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

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Abstract

The International Energy Association has observed that nearly all countries now offer or are planning feed-in tariffs (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'*. 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.

In this paper, 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 Association (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 rich over the poor; challenges to policy credibility; c 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).

Our focus here is on residential solar PV install 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 set of 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.

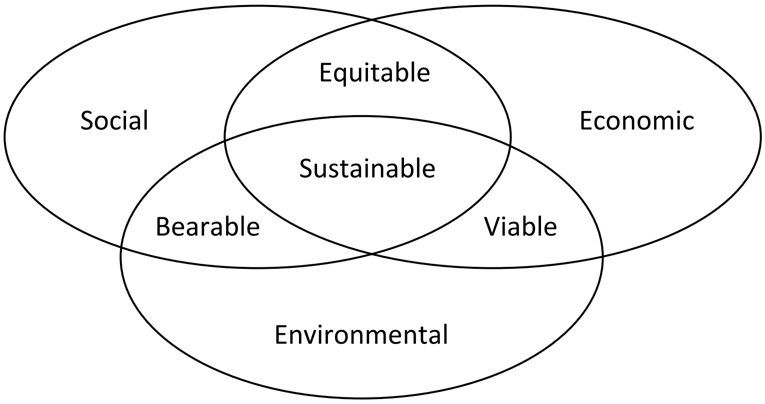
The implications of adopting a sustainable FiT are:

- steadier economic 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).

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.

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 requiring 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 equals 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 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 over 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 to financing and clearly observe the presence of investment myopia. A similar kind of long term investment market failure that has been well researched is in the superannuation industry. 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 a market failure in the provision 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 (CPRS). 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.

4 Maintaining policy credibility and perpetuating social inequality

As discussed in the previous section, Garnaut (2011, p. 15) and Nelson, Simshauser and Kelly (2011) observe how richer households receiving FiTs are being cross-subsidised by poorer households. So, there is a policy dilemma, which is, maintaining policy commitments and credibility can perpetuate economic inefficiency and 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 the influence of the agreed FiTs would gradually fade out with time and these replaced by a more sustainable FiT regime (Garnaut 2008).

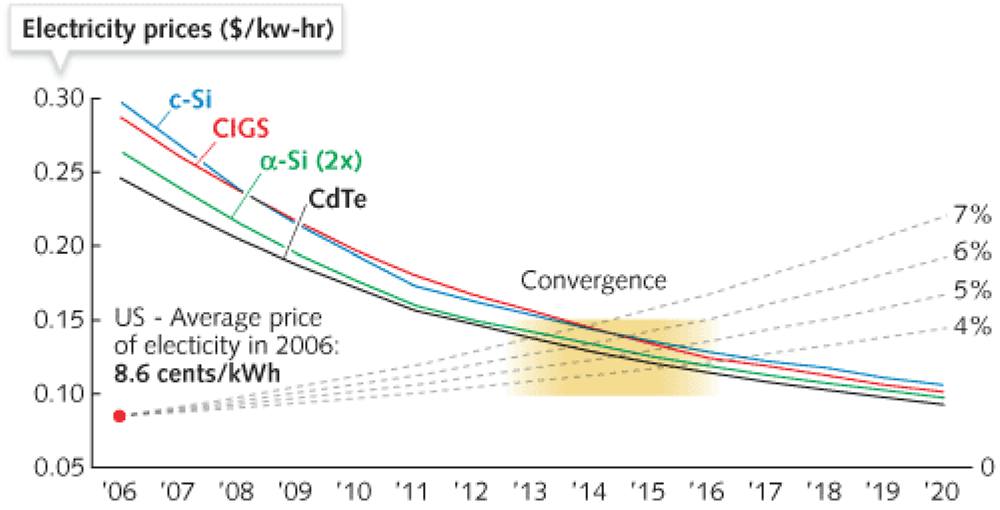
5 Infant industry and solar PV's parity with retail tariffs

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. As the volume of adoption rises, unit costs fall, usually log linearly (exponential) to a minimum level. 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. 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).

