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The financial impacts of PV systems and plug-in hybrid electric vehicles on customers who do not have them

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Abstract

In Australia, PV uptake has increased rapidly, with around 20% of households now owning a system, and Electric vehicle (EV) deployment may increase markedly over the coming decade. While there is growing discussion of the implications of these developments, the focus has generally been on the impacts on households deploying these options, not on their potential cost impacts on customers that do not buy them. This paper aims to identify and quantify the potential cost impacts of plug in hybrid EVs (PHEVs) and PV in the Australian National Electricity Market for key stakeholders including other customers and the network businesses. Using real household load and PV data from several hundred houses in Sydney and current retail tariffs and network regulatory arrangements we find that even when 40% of households take up PV there need only be a relatively small impact on the total electricity bills of other customers. PHEVs can actually decrease the bills of customers that do not take them up, even in 'uncontrolled charging' mode. The combined effect of PV and PHEV under current tariff structures is that the bills of owners of these technologies can be significantly lower than would be expected from a simple addition of the separate outcomes of each technology, while the combined result for other customers is that their bills are very slightly higher.

Keywords: plug-in hybrid electric vehicles, photovoltaics, cost impacts, network regulation, tariffs

1. Introduction

A range of distributed energy technologies have begun to transform electricity industries around the world including Australia. Most notable here and in many countries has been residential uptake of PV systems (IEA-PVPS, 2013). Other technologies, including EVs, show considerable promise, although deployment to date has been limited.

Although the vast majority of studies assess the value of the PV system to the owner (eg. Pillai et al., 2014; Breyer and Gerlach, 2013), other studies assess such aspects as PV's impact on wholesale prices (Cludius et al., 2014; Haas, 2014; McConnell, 2013), the lifecycle impacts on society in general (Hammond, et al., 2012), the generation capacity value of PV (Burke, 2014), and the broader societal value of avoided conventional electricity generation, avoided line losses and reduced emissions (Oliva et al., 2014). Oliva and MacGill (2013) assess the value of PV electricity to owners, retailers and DNSPs.[1]

Electric vehicle (EV) ownership in Australia is also projected to increase, although the rate of uptake is uncertain (AEMC, 2012). EVs are of particular interest because of their potential to accentuate the existing afternoon/evening demand peak as householders return home from work, to complement PV system uptake due to their storage capability and also to reverse the

[1] Distribution Network Service Providers

recent trend in declining electricity use. In Australia, the research has largely focussed on whether the utilities could cope with the increased demand and options to optimise the technical impacts (Albrecht et al., 2009; Taylor et al., 2009; Cain, et al., 2010; Järvinen et al., 2012; Mullan et al., 2011; Paudyal and Dahal, 2011; Khayyam et al., 2012; Masoum et al., 2012; Speidel et al., 2012; de Hoog et al., 2013; Ustun et al., 2013), and in some cases have estimated the financial impact of the increases in generation and/or network capacity that may be required, as well as the provision of services such as peak shaving or ancillary services (Feeney et al., 2011; Wagner and Reedman, 2010; Usher et al., 2011; Mullan et al., 2012; Vithayasrichareon et al., 2013). Other papers focus on the financial impact on the owner of the vehicle (Feeney and Adams, 2009; Kinghorn et al., 2010; Sharma et al., 2012; Tushar et al., 2012).

However, to date, no work has assessed the financial impacts from the point of view of 'Other customers' (those who do not take up EVs or PV) – as we attempt to do here.[2]

2. Method

The uptake of any new technology can affect the bills of 'Other customers' in two different ways. Firstly, increased use of electricity can increase payments to the electricity networks, and this may decrease the bills for 'Other customers', if TUOS and DUOS tariffs[3] are then decreased to cap total network revenue – and vice versa. Secondly, increases to demand peaks may increase the size of the network, which can increase the bills of 'Other customers' due to augmentation costs.

