Feed-in tariffs for promoting solar PV: progressing from dynamic to allocative efficiency

Bell, William and Foster, John

University of Queensland, University of Queensland

27 March 2012

Feed-in tariffs for promoting solar PV: progressing from calculated to market determined feed-in tariffs

2013

William Paul Bell
John Foster

Energy Economics and Management Group

Working Paper

Version 51

THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

Please cite this paper as:
Bell, WP & Foster, J 2013, *Feed-in tariffs for promoting solar PV: progressing from calculated to market determined feed-in tariffs*, Energy Economics and Management Group, The University of Queensland, Brisbane.

Version 51

Energy Economics and Management Group
Postal address: School of Economics, The University of Queensland
St Lucia, Brisbane QLD 4072, Australia
Phone: +61 7 3346 0594 or +61 7 3365 6780
Fax: +61 7 3365 7299
E-mail: webeemg@uq.edu.au
Website: http://www.uq.edu.au/eemg/

Acknowledgements

This work was carried out with financial support from the Australian Government (Department of Climate Change and Energy Efficiency) and the National Climate Change Adaptation Research Facility. The views expressed herein are not necessarily the views of the Commonwealth, and the Commonwealth does not accept responsibility for any information or advice contained herein.

We thank Warwick Johnston of Sunwiz, Australia for his feedback on previous version of this paper and advice regarding modelling of solar PV and smart metering of solar PV.

We thank two anonymous reviewers for their numerous comments and in helping form this paper.

Feed-in tariffs for promoting solar PV: progressing from calculated to market determined feed-in tariffs

William Paul Bell, University of Queensland
John Foster, University of Queensland

Abstract

The International Energy Agency has observed that nearly all countries now offer, or are planning, feed-in tariffs (FiTs) for solar PV but the debate has shifted from *'if or how to implement a FiT'* to *'how to move to a self-sustaining market post FiT'*. The aim of this paper is to explain how a sustainable FiT can be designed for residential solar PV installations, focusing on the case of 'solar rich' Australia. Solar PV is approaching price parity at the retail level where the electricity price charged includes both transmission and distribution costs, in addition to the wholesale price. So the economic rationale for paying a FiT premium above market rates to achieve dynamic efficiency is no longer warranted. Socially, FiTs can be a problem because they tend to exacerbate social inequality by providing a transfer of wealth from poorer to richer households. Environmentally, FiTs can also fall short of their full potential to cut emissions if they lack 'time of day' price signals that reflect movements in the wholesale price.

We provide a framework in which a sustainable FiT can be designed that positively addresses all three areas of concern: social, environmental and economic. This framework identifies the market failures that exist in the residential solar PV electricity market, which include exacerbating inequity, poorly targeting myopic investment behaviour, inadequate transmission and distribution investment deferment price signals and inappropriate infant industry assistance. We argue that these market failures require addressing before the market can operate in an allocatively efficient manner.

The sustainable FiT that we propose would lead to improvements in environmental, social and economic factors. The resultant transmission and distribution investment deferment would meet both environmental and economic objectives. Directly providing finance for solar PV installations would address both social equity and investment myopia. We argue that introducing appropriate pricing signals for solar PV installations via would be in the ongoing interest of all stakeholders. It is time to progress from FiTs focused on dynamics efficiency to a sustainable FiT that emphasises allocative efficiency as an explicit goal.

Contents

1 Introduction

The International Energy Agency (IEA 2011, p. 33) observes that nearly all countries now offer or are planning FiTs for solar PV but debate has shifted from ‘if or how to implement a FiT’ to ‘how to move to a self-sustaining market, post FiT’. Additionally, the IEA (2011, p. 33) acknowledges internationally FiTs have been poorly designed or poorly controlled, resulting in explosive markets, profiteering, political interference, over-reliance on imports, market collapses, business closures and so on. However there is now a wealth of information available worldwide to policymakers regarding the impact of various designs of FiT schemes and how and when to adjust tariffs to avoid overheated markets. For example, Couture and Gagnon(2010), Timilsina, Kurdgelashvili and Narbel (2012) Solangi et al. (2011), Gipe (2011) and Zahedi (2009, 2010) provide an extensive and current discussion of FiTs.

Previous and current FiTs have been found to be a source of four market failures:

- exacerbating inequity (Garnaut 2008; Nelson, Simshauser & Kelley 2011);
- poorly targeting myopic investment behaviour (APVA 2011a, 2011b);
- inappropriate infant industry assistance (Farrell 2011); and
- lacking transmission and distribution investment deferment price signals (Futura 2011; PwC 2011).

Under the guise of an infant industry argument, many countries have implemented FiTs to establish a domestic PV industry. This policy has been overly successful causing a cross subsidy via electricity prices that has resulted in: inequity to favour the top four (richest) quintiles over the lowest (poorest) quintile (ABS 2012b); challenges to policy credibility; poorly targeted industry assistance; failure to connect with transmission investment strategies. In addition, in countries with state based FiT policies, such as Australia, Canada and the US, there has been inconsistent gross or net FiTs calculation between states (DSIRE 2012; REN21 2011; Wong 2008; Zahedi 2010). This inconsistency between states presents suboptimal allocative efficiency in distribution of solar PV and additional administrative and learning costs.

Our focus here is on residential solar PV installations because three features together differentiate them from other forms of renewable energy:

- they are embedded within the distribution network;
- there are many small suppliers without market power dealing with a few retailers; and
- suppliers are too small to offer bids in the electricity market.

We identify problems with the existing FiTs using a sustainability framework and then propose solutions. First, we discuss the investment myopia and social inequality problems that exist in existing FiT schemes and we explain why indexed interest free loans can directly address these issues. Next, we discuss price signal issues with existing FiT schemes and how an alternative price signalling system can be designed to achieve a sustainable FiT. This includes real time and locational pricing to guide investment deferment in distribution and transmission and to improve energy conservation.

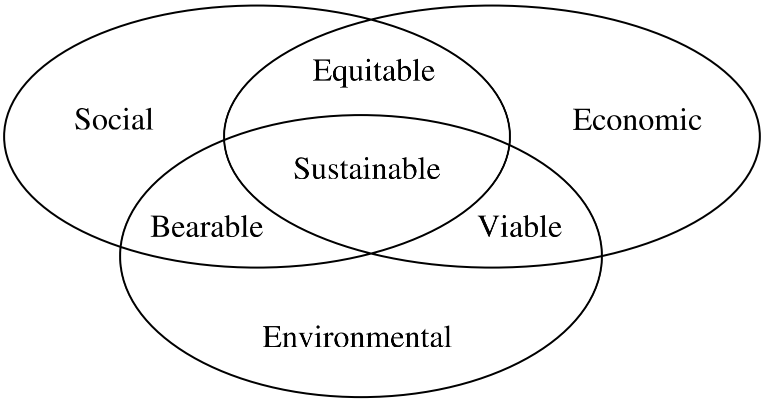
The implications of adopting a sustainable FiT are:

- steadier growth in the solar PV industry rather than the boom bust cycles that have ensued from numerous government regulatory changes required to keep up with the rapidly changing technology and decreases in prices;
- a more equitable arrangement by removing the cross subsidy from non-owners to owners of solar PV units; and
- more environmental protection potential to defer investment in distribution and transmission and to reduce CO2 emissions.

2 A sustainability framework

A sustainable FiT (see Figure 1) must positively address three factors: social progress, environmental protection and economic growth (IUCN 2006). The laws of physics and the ability for our environment to cope ultimately determine a limit to economic growth but in the interim innovations provide an avenue for economic growth through energy efficiency and less harmful energy production, such as, demand side management and solar PV (Beinhocker 2006).

Figure 1: Sustainability framework



(Source: IUCN 2006)

From an environmental perspective, roof top solar PV installations appear ideal, as they produce electricity with low life cycle emissions and help to defer investment in distribution and transmission. However, seen within a broader context, there are social and economic issues that require addressing. The US corn to ethanol biomass industry provides a useful illustration of social and economic problems that can arise when seemingly ideal environmental policies are implemented. The recent episode of the US government subsiding corn for ethanol production increased the price of corn, which is a staple diet for many poor people in Central America. This ethical dilemma of using food crops or arable land to produce biomass is an undesirable outcome. Fortunately, rooftop solar PV installations do not pose such serious ethical problems. However, Garnaut (2011, p. 15) discusses how those consumers receiving FiTs are being cross-subsidised by other consumers, generally on lower incomes. In agreement, Nelson, Simshauser and Kelly (2011) have estimated the household impact of FiTs by income groupings and conclude that wealthier households are clear beneficiaries and the effective taxation rate for low income households is three times higher than that paid by the wealthiest households. Therefore both the current FiT and the US government's corn to ethanol subsidies are socially regressive. The primary motive for introducing FiTs for solar PV and subsidies for corn to ethanol is to reduce GHG, which benefits everyone and justifies schemes to leverage private money for the public good. However, the implementation is socially regressive.

In addition to ethical considerations, Stebbins (2011) reports that there has been a farm price bubble in the Corn Belt created by the US government subsidies, which is proving politically difficult to manage, as rural communities become accustomed to higher wages and profits. So this well intentioned US government policy has unintentionally created ethical conundrums grounded in a maladaptive political economic dynamic. This provides a warning to those trying to implement infant industry legislation without a clear exit strategy that prevents such legislation becoming a permanent fixture. A strong case can be made that there are many parts of the emergent renewable energy sector that require R&D and initial assistance for commercialisation. But rooftop solar PV installations are no longer in the infant industry stage because residential rooftop solar PV is near market parity (Watt 2011), that is the cost of electricity from solar PV is approaching the costs of electricity from coal generators plus transmission and distribution costs. However Watt (2011) does concede that parity may be insufficient to induce investment in solar PV as people expect a much quicker payback on capital than net present value calculations would indicate. This myopic investment behaviour and other non-market barriers have to be addressed in any new policy initiative.

3 Investment myopia, irrational exuberance and social inequity

The Australian PV Association (APVA 2011b) and Watt (2011) discuss how solar PV has reached grid parity. Electricity can now be generated on residential rooftops at the same price as coal generation plus transmission and distribution costs. However, parity seems to be insufficient to ensure the appropriate economic level of residential solar PV uptake because people suffer investment myopia with regard to the returns from long term investments, such as the 25-30 year life of a PV unit. This is not uncommon in the case of long term investments because of the uncertainty involved. For example, in the case of PV panels, people are uncertain as to whether the cost of PV units is going to continue to fall significantly and, therefore, it may be rational just to defer the investment decision until later, even though the investment looks attractive from a net present value perspective.

Yates and Mendis (2009) and Williams (2011) discuss the sensitivity of demand for solar PV installation to interest rates and after financing considerations and clearly observe the presence of investment myopia. A similar kind of long term investment myopia that has been well researched is superannuation. This has spurred government intervention in the form of a complex array of policies including tax breaks for both voluntary contributions and compulsory contributions. Similarly, the Australian government has intervened to remedy myopia in the uptake of tertiary education by offering indexed interest free student loans, repayable through the income taxation system, to provide equity and to acknowledge the positive externalities of education.

Origin Energy (2007) argued for interest free loans to promote efficient energy investments to address positive externality and equity concerns. Sunders, Gross and Wade (2012) discuss the socially regressive aspects of the Renewable Heat Incentive in the UK and how low interest loans for low income households could address the issue. A similar argument can be made for interest free loans for investments in solar PV. In trying to address equity and investment myopia issues, the use of tax breaks tends to favour richer households over poorer, while making interest free loans, with repayments based on the ability to pay similar to the Australian student loan scheme (HECS), is a much more equitable way to address investment myopia. Additionally, a loan is more appropriate form of assistance, as there is an incentive for the prospective buyer to consider the solar PV installation as an investment requiring a cost benefit analysis rather than a means to obtain a tax break. Additionally, loans for these long term investments are appropriate candidates for the revenue generated from carbon pollution reduction schemes. In Australia the schemes is called "The clean energy package" from the Department of Climate Change and Energy Efficiency (DCCEE 2011). Furthermore, identifying which transmission and distribution lines are nearing their maximum capacity would yield locational priorities for lending to target transmission and distribution investment deferment.

