Rooftop solar PV and network tariffs: Information and discussion

Prepared for UnitingCare Australia
Enhancing consumer engagement in network tariffs project

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1 Introduction

This paper is the second research paper in a series prepared for UnitingCare Australia and funded by the Consumer Advocacy Panel as a research project. The first paper focussed on providing information on actual electricity network tariffs charged to households in Australia. This paper focuses on electricity network tariffs and the issues associated with the rise of rooftop photovoltaics (PV) for households. The Attachment, a separate paper on the theory of electricity pricing that informs this project, looks at the role of theory in the construction of household tariffs.

The density of rooftop PV per household in Australia is now the highest globally, and continued growth in the residential, commercial and industrial sectors seems likely. As a result of this, there are increasing concerns that demand for traditional grid supplied electricity will continue to decline. This has resulted in a renewed focus on the way that electricity network services are priced. The paper is set out as follows:

- **Section 2** examines network charges for households with rooftop PV compared to those that have not installed PV.

- **Section 3** examines the impact of rooftop PV on network services business' income.

- **Section 4** discusses the equity and fairness issues associated with rooftop PV. The focus of the section is to conclude whether, and if so how, network tariffs for households that have installed rooftop PV should change.

2 Network charges for households with rooftop PV

This section examines the network charges that apply to households with rooftop PV. These charges are billed by Network Service Providers (NSPs) to retailers that supply those houses – households do not have a contractual relationship with NSPs. Some retailers reflect the network charges in their contracts with those households (i.e. the retail tariffs reflect the form of the network tariffs). In other cases the retailers' contracts do not reflect these network charges. This was examined in detail in the paper on 'Network Tariffs applicable to households in Australia' (the Network Tariffs paper), and we refer readers to that.

This section focuses on how network charges to households that have installed PV differ in comparison to households that have not installed PV.

2.1 Analysis

Households with rooftop PV served by the same NSP, are not always charged the same network tariff. Specifically, in some cases households with PV are charged different network tariffs if they receive jurisdictional government feed-in tariffs (FiT) (Table 1).

Table 1. Difference in tariffs for rooftop solar PV households

NSP	Difference in household network tariff if receiving a feed-in tariff
SA Power Networks (SAPN)	No difference until 2015/16, SAPN have introduced a new tariff class in their 2015/16 Pricing Proposal, "Low Voltage Residential Solar" applicable to all solar PV customers.
Ausgrid	Solar PFiT customers who wanted to participate in the 'Solar Bonus Scheme' (1 Jan 2010 to 28 Apr 2011) were placed on a TOU tariff (EA025) as opposed to standard Inclining Block Tariff (EA010).
Endeavour Energy	Solar PFiT customers placed on an IBT tariff class (NFTG), no difference in tariff rates. Solar customers placed on another IBT tariff class (NS70) – no difference in tariff rates. In the 2015/16 Pricing Proposal, Endeavour Energy removes these tariff classes and solar customers are no longer differentiated – no difference in tariff rates.
CitiPower	Solar PFiT/TFiT customers were moved to peak/off peak tariff class (C3R).
Jemena	No difference
Powercor	Solar PFiT customers were moved to an IBT peak / off peak tariff class (D3)
Ausnet Services	Solar customers are prescribed to a peak/off peak tariff class with credit for grid export during the summer period (NEE23). Solar PFiT customers are assigned to a peak/off peak tariff class with credit for grid export (SUN23), same rates as solar customers on NEE23.
United Energy	The default tariff class for solar customer's is a peak/shoulder/off peak (winter/summer seasonal) tariff class (TOD9)[1], contrasting non-solar customers on a flat (seasonal) tariff class (LVS1R).
Energex	No difference
Ergon Energy	No difference
TasNetworks	No difference

Essential Energy	No difference

Because of these variations, the comparison we draw in understanding the incremental impact of rooftop PV is between:

1. Households with no rooftop solar;
2. Households with rooftop solar but that do not receive jurisdictional feed-in tariffs;
3. Households with rooftop solar that receive jurisdictional feed-in tariffs for their export to the grid.

Our model calculates the electricity produced by rooftop PV based on the information in the Clean Energy Council's Grid Connected Solar Design Guidelines.[1] We then calculate jurisdiction-specific hourly and monthly PV production[2]. Combined with the applicable network tariffs for solar customers outlined in Table 1, annual energy throughput for an average household in each NSP region, sourced from the latest AER Regulatory Information Notices (RINs)[3], and data on number of rooftops with PV we determine the solar PV exports, self-consumption and grid imports for each network area.

For households with PV, the annual amount purchased from the grid, as determined by our calculation, is used to calculate the average network price (c/kWh) and also to calculate how much of their bill is fixed as a proportion of their total network services bill.

We calculate the rooftop PV household's reduction in network payments as the average network price (c/kWh) for the energy deliveries (kWh) displaced by the rooftop PV. The household's attributed reduction is applied across all solar PV systems installed in the year to give an annual total. As a proportion of the total regulated distribution network services revenues, we use actual revenues sourced from the RIN[4].

Section 2 discusses network prices covers the period 1 July 2007 to 30 June 2016, accounting for the latest Pricing Proposals 2015/16 by the NSPs. The analysis in Section 3 which discusses rooftop PV installations and network payment reductions covers the period 1 July 2007 to December 31 2014.

2.2 Results

[1] The average system sizes, by jurisdiction, by year are used for the rooftop PV calculation - 4.1 GW installed covering 1.4 million installation - CLEAN ENERGY REGULATOR. 2015. *Small-scale installations by postcode* [Online]. Available: http://ret.cleanenergyregulator.gov.au/REC-Registry/Data-reports [Accessed 01 Jun 2015].

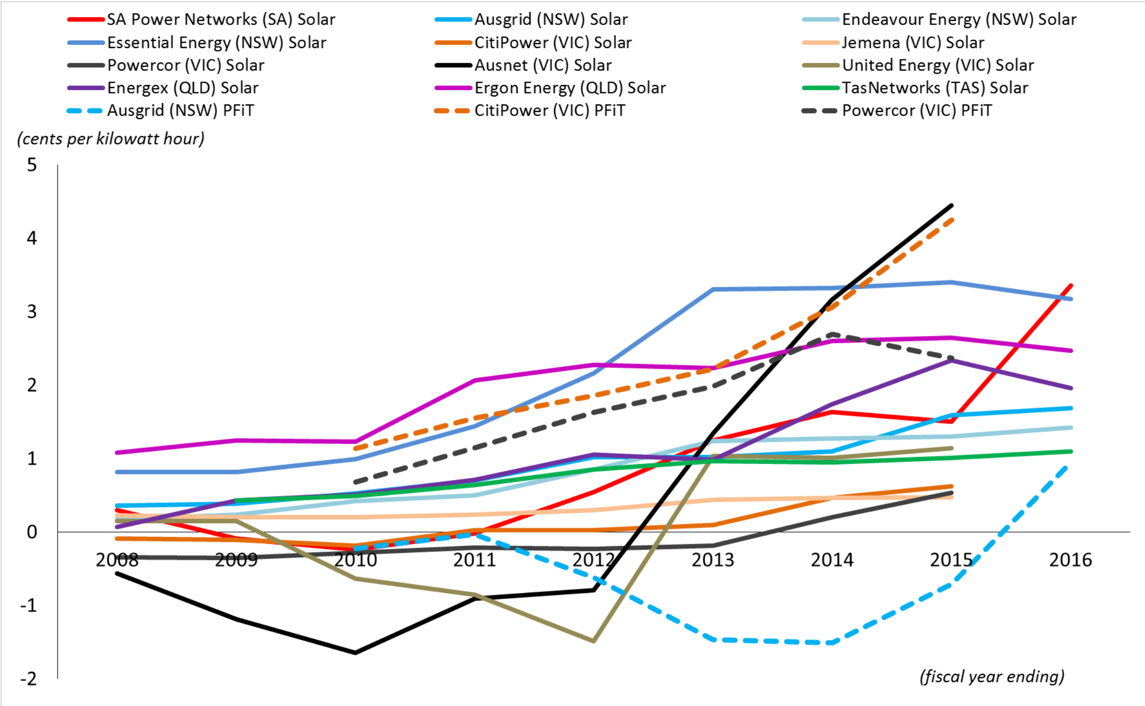
[2] Data from ANZSES 2006. Australian Solar Radiation Data Handbook (ASRDH). 4 ed. used for hourly irradiance at capital cities on a north facing plane inclined at the capital city's angle of latitude

[3] Australian Energy Regulatory (AER) RINS - annual residential energy deliveries and number of residential customers from 2007 to 2014 - https://www.aer.gov.au/taxonomy/term/1495

[4] Sourced from the latest AER Regulatory Determinations, per NSP

Figure 1 shows how much more (or less) the average household with rooftop PV is being charged for network services (via its retailer), compared to the average household without PV, per kWh each consumes from the grid. The chart also shows how this has changed from 2007/8 to the present. The solid lines in the chart apply to the comparison for solar households (with or without a FiT) for all 12 NSPs. The dotted lines apply to the comparison of households with solar premium FiT consumers.