The analyses are undertaken using a representative network region, created using real half hour household load and PV generation data, then assessing PV impacts and modelled EV charging under a range of scenarios. Financial analysis is undertaken for those households deploying technologies, as well as networks, electricity retailers and, critically, customers that don't deploy these technologies. The methodology is the same as used in Passey and Watt (2014). The aspects that are most relevant to this paper are summarised below.

2.1. Load data

The model's annual load profile is based on separate half hourly data for the period 1 July 2010 to 30 June 2011, from 271 houses in the Greater Sydney Area, New South Wales (NSW), Australia.[4] The load data were scaled to an annual average of 19kWh/day including off-peak use, which is a rounded average of two estimates of average electricity use in NSW (IPART, 2013, p5; Ausgrid, 2012, p1).

Figure 1 shows the day with the highest peak demand for 2010/11, which was in summer, Saturday, 5th Feb 2011. It also shows the modelled load from uncontrolled charging of PHEV (PHEVU; weekend and weekday), as well as the PV output from the 271 houses. The PHEVU and PV data are described in Sections 2.2 and 2.3 respectively.

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[2] Note that we look only at the direct financial flows between stakeholders, not at the technical impacts or their potential financial costs and/or benefits. We have also not looked at the potential financial impacts of the provisions of vehicle-to-grid services such as peak shaving and ancillary services. This would add a considerable degree of complexity and uncertainty, especially since the financial viability of such options is still uncertain (Mullan et al., 2012).

[3] TUOS, Transmission Use of System; DUOS, Distribution Use of System

[4] These data were obtained from 271 houses considered to have reliable load data from the 300 houses available at Ausgrid's Solar Home Electricity Data website - http://www.ausgrid.com.au/Common/About-us/Sharing-information/Data-to-share/Solar-household-data.aspx#.Un4NeeBibdl

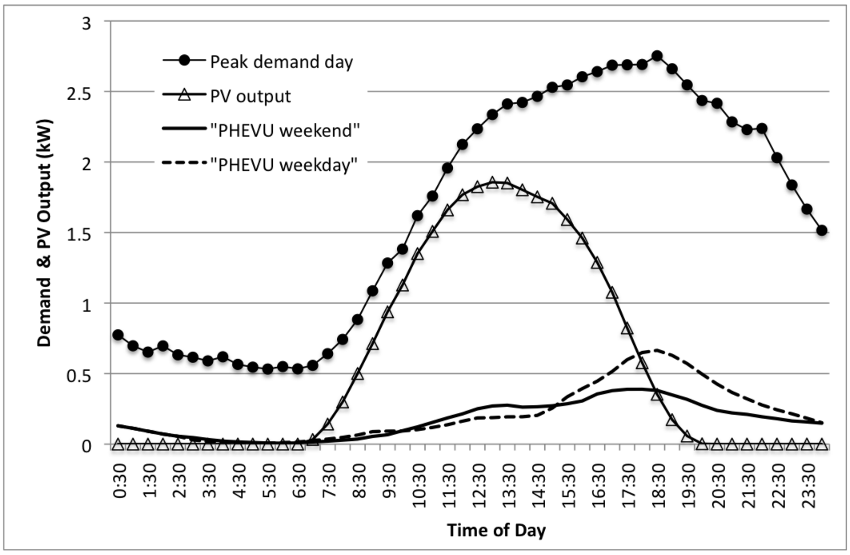

Figure 1. General consumption load, simulated PHEVU load (both weekend and weekday), and PV Output during the Peak Demand Day for the Sample Houses: Sat 5 Feb 2011

2.2. *Photovoltaics*

The Greater Sydney dataset includes separately metered PV generation. This was scaled to be from a 2.5 kW rated PV system because, according to the Australian Clean Energy Regulator (CER) database, the average system size in NSW up to February 2014 is 2.33 kW, with systems installed recently being larger. Although only about 10% of households in NSW have a PV system, there is significant variation between regions (ACIL Allen, 2013). In most regional areas, between 15% and 25% of households have PV, and some have over 30%.[5] In South Australia and Queensland, just over and just under 20% of households have a PV system respectively (ACIL Allen, 2013). For this analysis, we have modelled PV uptake starting at 20% of households and increasing by a further 20%.