People usually pay for their solar PV installation by increasing their house mortgage. This is appropriate in the case of long term investments such as solar PV. The RECs make the cost of installation more affordable. This approach works for house owners but not for renters. The fact that proportionately more low income individuals rent houses goes some way to account for the highest (richest) quintile having twice the rate of solar PV installations compared with the lowest (poorest) quintile, see Table 1 and Table 2. The situation is similar for solar hot water. Unfortunately, ABS (2012b) only provides data for the state of Victoria that is seen in Table 1 but the assumption is made that the other states in the NEM would follow a similar quintile pattern.

Table 1: Solar energy use in dwelling in Victoria Oct 2011

Equivalised household income quintiles	Solar photo-voltaic panels	Solar hot water
Lowest	3.1	3.8
Second	5.5	5.0
Third	5.8	6.4
Fourth	5.6	6.7
Highest	6.2	6.8
Total	5.4	5.6

(Source: ABS 2012b)

Table 2: Mean equivalised disposable household income per week by tenure and landlord type

Owner without a mortgage	Owner with a mortgage	Renter				Other tenure type	All households
		State/territory	Private	Other	Total		

		housing authority	landlord	landlord type	renters		
793	957	408	772	812	729	852	848

(Source: ABS 2011b)

The low solar PV penetration in the lowest quintile is due to the dual problem of low income and rental accommodation. Trying to address this poverty trap with subsidised loans is insufficient. A solution is required that acknowledges the tenant-landlord relationship and the consequent misalignment of benefits and costs. Targeting fuel poverty in this group through solar PV installations not only addresses equity but makes effective use of solar PV, as individuals on low incomes are likely to spend more time at home during the day (Clark & Hay 2012). Clark and Hay (2012) discuss the feasibility of implementing renewable energy within the public rental housing sector where social equity concerns provide a rational. In contrast, the profit motive of the private rental sector provides a deterrent that is more difficult to overcome.

Thus, the state and territory housing authorities should be required to directly support installation of solar PV and solar hot water. This action has become imperative given the recent moves to deregulate the domestic tariff in Australia, to protect the most financially vulnerable in society, see Table 2 . The installation of solar PV, along with smart meters, would aid acceptance of the time of use tariffs. However, Table 3 shows that the state or territory housing authorities hold a small and diminishing proportion of the rental accommodation. In contrast, the proportion of private rental accommodation is increasing. This is associated with an overall increase in the proportion of people living in rental accommodation.

Table 3: Percentage of household types by tenure and landlord type

		1994 –95	1995 –96	1996 –97	1997 –98	1999 –00	2000 –01	2002 –03	2003 –04	2005 –06
Owner	Without mortgage	41.8	42.8	41.3	39.5	38.6	38.2	36.4	34.9	34.3
	With mortgage	29.6	28.1	28.3	30.9	32.1	32.1	33.1	35.1	35.0
Renter	State/territory housing authority	5.5	6.0	5.6	5.8	5.8	5.0	4.9	4.9	4.7
	Private landlord	18.4	19.0	20.4	20.0	19.9	21.0	22.0	21.2	22.0
Total renters		25.7	26.9	27.9	27.2	27.2	27.4	28.2	27.6	28.5
All households		100	100	100	100	100	100	100	100	100

(Source: ABS 2011a)

So, addressing ways of encouraging solar PV installations in private rental accommodation is a priority than in state or territory housing authority accommodation. Because the renter enjoys all the benefits of reduced electricity bills, there is no incentive for the renter or landlord to install solar PV. A higher rent could be charged but, again, long term investment myopia tends to dominate.

The shift in demand for rented accommodation has been met by increasing private investments in rental properties. This has been spurred by negative gearing, which allows losses to be set against other income, and capital gains legislation that allows investors to keep a larger portion of the capital gain. The resulting rise in house prices has made housing less affordable for those on lower incomes and has sustained the expectation of ever rising capital gains amongst investors. These dynamics provided the conditions for a housing bubble which, in Australia, has been followed by only a minor slow down.

Addressing the conundrum of the misaligned incentives for solar PV installation in a landlord –tenant relationship has been exacerbated by the irrational exuberance (Schiller 2000) of a housing bubble. Traditional economics has been spectacularly unsuccessful in understanding bubble conditions for instance the recent Global Financial Crisis. The traditional economic prescription for such a misalignment of incentives in this relationship is to focus on property rights and price signals assuming unbounded rationality but this alone is inadequate given irrational exuberance and investment myopia. However, a discussion of price signals in an idealise world does provide a good starting point before addressing irrational exuberance and investment myopia.

The landlord is the natural owner of a fixed capital asset on a house such as a solar PV installation. As such, the landlord sells all the electricity generated to a retailer. This provides the landlord with the incentive to optimise the size of the installation, given the gross feed-in tariff, as discussed below in section 6.1. The advantage for tenants is that they do not pay for the TUoS and DUoS charges for electricity consumed from the solar PV located on their rental accommodation, which is also discussed further in section 6.1.

Investment myopia can be addressed by subsidised loans targeted at landlords. But we know that loans in isolation have already proved unsuccessful in the UK's green policy program. The irrational exuberance effect can be addressed by appealing to the landlord's desire for capital gains by making houses without solar PV ineligible for tax free capital gains. Consideration needs also to be given to the fact that some houses are unsuitable for solar PV. The carrot and stick approach to investment myopia and irrational exuberance, respectively, could encourage an increased uptake of solar PV in the private rental accommodation.

4 Conundrum: policy credibility versus social inequality

The ABS data discussed in the previous section supports Garnaut (2011, p. 15) and Nelson, Simshauser and Kelly (2011) observation that richer households receiving FiTs are cross-subsidised by poorer households. So, there is a policy dilemma: maintaining policy commitments and credibility can exacerbate social inequity. One resolution to this policy dilemma, without disrupting the market, would be to maintain FiTs fixed permanently in nominal terms to those consumers contracted, so inflation would erode the FiT overtime (Garnaut 2008). But this politically easy solution only attenuates social inequality.

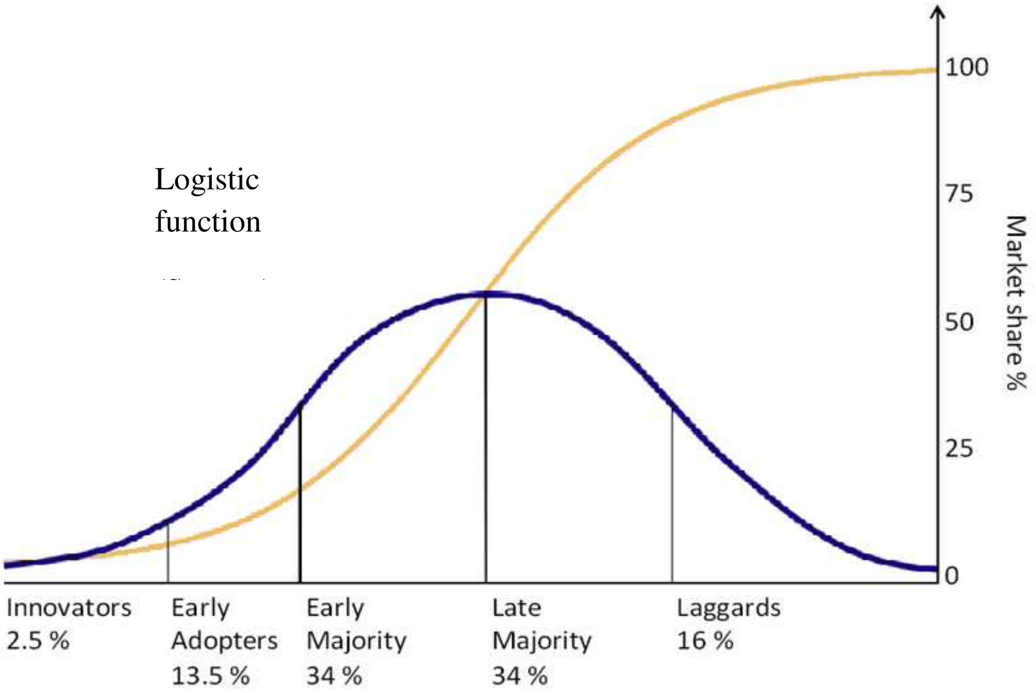
Generally the methods used to date to adjust calculated FiT have been disruptive. Abrupt closures of schemes and large reductions in FiTs have been common. For instance the

Queensland government closed it generous FiT to new applicants in mid-2012. The replacement FiT has been set close to the wholesale price. This is a politically easy solution that is inoffensive to those voters already receiving the generous FiT but perpetuates social inequality by effectively locking it in for many years to come. Compounding this social inequity, an abrupt solution is economically poor because a sudden large drop in the FiT stalls the growth of an emergent solar PV industry. A FiT subsidised directly by government lacks the regressive aspect of funding the subsidy via a surcharge on electricity tariffs.

5 Infant industry support and solar PV's parity with retail tariffs

A key issue in the assessment of the economic viability of solar PV energy supply is the trajectory of future cost per kWh. All new technologies follow S-shaped diffusion curves that can usually be tracked by a nonlinear logistic or a Gompertz function, see Figure 2.

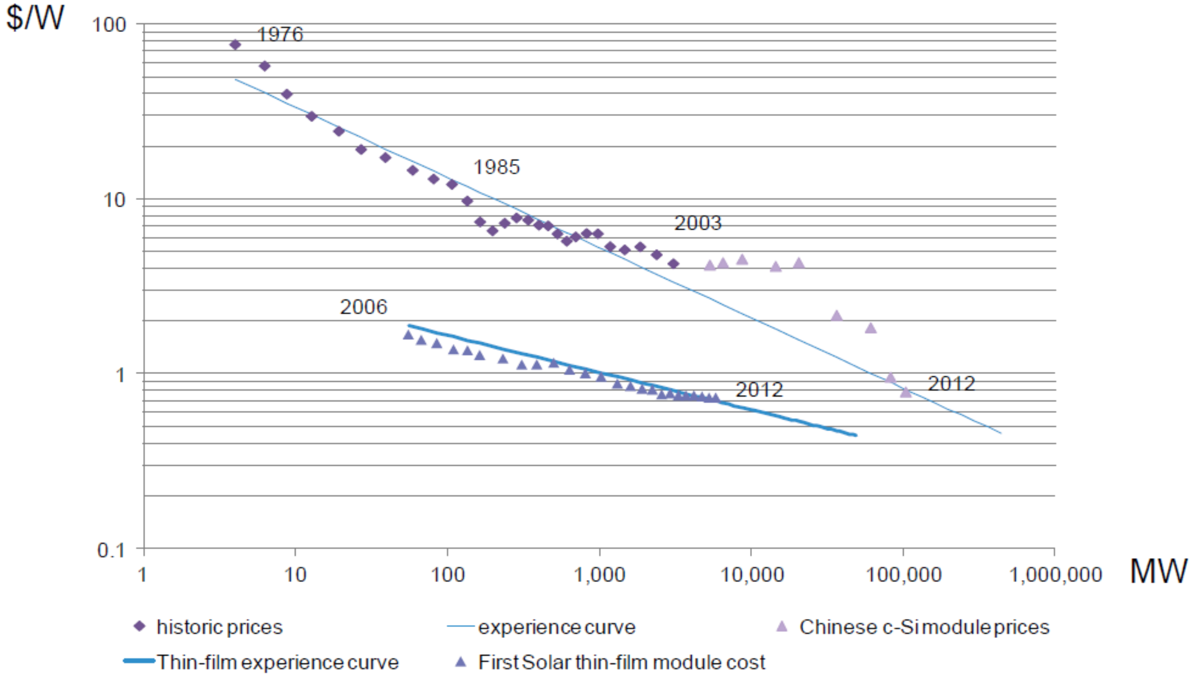
Figure 2: Diffusion of innovation



(Based on: Rogers 1962)

As the volume of adoption rises, unit costs fall, usually approximately log linearly (exponential). There are four reasons for this: economies of scale in production, the accumulation of experience in production and marketing, the introduction of incremental innovations and growth in demand for products using the technology. Figure 3 shows the so called 'experience curve' for PV modules for the period 1975-2011. The 'experience curve' is also known as the 'learning curve'. There is a well-developed literature on forecasting future diffusion paths based on observations in the early phase of the diffusion curve. Similarly, forecasts of future unit costs have been conducted using early phase cost data (see Alberth (2008) for a recent study of several cases, including solar, Nemet (2006) deals specifically with PV).

