DYNAMIC MODEL APPROACH TO ASSESS FEED-IN TARIFFS FOR RESIDENTIAL PV SYSTEMS

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Abstract

A brief period of significant PV policy support that occurred concurrently with major PV system cost reductions has led to an explosive deployment of distributed PV systems in the Australian state of NSW. At the same time there has been a lack of a long term economic assessment of these policies in Australia, from both a social and a private perspective, which has ended up in unsustainable and economically inefficient programs. In this paper we assess a range of different feed-in tariff (FiT) options that have been used or proposed within NSW using a dynamic model that estimates longer term PV deployment; consequent impacts on key stakeholders including electricity retailers and distribution network service providers (DNSPs), as well as electricity tariffs; and the social benefits and costs of particular scheme designs and settings. We find that for the majority of the PV policy options we have assessed, their public costs fall within the range of social benefits of avoided carbon emissions using either (lower) control cost or (higher) damage cost estimates. Moreover, commercial returns of PV deployment vary considerably for system owners, retailers and DNSPs for different scheme designs with notably adverse impacts on DNSPs under net metering (NM). Finally, we suggest a possible approach to choose the most appropriate scheme design for different policy objectives.

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, 2012; 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. 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.

On the other hand 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, 2012). 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 this paper we assess a set of household PV policies from both a social and a private perspective under current retail market arrangements in the NSW region of the Australian National Electricity Market (NEM). These policies include FiT subsidies and gross and net metering arrangements. We assess policies estimating their effectiveness in terms of PV deployment, their social environmental value, their costs and the financial impact on retailers, PV customers and DNSPs. Thereby, this analysis intends to assist policy makers to consider 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. The methodology used for our study is presented in Section 2, and the data and assumptions in Section 3. Section 4 presents results, using our dynamic model in the NSW context and under different PV policy options. Finally, Section 5 presents some tentative conclusions of the study.

2. Methodology

Our approach to assess the FiT designs using the social and private value of PV uses two models, a static and a dynamic model. The static model estimates the average annual value of PV for 2013 in $/kW for society, PV customers, retailers and DNSPs using half-hourly PV generation and retail, network and wholesale electricity prices data for 2013. With the dynamic model we estimate future PV deployment based on the future financial attractiveness of PV. Thereby, multiplying such PV deployment by our escalated future annual social and private values from our static model we determine the total environmental value of PV for society and private value for retailers and DNSPs. Details of these two models are explained below.

2.1 Static Model

The societal environmental value of residential PV in NSW was obtained based on a methodology presented in Oliva and MacGill (2011) which estimates the value of avoided CO2 emissions by multiplying the average emission intensity factor of the power plant whose generation is being displaced by a social carbon cost (SCC). In this paper, to estimate environmental benefits of PV, we consider two SCC scenarios: a 'damages' carbon cost from (Hope, 2011) which aims to estimate impacts of climate change caused by greenhouse emissions and a 'control' carbon cost approach from (Treasury, 2011) which is a carbon price imposed via an emissions trading scheme.

Financial impacts on PV customers, retailers and DNSPs are obtained from a different model developed in (Oliva and MacGill, 2012) based on commercial arrangements in NSW which include gross metering (GM) and net metering (NM). 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 reduces metered loads for the household instead.

In this model under gross metering, every half-hour PV customers get the feed-in tariff for the gross PV generation while retailers get assigned these exports and save the cost of purchasing that electricity in the wholesale market. Some retailers can offer voluntary FiTs to PV owners or be obliged to pay a retail contribution to the government. DNSPs pay the FiT under the NSW SBS. However, they are not financially affected since they recover the direct tariff FiT costs from the NSW Climate Change Fund which is ultimately paid by all electricity and water end-users. Under NM, half-hourly, the self-consumed PV generation is valued at the actual retail tariff whereas exports are paid at the feed-in tariff paid by all end-users and to which retailers could contribute. The latter under both NM designs experience less sales of electricity for the self-consumed PV electricity which means that on the one hand they don't sell that electricity at the retail tariff yet on the other hand they save costs of purchasing it in the wholesale market, as well as network charges and green surcharges related with the Australian Renewable Energy Target (RET). Also under both NM and GM retailers are financially 'assigned' their PV customers exports at the wholesale price. Finally DNSPs experience less revenue for the self-consumed electricity which is valued at the variable distribution network charge per kWh called 'Distribution Use of Systems' (DUOS). A summary of the half-hourly equations of this static model is shown in Table 1. Obtaining values in $/kW/year requires summing those half-hourly values for the whole 2013 year period.

