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Estimating the Financial Costs and Benefits of Distributed Grid-Connected Photovoltaics for Different Electricity Industry Participants

by

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Executive Summary

Falling costs and supportive government policies have seen remarkable growth in residential photovoltaic systems in jurisdictions around the world. While there have been detailed studies of the financial attractiveness of PV for home owners under different policy and retail market arrangements, there has been less consideration of the impacts of such systems on some other key industry participants. In this paper we undertake a preliminary investigation of the financial costs and benefits of PV for households installing them, their electricity retailers and their distribution network service providers (DNSPs) in the Australian State of NSW. We use actual half-hourly PV generation and electricity consumption for over 60 households in Sydney to estimate the impacts of a range of former, current and possible future PV policy and retail tariff arrangements including gross and net Feed-in-Tariffs (FiT), and flat and time-of-use (TOU) tariffs. Results highlight that net FiT policies may provide only very modest financial incentives to households, can have modestly positive financial impacts on retailer revenue yet quite adverse impacts on DNSPs depending on the level of PV export. TOU tariffs can worsen these impacts. Poorly designed policy and regulatory arrangements may therefore fail to appropriate align private incentives with societal welfare.

Keywords: cost-benefit analysis, energy policy, solar photovoltaics

Contents

1 Introduction

Photovoltaics (PV) has experienced remarkable growth in deployment over the past decade driven by falling system costs and supportive government policies in a number of key countries. Over 100 countries have implemented policies to support renewable power generation with many of these targeted towards PV. Feed-in tariffs (FiTs) which provide a premium 'tariff' for eligible renewable generation have been the most widely implemented policy mechanism, and were in place in more than 65 countries and 27 states/provinces worldwide in 2012 (REN21, 2012).

While FiTs have demonstrated their effectiveness in promoting PV deployment in a number of countries, the success of PV has raised growing concerns about the expense of such FiT policies on other energy users who pay the program costs (Elliston et al., 2010; NSW Auditor-General, 2011) and their implications for market participants such as retailers and network service providers (IPART, 2012b; QCA, 2012). Although PV costs have fallen markedly in recent years (Bazilian et al., 2013), it still generally doesn't make financial sense for energy users to install systems given current retail electricity market arrangements and tariffs in most jurisdictions. FiT payments have played a key role in making PV financially attractive for home owners and businesses, and in some cases the financial returns they have offered have proved extremely attractive. The policies have often been justified on the basis that current energy markets do not price the adverse environmental impacts and energy security risks of conventional fossil-fuel generation, and hence benefits of PV. Other policy motivations have included PV's investment and job creation potential, and the promise of reduced future PV costs and, eventually, an economically self-sufficient PV industry.

As such, PV policy interventions might be argued as necessary to address the existing divergence between the societal value that PV offers, and the current commercial returns (value) available to electricity industry participants should they deploy PV systems. There are, however, significant challenges for policy makers looking to establish the most appropriate PV policies to address this divergence in public and private value as noted previously by Borenstein (2012).

One key difficulty is establishing the societal value of PV. As noted above, some key social and environmental benefits of PV by comparison with conventional electricity generation are currently externalities – that is, not priced – within existing electricity markets. However, the industry's underlying economics of energy provision are also inherently complex. The industry must ensure that supply from a diverse range of generation options, flowing instantaneously through a shared specialised grid without significant energy storage, continuously meets a wide range of diverse and ever-changing end user demands. The real energy costs and value of electricity therefore varies by time and location within the network, and is subject to a wide range of uncertainties (MacGill, 2010). PV generation's own temporal and locational variability and unpredictability, and its generally distributed deployment at the end of the network on end-user premises, means its energy value is particularly difficult to estimate. For example, PV typically generates at times of higher electricity demand and hence typically energy value. However, its potential network value depends on its impact on losses and peak demand (which drives network investment), and this depends on the nature of both the solar resource, yet also the aggregated nature of all loads in adjacent areas of the network (Elliston et al., 2010).

Commercial arrangements for electricity customers typically do not reflect these underlying economics. Many small end-users have only basic metering and pay simple (often flat) electricity tariffs for their consumption. Such tariffs have often been set to achieve broader societal objectives and some measure of overall industry cost recovery, rather than to provide economically efficient price signals to all end-users. They are better described as a schedule of fees than as prices in the real economic sense of the term, and may involve significant cross-subsidies between electricity industry participants. The commercial value, or costs, of PV deployment for different participants including end-users, retailers, network service providers and even large-scale generation depends markedly on these tariff arrangements. For example, the value of PV to an end-user, in the absence of specific PV policy beyond net metering, will often be the tariff that would have been paid for the electricity that is avoided through self-generation. The implications of this for retailers are reduced kWh sales for that customer. Under typical consumption based network tariffs, PV also drives a fall in the revenue of network service providers. Other complexities include the very variable and somewhat uncertain performance of distributed PV installations (particularly with regard to orientation and possible shading), changing retail electricity tariffs over time, and falling PV system costs.

Targeted PV policies, therefore, are invariably introduced into a diverse, highly uncertain, rapidly changing and complex context where the social and private value of PV is rapidly changing. While FiT policies have played a critical role in PV deployment and cost reductions, some recent jurisdictional efforts have created an extremely compelling financial case for energy users leading to unexpected and overwhelming rates of installation. As a consequence, many existing FiTs have been revised over recent years including those of France, Germany, Italy, Spain and the UK (DECC, 2012, p. 6; REN21, 2012). In Australia, the FiTs Solar Bonus Scheme (SBS) implemented in the state of New South Wales (NSW) led, in conjunction with Federal Government support and falling PV prices, to the deployment of over 150,000 PV systems in little more than a year (IPART, 2012b). This has involved significant financial transfers from all energy customers to those households who installed PV systems (NSW Auditor-General, 2011), and led to the sudden cancelation of the scheme for new participants little more than a year after the scheme commenced. This unfortunate outcome 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 other than those who have deployed PV. For example, the Independent Pricing and Regulatory Tribunal (IPART) of NSW was tasked with determining a fair and reasonable value of PV sourced electricity exported to the grid and its impacts on Distribution Network Service Providers (DNSPs) and electricity retailers.

In (Oliva and MacGill, 2011) we explored the societal economic value of residential PV systems in NSW, applying a broad perspective that included potential energy, network and environmental costs and benefits. Results suggested that investments in household PV systems there could be socially beneficial given appropriate system performance, and reasonable assumptions regarding factors such as social discount rates.

This analysis, however, did not consider how the costs and benefits of household PV are currently shared across key industry stakeholders. Beyond the households actually deploying PV, such stakeholders include electricity retailers that buy electricity from the wholesale market and retail it to end consumers, and the monopoly, economically regulated, network service providers that are responsible for capital and operational expenditure on the electrical network. Such analysis has potentially considerable policy relevance. As PV deployment grows, even modest financial impacts, adverse or positive, on key stakeholders under current commercial arrangements may grow to represent very considerable financial transfers. Ideally, and subject to the uncertainties and complexities noted above, PV related policy should look to better align private costs and benefits of PV across all these different stakeholders, with societally optimal decision making on PV deployment. Furthermore, commercial arrangements need to be compatible with other challenges of the electricity industry like security of supply and environmental and equity goals.

In this paper we undertake a preliminary and high level investigation of the commercial (private) costs and benefits of household PV systems for key market participants under current retail market arrangements in the NSW region of the Australian National Electricity Market (NEM). We assess the marginal change in financial transfers for households deploying PV, their retailers and their distribution network service providers (DNSPs). We assess this using a year of half hourly PV generation data from over 60 household PV systems installed in Western Sydney in order to capture the implications of better and worse system performance. We consider a range of former, current and possible future NSW PV policy and retail tariff arrangements including gross and net PV FiT, and flat and time-of-use (TOU) retail tariffs. The intent of this analysis is to assist policy makers considering the possible implications of different commercial arrangements in retail electricity markets, and any associated PV support policies.