Figure 1: Network price difference (cents per kWh): solar vs non-solar household



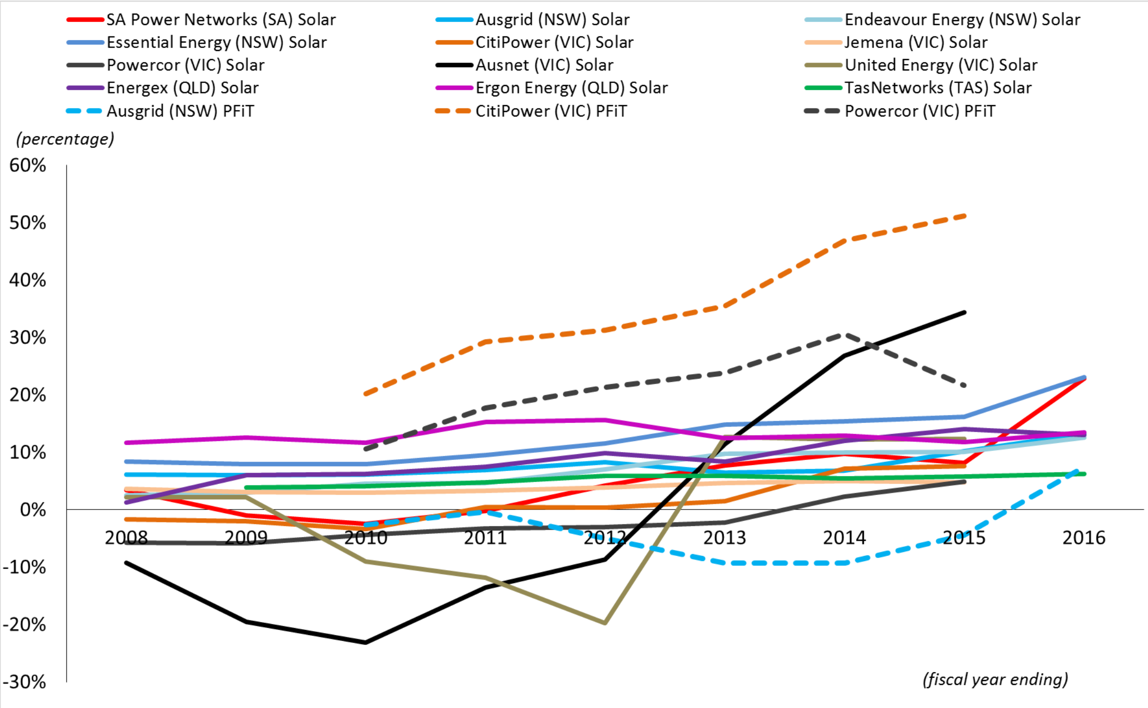
Source: Published network tariffs, CME Analysis

From the start of the 2015/2016 financial year, all households with rooftop PV will be paying a higher average price for use of the network than households without rooftop PV. Solar households have lower grid imports but pay the same (or in some cases higher) fixed charge as non-solar customers but since they consume less from the grid the effect of absorbing the same fixed price on low consumption means that average prices are higher.

AusNet Services (in Victoria) in Figure 1 shows a particularly large increase in the average price for network services charged to households with rooftop PV. On the other hand, Ausgrid's (in NSW) PV customers are paying a lower average price for network services than their customers that do not have rooftop PV. This is explained by the fact that Ausgrid has developed a cost-reflective tariff for households with rooftop PV that has significant differences in the prices in peak, shoulder and off-peak periods. Since households with rooftop PV consume less in peak and shoulder periods than they do in off-peak periods, their network tariffs are consequently lower.

Figure 2 below uses the same data as Figure 1, but with the difference in the average price (for solar households) expressed as a percentage of the average price for households without rooftop PV. It shows that AusNet Services' 5 cents per kWh difference translates into an increase in the average price charged for network services of about 40%. In other words, households with rooftop PV served by AusNet Services are being charged an average price that is 40% higher than households that have not installed rooftop PV. Also notable in Figure 2 is that the percentage premium for network services paid by Powercor customers is about equivalent to that for AusNet Services.

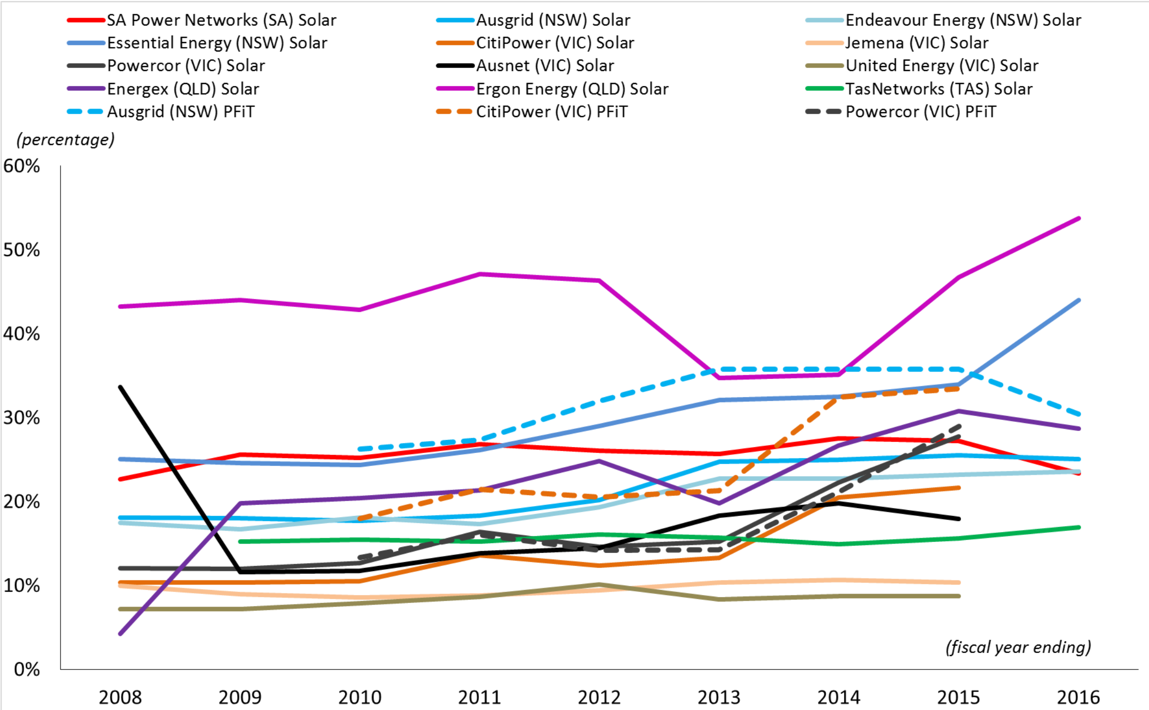
Figure 2: Network price difference stated as a percentage: solar vs non-solar household



Source: Published network tariffs, CME Analysis

We also examined the effect of fixed charges as a percentage of the bill for households with rooftop PV. This is shown in Figure 3. Ergon stands out as having a fixed charge that is about 50% of the network bill for households with PV. As we have noted in the Network Tariffs paper, Ergon does not actually charge this amount under Queensland's residential network tariff arrangements. However Ergon's payment under the Queensland Government's Community Service Obligation is based on Ergon's tariff on the basis that this is what Ergon suggests is a cost-reflective rate. Other than Ergon, the retailers that serve households with rooftop PV are typically being charged network tariffs that have fixed charges that range from 15% to 30% of their network bills. Figure 3 shows however that there are three NSPs (Aurora in Tasmania, United Energy and Jemena in Victoria) whose fixed charge is lower, around 8% of the network charge.

Figure 3: Network fixed charge as percentage of network services bill



Source: Published network tariffs, CME Analysis

3 Impact of rooftop PV on network services business' income

The previous section examined how network charges for households with rooftop PV differ from those in households that do not have PV.

This section presents analysis of how the revenues collected by NSPs in 2014 from households with rooftop PV has changed.

Firstly by way of context, the following figures show the cumulative total installed number of rooftop PV systems (Figure 4) and cumulative total installed PV capacity (Figure 5), per jurisdiction from 2007 to the end of April 2015.

Figure 4: Cumulative total installed rooftop PV capacity (number)