Value of PV	**Formula**
Environmental social benefits	= average NSW CO_2 emission intensity x SCC x PV generation
Under GM	
PV customers	FiT x gross PV generation
Retailers	(wholesale price – retail contribution) x PV generation
DNSPs	0
Under NM	
PV customers	Retail tariff x PV self-consumption + FiT x PV Exports
Retailers	(-Retail tariff + Network tariff + green surcharge + wholesale price) x PV self-consumption + (wholesale price – retail contribution) x PV Exports
DNSPs	DUOS x PV self-consumption

Table 1. Equations of change of benefits and costs for participants with PV.

2.2 Dynamic Model

Our dynamic model estimates future PV installations using a linear uptake of PV with respect to a referential historical uptake scenario similar to Hsu (2012). It estimates PV customers annual return of investment (ROI) offered by the PV costs, the FiT subsidies and the retail market arrangements in place. Thereby, assuming a lineal relationship between the historical deployment scenario, its associated ROI and the estimated new annual ROI, we estimate the new PV installations for that new year. We then estimate the social environmental benefits of these new systems by estimating the avoided CO2 emissions during the whole life of the system multiplied by a SCC, while for the total annual value for retailers and DNSPs we multiply this new PV installed capacity by the value of PV in $/kW from the static model. As has been the case in NSW so far, we assume that DNSPs annual less revenues under net metering are recovered the next year period through increased network tariffs which, in turn, impacts on the next year PV customer ROI and hence on new PV installations. Network tariffs are adjusted every year, so that DNSP revenues are the same as originally expected with the projected residential demand in NSW plus the loss of revenues from the previous year. Finally FiT rates are adjusted for some policy scenarios so that the annual ROI is always under a maximum allowed ROI. Fig. 1 shows a flow diagram of this dynamic model while Table 2 and Table 3 show the input parameters and yearly equations of our methodology respectively. Our policy scenarios are described in Table 4.