The remainder of this paper is organized as follows. In Section 2, we review existing research on establishing the societal value of PV, and assessing the commercial implications of PV deployment to different electricity industry stakeholders. Section 3 outlines existing commercial arrangements for small-scale PV systems in NSW and 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. The methodology used for our study is presented in Section 4, and the data and assumptions in Section 5. Section 6 presents results, using actual generation and load data for a sample of 61 household PV systems in Sydney, of the financial impacts (net changes in revenues and costs) for these different electricity industry participants for 2012/2013. Finally, Section 7 presents some tentative conclusions of the study and thoughts on future work.

2 Previous work on the societal and private value of PV

There is a diverse and growing literature on PV economics that presents cost-benefit assessments with respect to both society as a whole - hence considering externalities such as the environmental harms avoided with PV - and private industry stakeholders such as PV owners and their electricity utilities. Haas (1995) proposed a descriptive approach to assess the value of PV for customers, electric utilities and society. While the first two valuations are based on private individual benefits; the social value is considered as the sum of benefits for private participants plus environmental benefits. More recent articles that estimate the value of PV for a variety of industry participants include (Chaurey and Kandpal, 2010; Hammond et al., 2012; Yamamoto, 2012). Hammond et al. (2012) assess the value of PV from the householder and societal perspective in the UK concluding that under current PV policies, systems don't pay back the investment for either party. Using a more theoretical approach Yamamoto (2012) compares FiTs and net metering arrangements for consumers, utilities and society to relate the reduction of electricity consumption with the social welfare of such payment schemes. Chaurey and Kandpal (2010) assess the value of PV microgrids, again for these three participants, concluding that such microgrids are generally more economic than rural electrification.

The marginal societal value of residential PV in NSW was estimated by the authors Oliva and MacGill (2011) using a methodology that separately assessed energy, network and environmental benefits. PV's energy value was estimated as the wholesale price of electricity in the NSW region of the Australian National Electricity Market (NEM) given that PV generation (PVelec) offsets the generation of the marginal unit which generally sets the price. Under competitive market arrangements, this generator's offer price should be close to its production costs. Avoided losses in the network are estimated using a methodology that considers the non-linear relation between power flow and losses proposed in (Borenstein, 2008) whereas some potential values of deferral network augmentation are obtained for a number of locations in Sydney based on NSW DNSPs data. Finally the environmental value of PV considers the avoided CO2 emissions using a methodology that uses the emission intensity factor of the power plant whose generation is being displaced, multiplied by a social carbon cost. Results suggested that household PV could be socially beneficial under some circumstances.

Most of the economic assessment of PV in the literature, however, has focussed on assessing the value of PV for owners, particularly grid-connected households, generally to evaluate whether commercial arrangements and PV policies in place are encouraging consumers to invest in solar energy. In this regard Borenstein (2007), Mills et al. (2008) and Darghouth et al. (2011) investigated the impact of different electricity retail tariff design and arrangements on residential and commercial PV customer returns in California. As well, innovative PV business models has been assessed for households in California by Drury et al. (2012) who shows that third-party PV ownership effectively expands the PV market. More recently, again in the US context, Burns and Kang (2012) compare different type of PV incentives for households focusing in the Solar Renewable Energy Credits whereas Darghouth et al. (2013) presents the long term electricity bill savings of residential PV customers under net metering, for different scenarios of PV deployment and electricity tariffs, highlighting that PV returns in the long term are highly uncertain.

Other international work includes an assessment of the profitability of PV for households under gross FiTs in Malaysia (Muhammad-Sukki et al., 2011) and under net FiT with the addition of storage systems in Spain (Colmenar-Santos et al., 2012). Both studies concluded that the FiTs generate good returns for investors. In the context of more developing countries Rüther and Zilles (2011) argues that grid parity will be reached in Brazil in the present decade whereas Radhi (2011) argues that the PV technologies are not a cost-effective solution in the residential sector for the Gulf Cooperation Council countries. McKinsey & Company (2008) used current and estimated future retail electricity tariffs in a range of countries with estimates of future PV system cost reductions to estimate when different countries might see PV achieve grid parity.

In the Australian context SKM MMA (2011a) estimated the FiT rate for payments to PV owners for their PV generation that would be required to pay back their investment for specified numbers of years. However, PV costs have reduced considerably since those estimations were carried out. More recently McHenry (2012) assessed the net present value for PV owners in Western Australia obtaining negative values even considering capital subsidies. Oliva and MacGill (2012) made a preliminary assessment of the PV value not only for PV customers but also retailers and DNSPs whilst the most recent determination of the IPART in NSW estimated the value of PV exports for retailers for 2012/2013 at a rate close to the wholesale price of electricity (IPART, 2012a).

In summary, it is clear that both public (social) and private PV valuations are very context-specific. Both depend on assumptions about the performance of the PV systems in practice. Private valuations depend primarily on the specific commercial arrangements in place (which can be highly complex and rapidly changing as seen with FiT tariffs). FiT measures have had, in a number of cases, made very marked improvements to the financial attractiveness of PV for households, but have also had, in some cases, adverse impacts on some other electricity industry stakeholders. Furthermore, the falling costs of PV seen over recent years, rising electricity prices in many countries and growing efforts to price environmental externalities such as greenhouse gas emissions are certainly closing the current gap between private benefits and costs for households around the world irrespective of specific FiT tariffs. This poses opportunities, yet also challenges for policy makers seeking to appropriately facilitate PV deployment, and provides a key motivation for this study.

3 Commercial Arrangements for Small-scale PV Systems in NSW

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

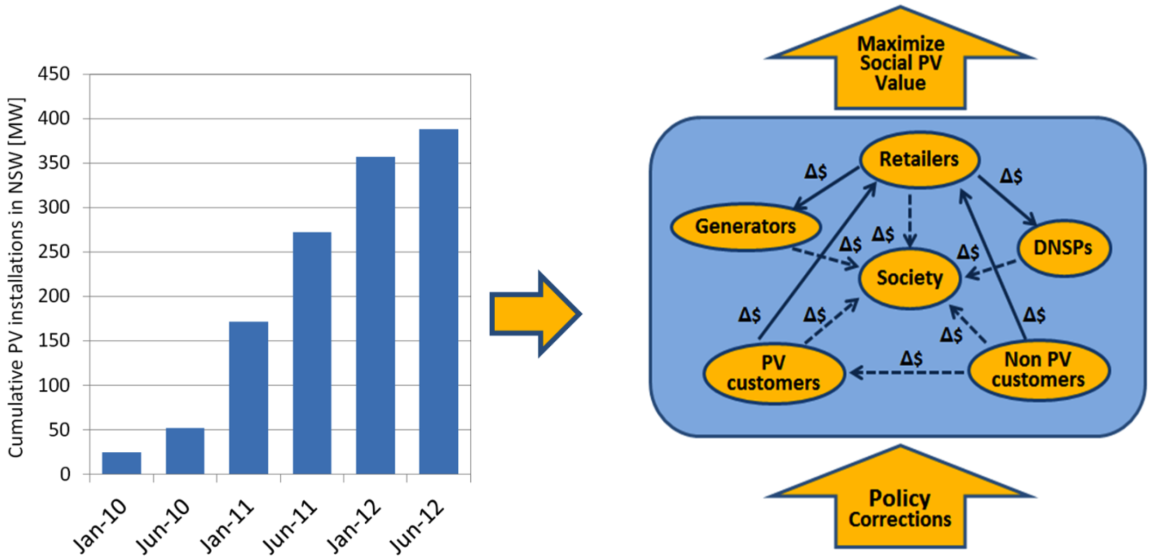
- Retailers (known as suppliers in some other industries such as the UK) who purchase electricity from the wholesale market and sell to energy users through retail tariff contracts;
- Distribution Network Service Providers (known as DISCOs in some industries) who are regulated monopolies within their service region that own and operate the distribution network, and charge regulated network tariffs to 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 presently have a PV system installed.

