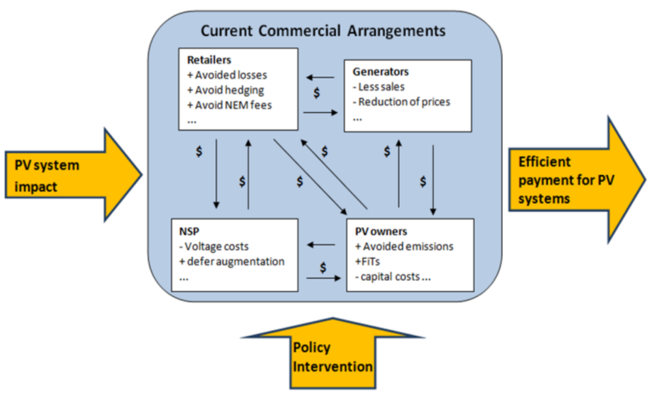

Fig. 1. Some of the potential impacts that household PV systems might have on financial flows between key electricity industry stakeholders. Actual flows will depend on the actual commercial and any additional PV support policy arrangements.

In [7] IPART proposed a benchmark range between 8 and 10 ¢/kWh in 2011/12 for PV value with no obligation for retailers to offer FiTs, hence leaving the offering of payments for the PV exports to competition for customers with PV systems within the retail market. However, further investigation is required to capture the impact of PVelec on the profits not just for retailers but also for DNSPs and PV customers as well as determination of what consequences that first impact will bring in the wider market.

III. Impact of PV Generation on Stakeholder Profits under Net Metering Arrangements in the Australian NEM

A. Impact on Retailer Profits

The impact of PVelec on retailer profits can be calculated taking into account the impact on each source of profits and costs which includes the less electricity sale to end-users, the avoided network charges for the self-consumption, the avoided cost of purchasing electricity from the NEM and the assignation of PV exports by the Australian Energy Market Operator (AEMO). With the installation of a new PV system, the customer's retailer will sell less electricity to that household due to the self-consumption of PVelec causing a financial loss valued at the retail tariff. However, self-consumption involves avoided costs for retailers as well. These include avoided network charges per kWh, avoided purchase of electricity from the NEM including losses and associated NEM fees per kWh, and avoided environmental obligation of the Federal Government's Renewable Energy Target scheme (RET). Furthermore, given that AEMO's settlement process bills retailers based on the measure of the total imports minus the total PV exports of their customers, a financial value of PV exports valued at the wholesale electricity price is effectively assigned to the retailer. Retailers may pay PV customers for their PV exports. This payment can be optional or compulsory depending on the particular regulatory framework of the market. In the case of no obligations retailers may still offer voluntary payments to PV owners in order to compete for these customers. This would depend, significantly, on how competitive the retail market is.

As such, if R is the retail tariff for that PV customer, $NExp_t$ is the self-consumption (non-exported component) of electricity, Exp_t is the PV exported electricity, N is the network charge, w_t is the wholesale price of electricity at the node where the retailer buy from the NEM adjusted with the corresponding loss factors, g is a reference price for the RET obligations and P is the payment to reward PV owners for the electricity they export to the grid, then the variation of the retailer operating profits at time t, can be expressed as in (1).

$$\Delta\pi_{Rt} = (-R + N + w_t + g)\times NExp_t + (w_t - P)\times Exp_t \quad (1)$$

From (1) we can see that is not clear if the retailer will always experience a financial gain or loss but that depends mostly on the level of self-consumption of the household and the level of wholesale prices.

B. Impact on DNSPs Profits

Under current commercial arrangements the DNSPs charge a tariff to retailers per kWh they sell to customers which is intended, in aggregate, to recover network costs and establish a proper level of profits to the business. The setting of these tariffs is undertaken through a regulatory process that requires the approval of the Australian Energy Regulator (AER). In the first instance, the commercial impact of PVelec on DNSPs revenues is a reduction of collected network tariffs from that customer equivalent to their reduced kWh consumption. Interestingly, the DNSP does earn the network tariff on exported PV energy that is sold on to other customers. The reduction of revenues can be expressed as in (2).

$$\Delta\pi_{DNSP\,t} = N \times NExp_t \quad (2)$$

PVelec will, in the longer term certainly, impact in other ways on DNSP costs and benefits. For example, there is some potential for PV to assist in deferring network augmentation in some limited circumstances [8]. Alternatively, it is also possible that high PV penetration levels may increase network expenditures to manage voltage rise and reverse power flows in the LV network. As PV penetrations grow, given that the loss in profit from PV customers almost certainly outweighs any potential benefits, this will need to be reflected in future tariff determinations for the DNSPs which will require higher profits for electricity transmitted through the network. We discuss this further in the following Section.