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.

Stephen O'Rourke has estimated unit cost curves for different PV technologies. His chart is reproduced in Figure 2.

Figure 2 Solar PV industry outlook



(Source: O'Rourke 2007)

O'Rourke compares high-efficiency crystalline silicon (c-Si), currently most preferred; thin-film copper-indium-gallium-selenium (CIGS), which is just entering the market; thin-film amorphous silicon (α-Si); and thin-film cadium-telluride (CdTe) on glass. He concludes that all of these technologies will become competitive with conventionally generated electricity prices in the 2013-2016 period. As is sensible in such studies, ranges rather than point estimates are reported but it is clear that solar becomes viable by about 2013 onwards.

Incremental innovations will increase the efficiencies of distributed PV collectors very significantly and unit costs will come to strongly out-perform coal-based power station generated electricity in terms of consumer price. 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. And, evidently, the introduction of a carbon price or a tax would shift the unit cost of coal-based power upwards, bringing the price crossover forward.

In Germany, the tendency for unit costs to fall has been acknowledged and FiTs have been adjusted downwards as the price of solar PV units has declined. However, the issue arises as to when parity is reached, and what kind of 'market based' FiT, if any, should be implemented. The timing of arrival at parity will differ between countries and between residential and large scale solar PV. For instance O'Rourke (2007) estimates the US will reach parity sometime between 2013 and 2016 whereas Watt (2011) calculates that Australia has already reach parity. Five factors explain why Australia is likely to arrive at parity earlier than most other countries:

- the high level of solar radiation in Australia makes the equivalent solar PV panel more productive than in most other countries;
- by international standards, electricity prices in Australia are particularly sensitive to the upward movement in fossil fuel prices, as Australia has a high reliance on fossil fuel generation;
- Australia lacks solar cell production, so can look internationally to secure the cheapest panels without concern about destroying domestic production;

- the commodity boom has pushed up Australia's exchange rate, making the importation of solar panels cheaper; and
- the imposition of a fixed carbon price of $23/tCO_2 as of July 2012 is predicted to have a 8.9% increase in residential electricity prices (Wild, Bell & Foster 2012).

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 consideration of institutional arrangements that impede the effectiveness of the market mechanism. This section focuses on price signals but 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. Large scale solar has yet to reach parity; by contrast residential solar PV in Australia has arrived at parity. This differing level of industry development warrants alternative treatment for large scale and residential solar PV. Section 6.8 discusses developments in the Australian Capital Territory using a reverse auction for capacity for large scale solar PV. The reminder of this section is devoted to developing appropriate price signals for residential solar PV. In contrast to Lessar and Su (2008), this section stresses 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) and Solangi et al. (2011).

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) considered DSP as helping to manage demand via three routes:

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

Contributing to the DSP review, PricewaterhouseCoopers (PwC 2011) considered that 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 solar PV installation is both a business and a consumer. Such price signals alone would fail to address social equity and investment myopia, as discussed in the 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 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. Additionally, networks service providers (NSP) base their profits on their capital investment, so to connect solar PV installation with the ability to defer investment in transmission and distribution 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 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 can make the decision to install solar PV based on the contribution to the grid. 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. Section 6.4 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 1 shows breakdown of the cost components of the retail price of electricity to households as an average of the national retail prices.

Table 1 Breakdown of the national 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%**

(Source: PwC 2011, p. 14)

Paying solar PV owners at least the wholesale price of the electricity is obvious. In addition, the solar PV unit delivers electricity directly into the distribution grid without the requirement for transmission, so payment for the deferred cost of transmission is warranted. 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.

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. This method requires itemising charges for TUOS and DUOS on invoices. However, the wholesale price for electricity and the cost of TUOS and DUOS vary over time and between locations. These factors would require addressing.

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 can help customer reduce their consumption of electricity, which 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.