All of these market participants may be 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 renewable energy credits, and how this additional revenue is raised.

Under the former NSW Solar Bonus Scheme PV customers get paid a gross FiT of A60 ¢/kWh which is raised through a tariff imposed on all end-users through the DNSPs (NSW Auditor-General, 2011). It might be expected that retailers would not be impacted under these arrangements. Interestingly, however, retailers have the generation from a customer's PV system 'assigned' to them within the market clearing process and can therefore actually experience financial gains under the SBS since they don't have to purchase the equivalent kWh from the wholesale market. Some but not all retailers do provide a PV premium for their customers PV generation that is also receiving the SBS FiT (which corresponds to their estimated value of avoiding that wholesale purchase).

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 and any residual exports are paid at a retailer-set tariff. Current financial flows between key electricity industry stakeholders are highlighted in Fig. 1 (b) which shows how rapid PV deployment in NSW (as shown in Fig. 1 (a)) is altering current commercial transfers in the NSW electricity industry, with consequent overall impacts on society. The potential complexities are apparent for policy makers looking to align private commercial price 'signals' for PV deployment with socially optimal PV outcomes.



(a) (b)

Fig. 1. (a) Cumulative small-scale distributed PV installations in NSW. Data source: (NSW Trade & Investment, website). (b) Change in benefits and costs for participants due to PV deployment. Solid lines represent a direct commercial transfer whereas a dashed line is an indirect transfer. Actual flows will depend on the commercial and additional PV support policy arrangements in place.

4 Methodology

This section presents the methodology we use to obtain the marginal operational financial impact of 1 kW of residential PV in NSW on households deploying PV, their retailers and their DNSPs. Note that this analysis is undertaken on the margin – that is, the impact of an additional 1kW residential PV system with the assumption that it doesn't directly influence fixed retailer costs, change DNSP expenditure through changes to peak demand, or drive changes in future commercial settings such as tariffs on the basis of its impacts on retailer and DNSP revenue. Such dynamics from greater PV deployment are an important issue and we discuss this further in the paper's final section.

Given this assumption we also don't consider the impacts of PV on non-PV electricity consumers or the major generators. We consider both gross metering (GM) based on the NSW SBS and net metering (NM) of PV systems. Under GM, total PV generation is measured separately from the household load and hence the gross generation is 'counted' as exported to the grid. With NM, by comparison, the meter only records PV generation when it exceeds household load. At other times, the PV generation, instead, reduces metered loads for the household. Note that the size of the systems on these households (around 1kW) has a significant impact on the NM findings. Larger systems with greater export would see potentially very different financial flows and this is also an area for future work. We also consider the implications of flat retail tariffs versus TOU tariffs as both are available in the NSW retail market.

4.1 FiT for gross PV generation

The NSW SBS initially offered a FiT to eligible customers for all PV generation at a rate of A60 ¢/kWh. While both GM or NM are possible under the SBS, the vast majority of PV systems were installed under GM arrangements (IPART, 2012b, p. 146). Retailers bill these customers for their total electricity consumption. The FiT is paid to customers by DNSPs (through the customers' retailers) which recover the entire amount of these payments through the NSW Climate Change Fund (CCF). This fund is collected from water and electricity utilities which are permitted to pass-through these contributions to all end-users.

4.1.1 *Value for PV customers*

The NSW SBS rewards eligible PV customers with a FiT for their gross PV generation. Thus, if $\Delta Crev_t$ is the operational revenue of a kW of PV generation over period *t*, $Cpvelec_t$ is the total PV generation (kWh) from that kW over time *t*, and FiT_{gross} is the gross FiT rate ($/kWh) then,

$$\Delta Crev_t = Cpv_{elec\,t} \times FiT_{gross} \qquad (1)$$

4.1.2 *Value for Retailers*

Retailers are 'allocated' the PVelec of their PV customers and can therefore avoid purchasing the equivalent kWh from the wholesale market. These savings include avoided electricity purchase costs, avoided losses costs and avoided NEM fees (IPART, 2012b). Of particular note, some but not all retailers paid their customers who have PV systems a 'premium' broadly equivalent to these savings. Some didn't, and therefor profited from their PV customers. In an IPART review of the SBS in the year following its introduction, it was decided that retailers should contribute to the scheme and a compulsory contribution of A7.7 ¢/kWh of PV generation by their customers must now be paid to the NSW government (IPART, 2012a).

Our formulation values PVelec at the wholesale price of electricity w_t at time *t* adjusted by loss factors to account for losses as Eq. (2) shows. R_c is the retail contribution to the FiT scheme noted above and $\Delta R_{prof\,t}$ is the final value for retailers.

$$\Delta R_{prof\,t} = (w_t - R_c) \times Cpv_{elec\,t} \qquad (2)$$

We ignore NEM fees since they represent less than half a percentage of the typical retail bill (IPART, 2012b, p .123).

4.1.3 *Value for DNSPs*

DNSPs pay the FiT under the NSW SBS. However, as mentioned above, they are not financially affected since they recover the direct tariff FiT costs from the NSW CCF which is ultimately paid by all electricity and water end-users. Note that there is some concern regarding the administration costs of the SBS on the DNSPs. However, we do not consider this here.

4.2 NM arrangements

This type of metering arrangement causes the separation of the PVelec into two components: the PV self-consumption (SC) by the system owner and the PV exports when system generation exceeds customer load. PV customers experience savings in the electricity bill by buying less electricity from their retailers, as well as receiving a payment from their retailer for any exported PV generation. This arrangement has more significant implications for DNSPs and retailers, as presented below.

4.2.1 Value for PV customers

Under NM the value of PVelec for PV customers consists of electricity bill savings plus any additional payment for their exports. Eq. (3) shows this cash flow where at time *t*, $R_{tariff\ t}$ is the retail tariff, SC_t is the self-consumption (kWh), Exp_t are the PV exports (kWh) and $R_{nm\ t}$ is a retailer FiT payment.

$$\Delta Crev_t = R_{tariff\ t} \times SC_t + R_{nm\ t} \times Exp_t \qquad (3)$$

4.2.2 Value for Retailers

Estimating the overall value for retailers in this case requires assessing the financial impact of both PV SC and exports. Retailers experience less sales of electricity for the SC which means that they don’t sell SC at the retail tariff, however, they do save the costs of purchasing the equivalent kWh in the wholesale market, as well as avoiding network charges $N_{tariff\ t}$ and green surcharges *g* related with the Australian Renewable Energy Target. Additionally, as previously noted, retailers are ‘assigned’ their PV customers exports at the wholesale price, whilst paying their PV customers $R_{nm\ t}$ for it. The operational PV value for retailers is therefore calculated as in Eq. (4).

$$\Delta R_{proft} = \left(-R_{tariff\ t} + N_{tariff\ t} + g + w_t\right) \times SC_t + \left(w_t - R_{nm\ t}\right) \times Exp_t \qquad (4)$$

4.2.3 Value for DNSPs

At the residential level DNSPs obtain in part their revenues from consumption-based charges per kWh to retailers. Therefore, due to household SC, DNSPs experience less operational revenues without necessarily reduced costs. Such financial loss □$DNSPrev_t$ is estimated here at the variable component of the distribution network charge called ‘Distribution Use of Systems’ (DUOS) $DNSP_{DUOS\_tariff\ t}$ as shown in Eq. (5).

$$\Delta DNSP\ rev_t = -DNSP_{DUOS\_tariff\ t} \times SC_t \qquad (5)$$

Daily and seasonal variation in PV generation and wholesale electricity prices requires solving these equations over an extended period of time. Thereby, to capture representative patterns in NSW we use data and commercial settings for a one year period as we describe in the next section.