2.3. *Plug in Hybrid Electric Vehicles*

The plug in hybrid electric vehicle charging data were obtained according to the method of Vithayasrichareon et al. (2013). In summary, the PHEV charging data was based on 10 years of transport survey data, of 51,800 individual vehicles and 216,566 vehicle trips, where cars were able to charge whenever they were (i) at a residential address for more then 10 minutes (uncontrolled charging) and (ii) only when at a residential address and only between 11pm and 7am (controlled charging). The additional average electricity use for customers that had a PHEV and used uncontrolled charging was 4.79 kWh/day, and where controlled charging was used was 4.57 kWh/day.

2.4. *Tariffs used*

The financial impacts are assessed assuming all customers are on EnergyAustralia's[6] regulated 'Domestic All Time' tariff and their Controlled Load tariff.

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[5] These values are taken from http://pv-map.apvi.org.au/historical, which uses current data from the Australian Clean Energy Regulator.

[6] EnergyAustralia is an electricity retailer in Australia. Their tariffs were chosen because they have franchise customers in the area the load data were obtained from, and because the transmission and distribution network components of their retail tariffs were available.

2.5. *Regulatory environment*

The regulatory environment in which TNSPs[7], DNSPs, and retailers operate adds an additional level of complexity to the process of assessing the impacts of changes to electricity use and demand peaks on their income. TNSPs in Australia are regulated under a revenue cap, which for the purposes of this paper means that any over (or under) recovery of network costs must be paid back (or recovered) in the following year. Although all DNSPs in Australia (except those in the state of Queensland)[8] are currently regulated under a WAPC[9], they are expected to move to a revenue cap over the next few years. For example, as of July 2015, DNSPs in NSW will be regulated under a revenue cap (AER, 2014). Here, we have modelled the impacts of PV and PHEVs under only the revenue cap scenario because we focus on their uptake in the future. The financial impacts have been divided into the following three types.[10]

First order impacts: The initial cost impacts of particular tariffs and technologies on the customers that take them up – the 'Responsible Customers'.

Second order impacts: Also includes the subsequent cost impacts in the following year – for both the 'Responsible Customers' and for 'Other Customers'. These capture the effect of network operators altering their tariffs due to changes in revenue. Thus, since both TNSPs and DNSPs are regulated under a revenue cap, both can alter their tariffs to conform to their caps.

Third order impacts: Also includes the subsequent cost impacts due to changes to demand peaks and therefore changes in network costs. These include the First and Second order impacts – and so represent the total impact of each option.

2.6. *Incorporating the cost of changes to peak demand*

The cost of increases in peak demand is based on the impact that each technology has on the annual peaks for 2010/11. The transmission peak (for NSW) was between 4:00pm and 4:30pm on Tues 1 Feb 2011 and the distribution peak (for the sample houses) was between 6:00pm and 6:30pm on Sat 5 Feb 2011.

Table 1 shows the changes to the annual peak demand for each technology option used in the model, as well as the costs imposed on the network, both per 'Responsible customer'. The PHEVU value is the increase in demand at the time of the annual peak according to the modelled PHEVU data. On average, only 14% of the rated capacity of the 271 houses' PV systems was available during the annual distribution network peak. During the transmission network peak, 51.5% of the PV systems' rated capacity was available. According to data provided by Ausgrid, the amount of PV capacity available on different distribution network peaks has been shown to vary from 11.8% to 48.5% (calculated from Ausgrid, 2011). An assessment of the correlation between PV output and state-wide demand peaks (transmission networks) in NSW, Queensland, Victoria and South Australia over the summers of 2011/12 and 2012/13, showed PV output at between 21% and 58% of its rated capacity (Burke, 2014). Thus, we have used the values shown in Table 2 because they are likely to be realistic ranges.