C. PV Systems Owners Profits

Under a net metering arrangement PV customers receive financial savings for the avoided purchase of electricity from their retailers which will be reflected in a reduction in their electricity bill. Furthermore, they may receive payments for the electricity they export to the grid as is shown in (3).

$$\Delta\pi_{PV\,t} = R \times NExp_t + P \times Exp_t \tag{3}$$

D. Generators and non-PV Customers

The possible commercial impact of household PV generation on large generator profits is extremely difficult to estimate. In general, these PV systems represent additional and zero operating cost generation that should, all other things being equal, reduce the aggregate dispatch of other generation and the prices they receive. The penetration of PV is clearly a key issue. At low penetrations, PV might merely reduce dispatch of the marginal generator which would not change price or income for any generator other than that marginal unit. However, given that Australia is now estimated to have a GW of PV, almost all household and within the NEM, it is quite possible that it is beginning to have price impacts. It could now meet some 2-3% of peak NEM demand (around 35GW) on those peak summer afternoons where very high prices often occurs. Reference [13] argues that PV deployment is a viable option to effectively hedge excessive spot market electricity prices in summer in the NEM given the highlighted coincidence of PV output with peak loads.

Such analysis is beyond this paper but has been raised in [5] also [13]. In practice, generator offers and hence dispatch and prices within the NEM is driven by a wide range of factors such as derivative contract positions, unit commitment considerations and occasional periods where some generators can exercise market power. The impact of PV systems on non-PV customers is also an important but extremely challenging question. Beyond the potential wholesale price impacts noted above, are their potential flow-through to the retail tariffs they are offered. Also important are the impacts of customers buying PV systems on DNSP revenues. To the extent that the PV systems do not reduce required network expenditures, such revenue reductions will need to eventually be made up through tariff increase. The impact of the NSW SBS on all customers has also been previously noted.

IV. Impact of Typical Residential PV Systems on Stakeholders Profits in NSW

In this section we estimate the impact of PVelec on retailers, DNSPs and PV customer operational revenues and costs for the full year period from July 2009 to June 2010. We use actual half hour PV generation and household consumption obtained from three residential 1.1kW PV systems located in the western Sydney suburb of Blacktown in the distribution area of Endeavour Energy.

These three PV systems were selected over a total of 32 1.1kW PV systems in that Suburb based on their generation performance which averages a production of 1,211kWh/kW during that year period. This is close to the median annual production of 1,282kWh/kW calculated from similar half hour dated collected for thousands of systems in the adjacent Ausgrid distribution area [7]. We can therefore consider these systems sufficiently representative for this case study and we average the results across the three households to obtain final values per kW of PV installed capacity. The retailer for these households is assumed to be Origin Energy which is Australia's largest retailer with a very significant NSW presence.

For the estimation of the avoided electricity purchase from the NEM and the assignation of PV exports to retailers the wholesale price w_t in (1) is the regional reference price for NSW each half hour obtained from AEMO [14] adjusted with the corresponding marginal loss factor and distribution loss factors associated to the loads whose values for the case of Blacktown are 1.0043 and 1.0803 respectively [15][16]. Since NEM fees represent less than half a percent of the retail bill [5] they are not considered in this analysis.

Most NSW households still have disc-type accumulation meters and although installation of a PV system generally requires that an interval meter be used, current retail contract arrangements still typically permit customers to be on flat or inclining block tariffs. In our case study we assume that the customer is on the so-called 'Domestic peak' retail tariff offered by Origin Energy in the distribution area of Endeavour Energy. This tariff consists of two blocks where the first 1,750 kWh each quarter are charged at 24.035 ¢/kWh whereas the balance is charged at 26.609 ¢/kWh [17]. Network charges can be flat or TOU according to the particular households metering and retail contract. For such retail tariff the corresponding network charge for Endeavour Energy is called residential peak tariff [18] whose value is 11.4708 ¢/kWh for the first 1,750 kWh/qtr and 14.9116 ¢/kWh for the balance. We take a reference value of g of 9.8 \$/MWh obtained from the green costs component of regulated retail prices for 2011/12 [19].