5 Data and Assumptions

5.1 PV and NEM data

To carry out these estimations we use actual half-hourly household electricity consumption and PV generation data for a one year period FY2010[1] obtained from 61 households in Sydney that each have PV systems of around 1 kW capacity[2]. Much of the existing financial analysis of PV uses measured or modelled performance of single systems. In practice, residential systems will often vary significantly in performance due to varying equipment quality, system orientation and tilt, and non-ideal solar access. Furthermore, household electricity consumption varies very markedly. Our approach therefore uses load and PV data from a large number of households in order to provide more realistic estimates of PV generation and financial impacts. The average annual PV production of these houses over the year was 1,200 kWh/kW/year. This value is actually slightly lower than the average 1,282 kWh/kW/year for 1 kW PV systems during FY2011 in the Ausgrid distribution area of Sydney according to (IPART, 2012b, p. 32). We do see some significant year to year variation of total solar insolation, however, there may also be some adverse factors for the systems used in this study as they were all installed as part of a single government program. As such, our results may under-estimate the typical value financial flows associated with PV systems in Sydney.

Furthermore we use actual half-hourly wholesale electricity prices for the NSW region of the NEM over the study period. This dataset appears reasonably representative of the long term average wholesale price in NSW. The average NSW wholesale price during FY2010 was A44 $/MWh while the average NSW wholesale price of the last 7 years is A46 $/MWh (AER, website).

These prices were escalated to FY2013 prices using the projections of (Australian Treasury, website) under its so-called ‘Clean Energy Future’ scenario which incorporates current Australian clean energy policies such as the Australian carbon price. These prices were also adjusted by the corresponding marginal loss factor and distribution loss factor of the location of these PV systems; 0.53% and 7.7% respectively according to (AEMO, 2012a, 2012b). This approach captures the correlation between PVelec and wholesale prices which has considerable relevance to financial flows for retailers under some scenarios.

5.2 Assumptions

Most NSW households still have conventional disc-type accumulation meters and while installation of a PV system generally requires that an interval meter be installed,

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[1] FY indicates the Australian financial year which starts on the 1st of July of the previous shown year and finishes on the 30th of June of the shown year.

[2] These residential PV systems were installed in the Western Sydney suburb of Blacktown, within the distribution network of Endeavour Energy, as part of the Australian Solar Cities program.

current retail contract arrangements still typically permit customers to be on flat or inclining block tariffs – that is, a fixed $/kWh charge for all, or a given portion of consumption. Network tariffs can also be flat or TOU according to the particular household metering and retail contract. Therefore, private commercial cash flows between market participants were estimated using regulated FY2013 flat and Time of Use (TOU) Endeavour Energy network charges and Origin Energy[3] retail electricity tariffs for residential customers in Sydney (Endeavour Energy, 2012a; Origin Energy, website)[4] . The chosen tariffs are shown in Table 1.

Table 1. Retail Tariffs and Network Charges for FY2013[5].

Type of Tariff	Tariff Component	Retail Tariff [¢/kWh]	Network Tariff [¢/kWh]
Flat tariffs			
	Consumption of first 1,750 kWh/quarterly:	26.7	11.9
	Remaining consumption kWh/quarterly:	29.8	16.0
TOU tariffs			
	Peak consumption (1pm - 8pm on business days):	38.9	21.3
	Shoulder consumption (7am-1pm and 8pm-10pm business days):	29.8	12.3
	Off peak consumption - (10pm-7am everyday):	15.0	5.2

For customers with PV systems, we consider two scenarios under gross metering, a FiT rate of 60 ¢/kWh as per the original NSW SBS offer and a FiT rate of 7.7 ¢/kWh as the recent proposal of the Queensland Competition Authority (QCA) for the review of Queensland FiT for FY2014 (QCA, 2012). Regarding net metering, we assume payments for exports at 0 ¢/kWh based on potential no payments from retailer and at 7.7 ¢/kWh according with the lower bound of the benchmark range set by the IPART (2012a). As well, from IPART (2012a), we use a retailer contribution to the gross FiT of 7.7 ¢/kWh.

Network tariffs of Table 1 include not only DUOS yet also transmission costs and pass-through elements related to the NSW CCF. According to Endeavour Energy (2012b, p. 61) DUOS charges correspond to 87% of the total average network bill – based on an average annual consumption of 6,000 kWh - for regulated residential customers located in its distribution area. Such percentage includes both fixed and variable DUOS charges. Thereby, assuming that the variable charge of a network bill represent around 85% of a total annual bill – for a 6,000 kWh/year customer with tariffs of Table 1 plus fixed charges - we apply the same proportion for DUOS. As such,

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[3] Origin Energy is the Australia's largest retailer with a very significant NSW presence.

[4] NSW does have a so-called competitive retail market, and a wide variety of retail tariff offers at the residential level. However, they don't appear to vary greatly given the default tariffs that are available under the current regulatory arrangements. The chosen tariffs would therefore appear to be generally representative for NSW under current arrangements.

[5] Note that all prices are shown in Australian dollars - at the time of publication the Australian and US dollar were near parity. These prices include the so-called 'goods and services tax' (GST) which is a broad-based tax of 10% on most goods, services and other items sold or consumed in Australia.

the resulting variable DUOS corresponds to a 73% of the total network bill and hence we apply this percentage to each component of the network tariff of Table 1 to obtain variable DUOS charges in ¢/kWh.

Also, to estimate the value for retailers we use a reference value of g of 1.15 ¢/kWh obtained from the retailer cost component of regulated retail prices for FY2013 (IPART, 2012c).

6 Results

6.1 PV policy and retail tariff scenarios

In this section we present the marginal value of residential PV systems in FY2013 Australian dollars for PV customers, electricity retailers and DNSPs over FY2013 for a range of different existing, and possible future, commercial arrangements and policy scenarios, as described in Table 2.

These scenarios attempt to cover the changing context for PV since the introduction of the SBS in 2010. Firstly we consider a PV system falling under the NSW SBS, with the original gross FiT payment of 60 ¢/kWh, for the cases where the retailer makes no payment for the PV sourced electricity that is allocated to them, or makes a payment to the government. As noted previously, until the government made such payment compulsory to assist in financing the FiT, some but not all retailers offered a voluntary payments to their PV customers (IPART, 2012b, p. 141). Regarding NM arrangements for those households who installed their PV systems too late to receive the FiT, we analyse both the case where retailers pay and don't pay their customers with PV systems for any PV electricity exports. This is a voluntary payment only and it's likely that some retailers won't offer such payments as was seen initially with the SBS. We consider the cases of these residential customers being on flat, or TOU tariffs for their electricity consumption. Finally we consider two possible future arrangements for NSW. One is an hypothetical NM scenario of interest in Australia where payments for export are set at the retail tariff of electricity. This has been argued by some Australian PV stakeholders as appropriate on the basis that current commercial arrangements are not suitable for distributed PV, and it effectively competes with the retail electricity tariff (APVA, 2011). The other is a preliminary proposal made by the QCA that residential PV systems should be gross metered but only paid for the energy value (around 7.7¢/kWh) on the basis that they don't reduce necessary network expenditure (QCA, 2012).