Figure 3: The PV Module experience curve, 1976-2011

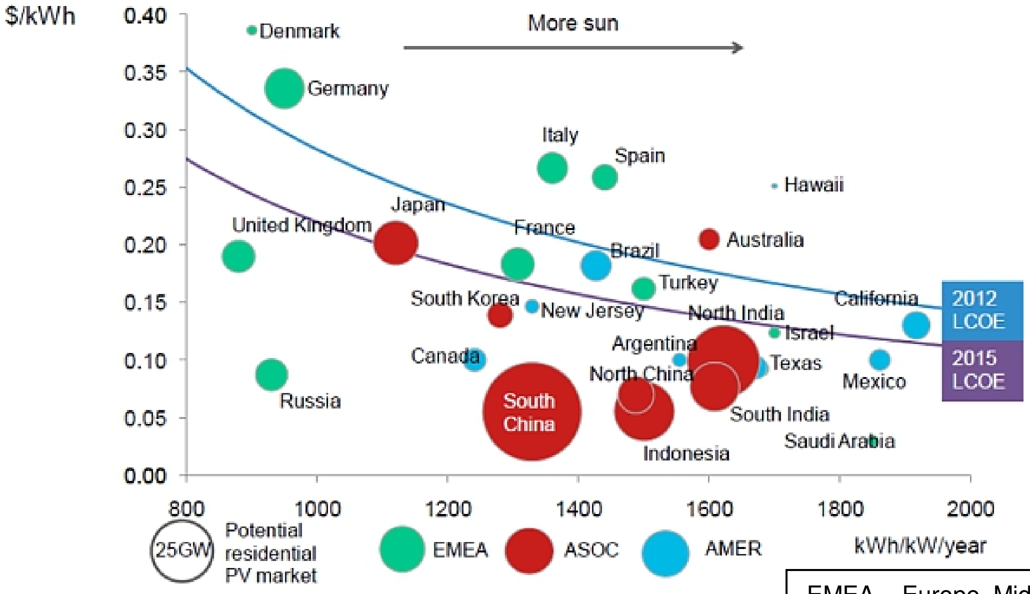


(Source: Bazilian et al. 2012)

Universally, unit costs fall significantly but this introduces something of a dilemma for a potential buyer. When is the best time to buy? When production volume is small and unit price is high, only ‘enthusiasts’ tend to buy, either for ethical reasons or to impress others as an affluent ‘first mover’ that can afford the high price. So, if the development of a technology is widely viewed as a social or environmental priority, it is vital that, in the early developmental phase, significant ‘infant industry’ subsidies are offered both to encourage purchase of products using the technology and to make producers feel secure enough to invest in expanding production. There is no ‘futures market’ in technologies, so both buyers and sellers have to be compensated for taking their respective risks in what is an uncertain context.

In addition, the decision to buy requires consideration of both the residential retail price and the solar intensity. Figure 4 shows the residential power prices and solar intensity for different countries. The horizontal axis shows the solar intensity and the vertical axis the residential electricity prices. The blue and purple curves are the Levelised Cost of Energy (LCOE) or parity lines for 2012 and 2015 respectively. The parity lines curve downwards with an increases in solar intensity, as countries with higher solar intensity reach parity at lower residential power prices. The countries sitting above the line have reached parity and the countries below have yet to reach parity. For instance Denmark, sitting above the blue 2012 LOCE line with the highest domestic power price, had reach parity well before 2012 despite having the second lowest solar intensity. In contrast Saudi Arabia with the third highest solar intensity is predicted not to reach parity until well after 2015 because its domestic power price is nearly the lowest in world. The assumptions used in Figure 2 include a 6% weighted cost of capital (interest rate on finance), fully installed system cost of $3.01/watt for 2012 in blue curve and $2.00/watt for 2015 in the purple curve, 0.7% per year module degradation, annual operations and maintenance cost equating to 1% of capital expenditure.

Figure 4: Residential PV price parity – residential power prices versus LCOE



EMEA = Europe, Middle East, Africa
ASOC = Australasia
AMER = Americas

(Source: Chase 2012)

Figure 4 illustrates that parity will occur at different time at different locations. However, Figure 4 cannot reflect the full complexity of the relationship. For instance many countries such as Australia and Canada span large latitude; consequently, there is a large disparity in solar intensity between and within each state, territory or province. Each state really requires a separate representative circle. For example, California and Texas have been identified in Figure 4. The high level of solar radiation in Australia makes the equivalent solar PV panel more productive than in most other countries. According to Figure 4 Australia has already reach parity but the actual situation is more complex.

The complexity of calculating parity at different levels of solar intensity is compounded by four factors: innovation, carbon pricing, fossil fuel prices and the LCOE calculating method. First incremental innovations increase the efficiencies of distributed PV collectors very significantly and unit costs will come to out-perform coal-based power station generated electricity in terms of consumer price. However, the technological variety within the coal fired generation fleet must be recognised and the opportunity cost of their fuel. It will take solar PV much longer to reach LCOE with coal fired generators in cases where coal is too low a quality for export or lacks access to export ports. We know that the unit price of coal generated electricity has shown little historical decline in recent years, consistent with it being a mature technology. The rapid innovation and decrease in the price of PV requires that any future LCOE calculations model the decrease in PV prices. In Figure 3 we identified the learning curve effect operating in the solar PV module industry. Australia now lacks solar cell production, so can look internationally to secure the cheapest panels without concern about destroying domestic production. Additionally, the commodity boom has pushed up Australia’s exchange rate, making the importation of solar panels cheaper. All these factors have to be taken into account to calculate a realistic LCOE.

Second the introduction of a carbon price or a tax will raise the unit cost of coal-based power upwards, shifting the countries in Figure 4 upwards and bringing the crossover to parity forward. The imposition of a fixed carbon price of $23/tCO_2$ as of July 2012 has induced an 8.9% increase in residential electricity prices in Australia as predicted by Wild, Bell and Foster (2012).

Third, electricity prices in Australia are sensitive to the upward movement in fossil fuel prices, as Australia has a very high reliance on fossil fuel generation, but moderating this sensitivity to international coal prices is the portion of Australia’s coal unsuitable for export, as discussed above.

Fourth there are differing approaches to calculating LCOE. Brazilian et al. (2012) discuss the comprehensive and vexing literature on LCOE. So, it is sensible to think in ranges rather than point estimates. Figure 4 conveys a sense of a price range but it is still clear that solar PV becomes viable in different countries at different times.

The debate in the literature over LCOE is not central to this paper but sufficient to say at some stage parity will be reached, if not already, and this will vary given the solar intensity and the four factors already discussed. The calculation of the exact point in time would be onerous given all the possible variables and is fickle give the rapid changes in technology. But the parity concept remains important to the theme of the paper because it is a tipping point at which the diffusion of technology accelerates without the need for subsidy. This accelerated diffusion without subsidy is conditional on the choosing correct institutional arrangements and pricing structure to reach a market determined feed-in tariff. The other important aspect of this tipping point is that continuation of a calculated feed-in tariff after parity raises at least two problems. First any miscalculations in FIT become amplified by a larger and accelerating installed base, which requires either an accelerating budget commitment or more rapid re-adjustments in the calculated FiT. This is the situation in Australia. Rapid adjustments to the calculated FiT because of budget blow outs have destabilised the solar PV market. The second problem is the possibility that the calculated FiT has been reduced too much, stifling potential future growth in the solar PV.

Table 1 compares the pros and cons of calculated and market determined FiTs. Our basic premise is that calculated FiTs are required to enable the PV industry to reach dynamic efficiency and enable economy of scale and learning economies. Calculated FiTs have been successful at achieving these goals. However after parity, a calculated FiT can be maladaptive inducing a rapidly expanding base and allocative efficiency becomes more appropriate to deal with this. Liebreich, Chase and Bazilian (2012) discuss how the current policy-making is inadequate to ensure intelligent integration of cheap solar into a complex power grid. The following sections review current policy operating in the Australian National Electricity Market (NEM) to inform the development of a market determined feed-in tariff for solar PV to reach its full economic, environmental and social potential.

Table 4 Comparing the pros and cons of calculated and market determined FiTs

Calculated FiT	Market determined FiT
Dynamic efficiency	Allocative efficiency
Infant industry support prior to parity	Rapid response to expansion after parity
Policy uncertainty and lags induce market instability which are exacerbated after parity	Market failure and institution arrangement require addressing for solar PV to reach its full potential

6 Developing price signals to further reduce emissions and to maintain solar PV market growth

Designing a market or developing appropriate price signals to reduce emissions and to maintain solar PV industry growth requires explicit consideration of the institutional arrangements that can impede the effectiveness of the market mechanism. This section focuses on price signals and highlights institutional impediments as they arise.

Lessar and Su (2008) propose market based FiTs using a two-part tariff consisting of a capacity payment that is determined through an auction process, and an energy payment that is tied to the spot market price of electricity. There are a number of differences between large scale and residential solar PV that warrant alternative arrangements for their feed-in tariffs. Wood and Muller (2012) provide a comprehensive discussion of the use of a reverse auction for large scale solar PV capacity. A reverse auction involves would-be sellers making lower bids to undercut other bidders to provide a good or service to a buyer. These are unsuitable for small scale solar PV for three reasons: inequity; the transaction costs involved for numerous participants in the auctions; and the logistical cost of maintaining numerous FiT rates. There is also an option to bid for supplying a given capacity to a market to overcome the need for individuals to bid to market. However, this would require coordination costs to setup contracts between the individual solar PV owners and the intermediary.

The reminder of this section is devoted to developing appropriate price signals for residential solar PV. In contrast to Lessar and Su (2008), we stress the importance of price signals for the cost of *transmission use of service* (TUoS) and *distribution use of service* (DUoS) as well as the spot market price of electricity. Additionally, this section's focus on residential solar PV differs to other broader studies on FiTs for large scale renewable generation in Timilsina, Kurdgelashvili and Narbel (2012), Solangi et al. (2011) and Wood and Mullerworth (2012).

The Australian Energy Market Commission (AEMC 2012) is currently reviewing Demand Side Participation (DSP) within the Australian National Electricity Market (NEM). As part of the DSP review, Futura (2011, pp. 27-8) argued that it helps to manage demand via three routes:

- peak load management;
- whole of load management; and
- distributed resources, including solar PV.