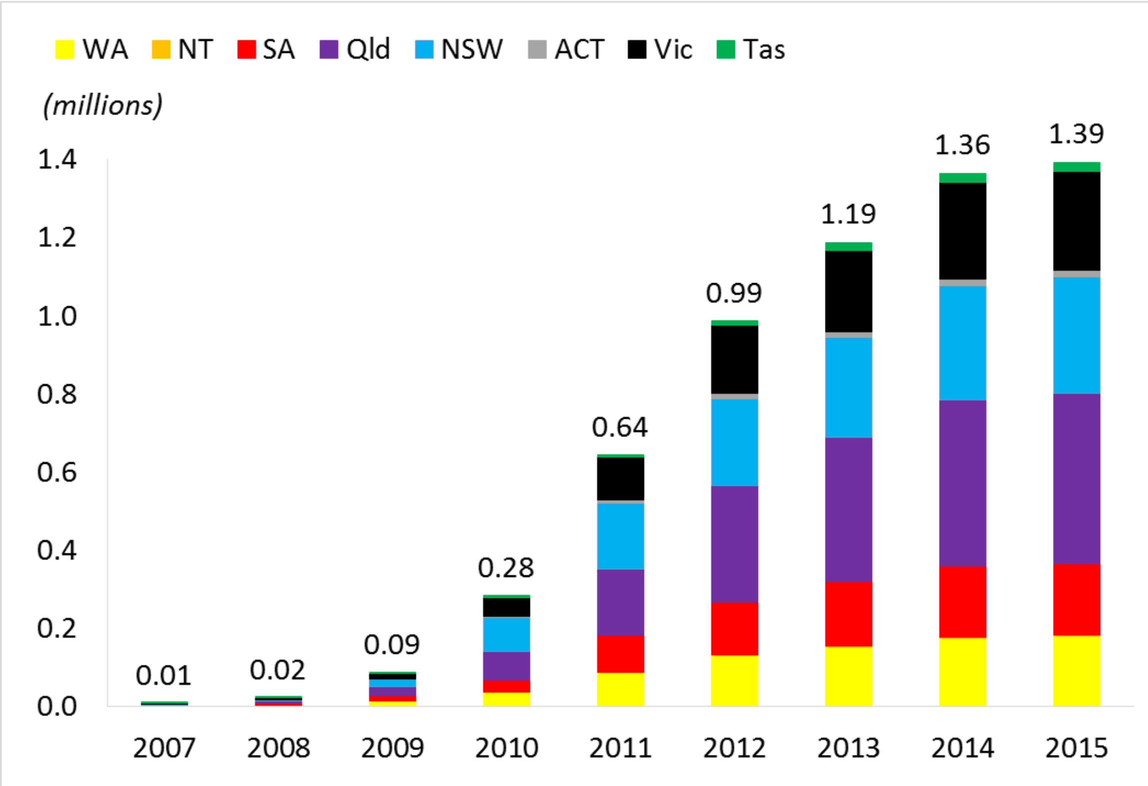
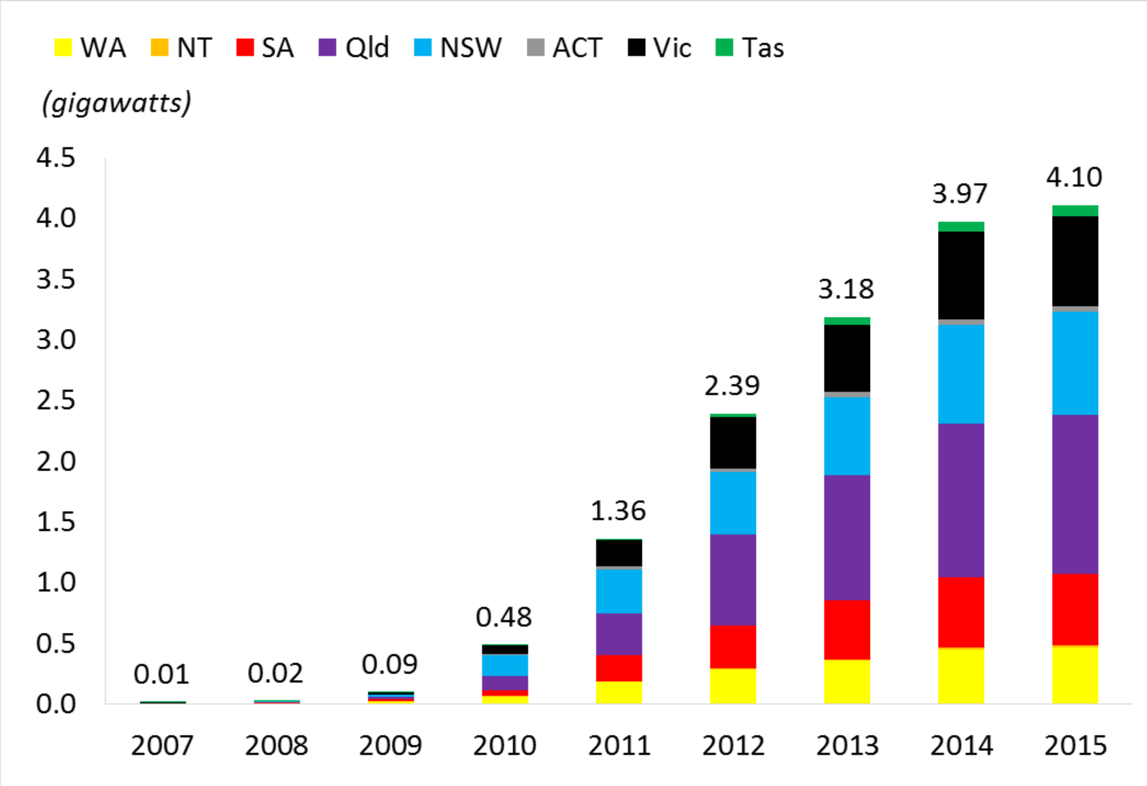


Figure 5: Cumulative total installed rooftop PV capacity (gigawatts)



Using the data in Figure 4 (to end 2014) in combination with our Solar Economics Model, our Regulated Networks Tariff database and Distribution Network Service Provider model, we have calculated the reduction in revenue to NSPs from households that have installed rooftop PV. Figure 6 below shows our estimate of the reduction in payments for network services in 2014 from households that have installed rooftop PV.[5]

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[5] Most NSPs in the NEM are subject to a cap on their prices, not their revenues. For these "price cap" NSPs, for the period of a regulatory control (5 years) the revenue they have lost from households that have installed PV is not recoverable during the period of the control. However, since NSPs prices are based on expected sales over the five years, the effect of expected demand reductions (of which PV is a part) could have already been factored in the determination of the regulatory control. As such, the information shown in Figure 4 cannot be thought of as actual lost revenue. All distribution network service providers will be moving to revenue-based regulatory controls, rather than controls over their prices. This will make them invariant to the loss of consumption from sales to households that install PV. However they will be exposed, to the extent that the loss of revenue during a regulatory control period is not adequately taken into account in the establishment of the revenue control. For this reason, with revenue controls, it is impossible to be certain whether, at any point during a regulatory control period, the network service providers or other consumers are bearing the losses associated with reduced through-put. However from the start of the next regulatory control period, unless there is some reduction in the value of the regulated networks' asset base, it will be the case that consumers rather than shareholders bear the financial impact of reduced consumption from households that install PV.

Figure 6: Reduction in network payments in 2014 per household with rooftop PV

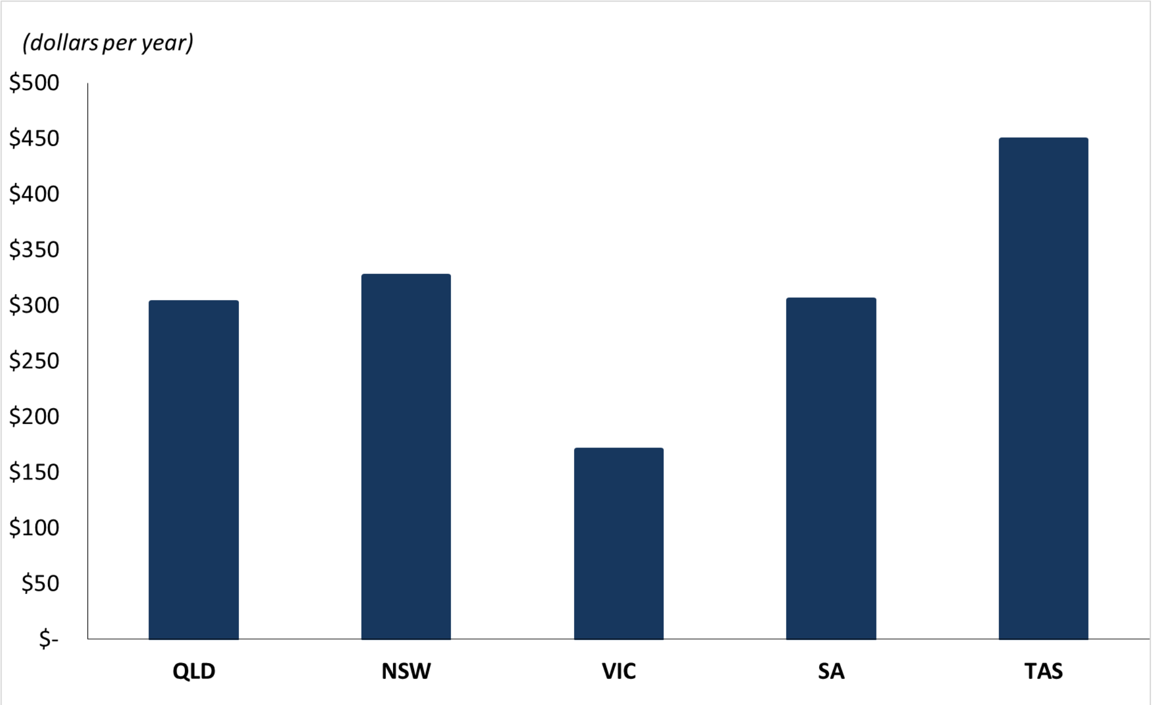


Figure 7 aggregates the lost revenue per household across all households with rooftop PV. It shows that the reduction in payment for network services from households with PV is higher in Queensland than anywhere else in the NEM. This is partly because the penetration of rooftop PV has been significant in Queensland, but partly also because Queensland's network charges are higher than anywhere else.