Table 2. Description of PV arrangements.

PV arrangement	Description
GM – no Rc	FiT payment to PV customers for gross PV generation at either 7.7¢/kWh or 60 ¢/kWh, with no retailer contribution to the FiT.
GM – Rc	FiT payment to PV customers for the gross PV generation at either 7.7¢/kWh or 60¢/kWh, with a retailer contribution to government funding of the FiT of 7.7¢/kWh.
NM-0 – Flat	NM arrangement with no PV export payment from retailers to PV customers who are on flat tariff.
NM-0 – TOU	NM arrangement with no PV export payment from retailers to PV customers who are on TOU tariff.
NM-7.7 – Flat	NM arrangement with a PV export payment of 7.7 ¢/kWh from retailers to PV customers, who are on flat tariff.
NM-7.7 – TOU	NM arrangement with a payment of 7.7 ¢/kWh for exports from retailers to PV customers who are on TOU tariff.
NM-Rtariff – Flat	NM arrangement with a payment at retail tariff for exports from retailers to PV customers who are on flat tariff.
NM-Rtariff – TOU	NM arrangement with a payment at the retail tariff for exports from retailers to PV customers who are on TOU tariff.

6.2 Annual PV value for participants

Using half-hourly PV generation and load data over FY2010 for 61 households, we estimate the annual value (change in cashflow) for households with PV systems, their retailer and their DNSPs using equations 1 to 5. Results are normalized with respect to PV capacity of 1kW.

6.2.1 Value of PV for PV customers

Results highlight the potentially very different value of PV systems to households as shown in Fig. 2 and Fig. 3. This is largely an outcome of the performance of the system in practice. Other analysis of these household systems has highlighted the impact of inappropriate system orientation and tilt, system configuration and shading on overall generation (Lewis, 2011). We show the value of PV for customers in a box plot format in Fig. 2 and per customer in Fig. 3. The latter is order according to annual PV production (lowest to highest).

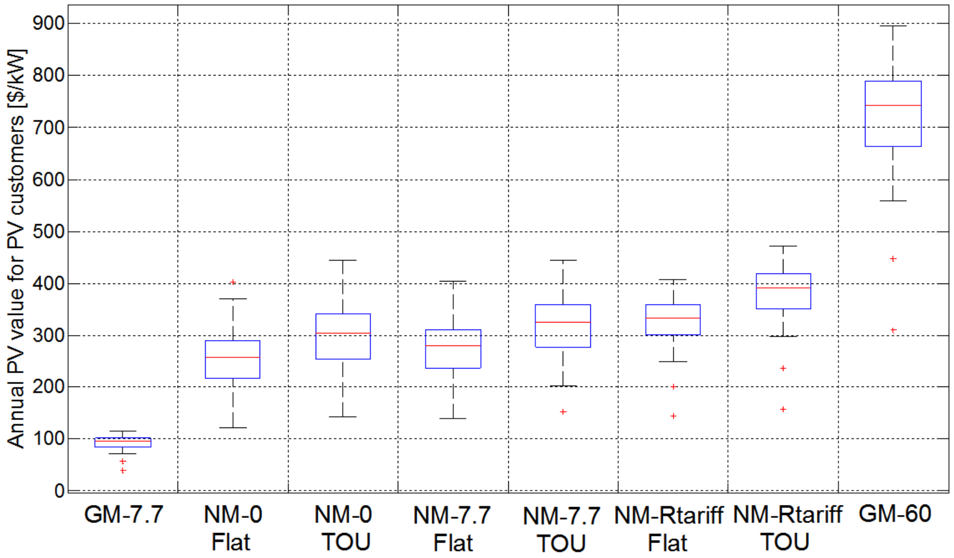


Fig. 2. FY2013 PV value for the Study households under key different PV and retail scenarios. Box plots identify the median, the 25th and 75th percentiles of system value while whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually.

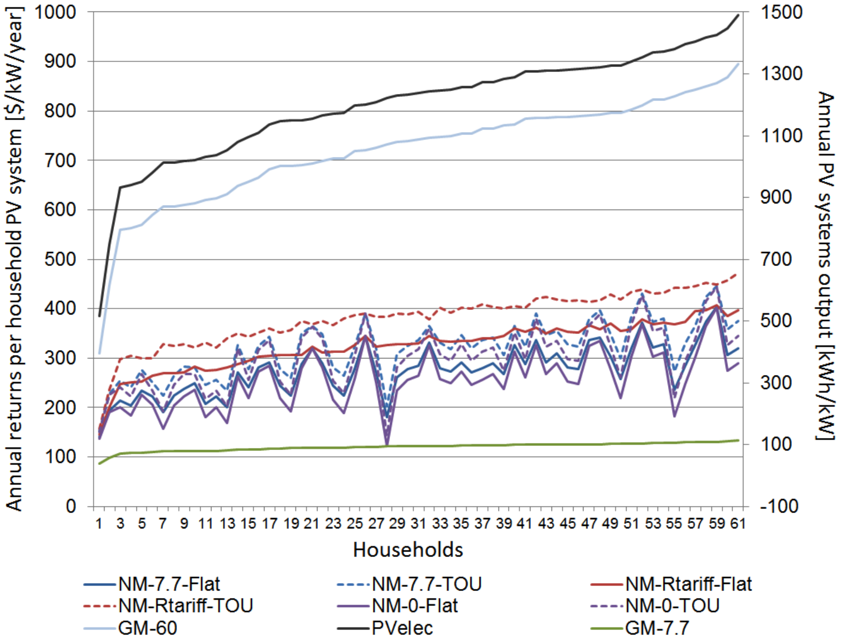


Fig. 3. FY2013 annual value of PV for each Study household for the different scenarios ordered against annual PV output from lowest to highest performing PV system.

Ignoring outliers, NSW households receiving the SBS FiT may be earning less than $600/kW/year or almost $900/kW/year. By comparison, a gross FiT of 7.7 ₵/kWh would see the median household receiving less than $100/kW/year. Households under net metering arrangements receive returns varying from an average $250/kW/year to nearly $400/kW/year depending on the net FiT rate and retail tariff arrangements. Returns depend not only on overall PV generation but also, now, the pattern and scale of household consumption which determines the amount of PV export. Households generally obtain more PV value if on TOU tariffs given the useful match between PV generation and shoulder and peak tariff times, and when retailers pay for PV exports. Interestingly, payment of the full retail tariff for exports doesn't greatly impact household value, although the relatively small size of the systems on these households (hence relatively low levels of export) is a major factor here. Average residential PV system size in Australia is significantly greater than 1kW and it can be expected this will significantly impact such results. Still it is clear that the main source of value for new PV customers today in NSW with relatively small systems arises from electricity bill savings due to reduced purchases from the retailer.

Fig. 2 and Fig. 3 also highlight that the impact of changing the tariff structure from a flat to a TOU tariff has a greater impact than passing from a case of no payment for exports to a 7.7 ¢/kWh payment for exports. However, the TOU tariff will have implications on household payments for their load, and this is not something included in the results. Without the PV system, Study households moving from a flat tariff to TOU tariff would see their bills increase by an average $73/year for electricity plus an extra $80/year for fixed charges. Shifting from flat to TOU tariffs when installing a PV system therefore poses the risk that whilst it increases the value of the PV, it also increases the electricity bill for household consumption.