The long run marginal cost (LRMC) of meeting peaks in demand are taken to be AUD$175/kVA/year and AUD$80/kVA/year respectively (Deloitte, 2012). Given the range of ESAA's values (138kVA to 331kVA), it is reasonable to assume the kVA value is equivalent to the kW value, and we have done so here.

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[7] Transmission Network Service Providers

[8] DNSPs in Qld are regulated under revenue caps

[9] Weighted Average Price Cap. Being regulated under a WAPC essentially means that as the total amount of electricity sold decreases, total revenue also decreases, and vice versa.

[10] The impact of special feed-in tariffs, Renewable Energy Certificates or other customer incentives have not been included in this assessment.

Table 1. Impacts on the Annual Demand Peaks by Different Technology Options per Household

	Transmission		Distribution	
	Demand (kW)	Cost (AUD$/yr)	Demand (kW)	Cost (AUD$/yr)
PHEVU	+0.446	35.68	+0.381	66.68
2.5kW PV - Low	-0.75	-60.00	-0.25	-43.75
2.5kW PV - Baseline	-1.25	-100.00	-0.50	-87.50
2.5kW PV - High	-1.75	-140.00	-0.75	-131.25

Table 2. Modelled Ranges of PV Availability During Demand Peaks

	Transmission	Distribution
Low	30%	10%
Baseline	50%	20%
High	70%	30%

3. Results

After establishing the 'baseline' outcomes for the average customer, we assess the financial impacts of the technology scenarios shown in Table 3.

Table 3. Scenarios Modelled

	Regulation	Description
40% PV	Revenue cap	Uptake of PV into the future: an additional 20% of households install PV
20% PHEV	Revenue cap	Uptake of PHEV into the future: 20% of households install PHEV
PV + PHEV	Revenue cap	Combination of 40% PV and 20% PHEV

3.1. Baseline outcome

The modelled first order annual financial outcomes for the average customer are shown in Table 4.[11] It can be seen that retail costs make up about half the bill, transmission about 15% and distribution makes up the remainder. Note that the wholesale electricity costs are incorporated into the retail costs.

Table 4. Residential Annual Bill, 'Responsible customer', Standard tariff (incl. GST)

	Variable (AUD$)	Fixed (AUD$)	Total (AUD$)	Percentage of total bill
Transmission	298		298	14.9%
Distribution	569	175	744	37.1%
Retail	835	128	963	48.0%
Total	1702		2005	

[11] All the annual bill outcomes have been presented to the nearest dollar. Although this is probably overly precise given the assumptions involved in the modelling, it was necessary because many of the changes are relatively small.

3.2. *Impacts of PV*

The impact of an additional 20% of customers taking up a 2.5kW PV system was modelled, with a 'Baseline' amount of PV available during the annual demand peak. Details of the changes to the transmission, distribution and retail components for the 'Responsible customer' first order impacts are shown in Table 5. The first, second and third order impacts, on both the 'Responsible customer' and the 'Other customers' annual bills, are summarised in Figure 2, where the DNSPs are regulated under a revenue cap.

It can be seen that PV decreases the 'Responsible customers' bills considerably. Because PV decreases the 'Responsible customers' electricity use, it decreases payments to network operators. The second order impact then increases both the TUOS and DUOS tariffs, and thus increases both the 'Responsible customers' and 'Other customers' bills. Under the third order impact, which includes the avoided costs of network augmentation, the 'Responsible customers' and 'Other customers' bills decrease because PV decreases the demand peak.