Figure 7: Reduction in network payments in 2014 attributable to households with rooftop PV

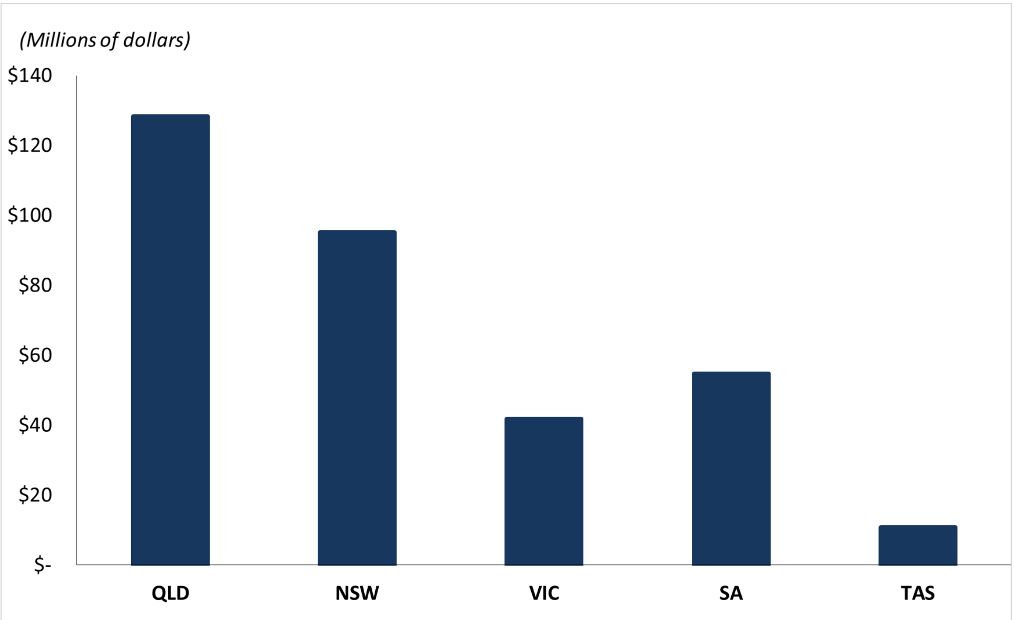
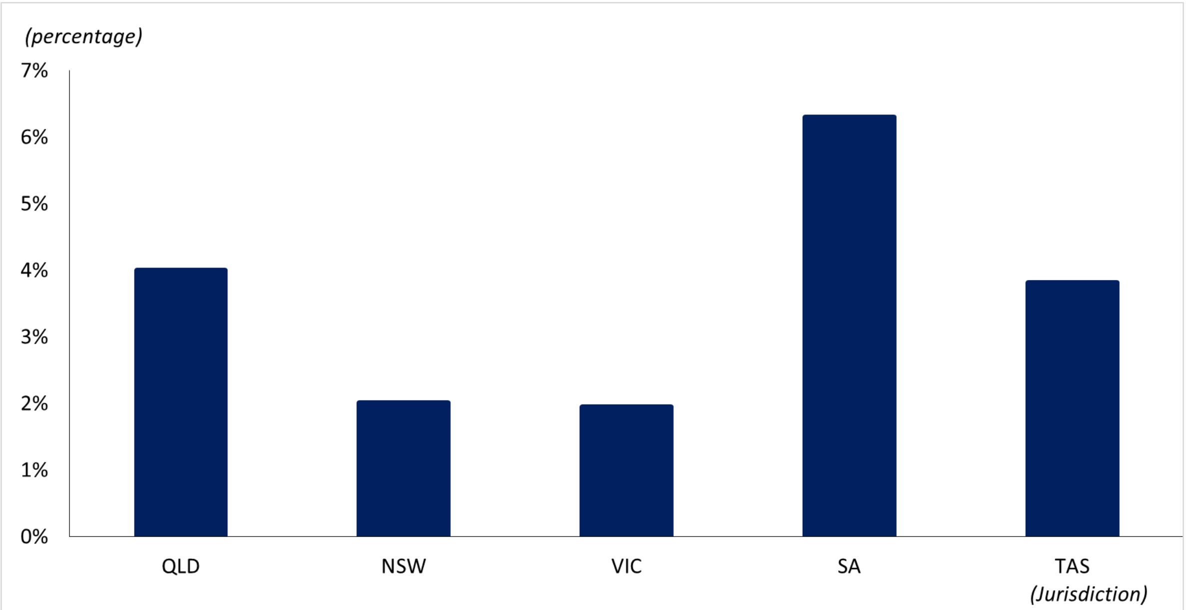


Figure 8 extends the analysis in Figure 7 by expressing the revenue reductions as a percentage of the allowed distribution network services business revenues in 2014. In South Australia households with rooftop PV deliver the fourth lowest reduction in NSP revenues (as shown in Figure 7). However, when stated as a percentage of regulated revenues, rooftop PV in South Australia has had the biggest impact on network service provider revenues, because it is the state with the highest proportion of households with rooftop PV.

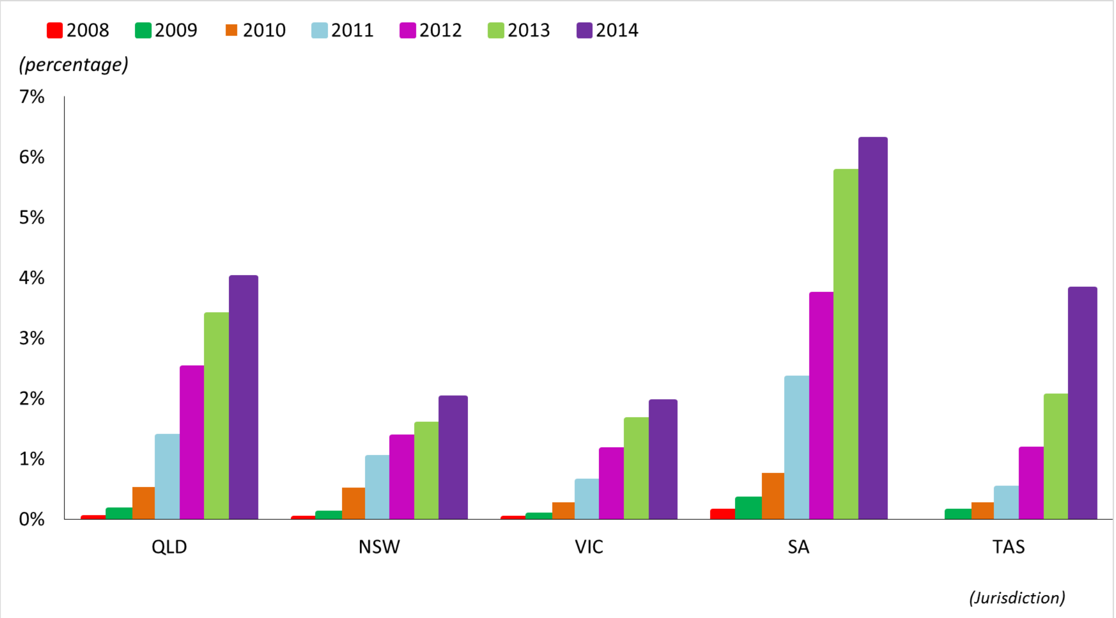
The amounts shown in Figures 7 and 8 are significant. For example in the case of South Australia, the data in Figure 8 says that as at the end of 2014, regulated network service provider charges would have to be 7% higher if the revenue that has been lost to households that have installed rooftop PV, is to be recovered.

Figure 8: Reduction in network payments in 2014 attributable to households with rooftop PV as a percentage of regulated distribution network services revenues



When examined, as a time series from 2008 to 2014, rooftop PV as a percentage of regulated distribution network services revenues has increased significantly from a negligible proportion in 2008 to as high as 9% of regulated revenues in SA in 2014, see Figure 9.

Figure 9: Reduction in network payments (2008 to 2014 time series) attributable to households with rooftop PV as a percentage of regulated distribution network services revenues



Rooftop PV has grown very quickly in Australia. Mountain and Szuster[6] quantify the impact of capital and production subsidies, the role of avoided energy purchases and retailer feed-in payments in supporting this very rapid growth. While premium feed-in tariffs are no longer available to new entrants, the installation of rooftop PV is still very attractive to households. For example, based on an actual quote obtained by the authors at the time of writing[7] households that install rooftop PV are able to produce their own electricity for around 6 cents per kWh.[8] This is less than one-fifth of the typical average price for electricity supplied from the grid, and one quarter the variable price. It can therefore be no surprise that despite the end of feed-in tariffs, Australia-wide installation rates of around 200,000 rooftop systems with an average size of around 4.5 kW are expected in 2015. Furthermore the very significant decline in PV costs, combined with the rise of leasing must surely soon lead to rapid up-take of both ground-mounted and rooftop PV in the commercial and industrial sectors. As such, further significant increases in distributed PV production, and concomitant reductions in demand for grid-supplied electricity are likely.

[6] MOUNTAIN, B. & SZUSTER, P. 2014. Chapter 4 - Australia's Million Solar Roofs: Disruption on the Fringes or the Beginning of a New Order? In: SIOSHANSI, F. P. (ed.) Distributed Generation and its Implications for the Utility Industry. Boston: Academic Press.

[7] For installation of a 5 kW PV system in Melbourne ($4,990 inclusive of GST after SRECs)

[8] This assumes a 20 year life, 5% real cost of capital and $50 per year annual maintenance.

4 Discussion

The first section of this paper examined how network charges for households that have installed rooftop PV have changed. It showed that average prices for network services are about 10% to 50% higher, except for one NSP where the average price paid by households with PV is lower. The section also showed that fixed charges in network tariffs are typically 10-30% of the network bill, but for one NSP are about 50% of the bill.

The second section of this paper demonstrated how the rise of rooftop PV has affected regulated revenues collected by network service providers. It showed that the impacts are becoming significant. For example in the case of South Australia, the data in Figure 6 shows that as at the end of 2013, regulated network service provider charges would have to be 7% higher if the revenue that has been lost to households that have installed rooftop PV, is to be recovered.

This final section considers the question of whether, and if so how, network tariffs for households that have installed rooftop PV should change.