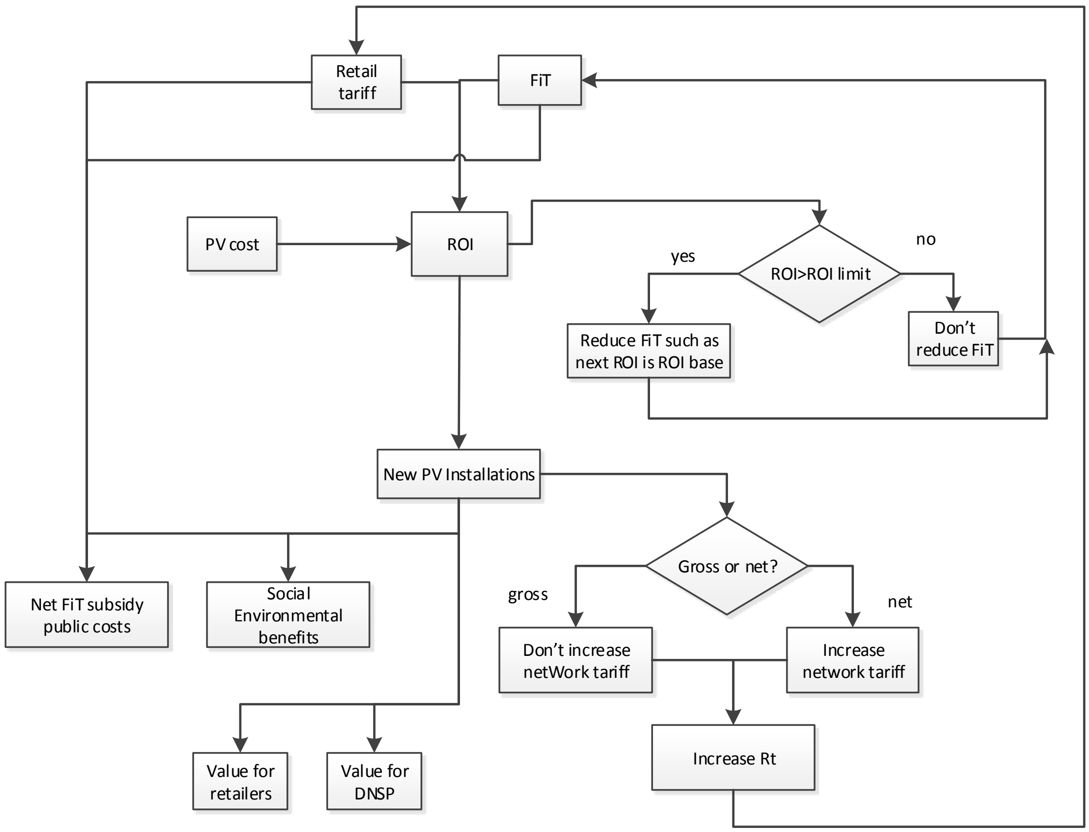

Fig 1. Flow diagram of the dynamic model.

Item	Input parameters	Value
1	Initial gross subsidized FiT rate	= 60 c/kWh
2	Initial present PV costs	= $4,400
3	2013 wholesale, network and retail tariff	= based on data from NSW
4	Average CO_2 emission intensity in NSW	= 0.98 tCO_2/MWh
5	Initial SCC under damage cost approach	= $150/$tCO_2$
6	Initial SCC under control cost approach	= $32/$tCO_2$
7	Average 2013 PV value for retailers under GM	= $86/kW/year
8	Average 2013 retailer less sales	= $300/kW/year
9	Average 2013 retailer avoided network costs	= $135/kW/year
10	Average 2013 retailer avoided green costs	= $11/kW/year
11	Average 2013 retailer avoided wholesale market costs	= $146/kW/year
12	Average 2013 retailer value of exports	= $12/kW/year
13	Average 2013 DNSPs less revenues	= $-117/kW/year
14	upper limit of ROI	= 20%
15	Allowed ROI base	= 15%
16	NSW reference ROI	= 26% (from NSW SBS: 1-jan-10 to 30-sept-10)
17	NSW reference new installations	= 209.3 MW (NSW SBS: 1-jan-10 to 30-sept-10)
	Average PV system generation	= 1,286 [kWh/kW/year]
18	Systems level of exports under NM	= 21% (from PV generation and consumption data)
19	Discount rates	= 4% for social valuations and 8% for private valuations
20	Retailer contribution for PV exports	= 7.7 c/kWh

Table 2. Input parameter of our model.

Item	parameters	Formula
1	FiT	= Initial FiT – previous years FiT reductions [if policy = “4xFiT” or “7xFiT”] = Set as in Table 4 [if policy = “FiT-2013” or “FiT-2013-14”]
2	Retail tariff	= Initial retail tariff * annual retail tariff increase
3	annual ROI	= 1,286*FiT / PV costs [if metering = gross] = 1,286*((1- %exports)*retail tariff + %exports*retail contribution)/ PV costs [if metering = net]
4	annual FiT reduction	= 0 [if annual ROI < upper limit of ROI] and [if policy = “4xFiT” or “7xFiT”] = FiT – ROI base x PV cost next year / 1,286 [if annual ROI > upper limit of ROI] and [if policy = “4xFiT” or “7xFiT”]
5	New PV Installations	= (annual ROI / NSW reference ROI)* NSW reference new installations
6	***Social environmental value***	= (New PV Installations- New PV Installations under BAU)*sum of SCC* Average CO_2 emission intensity in NSW*1286 for the next 25 years
7	FiT subsidy net cost	= sum of 1,286*(FiT-retail tariff)*New PV Installations for the next 7 years
	Private value:	
8	annual network tariff escalating factor	= (DNSP less revenues previous year / projected residential demand + initial network tariff) / initial network tariff
9	DNSP less revenues	= Average 2013 DNSPs less revenues * annual network tariff escalating factor * sum of New PV Installations for NM years [if metering = net] = 0 [if metering = gross]
10	annual retail tariff escalating factor for PV	= (DNSP less revenues previous year / projected residential demand + initial retail tariff) / initial retail tariff
11	annual overall retail tariff escalating factor	= annual retail tariff escalating factor for PV – 1 + annual retail tariff escalating factor from Treasury (2011) – 1 + 1
12	Value of PV for retailers	= average 2013 PV value for retailers under GM * wholesale price escalating factor * sum of New PV Installations [if metering = gross] = (- average 2013 retailer less sales*annual overall retail tariff escalating factor + average 2013 retailer avoided network costs*annual network tariff escalating factor + average 2013 retailer avoided green costs + (average 2013 retailer avoided wholesale market costs - average 2013 retailer value of exports) * wholesale price escalating factor) * sum of New PV Installations) [if metering = net]
13	Retail tariff	= Initial retail tariff * annual overall retail tariff escalating factor