Solar PV electricity production matches the daily electricity demand of cycle of commerce and industry. 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.

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 percent bigger to meet peak demand for 1 percent of the year. Over the past decades 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.

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. Section 6.6 further discusses storage.

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 transfers risk to the retail customer. This transfer of risk necessitates protection for vulnerable consumers and education of consumers aided with in-house displays or internet portals on electric 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 6.5 further discusses the Victorian experience leading to the moratorium.

6.3 Pricing electricity from solar PV and the Merit Order Effect

In Australia, the price for electricity is set every half hour using a merit order dispatch (MOD) system where the bids to sell electricity into the market are ranked in order of price in 5 minute blocks. The electricity settlement price is set every half hour as the average of the six prices in the 5 minutes blocks that equates electricity supplied and demanded. Using the MOD system means that the electricity from renewable sources such as wind and solar is used first because their marginal cost is close to zero, having no fuel costs. Importantly, the system provides a half hourly market price for electricity produced by residential solar PV without the requirement for active participation by households in the market bidding process. Additionally, the Melbourne Energy Institute (MEI 2012) has discussed a Merit Order Effect (MOE) operating in Germany where the MOD system and substantial solar PV installation have reduced the wholesale electricity prices. Melbourne Energy Institute (2012) has modelled a MOE for the NEM assuming various solar PV penetration rates comparable to the German rates and has shown that a significant reduction in price spikes could have been achieved over a the simulated summer period of 2010. This MOE enhanced price stability is another positive externality that justifies policies to support solar PV installations. Significantly, the German solar PV implementation has proven system stability at much higher penetrations of solar PV than those in Australia. Furthermore, Futura (2011, p. 11) stated that appropriately located solar PV in the grid can dampen the system wide peak demand for electricity. The next section investigates developing appropriate price signals for such deployment.

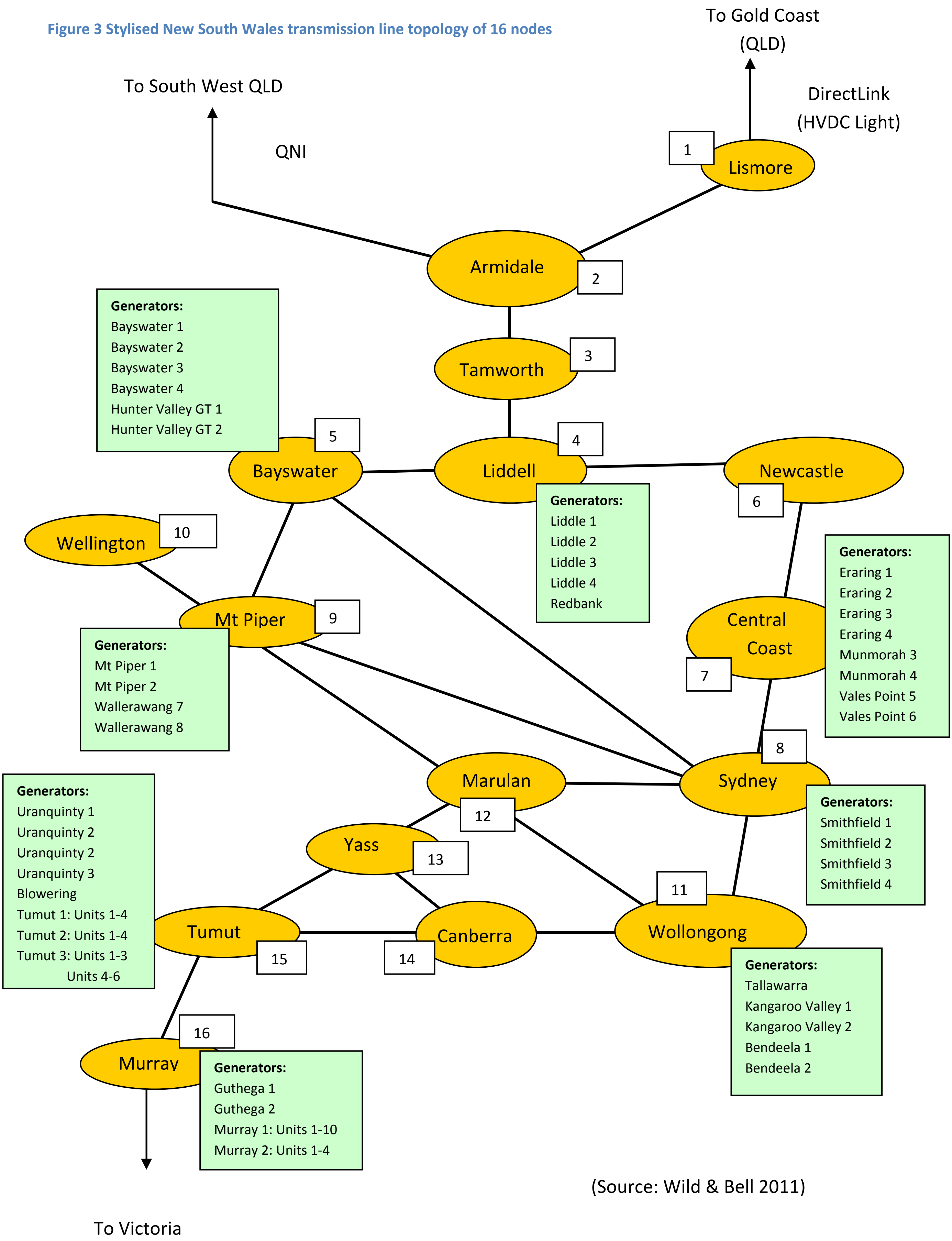
6.4 Time of use and locational price signal for TUOS and DUOS