The issues are complex and crucial precepts underlie proposed solutions. To deal with this systematically, we begin by describing the nature of the rights and obligations that monopoly network service providers have with their consumers. From there we describe the issues arising from declining demand in general and then for PV in particular. We then examine tariff changes for households with rooftop PV that are economically efficient and fair but note that such tariffs will not "solve" the problem of stranded network assets.

Rights and obligations

The business of distributing electricity is capital intensive, but variable costs are low. Setting prices equal to variable costs will not produce enough revenue to remunerate the fixed costs. For this reason, amongst others, electricity distribution is a regulated monopoly.

However, the precise nature of the rights and obligations that are conferred through this monopoly have not always been clear. Before the corporatisation (and privatisation in Victoria and South Australia) of NSPs, electricity was distributed by local and regional authorities. They were under direct government control and prices were determined in a way that reflected many factors including political concerns over high prices. It may well have been that the effect of this was that government (in other words the community) rather than electricity consumers, effectively bore some part of the sunk investments.

After corporatisation and privatisation the delineation of risks between consumers and owners (state governments in most cases, private in SA and VIC) became much clearer. In this regard, the essential construct that exists since corporatisation and privatisation is that NSPs have a right to recover their costs including a financial return on their investment. This means that if demand declines for whatever reason, the distributors are able to raise their prices in order to recover revenues sufficient to remunerate their sunk and current costs, from remaining customers.

For most of the history of the industry demand – both average and peak – has been rising. Though from time to time capacity installed has exceeded demand, rising demand has meant that the problem of needing to raise charges to compensate for declining demand has not arisen.

However in many parts of Australia (and now also in other developed economies) demand has started to decline and appears to have become an on-going trend. This is driven by many factors including structural changes in the economy, technology change, responses to high prices and the rise of distributed generation, particularly rooftop PV. Rooftop PV has not however been the biggest factor explaining declining demand. In fact Saddler suggests[9] that it is only the fourth most significant factor.[10]

Nonetheless as set out in the previous section, distributed PV is likely to become an increasingly significant factor driving a decline in demand for grid supplied electricity. Perhaps for this reason, amongst others, network service providers have focussed on PV and have been seeking changes to regulatory arrangements, including changes to tariffs.

Tariffs for households with rooftop PV

In the Australian Energy Market Commission's (AEMC's) Draft Rule Determination on distribution network pricing arrangements, the AEMC refers to a case study that a consultant, NERA, developed for it. That case study is of a South Australian consumer with a 2.5 kilowatt north-facing solar panel, which NERA suggests would pays about $200 a year less than a similar consumer without solar panels, but that this PV would only reduce future costs by $80.[11]

The thrust of the AEMC's recommendation in dealing with this "problem" is that tariffs should better reflect costs, and specifically the way that costs at the margin vary with demand during the day.

An example of a tariff that does this is AusGrid's time of use tariff for households that have installed rooftop PV and that receive the New South Wales Government's premium feed-in tariff. In the second section we compared the network prices for such customers with the prices paid by AusGrid's other household customers without rooftop PV who typically do not have a time of use tariff. As shown in Figure 3, the average price for network services for households with rooftop PV, is lower. This is as we would expect: households with rooftop PV consume less during more expensive peak and shoulder periods and more during less expensive off-peak periods. A tariff that reflects the temporal variation in costs is sensible and the outcome in terms of average network prices for households with rooftop PV reflects their beneficial pattern of consumption and production.

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[9] SADDLER, H. 2013. Power down: why is electricity consumption decreasing? : Australia Institute.

[10] The other three more significant factors are declining industrial demand, the impact of higher prices and increased electricity use efficiency of appliances, equipment and buildings.

[11] The reduction in future costs occurs because the rooftop PV reduces demand in peak periods and so avoids the need for network expansion.

More cost reflective tariffs do not however solve the "problem" that households that install rooftop PV pay less for network services than they did before the PV system was installed. In fact "cost reflective" tariff make the problem worse (in the sense that the revenue shortfall against what was previously recovered, increases).

To address this, many in the industry have been pushing for an increase in fixed charges particularly for households that install rooftop PV. In Attachment 1 below we note that the Brattle Group in their report for the AEMC said that fixed charges might be efficient (because customers would not change their consumption as a result of such charges). But, as we note, consumers lose as a result of such charges because even if they do not decrease their consumption of electricity, they forego consumption of some other good or service as a result of higher payments for electricity. A solution that might be more efficient for the industry therefore comes at the customers' expense. For this reason, higher fixed charges cannot be described as an efficient solution or fair way to deal with the problem of increasingly stranded network assets[12].

We also noted in the Attachment that in the theory of electricity pricing there is no acceptance of fixed charges to recover sunk costs, and in the design of two-part tariffs the standing (fixed) charge was meant merely to recover customer-specific costs such as meters and meter reading and bill costs. We found in the Network Tariffs paper that increasingly in Australia, fixed charges in network tariffs are rising, despite the fact that the fixed element in network charges for households in Australia is already much higher than in many other comparable countries.

Finally irrespective of whether they are efficient or fair, higher fixed charges may well not be successful in choking demand for rooftop PV. Network service providers do not contract with households directly and so the structure of network tariffs will not be visible to households unless retailers mirror them in their retail tariffs. In our Network Tariffs paper we noted that they generally do not: retail prices have high fixed charges in Victoria, but the network service providers have relatively low fixed charges, and vice versa in Queensland. In their relationship with customers, retailers may consider various combinations of fixed and variable charges to win business. They may therefore choose to recover through variable charges, the fixed charges that they face from networks. As such changing fixed charges in networks may, ultimately, have little impact on customer behavior.

Do NSPs have a right to "lost revenue"?

The AEMC's characterisation of the problem of rooftop PV is that households that have installed PV reduce their payments to their network service providers, but that this is not sufficient to offset the beneficial impact on future network investment. Therein, from the AEMC's perspective lies the problem. Underlying this characterisation is the assumption that NSPs have a right to recover whatever amount of revenue they recovered before a household installed PV. But why is this an appropriate assumption? A decline in demand for grid-supplied electricity as a result of distributed generation is, from the

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[12] The attachment sets out greater detail on the theoretical aspects.

perspective of network throughput, no different to a decline in demand for the grid for other reasons such as more efficient consumption or reduced consumption or closure.

The point is that technology change has created opportunities for households, and increasingly industry and commerce, to meet part of their own needs more cheaply by installing their own generation. The grid retains a monopoly in the provision of back-up and a route to market for surplus production, although the development of batteries may change this in future.

Networks are now being asked to deliver a different service at least to some energy users, than the service they were designed to deliver. The new demands are different and lower than the original demands, if not in the peak demand on residential feeders, then on peak demands on the shared network. As result there is now increasing excess "stranded" capacity and with that the question of who should pay for this.

This problem cannot be solved by tariffs that better reflect costs. To the contrary, tariffs that better reflect costs, will simply make stranded assets more obvious. For the reasons set out in this section and on the basis of the evidence in our previous paper, and the attachment to this research, it is clear that policy makers and the industry would be making a bad mistake if they tried to protect network service providers through higher fixed charges. Such charges are inefficient and regressive. The problem of stranded assets will need to be shouldered by consumers and shareholders in some other way, including the revaluation of assets. Economic efficiency and fairness, not the preservation of the incumbents' rents, must be the guiding objectives.

Attachment 1

Notes on the theory of electricity pricing

Prepared by CME

Introduction

This paper was prepared for UnitingCare Australia as part of a project focussed on electricity network service provider tariffs.

This paper presents a brief overview of relevant theory on the pricing of services provided by network monopolies. Together with the previously-released paper on empirical evidence on network tariffs, and the paper above, on rooftop PV and network tariffs, this work has contributed to UnitingCare Australia's development a roadmap for consumer-oriented tariff reform.

Theory on the pricing of monopoly services, including electricity, has been developed over the last 120 years particularly in the period until the competitive restructuring, deregulation and vertical separation of the electricity industry in the late 1980s. The theory has been focussed mainly on what were previously monopolies for the production, distribution and retailing of electricity. Because at that time most electricity supply utilities were vertically integrated and generation was the largest part of total supply costs, the writing frequently focuses on generation. However the theoretical issues are the same, because they consider pricing of monopoly services.

The main pre-occupation of this paper is with the theory of electricity network pricing as it relates to economic efficiency. We explore the theory to see whether it offers what it is often purported to offer: a clear guide to the "right" (economically efficient) way to price network services. In other words, when a network service provider claims that its tariffs are "cost reflective", is there some objective way to know whether this is true. One of the important challenges, considered in the literature, is how to price a service in which there are significant common costs. A significant proportion of the cost of an electricity network is what is called a common cost. High voltage transmission lines, transformers, poles and wires that carry electricity to many customers – these represent costs that are common to all the customers that use the service. Similarly there are many operating costs, such as clearing trees around wires to lower bushfire risk, that benefit all users of the electricity network: they are common costs for which it is not obviously possible to attribute a specific price to each individual consumer.

Finally, unlike other larger electricity users, households are not charged separately for network services. Network tariffs are an input cost to retailers and in many cases the tariffs that retailers offer households bear no relation to underlying network costs. While this may superficially diminish the relevance of network tariffs to households, there is value in ensuring that network tariffs are reasonably constructed, so that all participants in the market can see the relationship between the retail tariffs paid and the network costs.

This paper's first three sections review the theory on short run marginal costs (SRMC) and long run marginal costs (LRMC), and then the treatment of the residual between total costs and short run or long run costs. The final two sections consider the gap between theory and practice, and offer some thoughts on the main points that consumers might take from the theory.