Table 3. Yearly equations of our model.

3. Data and Assumptions

In this section we describe our model assumptions about PV and pricing arrangements data, their future projections and their implications on our findings.

3.1 Data

Results of our static model are average annual values of a sample of 61 residential PV systems over a year of actual half-hourly PV production, consumption and wholesale electricity costs in the Australian state of New South Wales. Also, for our analysis we use time of use (TOU) electricity retail and network tariffs available in Sydney, since the majority of PV customers are under TOU tariffs. We note that our sample systems size is around 1kW and that the average system size installed today in NSW is around 2.5 kW and hence we may be underestimating the level of exports and therefore DNSPs less revenues and retailers financial gains under NM. Also, under NM, PV systems would be less attractive if levels of exports are higher which would slightly decrease our PV deployment projections.

3.2 Static Model

To estimate PV environmental valuations we consider both a control and a damage cost approach for the value of the SCC. For the first one we use the value of the Australian carbon price under the so-called 'High Price Scenario,' while for the second one we use the recent estimations of the SCC by Hope (2011). We project these SCCs by the Treasury (2011) projections for the HPS carbon price and by a 2.5% annual increase escalator for the damage SCC approach obtained from Watkiss (2005).

In this paper we ignore other potential social benefits of PV such as avoided health damage cost of fossil-fuel generation, deferring augmentation of the network, security of energy supply, reduced land use, job creation, etc.

3.3 Dynamic Model

In this paper we use a PV cost before subsidies of $4,400/kW which we calculated including an inverter replacement cost of $1000/kW (CEC, 2011) carried out in the year 10 and year 20 and that we discount at 4%. We use a solar system price of 2.4 $/W according to Climate spectator (website) which includes capital subsidies which we subtracted obtaining an initial PV system cost of $3,500/kW. We projected this cost at a 6.4% annual decrease based on IEA (2012). However, estimating annual ROIs requires using PV costs after capital subsidies associated with the Australian RET. This type of subsidy is not included in our subsidy cost assessment. We assume a lifespan of the systems of 25 years.

To estimate FiT subsidy net costs we assume a market design where the government can receive an income for the PV electricity at the retail electricity tariff and hence in our model the net subsidy cost per kWh is the total cost of FiT subsidies minus the electricity price. Such income recognizes a value of PV generation at the retail tariff, yet such value is somewhat arbitrary since, although the energy value of PV can be estimated as the energy component of the retail tariff (Oliva and MacGill, 2011); the potential network value that PV can offer is not necessarily the network component of the retail tariff. In our model retailers contribute with only the energy component of the retail tariffs, which is their financial gain under current arrangements in NSW.

Environmental benefits are estimated considering not all the new PV installations but only the FiT subsidy added new installation, that is the total new PV installations minus the installations under BAU in NSW which is the "NM-7.7" scenario as described in table 4. After the subsidized FiTs period new PV customers are under NM-7.7.

Furthermore we ignore the impact of PV deployment on the reduction of wholesale prices and on the CO2 emission intensity factor. Such impact can cause the reduction of the social value of PV over time, both by reducing the value of PV energy and fewer avoided emissions. However this analysis focuses in the medium term and it is likely that deployment will not reduce the social value under these policy scenarios.