These annual operating revenues under the different scenarios need to be compared against the likely purchase cost of the system which is around $3,000/kW including capital subsidies. We explore the overall PV customer returns in more detail later in the paper.

6.2.2 Value of PV for Retailers

Fig. 4 shows the value (change in cashflow) for the electricity retailer of having residential customers installing a PV system under all of the tariff and policy scenarios. Note that there are significant complexities in determining the retailer margin associated with the sale of an additional kWh due to factors including the mix of fixed and variable costs involved in servicing a customer and potential costs other than wholesale energy, losses, network tariffs and green energy surcharges (for example, the costs associated with hedging energy price risk with changing net customer demand profiles). These results need to be treated as preliminary and indicative in these regards.

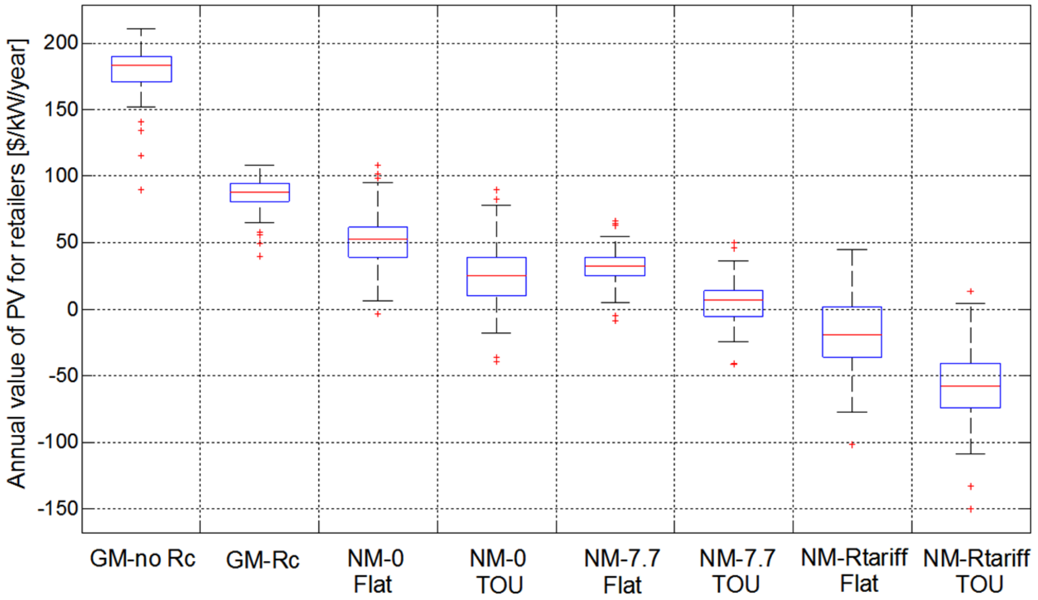


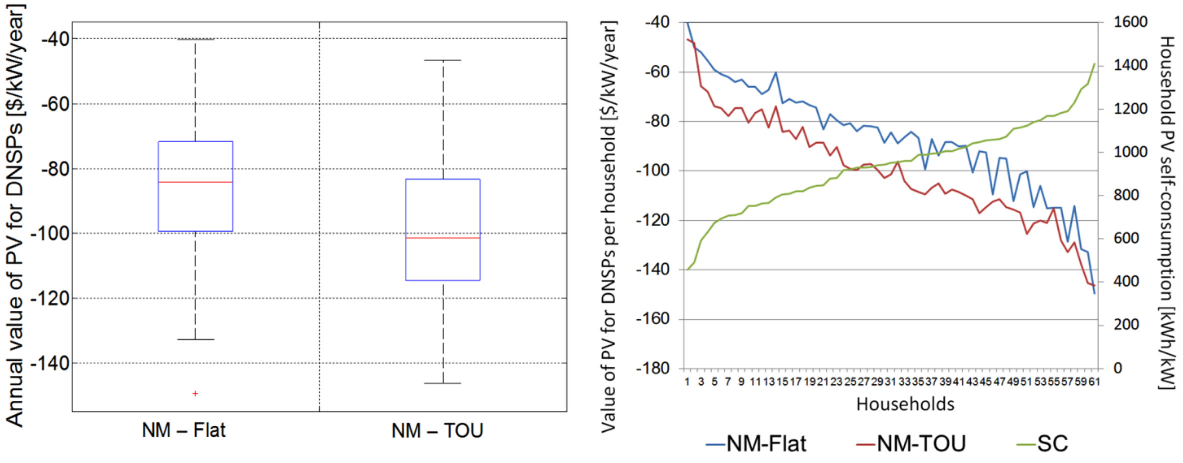
Fig. 4. FY2013 PV value for retailers under different PV arrangements. Box plots identify the median, the 25th and 75th percentiles while whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually.

It is clear that the impact of PV deployment on retailer net operating revenues from a residential customer varies dramatically depending on the arrangements. Under the GM arrangements retailers benefit from having the generation from their customers with PV systems assigned to them. In some cases they may pay the PV system owner nothing for this electricity and therefore profit from each kWh at the wholesale price. Even when required to pay 7.7 ¢/kWh to either the customer or the government, they still receive some benefit from these systems. Such rate was set by the IPART (2012a) as the compulsory retailer contribution to the NSW SBS, however, it corresponds to the bottom of the range of the estimated benchmark PV value for retailers. An additional factor that contributes to the retailer gain is the generally good correlation between PV generation and very high wholesale prices in the NEM, particularly in summer season as noted before by Sivaraman and Horne (2011). Moreover our projected FY2013 wholesale prices consider the effect of the introduction in mid-2012 of the Australian carbon pricing mechanism that increases the wholesale cost of electricity.

Under NM arrangements retailers experience a loss of revenue from reduced sales of electricity although this is offset somewhat by avoiding wholesale purchasing costs and network payments on consumed electricity. Under TOU tariffs retailers experience higher losses than under flat tariffs as the good correlation between PV output and shoulder and peak periods reduces their sales at these higher price times. Despite this, the retailer still benefits from being assigned the exported PV generation under NM arrangements and under most NM scenarios receives a net benefit from PV deployment. The exception is where they are required to pay the retail tariff for exported PV.

6.2.3 Value of PV for DNSPs

As noted previously, DNSPs only see a change in net revenue with residential PV systems under NM arrangements. Fig. 5 shows such these impacts in a box plot (a) and per household (b). Recall also that there are complexities with the potential impact of PV on DNSP net revenue due to factors including their fixed and variable costs of servicing customers, and the potential implications of PV on longer-term network expenditure requirements. As such, these results are best seen as preliminary and indicative.



(a) (b)

Fig. 5. PV value for DNSPs with net metering. (a) Box plots identify the median, the 25th and 75th percentiles while whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually. (b) The individual household values are plotted against self-consumption of the households from lowest to highest.

It is apparent that DNSPs experience the strongest negative financial impact with PV deployment. This reflects the reduced consumption upon which they receive a flat or TOU network tariff component of the retail tariff. Under TOU arrangements revenues are even more adversely impacted since shoulder and peak tariff rates are reasonably well correlated with high solar output. Furthermore, the higher the self-consumption, generally the greater the adverse impact on net revenues (although this is not a perfect relationship because network tariffs either vary with time, or with the level of quarterly consumption). As noted earlier, these reduced revenues don't necessarily involve a reduction in DNSP expenditures which are significantly driven by capital investment to meet peak demands which may not be reduced by PV.