Ideally a price signal should:

- allow a business to recover at least the costs of providing a good or service, thus facilitating long term sustainable service provision; and
- provide a signal to consumers to consume only where the value of consumption is more than the social cost of production

Using such a price signal, a householder with a solar PV installation is both a business and a consumer. Such price signals alone fail to address social equity and investment myopia, as discussed in previous sections. The market needs careful design to ensure the right price signals are produced for all participants in the market to receive a fair allocation of the wealth generated by solar PV panels and to maximise the reduction in emissions.

There is an asymmetry in market power between the many residential owners of small solar PV units and a few retailers, or a single retailer in some states. Left to the free market, without intervention, retailers using their market power to maximise their profits could reduce the return on investment on solar PV to the householder to the point where the residential solar PV market ceases to grow and fails to reduce emissions further.

The Independent Pricing and Regulatory Tribunal of New South Wales (IPART 2011) investigated the potential for retailers to use market power to fix prices for power generated by solar PV below a fair price. Their finding were that 7.7c/kWh was a fair price and that retailers were offering between 6 to 8c/kWh. Table 5 shows a breakdown of average Australian retail price of a unit of electricity for 2009-10. What the regulator considers a fair price is only the wholesale electricity price and no payments for transmission or distribution deferment.

Additionally, network service providers (NSP) base their profits on their capital investment, so solar PV installation, with its ability to defer investment in transmission and distribution and exacerbate underutilisation of the existing infrastructure during the day, is in direct conflict with the profit motive of NSPs. These environmental and market failures warrant government intervention to determine a fair share of the generated wealth and to ensure appropriate price signals exist. The following sections discuss distorted price signals and their remedy.

6.1 Gross versus Net Feed in Tariff

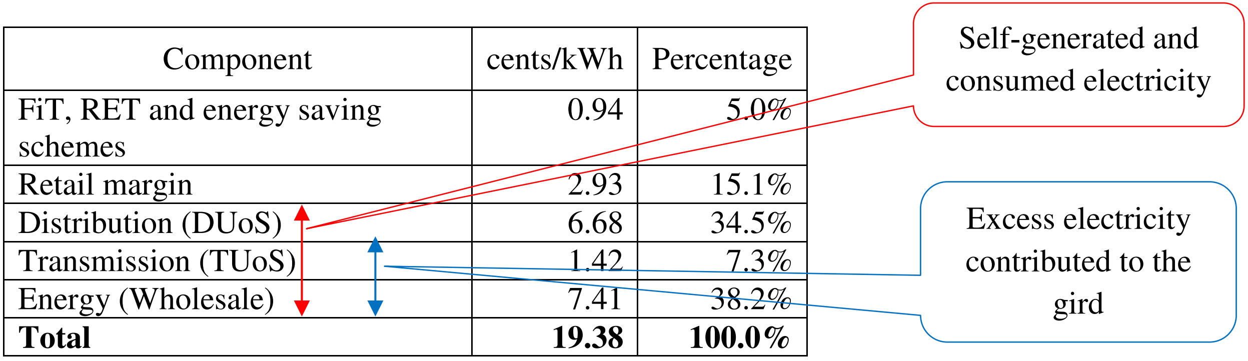
There is debate over whether a FiT should be paid for the net or the gross contribution of power to the distribution grid. Farrell (2011, p. 33) discusses the major drawback of net metering, which is to encourage optimization of the size of a solar array for on-site load rather than maximising the solar array. The economic argument favours gross; this way the investor optimises the size of the solar PV installation to match the wider economics conditions prevailing on the grid at the point of connection. Under the gross payment method, the householder pays the retail rate for the total electricity consumed whether sourced from the grid or from their own generator. This provides an incentive for the customer to conserve electricity and maintains a profit motive for the retailer.

A further problem with using a net FiT on accumulation meters is pricing the production of electricity from the solar PV unit and the consumption of a unit of electricity equally regardless of time of production or consumption. This situation is exacerbated where exported power is paid more than the prevailing tariff because this introduces an incentive to reduce use during sunlight hours to enable export, which amplifies the residential evening peak. Section 6.3 discusses a resolution to this problem.

The question arises 'what is a fair payment for the contribution to the grid from residential solar PV?'

Table 5 shows a breakdown of the cost components of the retail price of electricity to households as an average of the Australian retail prices. These prices are only indicative and used to aid the discussion. As with LCOE calculations, electricity prices and their exact breakdown into components can be a vexed subject.

Table 5: Breakdown of the average Australian retail price of a unit of electricity for 2009-10



Component	cents/kWh	Percentage
FiT, RET and energy saving schemes	0.94	5.0%
Retail margin	2.93	15.1%
Distribution (DUoS)	6.68	34.5%
Transmission (TUoS)	1.42	7.3%
Energy (Wholesale)	7.41	38.2%
Total	**19.38**	**100.0%**

Self-generated and consumed electricity

Excess electricity contributed to the gird

(Source: PwC 2011, p. 14)

Paying solar PV owners at least the wholesale price of the electricity is obvious. This already is happening according to the Independent Pricing and Regulatory Tribunal of New South Wales (IPART 2011). However, this price signal could be improved by using time of supply to reflect the variation in the wholesale price of energy over the course of the day at each node in the NEM. Time of supply pricing is discussed further in section 6.2 and 6.3.

In addition, the solar PV unit delivers electricity directly into the distribution grid without the requirement for transmission, so a payment for the deferred cost of transmission is warranted. This is approximated by the current TUoS charges. However, the potential for deferment only occurs when the lines are near or at peak load. So, payment for deferment is only justifiable during these periods. Again, this requires time of supply metering.

Section 6.3 below discusses the impracticability and disparity between the current TUoS and DUoS charges and the Long Run Marginal Cost (LRMC) to act as a price signal to reflect the deferred cost of transmission. Section 6.4 introduces the concept of gross and net demand to frame discuss of the implications of distributed non-scheduled supply on shifting net peak demand and exacerbating underutilisation of the network.

Furthermore, the household will consume some or all of the electricity produced by the solar PV unit, so payment for the deferred cost of distribution is warranted for this self-produced and consumed electricity. This is approximated by the current DUoS charges. However, deferment only occurs when the lines are near or at peak load. So, payment for deferment is only justifiable during these periods. Again, this requires time of supply metering. Section 6.3 discusses issues with the existing DUoS and TUoS charges.

The above FiT preserves the retailer's profit margin and creates the right price signals for maximizing the size of solar PV installations and for deferment of TUoS and DUoS. The proposed remuneration for solar PV can accommodate other forms of non-scheduled supply such as cogeneration, energy storage and future developments in supply. This method requires itemising charges for TUoS and DUoS on invoices and peak periods. However, the wholesale price for electricity, the cost of TUoS and DUoS and peak periods will vary over time and between locations. These factors would require addressing with real time pricing. However, almost all new solar PV connections are net metered and lack time of supply monitoring. They just measure total volume of export. The exceptions are in Ausgrid's distribution area and in Victoria where smart meters have been installed.

6.2 Real time pricing, smart meters and FiTs

There is a requirement for smart meters to enable real time pricing to provide efficient price signals for electricity produced by solar PV and for electricity consumed by the household. However there is a lack of incentive for retailers and NSP to install smart meters (PwC 2011, p. 47) since smart meters provide customers with feedback on their consumption of electricity, heightening their awareness and encouraging them to reduce demand or shift demand to a non-peak period, which, in turn, reduces the retailer's profit. Additionally, smart meters can help ameliorate peak-loads which drive the expansion of the network linked to the profits of the NSPs.

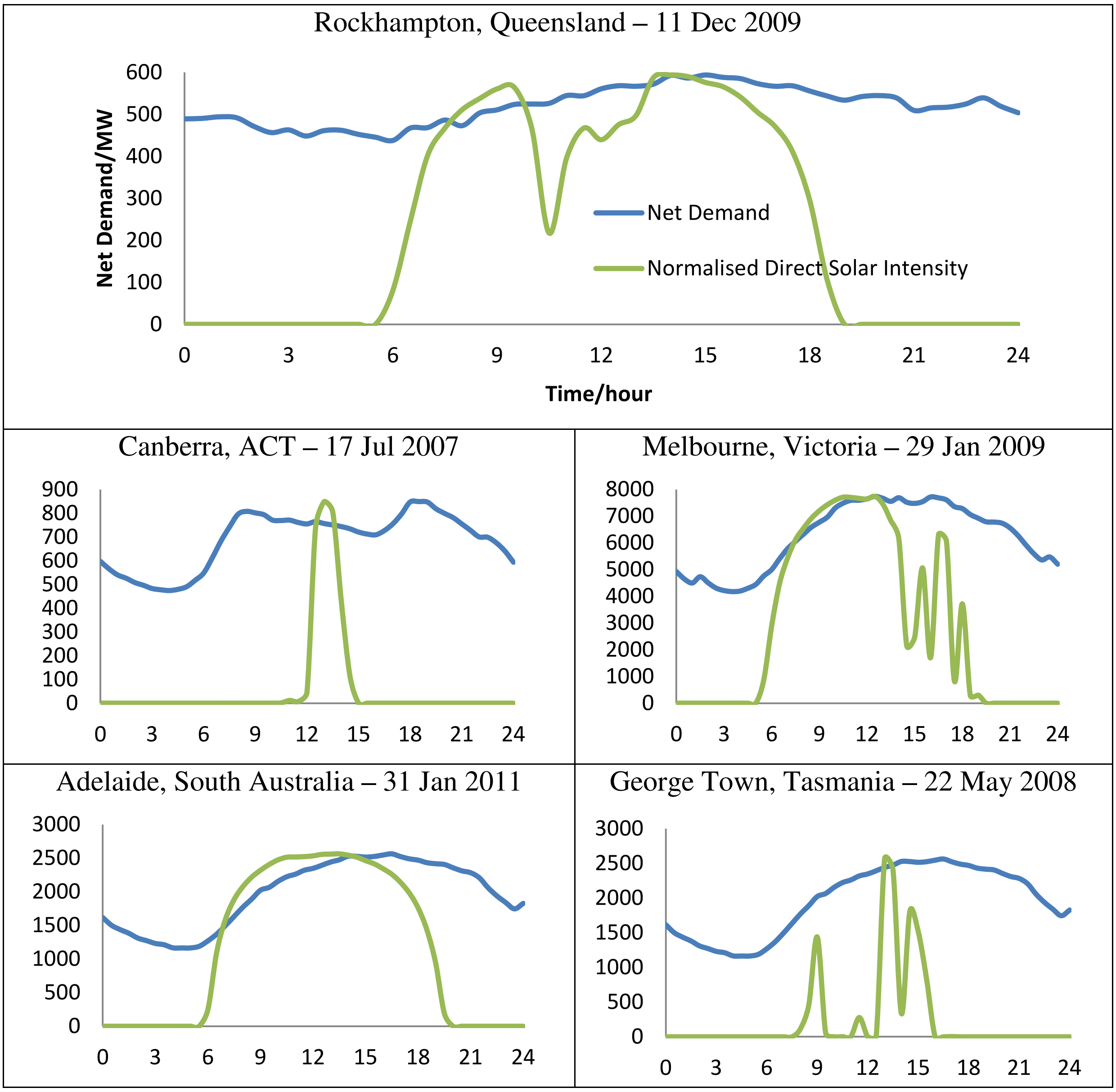
Figure 5 compares the normalised direct solar intensity against the highest peak demand day over the period 2007 to 2011 for 5 nodes in the NEM. These five demand nodes in the NEM are chosen because they are the closest nodes to the only Australian weather stations that provide half hourly solar intensive reading within the NEM. Table 6 matches the weather station with the nodes in Figure 5. The nodes Rockhampton, Melbourne and Adelaide and their weather stations at their local airports provide a good match. However, the node Canberra and its closest weather station at Wagga Wagga are about 200 km apart and the node George Town and its closest weather station Cape Grim are about 250 km apart. This separation must be considered when interpreting Figure 5.