Figure 2 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 2 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 based on a regional basis rather than the finer granularity 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 3 Stylised New South Wales transmission line topology of 16 nodes



(Source: Wild & Bell 2011)

A branch of economics called 'marginalism' 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. Under marginalism 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 marginalism.

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. There is a challenge 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

PwC (2011, p. 4) discusses the merits of charging the LRMC. The LRMC is the cost 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 would be modest. This LRMC method would spur customers with solar PV to install storage and customers generally to reduce load during peak times.

However, applying the LRMC has two drawbacks. There would be 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 the LRMC?"

PwC (2011, p. 23) discusses the importance of pricing TOUS and DUOS independently of wholesale sale 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 based on: the pass through of costs from NSP to retailer; and metering type.

The network costs are directly passed through to the customers in the New South Wales, Australian Capital Territory and South Australia but in Queensland and Tasmania the network costs go via the retailer. Direct pass through provides an unattenuated price signal whereas going via the retailer dulls the price signal. Direct pass through of network costs suits the arrangements for solar PV payments as discussed in section 6.1.

The current pricing structures for TUOS and DUOS are subject to three forms of metering:

- accumulation;
- interval; and
- smart meters.

Accumulation meters restrict the options for TUOS and DUOS pricing structures to: flat tariffs; 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 on accumulation meters make their contribution to the grid mainly in the off peak period but power is valued at the same price as the consumption of electricity during peak periods. This situation exacerbates the cross subsidy.

In comparison, the inclining-block tariff charges customers based on the quantity of electricity used. This pricing scheme provides an improvement over the flat tariff because customers who use larger quantities of electricity tend to have air conditioners and the peakiness of demand in the residential sector is mainly driven by air conditioners. 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 lacks 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.

6.5 Implementing real time pricing and behaviour modification

Futura (2011, pp. 13-5) reviews the effectiveness of the real time pricing schemes across the NEM and finds that all the schemes cause customers to reduce demand in peak periods. TOU has a moderate effect of about 4% and Critical Peak Pricing (CPP) of around 30%. Despite these positive results, a moratorium on real time pricing was established in Victoria caused 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.