Short run marginal costs

Alfred Kahn, economist at Cornell University, wrote a widely-used text, The Economics of Regulation[13], in which he identifies the central policy prescription of microeconomics as the equation of price and **marginal cost** (see glossary). He suggests:

"If economic theory is to have any relevance to public utility pricing, that is the point at which the inquiry must begin."

The seminal text in such inquiry is a 1938 paper by statistician and economic theorist Harold Hotelling,[14] on the theory of electricity pricing in its application to the pricing of monopoly utility services including rail, canals, water supply and electricity. Hotelling himself attributed the main ideas in his paper to French engineer Jules Dupuit, who had set his thoughts out in 1832.

Hotelling's main proposition – that prices for utility services be based on marginal costs not average costs – was a significant departure from established pricing practices at the time. He noted that:

"The confusion between marginal and average cost must be avoided. This confusion enters into many of the arguments for laissez-faire policies. It is frequently associated with the calm assumption, as a self-evident axiom, that the whole costs of every enterprise must be paid out of the prices of its products … It has become so ingrained by endless repetition that it is not even stated in connection with many of the arguments it underlies."

Rejecting this assumed link between price and average cost, Hotelling's argument was that the maximisation of social welfare[15] requires that prices equal to (short run) marginal costs. In industries such as rail and electricity supply, with declining marginal costs that are typically below average costs, Hotelling argued that the income shortfall arising from short run marginal prices would need to be recovered through "*taxes on*

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[13] KAHN, A. 1970. The Economics of Regulation: Principles and Institutions., Cambridge, Mass., MIT Press.

[14] HOTELLING, H. 1938. The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates. *Econometrica,* 6**,** 242-269.

[15] The sum of producers' profits and the consumers' surplus (the difference between what consumers are willing to pay and what they actually pay)

incomes, inheritances, and the site value of land … to cover the fixed costs of electric power plants, waterworks, railroads, and other industries in which the fixed costs are large".

Hotelling recognised however that, in the calculation of (short run) marginal costs, "*there are, to be sure, certain complications*". One such complication was that, when the demand was close to the maximum supply, the marginal costs could become very high. He proposed to deal with this by "*an averaging process … in the computation of rates*" which in the case of rail transport would be based on "*the probability of having to run an extra train*". This could be expressed in a "*rental charge*" levied on the least **elastic** demand, and the proceeds from this could pay part of the overhead costs:

" … in cases in which the available equipment is actually used to capacity, and it is not feasible or is of doubtful wisdom to increase the amount of equipment, something in the nature of a rental charge for the use of the facilities should … be levied to discriminate among different users in such a way that those willing to pay the most, and therefore in accordance with the usual assumptions deriving the most benefit, would be the ones obtaining the limited facilities which many desire. This rental charge for equipment, which for passenger travel would largely take the place of fares, should never be so high as to limit travel to fewer persons than can comfortably be accommodated, except for unpredictable fluctuations. The proceeds from the charge could be added to the funds derived from income, inheritance, and land taxes, and used to pay a part of the overhead costs. But there should be no attempt to pay all the overhead from such rental charges alone."

Hotelling had been frustrated at what he saw as the unthinking prevalence of average cost pricing. His work had success in establishing the case for tariffs based on (short run) marginal costs. He envisaged that this would be principally a usage charge per unit although he did allow the possibility of some form of price-elasticity based rental charge to recover some, but not all, common costs. At its heart, however, was a single tariff calculated on short run marginal costs – a single price tariff.

In 1946 English Economist and Nobel Laureate, Ronald Coase[16] noted that Hotelling's proposition "*has aroused considerable interest and has already found its way into some textbooks on public utility economics*". However Coase suggested that Hotelling had over-simplified

[16] COASE, R. H. 1946. The Marginal Cost Controversy. *Economica,* 13**,** 169-182.

the distinction between average and marginal costs and missed the importance of the allocation and recovery of common costs:

" *Any actual economic situation is complex and a single economic problem does not exist in isolation. Consequently, confusion is liable to result because economists dealing with an actual situation are attempting to solve several problems at once … The central problem relates to a divergence between average and marginal costs. But, in any actual case, two other problems usually arise. First, some of the costs are common to numbers of consumers and any consideration of the view that total costs ought to be borne by consumers raises the question of whether there is any rational method by which these common costs can be allocated between consumers. Secondly, many of the so-called fixed costs are in fact outlays which were made in the past for factors, the return to which in the present is a quasi-rent, and a consideration of what the return to such factors ought to be (in order to discover what total costs are) raises additional problems of great intricacy. These are, I think, the other two problems which usually exist simultaneously with a divergence between average and marginal costs. They are, however, separate or at least separable questions. Thus, the example used by Professor Hotelling, the problem of pricing in the case of a bridge,' is in fact an extremely complex case rather than the simple one it appears to be on the surface.*"

Coase then examined an extremely simplified example in which all costs are attributable to individual customers and all costs are currently incurred (i.e. he excluded the recovery of **sunk costs**). His example also assumed that the product is sold at the point of consumption, that the marginal cost of transport from the point of production to the point of consumption was zero and that the average cost would be higher than the marginal cost and would decline as the cost of the carrier was spread over an increasing number of units.

Based on this example, while Coase agreed that Hotelling's marginal pricing approach was superior to average cost pricing, Coase strengthened the argument that multi-part pricing was superior to a single part tariff:

" *… the consumer should be charged one sum to cover the cost of carriage while for additional units he should be charged the cost of the goods at the central market. We thus arrive at the conclusion that the form of pricing which is appropriate is a multi-part pricing system (in the* *particular case considered, a two- part pricing system) a type of pricing well known to students of public utilities*".

Coase noted that his analysis was only of a special case that excludes sunk costs and in which all marginal costs can be directly attributed to consumers. He left open the prospect that when including the existence of common costs, the Hotelling solution might in fact be preferred:

"*I have been examining the problem of pricing under conditions of decreasing average costs. I have, however, confined myself to one particular case, that in which all costs are attributable to individual consumers and in which all costs are currently incurred. Given these assumptions, I showed that the Hotelling-Lerner solution was inferior to a multi-part system of prices and that as compared with average cost pricing the balance of advantage was not clear. The next steps would appear to be to examine the problem of pricing when there are common costs. If there are costs which cannot be attributed to individual consumers, does the Hotelling-Lerner solution then come into its own … Should such common costs be borne out of taxation? Or is the right approach to discover some basis in accordance with which these costs should be allocated between consumers? Finally, there is the question of expenditures which have already been incurred for factors. Are these costs to be borne out of taxation? Or should they be borne by consumers? If the analysis in this article is accepted, these would seem to be the next questions to be examined*."

The many questions posed here by Coase are important, because these issues are all relevant to the economics of electricity networks in practice.

As we describe later, using short run marginal costs to set electricity prices remains the preferred approach of many academic economists. However, just as was the case when Hotelling set out his ideas, there is no evidence that this approach has been adopted in practice.

Long run marginal costs

Not long after Coase's paper, engineer and economist Marcel Boiteux in France and adviser to President Nixon Hendrik Houthakker in England responded to Coase's question on what to do about "*expenditures which have already been incurred for factors*". Their suggestion was that tariffs should vary dependent on demand so that the recovery of capacity costs was included in the calculation of charges when the system was close to capacity.

Reflecting on this contribution of Boiteux and Houthakker, Joskow and Noll[17] suggested that:

"*In the literature on monopoly pricing, the one great practical triumph of theory is the work on peak-load (variable) pricing*".

In fact the *practice* of variable pricing (both time-of-use and price discrimination on the basis of price elasticity) long preceded theoretical developments. Hausman and Neufeld[18] describe the time of day pricing by nascent electricity providers in the United States in the 1890s, right at the start of the electricity industry. Similarly Chick[19] describes price elasticity-differentiated tariffs in various parts of Paris prior to 1946, applied by the then privately owned companies.

Houthakker, an academic economist, set out his contribution to the debate in his 1951 paper "Electricity tariffs in theory and practice". He described his work as a "*theoretical sketch*", and that his recommendations "*are not merely based on … abstruse considerations: they will also be put forward on grounds of expediency, thus showing a reassuring correspondence between theory and practice*". He said his objective "*was to find a method of charging which reflects marginal costs to the greatest practicable extent … we only want to emphasise an intention to avoid perfectionism*."

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17 JOSKOW, P. L. & NOLL, R. G. 1981. Regulation in Theory and Practice: An Overview. *In:* GARY FROMM, E. (ed.) *Studies in Public Regulation.* The MIT Press.

18 HAUSMAN, W. J. & NEUFELD, J. L. 1984. Engineers and Economists: Historical Perspectives on the Pricing of Electricity. *Technology and Culture,* 30**,** 83-104.

19 CHICK, M. 2002. Le Tarif Vert Retrouvé: The Marginal Cost Concept and the Pricing of Electricity in Britain and France, 1945-1970. *The Energy Journal,* 23**,** 97-116.

His contribution in post-war Britain was at a time of rolling power black-outs, and where capital constraints limited the rate at which the supply-side of the industry could be expanded. Accordingly he suggested that solutions would have to be found on the demand-side, principally by raising prices during the day when demand was highest.

Unlike Boiteux,[20] Houthakker presented no mathematical proof, though he did refer to Boiteux's seminal contribution, which he said he saw for the first time after his draft paper was complete. Houthakker said his analysis is based on "*long-term cost, in accordance with practice in the industry itself*". He dismissed differences between marginal costs and average costs as "*merely signs of market imperfections or bad planning*."