Table 6 Matching the NEM nodes and weather stations that provide half hourly solar data

Node	Weather station
Rockhampton, Queensland	Rockhampton Aero
Canberra, ACT	Wagga Wagga
Melbourne, Victoria	Melbourne Airport
Adelaide, South Australia	Adelaide Airport
George Town, Tasmania	Cape Grim

The day with the highest peak demand is selected to assess the capability of solar PV to meet peak demand to justify payment for network investment deferment. It should be noted that demand in Figure 5 represents that met by scheduled and semi-scheduled generators or net demand. Gross demand would be met by non-scheduled and aforementioned generators. Solar PV contributes to non-scheduled generation. Consequently these figures underestimate the potential contribution of solar PV, as the installed solar PV has already modified these net demand curves. The difference between net and gross demand is becoming more significant as the penetration of non-scheduled supply increases. Section 6.4 discusses this issue futher.

Figure 5 Comparing normalised direct solar intensity to the highest peak demand day in 2007-2011 at 5 nodes in the NEM



(Sources: BoM 2012b; Wild & Bell 2011)

In Figure 5 we show that solar PV electricity production matches the daily electricity demand of cycle of commerce and industry in the summer months with a more modest contribution in winter. This cyclic match between commercial electricity demand and solar PV supply requires real time pricing and smart meter installations to provide the solar PV with appropriate recompense. This cyclic match contrasts with baseload electricity from fossil fuel generators that are required to maintain minimum stable operating levels 24 hours a day.

The minimum stable operating level has two negative aspects. First it puts an effective floor on the minimum level of carbon emission reductions that can be secured. Second this minimum level produces overnight negative spot prices (Pierce 2011), which drives out other forms of generation and in particular makes wind generation, which is often most productive at night, less economically viable. The replacement of electric hot water cylinders that provide overnight load traditionally met with coal generation, with solar hot water will exacerbate the situation.

Currently in Australia transmission and distribution investments are made to ensure that peak demand is met. Smith and Hargroves (2007) state that in Victoria the transmission system has to be 20 per cent bigger to meet peak demand for 1 per cent of the year. Over the past decade or so, growth in peak electricity demand in most of the states has grown at a faster rate than the increase in average annual demand. This is particularly an issue in South Australia. Spikes in peak demand only occur a few times during the year on extremely hot summer days when air conditioners are being run in households in addition to other appliances at the same time that the commercial and industrial sectors are consuming maximum power. Since climate change is expected to produce more heatwaves, rising peak electricity demand could compromise system reliability without massive new transmission infrastructure investments. Alternatively improvements in energy efficiency and demand side participation could help ameliorate and smooth demand. Energy efficiency improvements include non-electrical options such as efficient building. Demand side participation includes education and incentives, such as time of use billing, time of supply payments for non-scheduled supply, such as solar PV and battery storage, and load management, such as cycling of air conditioners (Honeywell 2013; Peakrewards 2013).

Futura (2011, p. 53) discusses, how in summer, distribution network load peaks occur around 4 pm to 7 pm. However, solar PV output is about 30% of nominal rated capacity at 4 pm, which provides a modest contribution to moderating this residential peak in demand. In winter, PV output is negligible during residential network load peaks. Introducing real time price signals would provide an incentive to solar PV owners to consider energy storage systems to save energy for use during the more expensive peak time, which would help to defer investments in distribution and transmission. As an alternative, the price signal could provide an incentive to face the panels due west, so they generate later into the afternoon.

Clearly, from Figure 5 there is justification for remuneration for solar PV to act to defer investment in transmission and distribution during the summer months in the late afternoon when air conditioners are at peak use. Furthermore, the peak demand periods at each demand region or node differs, so identification of a period suitable for remuneration of TUoS and DUoS charges for each node is required.

The AEMC (2009, p. v) considers fixed priced tariffs for retail customers a risk to the NEM, so it recommends more flexible pricing for retail customers to reflect movements in wholesale prices coupled with a national customer protection scheme to be introduced prior to the commencement of flexible pricing. A flexible retail consumer price reduces the risk for the electricity companies but the customer is at risk of significantly increased electricity bills without suitable education and feedback mechanisms. This risk necessitates protection for vulnerable consumers and education of consumers aided with in-house displays or internet portals on electricity usage. The World Energy Council (WEC 2010) has evaluated the residential smart meter policies of Victoria and claims that the lack of a promised in-house-display and of protective measures for the most financially vulnerable has caused dissatisfaction amongst customers, which led to a moratorium on real time pricing. Section 6.3 further discusses the Victorian experience leading to the moratorium.

The transaction costs of real time pricing require consideration against alternatives such as adjusted futures contract price during peak periods, charged on an annual or quarterly basis. Futures contracts would be much easier to implement and cheaper than using smart meters to provide real time pricing as there are expenses associated with the smart meter installations and the associated software and hardware to integrate the consumer, retailer and NSP. But offsetting this expense is the fact that smart meters offer many other features than just real time pricing. For instance meter readers are no longer required and there is the added ability to bill monthly. Budgeting for smaller monthly bills is easier than for larger quarterly bills, which helps to reduce defaults on payments. Additionally, real time pricing provides a much sharper price signal than futures contracts. Sharper pricing encourages adaptation of the NEM as well as linking usage to payment more immediately.

The AEMC's (2011) Transmission Framework Review discusses further option of charging for DUoS and TUoS. Our main contention is that, whatever option is selected, the price signal be as clearly transmitted to the customer as possible. Section 6.3 discusses DUoS and TUoS charges in more detail.

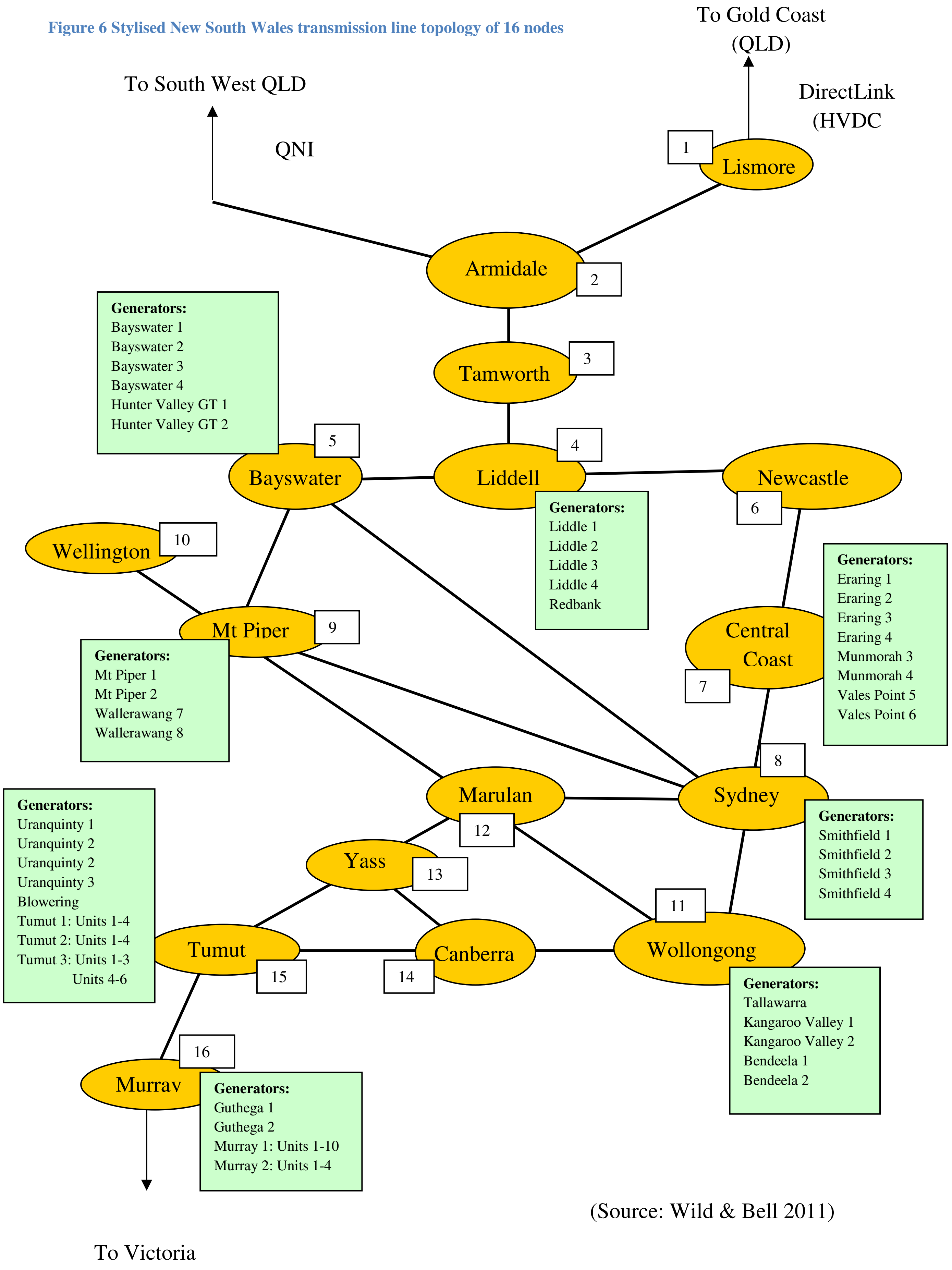
6.3 Time of use and locational price signal for TUoS and DUoS

Figure 6 shows the 16 nodes in a transmission line topology of Australian Capital Territory and New South Wales. These nodes serve three functions:

- Demand - the node represents an area or region of demand.
- Supply - the node represents the connection point for non-distributed generators.
- Transmission - two nodes represent the connection points.

Figure 6 represents the topology of the network rather than geographic distance. Geographically the demand is an area, the generators are points and the transmission lines are lines. However, settlement prices are regionally based rather than from the finer granularity of node based pricing, although node based pricing does occur. The AEMC (2011) proposes nodal pricing as one of five options in the transmission framework review.

Figure 6 Stylised New South Wales transmission line topology of 16 nodes



(Source: Wild & Bell 2011)

The ‘marginalist’ approach to optimization is frequently used to provide a theoretic basis for pricing. Applying marginalism to pricing the transmission and distribution of electricity is challenging. Nevertheless a discussion of marginalism informs the development of a pricing structure for TUoS and DUoS when making judgements over feasible pricing schedules given the metering available. Using the marginalist approach a firm maximises profit by supplying at marginal cost. Applying this theory presents two problems:

- NSP are regulated monopolies; and
- practical difficulties measuring and implementing the marginal cost.

The NSP are regulated monopolies and as such must provide pricing schemes within the national electricity rules of Australia, which can accommodate long run marginal costing but there are constraints on application, such as the annual rate of change at each location. But the national electricity rules could be modified to further accommodate the marginalist methodology.