The efficacy of feedback interfaces in trails 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). 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 percent. 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 two solutions to ameliorate the impact:

- offer a flat tariff to those on benefits; or
- increase payments to those on benefit support.

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.

6.6 Energy storage uptake driven by the aforementioned price signals

In this section, we discuss how the aforementioned price signals can work together to enhance the uptake of energy storage to defer investment in transmission and distribution.

Energy storage offers the benefit of ‘time shifting’ that allows electricity to be produced for consumption at a later time. Time shifting has at least two major applications. Firstly, generators have the ability to store energy off peak for release onto the grid during peak time, which provides investment deferment in generation. Secondly, storage located adjacent to net demand regions on the grid transfers energy during off peak to meet peak demand, which provides investment deferment potential for both transmission and generation.

The University of Queensland, in conjunction with an Australian battery storage developer, RedFlow, are testing the cost-effectiveness of RedFlow's 400kWh battery storage unit connected to 390kW of UQ's 1.2 MW solar array, which is the largest array in Australia (Foster et al. 2011). The RedFlow battery storage and the University of Queensland solar PV arrangement feeds into the grid. On a smaller scale, Ausgrid, as part of the Smart Grid Smart Cities Project, will be testing the effectiveness of 40 RedFlow 5 kVA batteries installed in residences in the Newcastle area. In a second trial, 20 RedFlow storage units will be deployed in residences in Scone, New South Wales to test whether battery storage can make rural electricity supply more reliable (Futura 2011, p. 93).

Battery storage is a proven technology that can defer investment in distribution and transmission but it is currently too expensive for general deployment to householders with solar PV installations. However, given the rapid pace of price decreases with technological developments and the slow pace of regulatory reform, it is prudent to start putting the aforementioned price signals in place, so householders can evaluate the cost of advantage of using storage in conjunction with their solar PV installation to meet their own demand during the peak periods. Alternatively, if price signals fail to provide fair recompense for the solar PV installations, householders could install battery storage and simply decide to disconnect themselves from the grid, which would prove economically suboptimal. Finally, energy storage does lend itself to technological innovation to enable switching between storing energy and feeding electricity into the grid during price spikes to provide market stability.

6.8 Reverse auction FiT for large scale solar PV

Foster et al (2011, p. 2) discuss how solar PV has acknowledged potential to defer transmission investments, which are largely driven by peak demand. However, residential solar PV is insufficient in scale to make a significant difference. This would require commercial solar PV installation on a large scale. However, unlike countries such as Germany and Spain, Australia has, until recently, had very few incentives for commercial installations.

Morris and Johnston (2011) estimate that 8 percent of suitable homes in Australia are fitted with solar PV and that solar PV contributed 0.284 percent of total generation in 2011 (Morris & Johnston 2011, p. 9). So, even if every suitable home in Australia installs solar PV, the penetration of the electricity market is still very small.

Williams (2011) discusses the commoditisation of residential solar PV, which is evidence that the residential segment of the solar PV market has moved beyond infant industry status and beyond infant industry support requirements. Large and medium-scale solar PV segments are still in their infancy and still warrant direct infant industry support, because the installation of medium and of large-scale solar PV requires a much higher degree of skill than residential solar PV.

Morris and Johnston (2011) discuss how the FiTs for residential solar PV around Australia are being wound back. Provided that the schemes are replaced by a sustainable FiT, this action is appropriate and will help to remove the boom bust cycle experienced by the residential solar PV industry under the various FiT schemes. Understanding how FiT legislation caused boom-bust cycles in other countries provides valuable lessons for developing a sustainable FiT for large scale solar PV.

In infant industry assistance, Corbell (2011) announced the first FiT in Australia for large scale solar. The plan uses a FiT reverse auction for the two large scale solar generation plants capable of powering 7 000 homes. The reverse auction appears to be a much more appropriate method to target an infant industry than the oversubscribed fixed residential or micro FiT. Reverse auction FiT includes the following advantages over previous FiT schemes:

- the technology matures each time the auction is held and the FiT becomes smaller, which provides an inexpensive way to maintain policy integrity and support infant industries;
- the auctions naturally become redundant once the FiT reaches a levelised cost of energy; and
- the two issues of over subscription and of overly supporting an infant industry become redundant.