Despite the considerable number of assumptions, this hypothetical scenario is reasonably representative for the many PV customers currently under flat tariffs in Sydney. Also, this methodology may be easily extended under different retail tariff structures.

Using these commercial arrangements, systems and the payment of 6 ¢/kWh that Origin Energy is currently offering for PV exports [20], (1) suggests that the total change on the retailer operating profit caused by this averaged household PV system during that year period is around -8 $/kW of PV, which represents a 2% of the total operating profit obtained from those households without the PV systems. To obtain such percentage we estimated the total operating profits for that year period (without considering fixed expenses and spot price hedging costs) for these three households without PV systems which average $459/household/year. Fig. 2 shows the total variation for each component of cost and revenues obtained from (1).

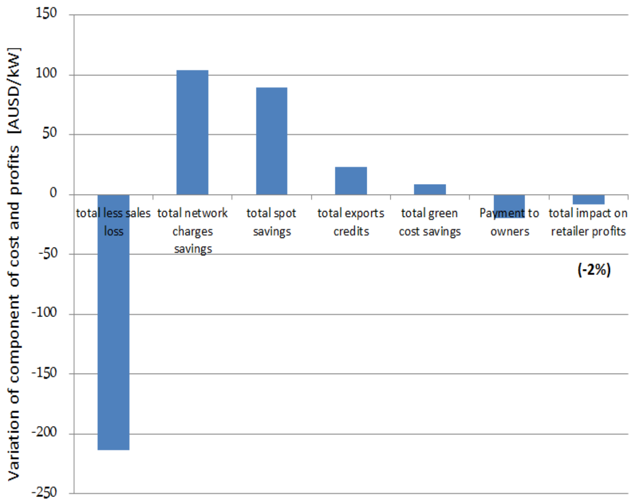

Fig. 2. Total variation for each component of cost and profits.

Fig. 3 shows the impact of PVelec on Origin Energy profits per month during that year period of the case study, and the contribution of each cost component. The total negative values can be seen as the financial gain of the PV customer under the net metering payment of 6 ¢/kWh. This figure shows us the seasonal behaviour of the change of each component of cost and profits for the retailer with the installation of a PV system.

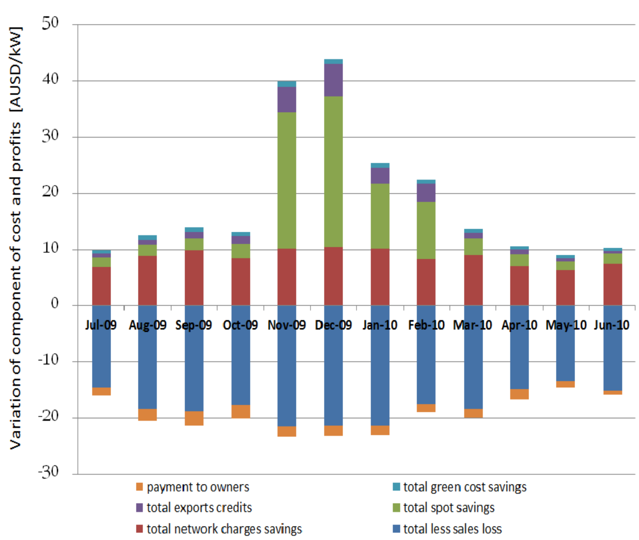

Fig. 3. Monthly change in Origin Energy profits.

It is interesting to notice that the value of total exports credits and avoided purchases from the NEM are much higher in summer since we see both high PV generation and high wholesale electricity prices. In particular, the NEM generally experiences its highest spot prices at periods of highest demand which coincides with very hot days and hence air conditioner loads. This generally coincides with high solar irradiance and hence high PV generation. Whilst household consumption also falls this is more than offset by the whole market savings.

By comparison, using (2), the DNSP, Endeavour Energy, would seem to be losing revenue of around 100 $/year per kW of PV per household.