Assessing the future value of PV for retailers and DNSPs requires the use of the projections of retail and wholesale electricity prices which we obtained from the Treasury (2011) report, including the impact of the Australian carbon price.

We use a discount rate of 4% for social and 8% for private monetary valuations.

4. Results

In this section we show our results and findings on the environmental social value, net costs of subsidized FiTs and the financial impact of PV deployment on retailers and DNSPs. All our monetary valuations are in 2012 Australian dollars and all years are Australian financial years.

4.1 Policy Scenarios

We have defined specific policy scenarios that we assess in this paper for a total period of 7 years using our model. We explore different policy scenarios by moving the FiT rates, the duration of FiT scheme and the type of household metering, that is, gross or net. To represent the case of NSW we set subsidized FiTs only under GM. The different net and gross FiT designs and settings are based on actual and proposed FiT implementations in NSW over recent years. Table 4 describes these PV commercial arrangements and policies.

PV policy	Description
NM-0	NM arrangement with no retailer contribution for exports.
NM-7.7	NM arrangement with a retailer contribution of 7.7 ¢/kWh for exports.
FiT-2013	FiT payment to PV customers for the gross PV generation at 60 ¢/kWh for 7 years for systems installed in 2013.
FiT-2013-14	FiT payment to PV customers for the gross PV generation at 60 ¢/kWh for 7 years for systems installed in 2013 and 40 ¢/kWh for 7 years for systems installed in 2014. Retailers contribute with 7.7 ¢/kWh for exports.
4xFiT	FiT payment to PV customers for the gross PV generation for 7 years for systems installed in 2013, 2014, 2015 or 2016. PV customers get paid a constant FiT rate over the 7 years, however such FiT rate depends on which year the system is installed. Systems installed in 2013 get paid a 60 ¢/kWh FiT rate whereas for systems installed in the next years the FiT rate decrease such as the ROI is around 15%. Retailers contribute with 7.7 ¢/kWh for exports.
7xFiT	FiT payment to PV customers for the gross PV generation for 7 years for systems installed from 2013 till 2019. PV customers get paid a constant FiT rate over the 7 years, however such FiT rate depends on which year the system is installed. Systems installed in 2013 get paid a 60 ¢/kWh FiT rate whereas for systems installed in the next years the FiT rate decrease such as the ROI is around 15%. Retailers contribute with 7.7 ¢/kWh for exports.

Table 4. Description of PV policy scenarios.

4.2 Impact on electricity prices

Our dynamic model estimates the impact of PV deployment on network tariffs and hence on electricity prices. To illustrate such impact we show in Fig. 2 the change of network, retail and wholesale electricity tariffs under NM-7.7 which is the scenario that causes the highest reduction in revenues for DNSPs. Although we assume that PV deployment doesn't impact on wholesale prices, we show the Treasury (2011) projections for comparison purposes. We show the increase of electricity prices caused by the future PV deployment only, without it and considering the both increases.

Fig. 2 suggests that the increase of electricity prices in NSW due to the PV deployment is very little and hence under these assumptions we see that it is unlikely that PV will cause an increase in retail electricity prices making PV more attractive for households end-users.