6.3 Characterizing PV customers under NM

It is notable that there is a very wide spread of PV value for households, retailers and DNSPs over the 61 households included in this study. This is a factor of the total level and profile of PV generation, yet also its match with the total level and profile of household consumption. The overall level of PV exports captures much of this relationship, and can be seen to have a major impact on PV value for our different industry stakeholders, as shown in Fig. 6.

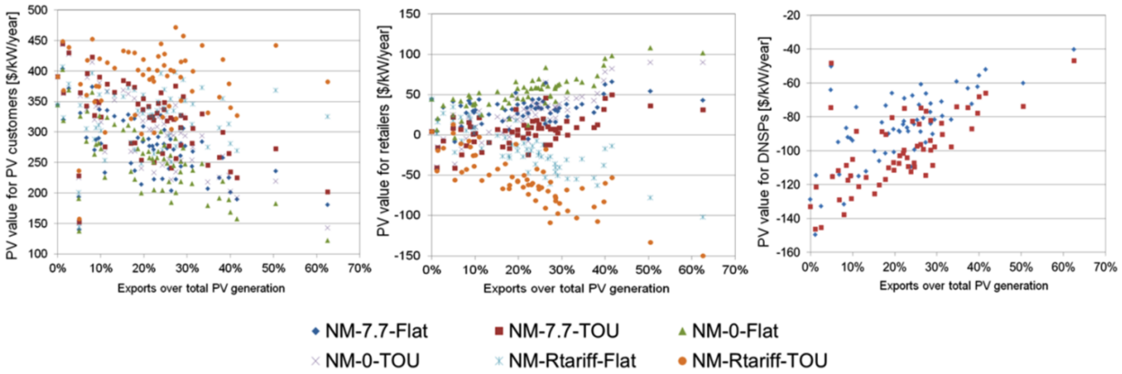


Fig. 6. PV value for PV customers, retailers and DNSPs for the 61 Study households under different NM arrangements, with the household data ordered according to their overall level of PV export.

As Fig. 6 highlights, the higher the level of exports the lower the income for PV customers for all NM scenarios other than when the net FiT is the retail tariff. By comparison, retailer value rises with export for all cases other than when the net FiT is the retail tariff. DNSP PV value increases (that is, losses are reduced) for higher PV export under all cases. There is an important tension here between households that may well seek to increase self-consumption to increase PV value under current NM arrangements, even though this reduces the value of PV for both retailers and DNSPs.

6.4 Overall PV customer returns

The main driver of the deployment of residential PV systems is for the value proposition they offer households. In this regard we estimate the potential overall net present value of PV for households under the range of PV and retail tariff scenarios, assuming system purchase in mid-2012, and for a range of potential discount rates.

To assess future PV returns for customers we escalate the retail tariffs presented in Table 1 by future retail tariff increases projected by SKM MMA (2011b, p. 25) in work undertaken for the Australian Treasury under its so-called ‘Core Policy Scenario’ (Australian Treasury, 2011, p. 88). We assume a PV system lifespan of 25 years and an annual performance degradation factor of 0.5%. Regarding the 7.7 ¢/kWh fixed payment for exports, we assume an annual increase according to the projections of future wholesale electricity prices of Australian Treasury (website) under the ‘Clean Energy Future’ scenario. We use a real discount rate of 8% as in (Hammond et al., 2012). However we explore our valuations by doing a sensitivity analysis with the discount rate using a 12% in line with the rate used by AECOM (2010) and a 5% in line with rates used by both SKM MMA (2011a) and Yang (2010).

Apart from the NM arrangements, and despite the fact that the NSW SBS is closed for new participants, we also include a hypothetical case where the scheme is still open and where customers receive the gross FiT until the year 2016 which is the year when the original scheme payments cease. Afterwards, we assume that customers move on to a NM arrangement with export payment of 7.7 ¢/kWh. Additionally inspired in the recent proposals of the QCA we consider a scenario of gross metering for the whole life of the system with a first year FiT rate of 7.7 ¢/kWh which we escalate again by the long term wholesale prices published by Australian Treasury (website) for future years.

Households installing PV in Australia receive capital subsidies under the Small-scale Renewable Energy Scheme (SRES) which allow them to generate renewable energy certificates associated with the Australian RET that they can sell in the market. In addition the number of certificates has in the past been increased by the so-called 'solar credit multiplier'. In practice installers offer PV prices including such subsidies. We determine payback periods using PV capital costs that include a multiplier of '2' as it was in the second half of 2012, and a multiplier 1 which is running from first half of 2013 onwards as well as for the case of no capital subsidies (CER, website). We use a solar system price of 2.4 $/W according to Climate spectator (website) which includes capital subsidies with multiplier 2. Maintenance costs related with the inverter replacement are 1,000 $/kW according to (CEC, 2011). NREL (2006) argues that the time to failure time of inverters are 5 to 10 years, hence we assume two inverter replacements in the year 10 and year 20 as in (Borenstein, 2012). As such after discounting the inverter replacement costs using our selected discount rate, total PV cost are around 3,100 $/kW for RET multiplier 2; 3,700 $/kW for RET multiplier 1and $4,250 $/kW if there's no capital subsides available.

As such, first summing the gross PV generation, exports and self-consumption of the 61 systems and normalizing by the total PV installed capacity to work with an average residential system; we projected retail tariffs, FiT payments and future PV generation. Fig. 7 shows the cumulative net present value of annual returns for PV customers under different arrangements and capital cost using a real discount rate of 8%.

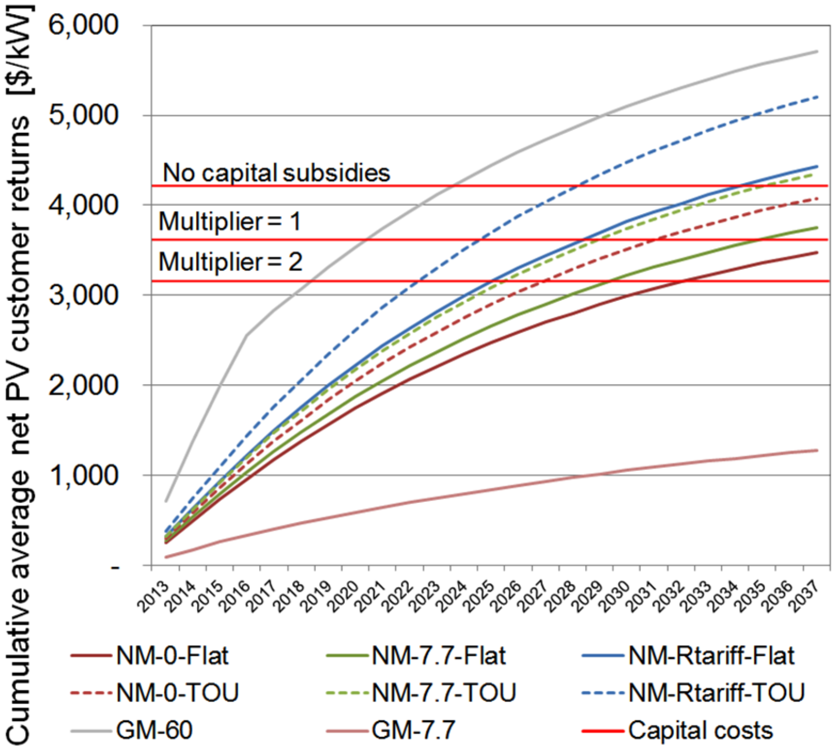


Fig. 7. Estimated PV customer returns for the next 25 years for different PV policy and retail tariff arrangements. The capital costs of the PV systems ($/kW) are shown for three possible cases of policy support to reduce upfront capital costs of the system, as currently available within the Australian Renewable Energy Target.