To visualize the effect of different possible PV support schemes and payments to reward households that install PV systems an estimation of the variation of operating costs and revenues for industry participants was conducted for the case of the NSW SBS and net metering. Under the NSW SBS retailers charge PV customers for the gross consumption and therefore the only change in their operating profits is the assignation of PV exports at wholesale price by AEMO. At the same time, DNSPs must pay the gross FiT to PV customers recovering at the end the total payments from the NSW Climate Change Fund (NSW CCF) which is ultimatelly funded by contributions from electricity and water utilities recovered through network tariffs which apply to all customers [6]. Fig. 4 shows the impact of PVelec on Origin Energy, Endeavour Energy and PV customer net incomes over the year under different payments reflecting the cronological changes for PV support in NSW over the last few years. This started from the gross Feed-in Tariff of the NSW SBS at 60 ¢/kWh, its reduction to 20 ¢/kWh, the current situation where the SBS is cancelled for new participants and some retailers are not offering payments, the recent proposal by IPART of a benchmark payment between 8 to 10 ¢/kWh, a net metering payment closer to a retail tariff level of 20 ¢/kWh and finally an hypothetic scenario of a net metering payment of 60 ¢/kWh. With regard to this final scenario, note that a number of other Australian States have offered net PV Feed-in Tariffs of around this rate.

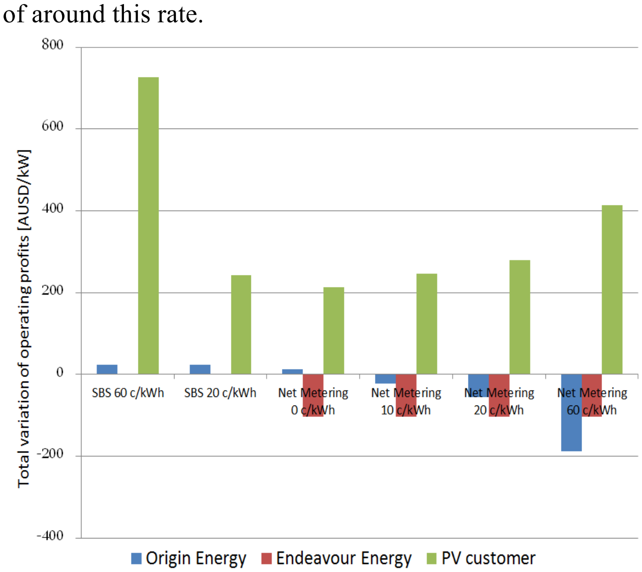

Fig. 4. Impact of different PV schemes and payments on stakeholder profits.

Fig. 4 shows the significant profits reduction for PV customers with the SBS change towards a much more moderate gross FiT of 20 ¢/kWh whereas the retailer experiences the same earnings from the PV exports at wholesale price and the DNSP recovers all the FiTs payments from the NSW CCF. Under net metering it is clear to notice that the negative impact of PVelec on the DNSP profits doesn't depend on the payments whereas the retailer experiences a financial gain when it doesn't pay for PV exports even if it is selling less electricity. Moreover, it was checked in this case study that a net metering payment of 3.5 ¢/kWh avoids the variation in the retailer operating profits whereas a payment of 7 ¢/kWh of exported electricity would be required to offset the financial gain that retailers are obtaining from these households' PV exports. In addition, for these PV systems, the case of a net metering payment of 10 ¢/kWh suggests that the superior limit of the benchmark range recommended by the IPART might reduce retailer operating profits by around $20/kW of PV, representing a reduction of 5% of the total operating profits obtained from those households without the PV systems. Finally for higher level of payments under net metering the cash flow goes from retailers to PV customers.

It is important to note that if the type of meter and retail contract of the household is time of use (TOU) then these results may vary significantly. For current NSW household TOU tariffs, the peak period and highest rate occurs on weekdays between 2-8pm, the shoulder period from 7am-2pm and 8-10pm on weekdays and 7-10pm on weekends and the off-peak rate applies at all other times. PV generation is typically maximum during the shoulder period but is also significant for the peak period as well. At present the shoulder rate is below the flat tariff whilst the peak is well above it. On average, PV is likely to be more valuable to the household, however, we have not undertaken this modeling to date. It is important to keep in mind that the current tariff arrangements do not include, to any significant extent, the environmental damage costs associated with the existing electricity supply system. The environmental benefits of PV with zero operating emissions are not currently reflected in the commercial signals seen by retailers, DNSPs and PV owners who are not receiving a FiT. We discuss this further in the conclusions.