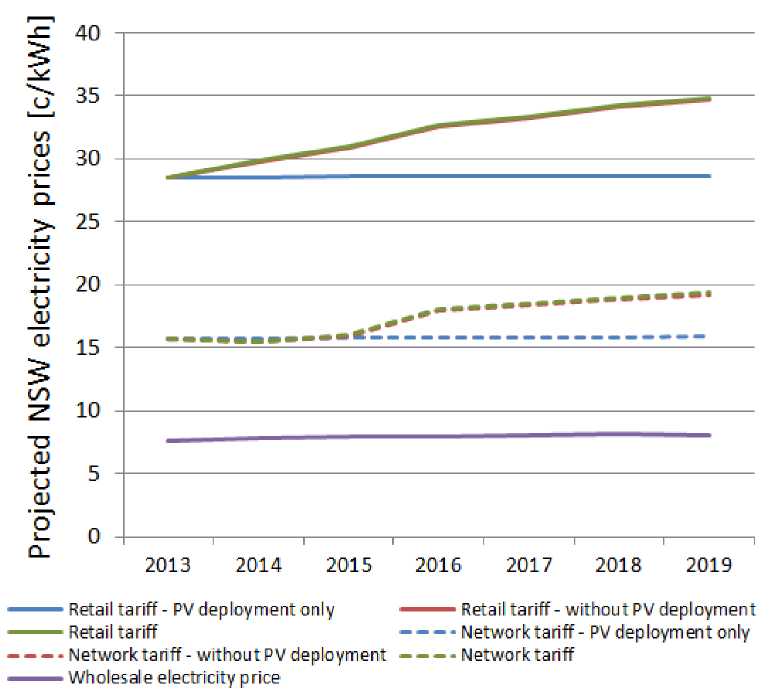

Fig. 2. Projected NSW wholesale, network and retail electricity prices.

4.3 Policy assessment

Our approach to assess policies with our model is to compare their total environmental social value, their net subsidy cost and the value for private participants. As such, we prefer policies that contribute to maximize the social benefits of PV, minimize subsidy costs contributing to social equity goals, and offset any unfair financial gain or loss for private participants in the industry. Thereby the performance of policy options of Table 4 is tested with our model based on such criteria. Fig. 3 shows the resulting impact of FiT subsidies on social benefits for two different SCC approaches and their public costs. Social environmental benefits are accounted for the whole life of the PV systems installed within the 7 years studied period considering the avoided CO2 emissions associated with only the extra new installations triggered by the FiT subsidies comparing with the NM-7.7 scenario.

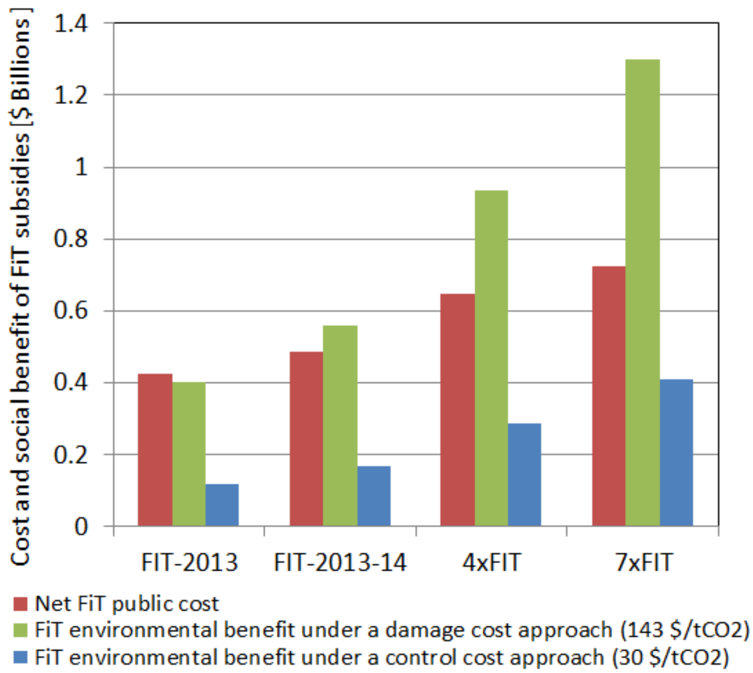

Fig 3. Total environmental benefits of FiT subsidy added new installations and total net costs of FiTs for society over 7 years.

Fig. 3 shows how different PV policies offer different environmental benefits and subsidy costs. It can be seen that FiT-2013-14, 4xFiT and 7xFiT net subsidy cost are in between the lowest and the highest value of FiT environmental benefits while such social benefits are largely driven by the value of the social costs of carbon whose impact is significant and complicate the assessment. Net subsidy cost represent from 55% to 105% of total benefits for a damage SCC approach and from 2 to 3 times benefits for a control SCC approach. Also we see that FiT-2013, which would represent a FiT scheme similar to the 2010 NSW Solar Bonus Scheme, suggests that this scheme would be the least socially beneficial given its high subsidy net cost and therefore high social wealth transfer –from all end-users to PV customers - and low environmental benefits.

Fig 4 shows the resulting future PV deployment by 2019 and its total value for retailers and DNSPs.