Addressing the marginal cost of NSP requires consideration of short run marginal costs and long run marginal costs (LRMC). In the short run, one variable is held fixed. The fixed variable is capacity. In the long run all variables can change, including building more capacity to relieve congestion. The challenge is to develop a pricing structure for congestion to allow short run marginal costing. The AEMC’s (2011) transmission framework review recognises a need to address complex problems of this sort and have identified the need for a framework based on the interrelationship among the following five factors:

- the nature of network access
- network charging
- congestion
- transmission planning
- connections

There are merits for charging LRMC. LRMC is the cost required to increase capacity to carry an extra unit of electricity at peak demand. In contrast, the LRMC during off peak time is effectively zero as load is easily carried within the existing infrastructure that is a sunk cost. This LRMC method for pricing TUoS and DUoS has implications for pricing solar PV output, as discussed in section 6.1, where payments for deferred TUoS and DUoS are modest. However, there are two major advantages to charging DUoS and TUoS fees that closely follow the LRMC methodology. The first is to encourage customers to reduce load during peak times. The second is spurring customers with solar PV to install battery storage because the LRMC methodology increases the differential between peak and off-peak electricity prices. Battery storage is currently uneconomic but having the correct price signals in place readies the NEM for battery storage solutions and encourages their eventual diffusion across the grid.

However, applying LRMC has two drawbacks. There would be times when there was insufficient revenue generated to recover operating costs and extremely lumpy pricing would prove unacceptable to customers. Then a question arises “What pricing schemes can address the two drawbacks of LRMC but retain the price signal provided by LRMC?”

PwC (2011, p. 23) discusses the importance of pricing TOUS and DUoS independently of wholesale electricity cost as pass through may not provide a good signal for network costing, given that peak wholesale prices do not always correlate with high demand periods. PwC (2011, p. 28) reviews the current TUoS and DUoS pricing schemes in the NEM and finds differences amongst the jurisdictions on two dimensions: clarity of the price signal passed through the retailer from the NSP to the consumer; the quality of the initial price signal, which is limited by the metering type.

Table 7 compares the pass-through quality amongst the different states in the Australian National Electricity Market (NEM), with the exception of Victoria. Only Queensland and Tasmania lack the ideal direct pass through to customers. Direct pass through of network costs suits arrangements for solar PV payments, as discussed in section 6.1. Victoria has been unregulated from 1 Jan 2009, so is excluded from the comparison.

Table 7 Comparison of clarity of pass through of network costs

Queensland	New South Wales	Australian Capital Territory	South Australia	Tasmania
Pass onto retailers	Direct pass through to consumers	Direct pass through to consumers	Direct pass through to customers	Transmission cost pass through but distributor and retailer the same entity so less transparent.

(QCA 2009)

The quality of the initial price signal or current pricing structures for TUoS and DUoS are limited by three forms of metering:

- accumulation;
- interval; and
- smart meters.

Accumulation meters restrict the options for TUoS and DUoS pricing structures to: flat tariff; and inclining block.

The flat tariff lacks a price signal to customers to restrain use during peak periods. In addition, customers that use electricity in off peak periods cross subsidise those customers using the electricity during peak period. As discusses in section 6.1, customers with solar PV are paid a flat rate for their contribution to the grid. Where the FiT is the same as the domestic tariff, there is little incentive to conserve electricity during peak time. This situation is exacerbated when the FiT is a multiple of domestic tariff as people can make more money by shifting their demand to periods outside production time of the solar PV. This increases the cross subsidy from the lowest income quintile to the four highest income quintiles.

In comparison, with the inclining-block tariff, customers are charged on the quantity of electricity used. This pricing scheme is an improvement over the flat tariff because customers who use larger quantities of electricity tend to have more or larger air conditioners. Air conditioners, in particular, add to demand during domestic peak periods. This peak demand drives increased investment in transmission and distribution infrastructure. Customers with solar PV undermine the mute price signal provided by inclining block, as solar PV reduces the accumulation meter reading of the quantity of electricity used, which may well move the customer onto a cheaper block rate even if the customer is a heavy user of electricity and air conditioners.

Both inclining block and flat tariffs cause cross substitution of costs from customers with solar PV to customers without solar PV, because the tariffs lack a ‘time of use price’ signal. Furthermore, a retailer’s margin is calculated on the quantities displayed on accumulation meters. This quantity is reduced for customers with solar PV, causing an additional cross substitution cost from solar PV owners to non-owners, as retailers try to maintain their profits. In Section 2 we discussed how this situation is inequitable. Furthermore, the cross substitution is a symptom of a poor price signal and poor economics. Both these tariffs, when used with accumulation meters, present an unsustainable FiT for solar PV. A remedy is real time pricing that requires replacing accumulation meters with interval or smart meters (EY 2011, p. 4; Futura 2011, p. 4; PwC 2011, p. 5)

In Victoria and New South Wales, where interval or smart meters are installed, there are TOU tariffs with peak, shoulder and off-peak prices and in some cases seasonally adjusted TOU (STOU) tariffs. These TUoS and DUoS tariffs provide the basis for a more sustainable FiT. However, developing a TOU or STOU tariff requires consideration of the fact that the demand load profile differs for each node and between seasons. However, as PwC (2011, p. 5) pointed out, there are limitations to the extent that TUoS and DUoS charges for residential and small business customers can fully reflect their locational characteristics due to the complexity and logistical costs associated with developing locational specific charges.

6.4 Network underutilisation, NSP remuneration and other non-scheduled supply

There are grounds to conclude that the suggested payments in Section 6.1 for deferred DUoS and TUoS are unjustifiable after comparing the net peak demand and solar intensity in Figure 5. But this conclusion assumes that DUoS and TUoS charges are fixed and considers solar PV purely in isolation. There are a number of factors when considered together make the suggested payment scheme in the paper most appropriate to address excessive NSP charge concerns raised by consumer advocates (Choice 2012). Additionally, these factors provide a sense of urgency to put the suggested scheme in place.

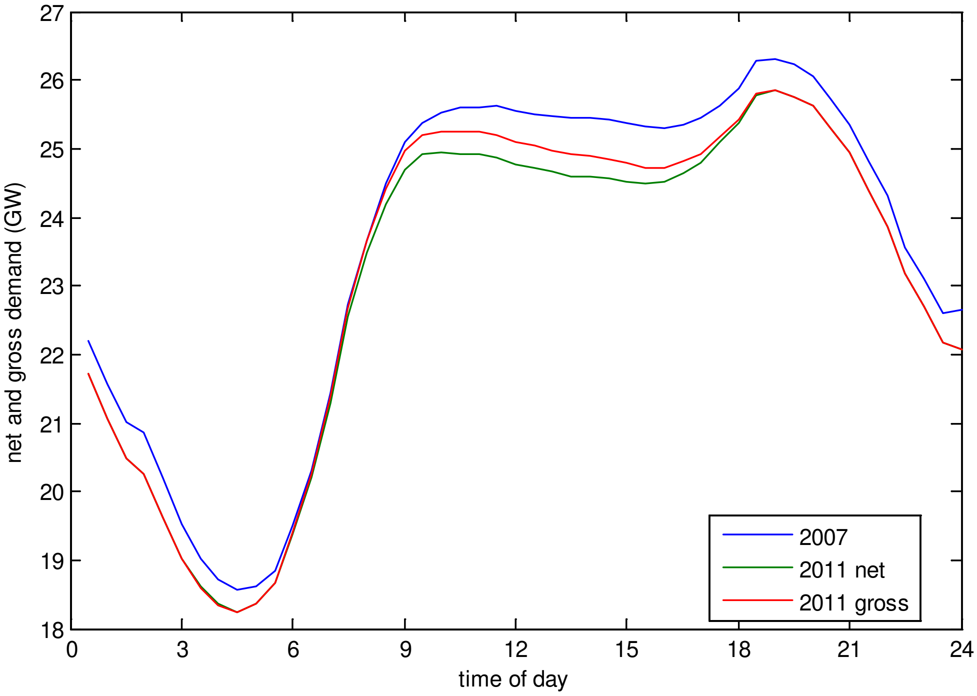
- the network underutilisation problem exacerbated by both solar PV and climate change
- perverse remuneration structure for NSP in the NEM stifling a more LRMC basis for TUoS and DUoS charges to incentivise DSM
- other forms of non-scheduled supply needing fair remuneration, such as

  - cogenertation/trigeneration
  - energy storage
  - new distributed energy innovations
- framing effect of gross and net peak demand and peak demand as a moving target

Bell, Wild and Foster (2013) investigate the transformative effect of unscheduled generation by solar PV and wind generation on net electricity demand. The non-scheduled generation is calculated using the Australian Bureau of Meteorology (BoM 2012a) half hourly solar intensity, temperature and wind speed data, the Australian Clean Energy Regulator (CER 2012) small generation unit (SGU) installations by postcode and the Australian Bureau of Statistics (ABS 2012a) postcode to statistical area translation.

Figure 7 compares the daily average gross and net demand for 2007 and 2011 for the NEM. The net demand is met by scheduled and semi-scheduled generation and gross demand by the aforementioned plus non-scheduled generation from solar PV and wind generators.

Figure 7: Comparing daily average gross and net demand for 2007 & 2011



(Bell, Wild & Foster 2013)

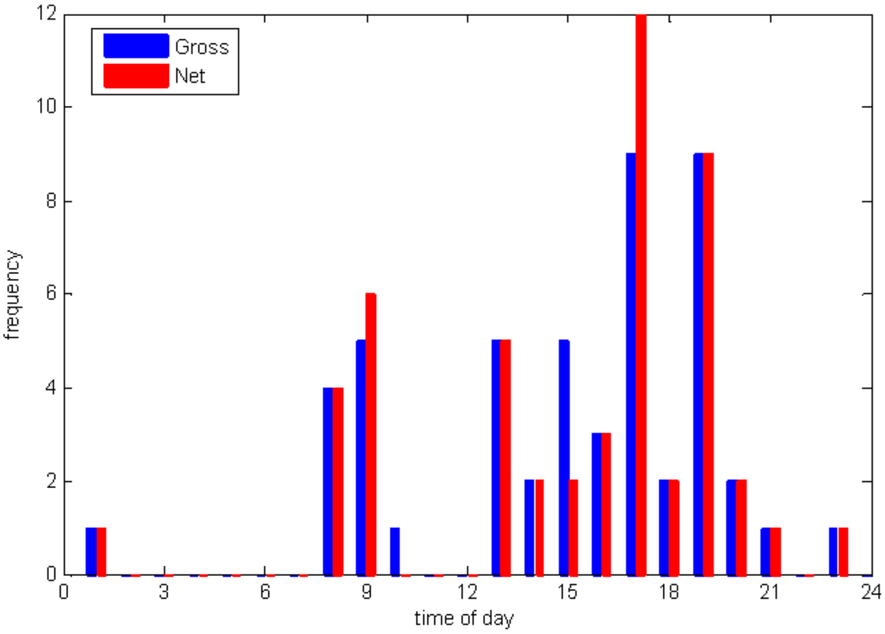
The net and gross demand for 2007 is almost the same because the amount of non-scheduled generation is trivial on 2007. The amount of non-scheduled wind generation is trivial compared solar PV generation. Noticeable is the overall decrease in net demand from 2007 to 2011. This decrease in demand is significant as it reduces the revenue base for NSPs, which implies an increase in DUoS and TUoS charges per unit of electricity to cover their existing capital costs and repair and maintenance. There are many causes for this decrease in demand but in this paper we are interested in the fact that the installation of new solar PV can explain a marked portion of the decreases in net demand from 2007 to 2011. The amount of solar PV installed in 2012 roughly doubles the amount installed in 2011. Solar PV is going to contribute to further underutilisation of the network and further erode the revenue base of NSPs. In Figure 7, the decrease in overnight demand can be explained by solar hot water displacing the electric hot water cylinders. Again this effect is expected to continue and further undermine the revenue base for NSPs.

Additionally, Bell and Wild (2013) find that the effect of climate change on electricity demand causes further underutilisation. This will exacerbate the underutilisation already caused by solar PV. Bell and Wild (2013) model the effect of climate change on electricity demand from 2009 to 2030 and find that the rate of increase in peak demand exceeds the rate of increase in total demand. Peak demand drives investment in new infrastructure and the rate of total demand is less than total demand, so climate change will increase the cost of network provision per unit of electricity.