This large scale FiT policy is a sustainable approach and appropriate for large scale solar PV but unsuitable for residential FiT for four reasons:

- inequity;
- the transaction costs involved for numerous participants in the auctions;
- logistical cost of maintaining numerous FiT rates; and
- residential solar PV no longer requires infant industry support.

6.9 Carbon Price Reduction Scheme is a component of a sustainable FiT

The CPRS in Australia provides a price signal for a major environmental aspect of sustainability, that is, a price on CO_2 emissions. The positive externalities of solar PV are: producing electricity with a low carbon life cycle; not using arable land and deferring investment in transmission and distribution. The CPRS is designed to help internalise these benefits to allow market prices to reflect these benefits. The CPRS starts with a fixed carbon price in July 2012, which converts to an emissions trading scheme (ETS) in July 2015 (DCCEE 2011).

The fixed carbon price and ETS both have pros and cons. A fixed price for carbon emissions provides a stable income for the government and a stable business environment as everyone knows in advance the price of carbon emissions. The disadvantage is the inability to accurately target the total amount of emission. In contrast, an ETS can target the total amount of emissions but the disadvantage is a variable price for emissions, which is determined by a market. Price variability creates an unstable income for the government and business instability.

In addition, the ETS, being a market arrangement, is susceptible to market failure. Ellerman and Joskow (2008) discuss three market failures in the case of the established European Union (EU) ETS: over allocation, price volatility and windfall profits for generators. Ellerman and Joskow (2008) consider these as part of the learning experience in a new kind of market, which can be overcome by using more accurate information, by allowing the banking of credits between compliance periods and by increasing the frequency of auctioning. Despite these learning experiences, Lewis (2011) reports that there has been a significant drop in EU ETS carbon prices due to a combination of over allocation and the aftermath of the global financial crisis in Europe. The EU ETS experience has provided Australia with many valuable lessons and shows that developing a robust ETS comes with many unforseen problems.

There are plans to extend the domestic ETS to trade carbon credits internationally, which invites other sources of market failure. Garnaut (2008) discusses how international trading provides a mechanism to lower the overall costs to the world of the transformation to lower CO_2 emissions. However, this trading proposal has three major problems:

- international corruption;
- losing government revenue; and
- losing a policy tool to promote renewable energy sources domestically.

In relation to international corruption, Transparency International (TI 2011) produces an international corruption perception index on 182 countries. Table 19 shows the 16 least corrupt countries where Australia is ranked 8th. The index is a compilation of the results from a number of surveys designed in a way that allows basic statistical analysis. Since most of the world ranks as being more corrupt than Australia, this does raise credibility issues over an international trade in carbon credits. For instance, in the least corrupt country, New Zealand (NZ), Stock (2011) reports on the NZ ETS experience in trading carbon credits internationally where the price for a NZ Unit (NZU) went from $22 in May 2011 to $11 in late November 2011. This halving in the price of a NZU was the result of NZ emitters' ability to import carbon credits. However Stock (2011) claims that some of the UN-backed Certified Emissions Reductions (CER) are of suspect validity and predicts that the NZ Government will substantially curtail the import of CER.