His recommended tariff structures included time-differentiated peak demand and energy charges for large users, and day-night tariffs for residential consumers, with energy charges in the day set to recover production plus "capacity" costs, and standing (fixed) charges to recover only costs directly attributable to individual consumers (metering, billing, individual connection charges etc.). He also countenanced cheaper tariffs for households who might have their electric fires controlled remotely through ripple control (a high frequency control signal superimposed on the distribution network).

While Houthakker's contribution was principally to provide academic credibility to the wishes of the industry for greater time-differentiation in tariffs, Marcel Boiteux's contribution was by contrast more mathematical. Boiteux distinguished between marginal costs in the case that capacity is fixed, and marginal costs where capacity can be expanded. He distinguished between short run marginal cost as commonly understood in economics and "long run marginal costs" (LRMC) a term which he defined. Both are "marginal" costs in Boiteux's conception and he presented his resulting tariff theory as a marginal cost theory. But he rejected the idea that tariff should be based only on short run costs (as Hotelling had proposed), saying that it "*baulks at common sense*". Similarly he rejected price deviation from short run costs on the basis of price elasticity of demand (as Hotelling had suggested and as Frank Ramsey had earlier developed in taxation theories) as merely adaptations to make the (short run marginal cost) theory "reasonable".

[20] BOITEUX, M. 1960. Peak-Load Pricing. *The Journal of Business,* 33**,** 157-179.

Boiteux's recommended solution was that selling at marginal cost meant that prices be set equal to what he called "*differential costs*". And he then asserted that optimal differential costs occur when plant is at optimum capacity, at which point differential cost is equal to development cost i.e. "*when differential cost pricing covers not only working expenses but also plant assessed at its development cost*". He summed up the proposals from his analysis:

For daily peak load pricing … it will be necessary:

- To fix rates according to the hours of consumption;
- To charge rates at times when consumption would tend to rise above the level of capacity, so as to bring out the corresponding portion of the load curve to the horizontal.

His proposal was to "*spread out the peaks* and *fill in the hollows*", a proposition he described as "*common sense*". As Electricite de France's Chief Economist and subsequently Director-General, Boiteux had the opportunity to put his propositions into practice in the utilities tariffs. For this reason, if none other, Boiteux's analysis has been highly influential. Contemporaneously to Boiteux, on the other side of the Atlantic, Peter Steiner[21] set out very similar arguments for peak load pricing on the basis of LRMCs.

The idea that prices should be established based on LRMCs quickly became popular in the industry and in the academy. Bonbright[22] summarised his analysis of short run and long run costs with a conclusion which he said would probably represent the majority position among economists:

"*… that, as setting a general basis of minimum public utility rates of rate relationships, the more significant marginal or incremental costs are those of a relatively long run variety – of a variety which treats even capital costs as variable costs*"

However, despite its strong following it would be wrong to suggest universal acceptance of LRMC rather than SRMC. Nobel Prize winning economist Oliver Williamson noted that Houthakker and Boiteux's analysis amongst others, while having "solved" the peak

[21] STEINER, P. O. 1957. Peaks loads and efficient pricing. *Quarterly Journal of Economics*, 585-610.
[22] BONBRIGHT, J. C. 1961. Principles of Public Utility Rates, Colombia University Press.

load pricing problem, lacked a motivation in welfare economics. Williamson[23] ultimately concluded that

"*the benefits of pricing according to short-run marginal cost (his recommendation) be weighed against the benefits of Boiteux's stable price proposal and an appropriate balance struck*".

While hardly a repudiation of Boiteux's LRMC approach, Williamson's analysis did clarify that the LRMC proposition relies heavily on simplifying assumptions and as such is essentially a practical, rather than theoretically robust proposition.

A final noteworthy contribution is Ralph Turvey's "Peak Load Pricing" published in 1968[24]. Turvey, then an employee of the National Board for Prices and Income sought to bring Boiteux and Williamson "*down from their ivory towers*", although his analysis was built on the same fundamental proposition as Boiteux and Williamson i.e.

"*That the optimum requires price to exceed marginal running cost in periods when demand is high by amounts which will both restrict demand to capacity output in all of those periods and which sums up over them to equal the marginal cost of capacity. In other periods price must equal marginal running cost*."

Turvey sought to incorporate knowledge on metering and billing and other limitations to propose what he called "practical" tariff alternatives. William Vickrey's[25] criticisms of LRMC was more explicit:

"One cannot simply get around the problems posed by indivisibilities and economies of scale by attempting to bring fixed costs into the picture through notions of long-run marginal cost. To attempt to do so leads only to confusion and inefficiency. Pricing decisions are relatively short-run decisions, or at least they should be flexible enough to adapt to changing conditions, even when physical plant cannot be. The marginal cost that is relevant to a pricing decision is a marginal cost of the output that will be affected by the pricing decision over the period for which that decision is to be considered not subject to possible revision. To attempt to import into a pricing

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[23] Williamson, O. (1966). "Peak-Load Pricing and Optimal Capacity under Indivisibility Constraints", The American Economic Review, 56 (4): 810-827

[24] TURVEY, R. 1968. Peak-Load Pricing. *Journal of Political Economy,* 76**,** 101-113.

[25] VICKREY, W. 1985. The Fallacy of using Long Run Cost for Peak Load Pricing. *The Quarterly Journal of Economics,* 100**,** 1331-1334.

decision considerations of fixed costs that will not be affected even indirectly by that decision is to chase a very wild goose indeed."

Residual costs

Setting electricity tariffs on the basis of SRMCs or LRMCs will result in residual unrecovered revenue due to the difference between total costs and short/long run costs.

Hotelling was quite clear that except in special circumstances all of the shortfall between total cost and short run costs should be recovered through charges levied independently from the industry, such as through land taxes, inheritance taxes and income taxes. Bonbright[26] however, saw the problems associated with the recovery of residuals[27] as fatal to the idea of using short run costs to set prices.

Other SRMC proponents (Vickrey, Williamson, Coase) were clear about the merits of short run costs, but offered no advice on the optimal recovery of residuals.

None of the LRMC disciples (Houthakker, Steiner, Boiteux, Turvey etc.) seemed to deal with the problem of differences between LRMC and total costs. Houthakker, for example, dismissed it as we noted earlier as "*merely signs of market imperfections or bad planning*". Brown and Faruqui[28] note that the academic literature on how to recover residual distribution costs when embedded costs exceed LRMC is virtually non-existent.

In Australia, it would seem LRMC will be much below total cost for the foreseeable future. This reflects not only the extraordinary valuation of regulated network assets in Australia (and hence extraordinarily high sunk and hence total costs) but also what might be an enduring decline in average and peak demand for grid-supplied electricity, in response to ever more distributed generation, ever higher energy efficiency and declining energy intensive manufacturing.

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[26] BONBRIGHT, J. C. 1961. Principles of Public Utility Rates, Colombia University Press.

[27] Bonbright questioned whether the "*almost undeniably superior efficiency of short-run marginal costs pricing as a means of securing the optimum utilisation of plant of temporarily redundant capacity warrants the surrender or impairment of all of the other important functions of utility rates*". He concluded not. His main concerns were: that short run pricing failed to provide long-run signals; that the knowledge needed to apply it was not available; that short run costs would fail to guide utility management as the needs for plant expansion; that it was unfair to burden non-consuming tax payers to subsidise beneficiaries; that political support for tax payer funding of utility services was not likely, and finally that the additional tax burden would have repressive or distorting effects.

[28] BROWN, T. & FARUQUI, A. 2014. Structure of electricity distribution network tariffs: recovery of residual costs. Prepared for the Australian Energy Market Commission. The Brattle Group.

In this context, the Australian Energy Market Commission (AEMC) asked the Brattle Group to prepare a report on how electricity distribution network tariffs can be structured to recover residual costs (which were treated by the AEMC as the difference between LRMC and total cost). The Brattle Report[29] takes a broad view of tariff design, mindful of the many factors that need to be considered. They then propose five different possible residential tariff structures that they suggest are consistent with LRMC. These are single rate; two-rate; inclining block; declining block; and three-part tariff (which would comprise a demand charge, a fixed charge and a variable charge). Of these options, they suggest that efficient tariffs would be ones in which variable charges are based on LRMC, but fixed charges or declining block tariffs recover the residual between LRMC and total cost. This is despite their finding, consistent with ours, that high fixed charges are unusual in other countries.

A tariff with a demand component (for example in a three part tariff) could be an important way of addressing "fairness" in relation to air conditioning loads and are also potentially very relevant to pricing structures for households with PV.

Brattle's argument on the recovery of residual costs is that recovering an additional $100/customer per year in a fixed charge will have no impact on customer behavior while recovering an additional $100/customer per year in a demand charge or in a volumetric charge would have some impact on customer behavior — as the price of electricity use increases, customers are likely to lower their usage. By implication they suggest that fixed charges would be the most efficient arrangement because network service providers continue to recover their profits and sunk costs, and consumers don't reduce their consumption because the additional revenue has been recovered through a charge that is independent of peak demand or consumption. Brattle suggest that opposition to such an arrangement may be legitimate on grounds of fairness (the consumers who buy the least are the most affected by higher fixed charges). But they suggest it is not legitimate to oppose it on grounds of efficiency. They go further by explaining the unpopularity in other countries of low fixed charges in residential tariffs, as reflective of regulators' preference for fairness above efficiency.

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[29] BROWN, T. & FARUQUI, A. 2014. Structure of electricity distribution network tariffs: recovery of residual costs. Prepared for the Australian Energy Market Commission. The Brattle Group.