Furthermore, the regulatory environment in Australia exacerbates the underutilisation problem. The regulatory investment test for transmission (RIT-T) requires that new investment is built to meet peak demand. The profits of the NSPs are calculated on their capital expenditure, which encourages them to build more infrastructure. If peak demand increases, the NSPs are legally obliged to build more infrastructures to accommodate the demand and the NSPs profit from accommodating the demand. This is a perverse dynamic from both climate change and economic perspectives. This remuneration calculation needs to be changed to align the profit motive of the NSPs with DSM. This can be achieved by making the utilisation of the existing infrastructure a business objective of the NSP. To this end focusing the DUoS and TUoS tariffs on periods of peak demand would help defer further investment in infrastructure and aid DSM. As previously noted the ability for solar PV to ameliorate the current peaks in net demand is modest but alternative non-scheduled generation such as co-generation would benefit from the scheme outlined in section 6.1. Additionally, the scheme provides appropriate price signals for the diffusion of energy storage technologies, such as batteries, into the NEM. The eventual deployment of Electric Vehicles (EVs), with their large battery storage, could aid DSM if the appropriate TOU and TOS price signals are in place. Without these price signals, EVs will exacerbate the existing peak demand problem in the NEM.

It must be noted that solar PV has already addressed some peak demand problems. Bell, Wild and Foster (2013) investigate the significance of framing the discussion of demand in terms of gross and net when considering the effect of non-scheduled solar PV and wind on peak demand. Figure 8 and Figure 9 use the same data as Figure 7 above but present the data by the 50 demand nodes or regions in the NEM. See Wild and Bell (2011) for demand node diagrams. Figure 8 shows the distribution of the peak loads by time of day for the maximum peak loads from 2007 to 2011 at each node in the NEM. At 15:00 the disparity between gross and net demand shows the success of non-scheduled solar PV and wind generation in addressing peak demand. However at 17:00 when framing the discussing in terms of net demand non-scheduled generation appears less effective at addressing peak demand. The net demand analysis, however, misses the point that non-scheduled generation has already addressed some peak demand issues and by doing so makes the remaining peaks in net demand peaks appear more prominent.

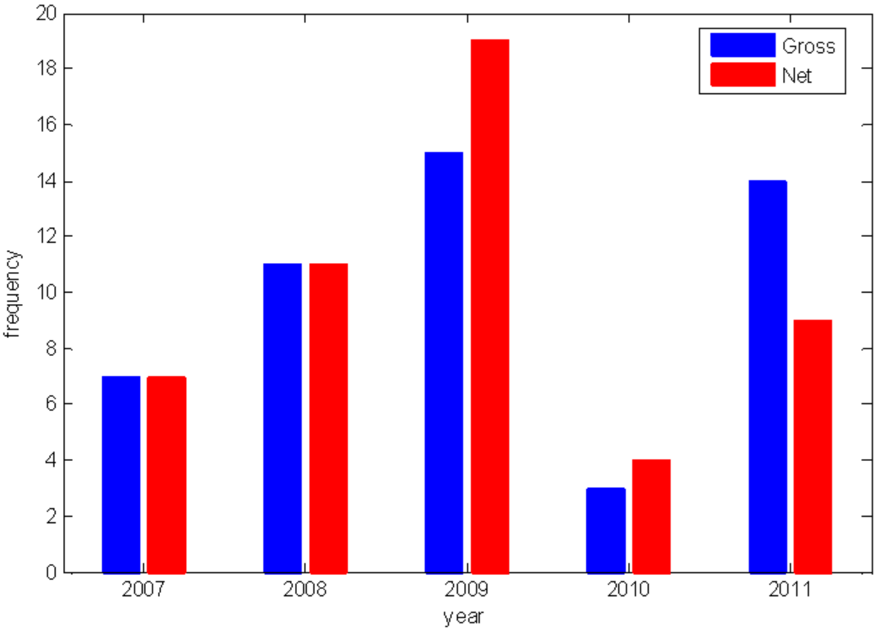
Figure 8: Distribution by time of day of the maximum peak loads from 2007 to 2011 at each node in the NEM



(Source: Bell, Wild & Foster 2013)

Figure 9 shows the distribution of the peak loads by year for the maximum peak loads from 2007 to 2011 at each node in the NEM. The frequency of maximum peaks for net demand between the years 2011 and 2009 shows the greatest disparity. Using net demand to frame the discussion could misattribute the decline to mild weather in 2011 compared to 2009. Using a gross demand analysis shows that much of the decline in the frequency of peak demand is attributable to non-scheduled solar PV and wind generation.

Figure 9: Distribution by year of the maximum peak loads from 2007 to 2011 at each node in the NEM



(Source: Bell, Wild & Foster 2013)

So, non-scheduled solar PV and wind generation have already addressed gross demand peaks and continue to do so but there is a framing effect that focuses peoples' attention on the now more prominent remaining net demand peaks. The TUoS and DUoS charges need to be focused on the net peak demand periods to help deter demand and encourage supply. Targeting net demand peaks with higher TUoS and DUoS charges is an ongoing and shifting process to improve utilisation of the existing network. The TUoS and DUoS charges discussed in section 6.1 are an integral part of an ongoing process to improve utilisation of the network. The issues surrounding solar PV have motivated this paper but the solution is far more encompassing and applies to all form of non-scheduled supply and presents a dynamic pricing system to address net demand peaks.

6.5 Implementing real time pricing and behaviour modification

Futura (2011, pp. 13-5) reviews the effectiveness of various TOU pricing schemes across the NEM and finds that all the schemes cause residential customers to reduce demand in peak periods. For instance Augrid (operating as EnergyAustralia) commissioned a comparative analysis of customers on TOU tariffs with those customers without TOU tariffs. The results showed TOU induced a decrease of about 4% in the customers peak demand relative to their average demand. In the Essential Energy trial, peak demand fell by 30% in response to Critical Peak Pricing (CPP) of about 38 cents per kWh. Similarly, Endeavour Energy's Western Sydney Pricing Trial found a 30-40% reduction in peak demand in response to a critical peak price of $1.67 per kWh. CPP is invoked when a customer's local sub-station is expected to reach its maximum load. The customer is informed prior to the critical price period, usually a day ahead. These CPP events happen a few times a year.

Despite these positive results, a moratorium on TOU pricing was established in Victoria caused in part by the lack of promised IHDs and protection for the most vulnerable consumers. The World Energy Council (WEC 2010, p. 31) discussed how the Australian and Victorian legislators paid considerable attention to the functionality of smart meters and cost benefit analysis but overlooked the customer engagement required to achieve peak load clipping. Engagement requires a well-designed pricing structure in conjunction with education and innovative feedback interfaces. Section 7 further discusses the problematic Victorian TOU and the smart meter rollout.

The efficacy of feedback interfaces in trials with Dynamic Peak Pricing (DPP) in the NEM find that IHDs have limited impact on consumer response to real time pricing compared to customers without displays (Futura 2011, pp. 68-70). The DPP differs from CPP in that customers can respond in real time to changes prices as demand peaks. However the trial only compared a web interface with an IHD with a web interface without an IHD. In contrast, Faruqui et al (2010) survey a dozen US and international sites and find that IHDs do induce customers to save on energy by an average of 7 per cent. However, the evidence for demand response to real time pricing augmented with IHDs is limited to two sites in the survey.

WEC (2010, p. 4) recommends that regulators calculate the impact of a smart meter rollout and new tariffs on vulnerable consumers. There are at least four solutions to ameliorate the impact:

- offer a flat tariff to those on benefits;
- increase payments to those on benefit support;
- assistance with energy efficiency; or
- assistance with the installation of solar PV.

Recipients of benefit support and low income individuals are less likely to own power hungry appliances, so a flat tariff that lacks a price-signal to deter consumption during peak demand is less problematic than a flat tariff with more wealthy individuals.

Increasing the payment to those on a benefit support to cover the increases in electricity prices induced by dynamic pricing has the advantage that the price-signal to defer electricity use during peak period remains. If a beneficiary is willing to shift demand from peak periods, they could be better off under such an arrangement.

Assistance with energy efficiency could come in three ways, providing assistance to replace appliances with more energy efficiency models, improving the thermal properties of the accommodation and education or advice on energy use. However, the dual problem of low income and living in rental accommodation presents an issue when spending on improving the thermal properties of the accommodation or replacing appliances that are permanent fixtures such as air conditioning.

Section 3 has already discussed the issue of installing solar PV on rental accommodation.

7 Conclusion

The motivation for this paper is to address issues surrounding the calculated feed-in tariffs for solar PV and proposing a process to determine a market based FiT. However, the proposed process can equally be used to address remuneration for other forms of non-scheduled electricity supply including renewable energy generation, cogeneration, tri-generation and energy storage. Importantly, the proposed pricing process readies the NEM for the diffusion of new technologies without necessitating new legislation to calculate a price for each technology. Additionally, this market determined pricing process can be part of the fix to address the dramatic rise in Network Service Provider (NSP) charges in the NEM that consumer groups are advocating (Choice 2012; EUAA 2011).

But back to the more specific focus on solar PV that originally motivated this paper. Sustainable feed-in tariffs for solar PV are at the confluence of social equity, environmental protection and economic growth. The calculated feed-in tariffs used in the past have been successful in developing the solar PV industry but are becoming unsustainable as the industry nears or surpasses parity. A market determined FiT is becoming more appropriate in a rapidly expanding market. However many governments, in reaction to budget blowouts, have drastically reduced the calculated FiT to the point where it may stifle the growth of the industry. It is imperative that the Australian state governments change from calculated FiTs to market determined FiTs to help maintain their budgets and ensure the future growth of this important industry in addressing climate change. The market failures and social inequities that arise have been identified in this article and recommendations to address these issues have been made:

- A national roll out of smart meters for time of use billing
- Itemised billing for the TUoS and DUoS charges, wholesale electricity price and retailer margin and green components.
- TOU charges for DUoS and TUoS passed through to the consumer as clearly as possible.
- Gross feed-in tariffs for solar PV with payments based on time of supply
    - Payment for self-consumed electricity includes: wholesale electricity price plus DUoS and TUoS charges and carbon pricing.
    - Payment for electricity supplied to the grid includes: wholesale electricity price plus TUoS charges and carbon pricing.
- The green charges other than carbon pricing (FIT, RET, and energy saving) to be spread across all electricity consumed, whether produced on site or taken from the grid. This pricing scheme will help reduce cross subsidy.
- The above payment schemes maintain a profit margin for retailers whether electricity is generated by residential solar PV or supply by conventional generators.
- Change the profit basis for NSP from a percentage of CAPEX to grid utilisation to encourage DSP and other non-scheduled supply options such as batteries and cogeneration
- State and territory housing authorises to install solar PV along with smart meters to help this most disadvantaged segment and aid acceptance of the change to TOU billing
- Those in private rental housing, the second most disadvantaged group and growing segment
    - Subsidised loans for landlords to install solar PV to address investment myopia
    - Forfeiture of tax free exemption on capital gains on property without solar PV installations to address irrational exuberance (consideration needs to be given for rental properties unsuitable for solar PV)
    - The landlord receives payment for electricity supplied from the solar PV to the grid. The payment to include: wholesale electricity price and carbon pricing.
    - The tenant receives the DUoS charges for electricity consumed from the rooftop solar PV and TUoS charges
- The small-scale renewable energy certificate be retained until the market has reach parity and the market determined FiT tariffs are successfully in place

The proposed price signals maintain a profit margin for the retailers, provide an incentive for NSP to engage in DSP, address the poverty trap for renters and incentivise landlords. Lack of action in developing appropriate price signals for connected solar PV could well see some households disconnecting from the grid, once battery storage becomes more inexpensive. This situation would be economically suboptimal for the economy as a whole.