Comparing cost and cumulative returns from Fig. 7 allow us to determine payback periods for an average residential system installed in July 2012 under different scenarios. Firstly we see how a scheme as the NSW SBS even for system installed today (which would receive payments for four years instead of seven years as the original scheme in 2010) would allow PV customers to experience very short payback periods that range around 6 years for the case of multiplier 2. Without capital subsidies customers under GM-60, their best financial scenario, would pay back the investment in 12 years. Acceptable payback periods for customers shouldn't exceed 10 years according to (SKM MMA, 2011a, p. 3) and given present political differences regarding the RET and carbon price, the current policy context would seem to pose significant risks for the future success of the Australian PV industry. The current situation in NSW of voluntary payments for exports plus bill savings offers PV customers to recover the investment in a PV system in 20 and 15 years under flat and TOU tariffs respectively if the retailer decides not to pay households for exports whereas if the retailer pays the IPART benchmark value of 7.7 ¢/kWh for exports payback periods are 18 and 14 years under flat and TOU tariffs respectively. Also Fig. 7 shows that it seems that the benchmark payment of 7.7 ¢/kWh determined by the IPART doesn't make a great difference for PV customer returns comparing with the case of no NM payments although, as noted previously, this result is significantly impacted by the relatively small size of the systems. None of the NM arrangements present payback periods less than 10 years.

More details on the overall value of systems for household can be seen in Fig. 8 where results and PV costs are shown for different discount rates.

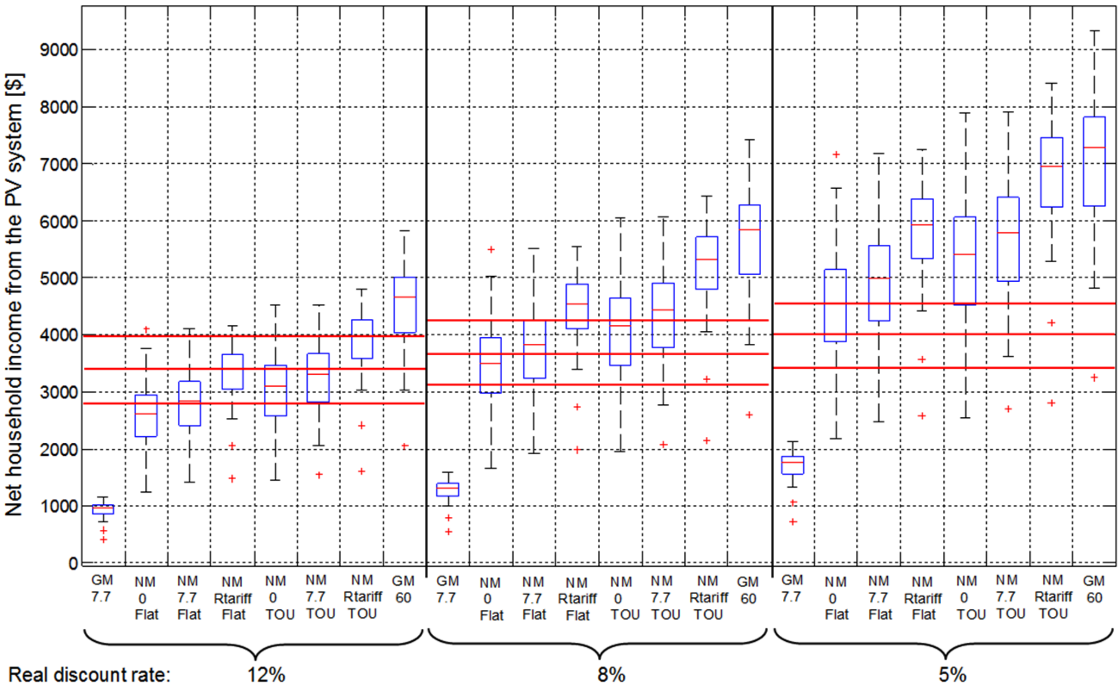


Fig. 8. Total customer net present value for different PV policy and retail tariff arrangements. The red lines represents system capital cost for the case of no, multiplier 1 and multiplier 2 RET support. Box plots identify the median, the 25th and 75th percentiles while whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually.

It is clear that the financial attractiveness of PV systems to households depends greatly on discount rates as well as the PV policies and retail market arrangements in place. The findings highlight the potential challenges for achieving greater residential PV deployment in NSW under currently available or proposed PV support arrangements.

7 Conclusions

This study has estimated the value of residential PV systems in the Australian State of NSW for households that install PV, their electricity retailers and their DNSPs. There are major challenges in making these value estimates so study findings need to be interpreted with caution. Still, results highlight that the costs and benefits seen by these parties depend greatly on the PV policies and retail market arrangements available to households. Furthermore, these costs and benefits vary significantly according to the actual 'real world' performance of the PV system. Systems with poor orientation or that suffer from shading provide significantly lower annual generation and hence drive significantly smaller financial flows than well installed and maintained systems.

Under net FiT arrangements, financial flows also depend greatly on the profile of PV generation and its match to household demand profiles. Under the current arrangements in NSW for households, PV owners are incentivised to maximise self-consumption of their PV generation, and would generally earn more from their PV system if on a TOU retail tariff. By comparison, retailers generally benefit from customers deploying PV because while they lose sales due to customer self-consumption of PV, the exported PV generation that is 'assigned' to them has considerable value, even if they are required to compensate the household for some portion of this value. DNSPs, however, lose revenue under all net metering arrangements due to reduced kWh sales from which they earn a fixed network tariff. TOU retail and network tariffs actually worsen the financial impacts of household participants for both retailers and DNSPs.

Households that modify the timing of their electrical demand to maximise self-consumption and hence the value of their PV system, increase DNSP financial losses, whilst also reducing retailer benefits. Whilst households with higher PV export actually cause lower losses for DNSPs they may potentially drive greater network expenditure in order to manage negative network flows during peak PV generation hours, and where load has been shifted from daylight hours to the evening which is when peak network demand is often seen.

Overall it can be concluded that current PV policy and retail market arrangements provide PV system benefits to households, who after all buy the systems, and their retailers, but reduce household revenue to the DNSP. There is an important issue regarding the longer-term sustainability of such outcomes.

More generally, at present PV system prices, the benefits that accrue to households may not be sufficient to offset the capital costs involved with payback periods generally more than ten years. Proposals to pay PV exports at the standard retail tariff could improve the attractiveness of PV systems considerably for households depending on the size of the PV system, load profile, and their opportunities to load shift. Retailers would likely see some net costs under such arrangements rather than the net benefits that they currently appear to receive. Such arrangements might well reduce adverse financial impacts on the DNSPs as there will be less incentive for households to self-consume PV, and hence less reduction in network tariff collections from kWh sales. An alternative proposal that PV be gross metered and only paid at a rate equivalent to its estimated wholesale energy value would benefit retailers, have virtually no impact on DNSPs but make PV systems entirely uneconomic for households.

Given that well installed and maintained household PV systems in NSW appear to have a net societal benefit, the poor financial returns for households deploying a PV system under current PV policies and retail market arrangements would seem to call for policy intervention. However, as highlighted in this study, such policy intervention needs to be very carefully designed so that PV provides a reasonable value proposition for all key market participants. This is clearly an important area for future work. Also important is a greater understanding of the longer-term dynamics under different possible policy and market arrangements, particular if and when PV deployment becomes even more widespread. Such dynamics are likely to include falling PV system prices, and changing policy and retail market settings as the financial implications of PV deployment on different stakeholders become more and more evident.

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