But their analysis ignores the losses consumers incur as a result of the higher fixed charges. Most residential consumers can be expected to prefer higher variable charges rather than higher fixed charges. This is because they have the ability to respond to higher variable charges by reducing consumption or producing their own electricity. In this way, consumers may lose less from higher variable charges, than they would from higher fixed charges. At the least they would have a choice in the matter.

Monopoly service providers would obviously prefer to recover their revenue through fixed charges and have made this preference clear. The Energy Supply Association of Australia has suggested that household tariffs in Australia should have far higher fixed charges than is currently the case because "the cost of supplying electricity to customers is largely fixed"[30] Similarly at a public forum in Sydney in March 2014 to discuss their revenue proposals, the Chief Executive of Networks New South Wales suggested that network service providers have such a high level of fixed costs that "really the whole bill should be a fixed charge like council rates".

It is not persuasive to suggest that this approach would be efficient;[31] in addition, to take such an approach, leaves alone the issue of fairness.

A discussion of the recovery of the growing gap between LRMC and total cost should consider why that residual exists. It is not just that demand in future is at best stagnant. In the Australian context, network service providers have extraordinarily high regulated assets that reflect in part significant capacity augmentation over the last decade. The NSPs have massively expanded their network's capacity just as demand has declined and technology change (rooftop PV) is undermining their monopoly.

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[30] (ESAA. 2013. Air-conditioners and solar - why electricity pricing needs to be reformed [Online]. Available: https://www.esaa.com.au/policy/air-conditioners_and_solar_why_electricity_pricing_needs_to_be_reformed)

[31] Littlechild (1975)[31] presents an analysis of welfare and profit maximisation with single part and two part tariffs, in the telecommunication industry, but the analysis and its conclusions apply equally to electricity distribution. Littlechild concludes in respect of two-part tariffs that:

"*surplus maximization subject to a minimum profit constraint calls for profit margins on both fixed and variable charges to be increased in the same proportion until the desired level of profit is attained. Where profit maximization would require a fixed charge below marginal customer cost, then surplus maximization subject to a minimum profit constraint would also require such a policy, and presumably as the profit requirement increased, so the fixed charge would actually be reduced*".

In considering ways to recover the residual between total costs and variable costs, it would be useful first to consider how excluding imprudent expenditures might reduce this residual. In this regard we point to Hotelling's pithy advice in 1939 in relation to railways in the United States, much of which was economically stranded through excessive investment and technology change:

"… the fact is that we now have the railroads, and in the main are likely to have them with us for a considerable time in the future. It will be better to operate the railroads for the benefit of living human beings, while letting dead men and dead investments rest quietly in their graves".

This is useful advice in the current context of electricity networks in Australia.

From theory to practice

Sixty three years ago Houthakker[32] observed that "*the vast literature on electricity tariffs shows so many different views that it would be difficult to be original in proposing tariff changes*". The multiplication of the literature since then makes originality no easier now. What then can be taken from the theory that is relevant to the current Australian electricity tariff debate, particularly as it pertains to network tariffs for supply to households ?

Well-known and accomplished tariff theorists are clear about the limitations of theory:

- Houthakker, an academic economist, proposed solutions that involve "*theoretical and empirical arguments*" and said "*our ultimate recommendations are not merely based on the following somewhat abstruse considerations (of welfare economics); they will also be put forward on grounds of expediency, thus showing a reassuring correspondence between theory and practice.*"

- Boiteux, referred to his proposals as "*common sense*" and noted that "*it is a long way from theory to practice*".

- Bonbright concluded his book saying "*one of the most frustrating problems of rate theory and practical rate making is that of suggesting and applying principles of workable compromise*".

- Turvey suggested "*The theoretical "solutions" to the peak-load problem are a beginning, not an end, serving to dispose of past confusion about the principles of allocating costs. While the matters which then have to be examined are less suited to the tools of the armchair economist, they are both important and fascinating*".

- Littlechild concluded his analysis of two-part tariffs suggesting that "*In practice, things are much more complex … it will be rather more fruitful to study empirically the ways in which companies and consumers actually accommodate these problems in the market.*"

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[32] HOUTHAKKER, H. S. 1951. Electricity Tariffs in Theory and Practice. *The Economic Journal,* 61, 1-25.

Questions about the best tariffs structures for natural monopoly network business have occupied the attention of a number of Nobel laureates, experts from a range of disciplines and numerous eminent economists who have advised Presidents and Prime Ministers. Despite all the attention it has received, more than sixty years since the concept of long run marginal cost was named, a handbook on its implementation has yet to be written. This can be no surprise. While conceptually LRMC is reasonably clear, its application is highly problematic. This is because there are many degrees of freedom (variables): how far ahead should one look, what regional definition should be used, how will future augmentations affect network capacity, how are demand forecasts established, how are future costs and technological impacts taken into account and so on. With so much flexibility in the way the calculations are done and the principles applied, almost any outcome and consequential tariff might be claimed to be consistent with LRMC, or inconsistent with it.

This is evident for example in the Brattle Group's recommendations on tariff structures. They identify all possible residential tariff structures (single rate, two-rate, inclining block, declining block and three-part) as consistent with LRMC. Similarly the AEMC and NERA suggest that setting tariffs on the basis of LRMC does not imply any particular tariff structure, and they suggest that flat tariffs, daily peak tariffs, critical peak tariffs, and capacity-based charges are all consistent with LRMC pricing. It might be said that a theory that allows anything is not terribly useful. In the next section we draw a few conclusions about what consumers might usefully take from tariff theory in general and LRMC in particular.

What might consumers take from the theory?

We noted in the introduction that welfare economics has provided the theoretical framework for the economic analysis of tariffs. Its underlying objective is the maximisation of the sum of the producers' surplus (profits) and the consumers' surplus (the difference between the price and consumers' willingness to pay).

However in practice, the focus in the theory has been on the design of tariffs that purport to make the industry more efficient, more or less without consideration of the consumers' perspective. Boiteux's seminal paper[33] on LRMCs and peak load pricing provides a classical example of this. The final paragraph of his paper, having hitherto focussed exclusively on the design of tariffs that best optimises the development and use of the supply-side of the industry, recognises also that the impact of tariffs on consumers matter, though he then concludes that what's good for the industry is good for its consumers:

"*Of course, not all of this will represent a net saving to the nation, for subscribers who have changed their load curve in order to obtain the benefit of lower prices have experienced some inconvenience which must be set against the saving made. It is nevertheless true that the very fact of making peak consumers pay what their consumption actually costs has lead subscribers to revise their behaviour in a way that can only be beneficial*."

So, what might consumers' take from the theory? We suggest the following:

1. LRMC is at best a philosophy or broadly defined principle. It can be applied in many ways and very different tariff structures and levels might be claimed to be consistent with it. It is not an objective, verifiable and certainly not a precise standard.
2. A good case exists in the theory of marginal costs (whether short run or long run) for some form of time differentiation in tariff charges for residential and other energy users. The theory does not however provide clear guidance on relative price levels (how much higher peak prices should be than off-peak) or the number of different time bands.

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[33] BOITEUX, M. 1960. Peak-Load Pricing. *The Journal of Business,* 33, 157-179. (His earlier paper on which this was based was published in French in 1949)

3. The theories of electricity pricing provide no substance to the idea that shortfalls between marginal costs and total costs are efficiently recovered through fixed charges. In fact, to the contrary, the use of fixed charges to recover sunk costs is anathema to the theory of marginal costs, whether long run or short run.

Finally, we return to the question posed in the introduction: does economic theory offer answers that allow us to understand the impact on tariffs of other seemingly non-economic objectives such as fairness, predictability and consistency? Or, to put it differently, can theory tell us with confidence what a cost-reflective tariff is? This paper suggests that the answer is "no". Despite the attention of many fine minds over a long period, there are many different views on the theories and even more on their implementation.

The tariff debate is often portrayed as one in which economically efficient cost-reflective tariffs are undermined by politics and non-economic factors such as fairness and equity. But the line that demarcates an economically efficient approach from others is not clearly drawn. On closer inspection, many seemingly non-economic factors are entirely relevant to the consideration of efficiency.

Consumers and their advocates should participate actively in the debate about tariffs to make their preferences known. Industry needs to find out what consumers want and to orient their pricing policies accordingly.

Key terms explained

Elasticity: This refers to the price responsiveness of consumers. A highly elastic good or service is when where a small change in price, changes significantly the amount purchased. For example say the price of bananas increases, the number purchased drops immediately as people switch to buying other, cheaper fruit. Electricity for households is inelastic (in the short term at least) because price changes will have minimal impact on daily use.

Marginal Cost: The actual cost of producing one additional good, or unit of a service. So the marginal cost for producing an additional car on a production line, for example, is the cost to the manufacturer of the parts and the labour to put this together.

Welfare economics: A term attributed to early economist Alfred Marshall, whose definition expands the field of economic science to a larger study of humanity. Specifically, Marshall's view is that economics studies all the actions that people take in order to achieve economic welfare "*man earns money to get material welfare.*" (we could paraphrase Marshall as saying that economics serves society, not the other way around)
Note too that this meaning of Welfare Economics should not be confused with the notion of the Welfare State which is often attributed to the application of the sort of economic principles applied by Keynes and others to foster economic growth after the 1930's depression and WW2. Nor does the term have any direct connection with the "welfare sector".

Sunk Costs: Sunk costs describe money that has already been spent, e.g. for aspects of a network that are not needed. The firm has spent money in anticipation of future income that has not eventuated.

NSP: Network Service Provider. This refers to both transmission and distribution network businesses.