V. Second Order Effects

Apart from the immediate impact of PVelec on stakeholder profits there will be what we might term second order impacts, which will include changes in wholesale prices, network charges and consequently retail tariffs, over the longer term as the industry, and industry regulators, respond to growing penetrations of PV.

Network charges are responsible for around half of current retail tariffs and their recent growth has caused a significant increase in regulated electricity retail prices over recent years [19]. As a result of the reduction of profits for the DNSPs they will presumably seek and be granted permission to increase the charge per kWh to retailers which ultimately will be passed through to end-users. However PVelec may offers other additional benefits and costs as well to DNSPs which may have an impact on the proposed network tariffs to the AER. One the one hand PVelec may provide financial savings to DNSPs for potential deferral of network augmentation. In contrast DNSPs may incur in additional costs to manage power quality issues caused by inverters in PV systems like voltage rise in the grid and harmonics. Reference [7] argues based on submissions from the DNSPs that PVelec doesn't offer at this stage material benefits and if it does it is very context-specific. Thus IPART doesn't recommend further modelling in this regard. What is clear is that increasing levels of PV penetration will impact on network economics. It is possible to envisage a vicious cycle under current tariff arrangements where growing network charges make PV more attractive whilst imposing greater costs on customers who don't have PV [2].

Reference [8] suggests some indicative possible values for deferrals of particular network investments in Sydney that may be triggered by PV deployment. In particular, it estimates the value per kW that a particular PV system located in the same neighborhood where the PV systems used in this paper are located obtaining a value of 65 $/kW based on the possible deferral of a planned new substation.

It is important to note as well that the recent increase of regulated electricity retail prices from 1 July 2011 was driven by major network costs undertaken to meet security and reliability standards [19]. Thus the importance to estimate what is the value that PV systems can provide to improve security of supply in the NEM as a distributed source of generation and how this can impact on network costs and retail prices.

As such, further investigation is required on these effects to determine if their modelling may be required to effectively support policymakers in this regard.

VI. Conclusions and Future Work

Our case study has involved significant assumptions and simplifications. The results therefore need to be considered as preliminary and imprecise estimates of the possible impacts that an average PV system might have on the profitability of different electricity industry participants under current NSW retail market arrangements. It seems likely that household PV systems will have modest impacts on the customer profitability for retailers depending on whether, and to what extent, they pay their PV customers for their exports On the other hand DNSPs would seem to clearly experience a loss of revenue due to reduced sales to households with PV under net metering arrangements. Furthermore, as total capacity of PV systems increase the second order impact like changes in wholesale and network prices will gain in importance. Finally, current commercial arrangements do not reflect the environmental value that PV can contribute to the electricity industry. In particular, greenhouse emissions are not currently explicitly priced within the Australian National Electricity Market and PV system owners who don't receive a FiT are therefore effectively providing emission reductions to the wider community without any financial return. As such the key issue in maximising the value that PV contributes to the electricity industry is not whether supporting policies are required, but what form such support should take. Alignment between social economic PVelec values, commercial arrangements and any PV support policies is crucial to have an efficient deployment of these systems. Efficiency is of course not the only criterion but it will become increasingly important as PV deployment grows. At present retail tariffs in most electricity industries should not be confused with economically efficient prices that reflect the varying value of electricity with time and location. Instead, they are better thought of as schedules of fees intended more for cost recovery than efficient resource allocation, whilst helping meet wider social objectives such as universal energy access. A key question for future work, therefore, ishow these arrangements can be made to better align PV incentives with the wider economic costs and benefits that they bring.

VII. Acknowledgment

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IX. Biographies

Sebastian Oliva received his BH in Electrical Engineering from the University of Chile, Chile in 2008. He is currently pursuing the Ph.D. degree at the School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney, Australia. His research interests include renewable energy policy and energy economics.

Iain MacGill is an Associate Professor in the School of Electrical Engineering and Telecommunications at the University of New South Wales, Sydney, Australia, and Joint Director for the University's interdisciplinary Centre for Energy and Environmental Markets. His teaching and research interests include electricity industry restructuring and sustainable energy technologies, with a particular focus on distributed resources and energy policy.