This case study should be useful for policymakers in other countries which have in place elements of the Australian National Electricity Market's unique combination of features, including competitive gross pool wholesale market, common carriage and regulated tariffs.

References

ABS 2011a, '4130.0.55.001 - Housing Occupancy and Costs, Australia, 2005-06 - Table 3', <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4130.0.55.0012005-06?OpenDocument>.

—— 2011b, '6523.0 Household Income and Income Distribution, Australia - Detailed tables, 2009-10 - Table 11b', <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6523.02009-10?OpenDocument>.

—— 2012a, *1270.0.55.006 - Australian Statistical Geography Standard (ASGS): Correspondences, July 2011 - Postcode 2011 to Statistical Area Level 2 2011* Australian Bureau of Statistics, <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.006July%202011?OpenDocument>.

—— 2012b, '4602.2 - Household Water and Energy Use, Victoria, October 2011 - Table 1a ALL HOUSEHOLDS - Sources of energy used at the dwelling by selected characteristics', <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4602.2October%202011?OpenDocument>.

AEMC 2009, *Review of energy market frameworks in light of climate change policies: final report*, Australian Energy Market Commission, Sydney, viewed Sep 2009, <http://www.aemc.gov.au/Market-Reviews/Completed/Review-of-Energy-Market-Frameworks-in-light-of-Climate-Change-Policies.html>.

—— 2011, *Transmission Frameworks Review, First Interim Report*, Australian Energy Market Commission, Sydney.

—— 2012, *Power of choice - giving consumers options in the way they use electricity*, Australian Energy Market Commission, Sydney.

Alberth, S 2008, 'Forecasting technology costs via the experience curve - Myth or magic?', *Technological Forecasting and Social Change*, vol. 75, pp. 952-83.

APVA 2011a, *Modelling of PV & Electricity Prices in the Australian Commercial Sector, 2011*, The Australian PV Association.

—— 2011b, *Modelling of PV & Electricity Prices in the Australian Residential Sector, 2011*, The Australian PV Association.

Bazilian, M, Onyeji, I, Liebreich, M, MacGill, I, Chase, J, Shah, J, Gielen, D, Arent, D, Landfear, D & Zhengrongi, S 2012, *Re-considering the Economics of Photovoltaic Power*, United Nations Industrial Development Organization, <http://www.bnef.com/WhitePapers/download/82 >.

Beinhocker, ED 2006, *Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics*, Harvard Business School Press, Cambridge, Mass.

Bell, WP & Wild, P 2013, 'The impact of climate change on electricity demand: Research', in WP Bell (ed.), *Analysis of institutional adaptability to redress electricity infrastructure vulnerability due to climate change*, National Climate Change Adaptation Research Facility, Gold Coast, In press.

Bell, WP, Wild, P & Foster, J 2013, 'The transformative effect of unscheduled generation by solar PV and wind generation on net electricity demand', paper presented to 2013 IAEE International Conference, Daegu, Korea, 16-20 June 2013.

BoM 2012a, 'Australian Bureau of Meteorology', <http://www.bom.gov.au/climate/data-services/>.

—— 2012b, *Direct Solar Intensity*, <http://www.bom.gov.au/climate/data-services/>.

CER 2012, *List of small generation units (SGU) and solar water heaters (SWH) installations by postcode*, Clean Energy Regulator, <http://ret.cleanenergyregulator.gov.au/REC-Registry/Data-reports>.

Chase, J 2012, 'Break throughs in solar power', *Bloomberg New Energy Finance University*, <http://www.newenergyfinance.com/Presentations/download/90>.

Choice 2012, 'Take the Power Back! ', <http://www.choice.com.au/green-home/energy-campaign/take-the-power-back-campaign/take-the-power-back-campaign.aspx>.

Clark, T & Hay, S 2012, *Renewable Energy: Getting the Benefits Right for Social Hosuing*, Joseph Rowntree Foundation <http://www.jrf.org.uk/sites/files/jrf/social-housing-energy-costs-full.pdf>.

Couture, T & Gagnon, Y 2010, 'An analysis of feed-intariff remuneration models: Implications for renewable energy investment', *Energy Policy*, vol. 38, no. 2, pp. 955-65.

DCCEE 2011, *Clean Energy Bill 2011*, Department of Climate Change and Energy Efficiency.

DSIRE 2012, 'Database of State Incentives for Renewables & Efficiency', <dsireusa.org>.

EUAA 2011, 'Home of the Energy Users Association of Australia', viewed 4 Nov 2011, <http://www.euaa.com.au/>.

EY 2011, *Rationale and drivers for DSP in the electricity market – demand and supply of electricity*, Ernest & Young report to the AEMC on the review: Power of choice – giving consumers options in the way they use electricity.

Farrell, J 2011, *Demoncratizing the electricity grid*, Institute for Local Self-Reliance, viewed 22 June 2011, <http://energyselfreliantstates.org/content/democratizing-electricity-system>.

Faruqui, A, Sergici, S & Sharif, A 2010, 'The impact of informational feedback on energy consumption—A survey of the experimental evidence', *Energy*, vol. 35, no. 4, pp. 1598-608.

Futura 2011, *Investigation of existing and plausible future demand side participation in the electricity market*, Report to the AEMC on the review: Power of choice – giving consumers options in the way they use electricity.

Garnaut, R 2008, *The Garnaut climate change review - final report*, Commonwealth of Australia.

—— 2011, *Garnaut Climate Change Review – Update 2011 Update Paper eight: Transforming the electricity sector*, Commonwealth of Australia, Canberra.

Gipe, P 2011, 'Bio: Paul Gipe', *Renewable Energy World*, viewed 24 September 2011, <http://www.renewableenergyworld.com/rea/u/paul-gipe-54022>.

IEA 2011, *Trends in photovoltalic applications: Survey report of selected IEA countires between 1992 and 2010*, International Energy Agency.

IPART 2011, *Solar feed-in tariffs: Setting a fair and reasonable value for electricity generated by small-scale solar PV units in NSW*, Independent Pricing and Regulatory Tribunal of New South Wales, Sydney.

IUCN 2006, *The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century*, ed. WM Adams, International Union for Conservation of Nature, <http://cmsdata.iucn.org/downloads/iucn_future_of_sustanability.pdf>.

Lesser, JA & Su, X 2008, 'Design of an economically efficient feed-in tariff structure for renewable energy development', *Energy Policy*, vol. 36, no. 3, pp. 981-90.

Liebreich, M, Chase, J & Bazilian, M 2012, 'Re-considering the economics of PV power', *Bloomberg New Energy Finance University*, <http://votesolar.org/wp-content/uploads/2012/09/bnef_ppt_2012-09-04.pdf>.

Nelson, T, Simshauser, P & Kelley, S 2011, 'Australian Residential Solar Feed-in Tariffs: Industry Stimulus or Regressive form of Taxation?', *Economic Analysis & Policy*, vol. 41, no. 2, pp. 113-29.

Nemet, GF 2006, 'Beyond the learning curve: factors influencing cost reductions in photovoltaics', *Energy Policy*, vol. 34, no. 17, pp. 3218-32.

Origin Energy 2007, 'Response to the National Framework for Energy Efficiency – Stage 2 – Consultation Paper ', viewed 28 Dec 2011, <http://www.ret.gov.au/Documents/mce/energy-eff/nfee/_documents/e2wg_nfee_stag26.pdf>.

Pierce, J 2011, 'Presentation to the Maddocks Energy Lunch', in *Maddocks Energy Lunch 2011, 27 October*, Sydney

PwC 2011, *Investigation of the efficient operation of price signals in the NEM*, PricewaterhouseCoopers report to the AEMC on the review: Power of choice – giving consumers options in the way they use electricity.

QCA 2009, 'Review of Electrcity Pricing and Tariff Structures', <http://www.qca.org.au/files/ER-QCA-RevEPandTS-Info%20Paper-0709.pdf>.

REN21 2011, *Renewables 2011 Gloabl Status Report*, REN21 Secretariat, Paris.

Rogers, EM 1962, *DIffusion of innovation*, Free Press, New York, USA.

Saunders, RW, Gross, RJK & Wade, J 2012, 'Can premium tariffs for micro-generation and small scale renewable heat help the fuel poor, and if so, how? Case studies of innovative finance for community energy schemes in the UK', *Energy Policy*, vol. 42, pp. 78-88.

Schiller, RJ 2000, *Irrational Exuberance*, Princeton University Press, Princeton, <http://www.irrationalexuberance.com/>.

Smith, MH & Hargroves, K 2007, 'Smart approaches to electricity use', *ECOS*, vol. 135, pp. 12-3.

Solangi, KH, Islam, MR, Saidur, R, Rahim, NA & Fayaz, H 2011, 'A review on global solar energy policy', *Renewable and Sustainable Energy Reviews*, vol. 15, pp. 2149-63.

Stebbins, C 2011, 'Is the US farm boom built on an ethanol bubble?', viewed 21 Nov 2011, <http://www.climatespectator.com.au/commentary/us-farm-boom-built-ethanol-bubble>.

Timilsina, GR, Kurdgelashvili, L & Narbel, PA 2012, 'Solar energy: Markets, economics and policies', *Renewable and Sustainable Energy Reviews*, vol. 16, pp. 449-65.

Watt, M 2011, 'Solar same price as grid electricity', *Australian Broadcasting Corporation*, viewed 7 September 2011, <http://www.abc.net.au/pm/content/2011/s3312340.htm>.

WEC 2010, *Evaluation of residential smart meter policies*, World Energy Council.

Wild, P & Bell, WP 2011, 'Assessing the economic impact of investment in distributed generation using the ANEM model', in J Foster (ed.), *Market and economic modelling of the impact of distributed generation*, CSIRO Intelligent Grid Research Cluster, Brisbane, Australia.

Wild, P, Bell, WP & Foster, J 2012, *The Impact of Carbon Pricing on Wholesale Electricity Prices, Carbon Pass-Through Rates and Retail Electricity Tariffs in Australia*, Working Paper 5/2012, Energy Economics and Management Group, University of Queensland, Brisbane, Australia.

Williams, C 2011, 'Why Pure Play Solar Installers Are Losing Ground in the Commercial Solar Space ', *Renewable Energy World*, viewed 28 Sep 2011, <http://www.renewableenergyworld.com/rea/blog/post/2011/09/why-pure-play-solar-installers-are-losing-ground-in-the-commercial-solar-space>.

Wong, P 2008, 'Progress on national approach to renewable energy', *Ministerial Media Statements*, viewed 6 Mar 2008, <http://www.climatechange.gov.au/~/media/Files/minister/previous%20minister/wong/2008/Media%20Releases/March/mr20080306.pdf>.

Wood, A & Mullerworth, D 2012, *Building the bridge: A practical plan for a low-cost, low-emissions energy future*, Grattan Institute, Melbourne.

Yates, A & Mendis, P 2009, *Climate change adaptation for the electricity sector : handbook*, Australian Security Research Centre.

Zahedi, A 2009, 'Development of an economical model to determine an appropriate feed-in tariff for grid-connected solar PV electricity in all states of Australia', *Renewable and Sustainable Energy Reviews*, vol. 13, no. 4, pp. 871-8.

—— 2010, 'A review on feed-in tariff in Australia, what it is now and what it should be', *Renewable and Sustainable Energy Reviews*, vol. 14, no. 9, pp. 3252-5.