Table 2 International Corruption Perception Index for 2011

Country Rank	Country / Territory	CPI 2011 Score	Country Rank	Surveys Used	Standard Deviation	Range		90% confidence interval	
						Max	Min	Lower bound	Higher bound
1	New Zealand	9.5	1	9	0.05	9.7	9.1	9.4	9.5
2	Denmark	9.4	2	8	0.05	9.5	9.1	9.3	9.5
2	Finland	9.4	2	8	0.07	9.8	9.1	9.3	9.5
4	Sweden	9.3	4	9	0.08	9.7	8.9	9.2	9.4
5	Singapore	9.2	5	12	0.13	9.5	8.1	8.9	9.4
6	Norway	9.0	6	9	0.07	9.3	8.7	8.9	9.1
7	Netherlands	8.9	7	9	0.11	9.3	8.1	8.7	9.1
8	Australia	8.8	8	11	0.12	9.4	8.2	8.6	9.0
8	Switzerland	8.8	8	8	0.22	9.4	7.5	8.4	9.1
10	Canada	8.7	10	9	0.15	9.3	8.1	8.4	8.9
11	Luxembourg	8.5	11	8	0.25	9.1	7.1	8.1	8.9
12	Hong Kong	8.4	12	11	0.17	9.1	7.3	8.1	8.7
13	Iceland	8.3	13	8	0.27	9.5	7.1	7.8	8.7
14	Germany	8.0	14	10	0.18	9.1	7.1	7.8	8.4
14	Japan	8.0	14	12	0.27	9.1	5.7	7.6	8.5
16	Austria	7.8	16	10	0.24	8.9	6.7	7.4	8.2

(Source: TI 2011)

The credibility problem could be overcome by only allowing the purchase of carbon credits from selected countries, such as the highly ranked countries in Table 19. However, the problems of losing government revenue and of dissipating CPRS's role in promoting renewable generation still exist.

Two options to address carbon emissions are a carbon tax or ETS. In Europe, the tax option is unviable as the British and French governments have both shown little interest in harmonising taxes between EU member states. So, there is little scope but to try to fix the EU's ETS. However, in Australia both options are available. The allure of an ETS to reduce carbon emissions at least cost has to be weighed against the failure of the ETS in Europe. A prudent approach would be to run the fixed carbon price arrangement as an explicit carbon tax scheme until a number of countries have developed a stable ETS, at which point the Australian ETS could be modelled on the successful overseas ETS. This approach is worth considering because Australia is more carbon intensive than other OECD countries, so a dysfunctional ETS is potentially more damaging to the economy and, correspondingly, to the solar PV industry.

The third hybrid option is using a floor on the carbon price within an ETS, as discussed in Daley and Edis (2010). This option combines the positive aspects of the carbon tax for price stability and of the ETS to find the least cost methods to address carbon emissions. The current CPRS legislation, the Clean Energy Bill 2011 (DCCEE 2011, p. 12) does provide for a price floor and ceiling for the first three years of the ETS. This Clean Energy Bill addresses most of the aforementioned problems with the ETS for the first six years; initially, three years with a fixed carbon price, then three years as an ETS with a price collar. These six years should provide enough time to learn from the successes and failures of ETS elsewhere.

7 Conclusion

Sustainable feed-in tariffs for solar PV are at the confluence of social equity, environmental protection and economic growth. Market failures arise in each and options to address these have been identified in this paper. Indexed interest free loans are proposed to address investment myopia and social inequity. This paper also discusses the lack of appropriate price signals for environmental protection and economic growth in the solar PV industry and options to address these market failures.

A key issue is the requirement to replace traditional accumulation meters with smart meters to provide real time pricing. Smart meters will introduce appropriate price signals for deferment in TUOS and in DUOS and contribution to the grid. Additionally, real time pricing will help remove the cross subsidy from poorer households to wealthier households.

The use of solar PV in conjunction with accumulation meters debases the profit margin for retailers. This dynamic destroys the incentive for retailers to engage with those who have solar PV installations. The proposed price signals maintain a profit margin for the retailers to ensure their ongoing interest.

However the profits of NSPs are based on their capital expenditure. This creates a dynamic that is at odds with environmental protection and provides a disincentive for NSPs to connect solar PV. Thus, the NSPs require incentivising to connect solar PV.

The proposed price signals are designed to accommodate developments in battery storage and maintain a profit margin for the retailers. The lack of action on 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.

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