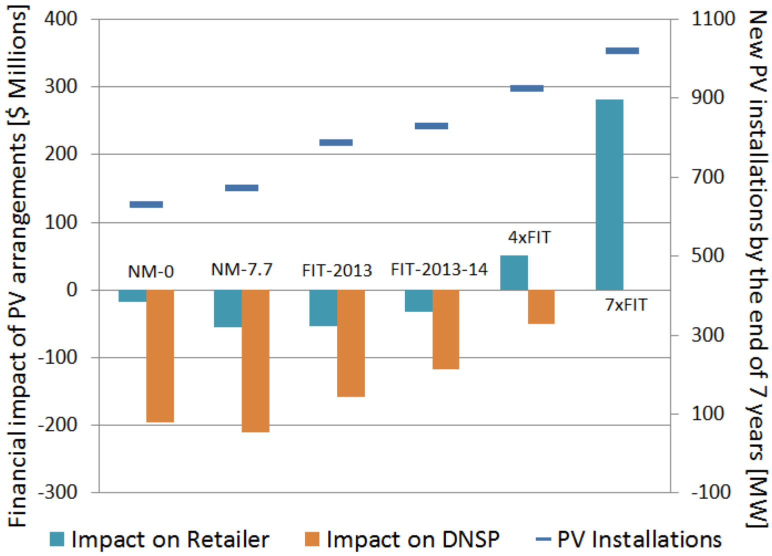

Fig. 4. Total new PV installations by 2019 and total financial impact of PV arrangements on retailers and DNSPs by the end of the 7 years.

PV deployment in Fig. 4 varies significantly with different policy scenarios whereas the environmental social value of Fig. 3 practically follows this deployment. Also FiT subsidy impact on deployment is significant as expected with these FiT subsidies which are considered quite generous.

The total impact on retailers and DNSPs depends on the commercial arrangements in place. It can be seen that while retailers and DNSPs generally experience losses under NM arrangements; retailers experience significant financial gains under gross FiT subsidies. However the overall impact is variable depending on how many years FiT subsidies are available.

DNSPs reduced revenues under NM are significant and increasing over time with the increase in new PV installations. Nevertheless, as in our model we assume a scenario where DNSPs are allowed to recover such loss in revenues by increasing electricity network tariffs for the next year period, such financial burden goes ultimately to all end-users as a form of another indirect subsidy, this time for the network usage. Such additional wealth transfer should be added on the top of the subsidy costs bar in Fig 3. We note that such network cross-subsidy has a negative and unsustainable social equity outcome since with increased electricity tariffs PV is more attractive, and in turn contributes to increase tariffs again, leaving this burden for less and less households without PV.

It can be seen that retailers experience losses with NM which are driven by the less margin they get from households PV owners due to the PV self-consumed electricity. Moreover looking at NM-0 and NM-7.7 scenarios it is possible to see what the impact of a retailer payment for PV export is. Furthermore, from the 7xFiT scenario we see that the retailer contribution of 7.7 c/kWh to the FiT subsidies is lower that the financial gain they experience for it, yet, again the overall value of PV is negative under NM due to the less sales of electricity.

5. Conclusions

This article highlights the need of aligning FiT rates with the environmental PV benefits whilst controlling the public FiT subsidy costs. However, such benefits depend considerably on what are still highly variable and controversial estimations of the SCC. Using these two extreme SCC values and policy options suggests a range for net FiT costs from 0.12 to 1.3 billion dollars.

On the other hand, by estimating annual DNSP less revenues under net metering we highlight that current network arrangements for household PV customers are not sustainable since over time less and less end-users would have to pay for the network expenditure as PV become more financially attractive with the increase in electricity tariffs.

Moreover, we found that considering a damage cost approach for the SCC the policy that maximizes social environmental benefits is 7xFiT while its net public cost represents the smallest percentage of its total benefits comparing with the other scenarios. The particular challenge of using estimated carbon ‘control’ costs, as seen in emissions trading schemes in the EU and Australia, is that current carbon prices are almost certainly well below the levels required to achieve the emission reductions goals that appear required to effectively address our climate challenges

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