For 'Other customers' the net result is an increase of about AUD$40 in their annual bills as PV uptake increases from 20% to 40% of households. It is important to note that, as discussed in Passey and Watt (2014), the first 20% of PV uptake that has happened to date generally had a neutral effect on 'Other customers' bills. This is because currently, DNSPs in all jurisdictions except Qld are regulated under a WAPC, and so the revenue losses are not passed on to customers in the form of higher tariffs. The impacts of PV at different levels of availability during the annual demand peak is assessed in Section 3.3.

Table 5. Annual Bill, Additional 20% take up PV, 'Responsible customers' – First order impact

	Variable		Fixed	Total	
	(AUD$)	% change cf Standard tariff	(AUD$)	(AUD$)	% change cf Standard tariff
Transmission	87	-70.7%		87	-70.7%
Distribution	468	-17.8%	175	643	-13.6%
Retail	608	-27.2%	128	736	-23.6%
Total	1163	-31.7%		1466	-26.9%
PV export	35				
Total minus PV				1431	-28.6%

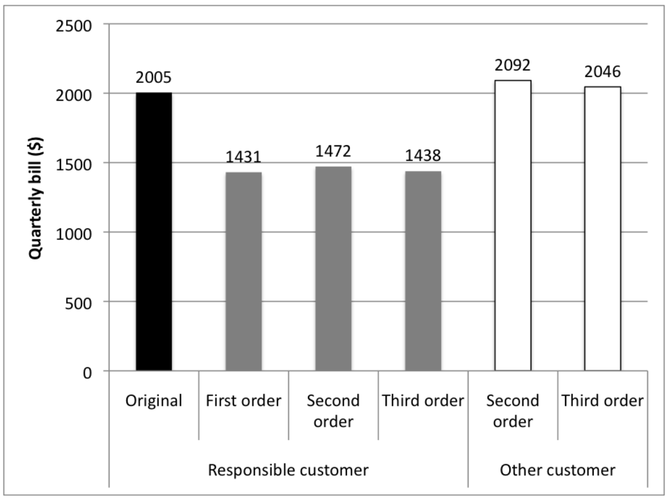

Figure 2. First, Second and Third order annual bill impacts under a revenue cap: Additional 20% households take up 2.5kW PV

3.3. *Impacts of PHEV and PV*

This section assesses the impact of PV at the three different levels of availability during the annual demand peak, PHEVU and PHEVU combined with PV,[12] where the DNSPs are regulated under a revenue cap.

Figure 3 and Figure 4 show the third order impacts for PV, PHEVU and PV+PHEVU for the 'Responsible customer' and the 'Other customer' respectively. As discussed in Section 2.6, sensitivity analysis is applied to the amount of PV capacity available during the annual transmission and distribution peaks. As expected, PV decreases the annual bills of 'Responsible customers' significantly – and having more PV available during the annual demand peak results in a greater reduction of both 'Responsible' and 'Other' customer's bills because of lower augmentation costs. It can be seen that adding PHEVU increases the average annual bill by slightly over 20%, or AUD$440. Because PHEVUs increase the 'Responsible customers' electricity use, they increase payments to network operators and so under the revenue cap scenario, the second order impact (not shown here) reduces the TUOS and DUOS tariff rates, and thus reduces both the 'Responsible customers' and 'Other customers' bills.

The PHEVU peak demand occurs between 6:30pm and 7pm, which corresponds to the distribution network peak, both for the summer average and for the annual peak. As a result, the third order impact, which includes the costs of network augmentation, increases the 'Responsible customers' and 'Other customers' bills. However, because the third order impact includes the second order impact, although the 'Responsible customers' annual bill is now higher, the 'Other customers' annual bill is about AUD$44 lower. The annual peak for the distribution network used here occurred on a Saturday. If it had occurred on a weekday, when the PHEVU peak is greater (0.665kW instead of 0.381kW), the 'Responsible customers' and 'Other customers' bills would have been AUD$454 higher and AUD$33 lower respectively, after the first, second and third order impacts had been taken into account.

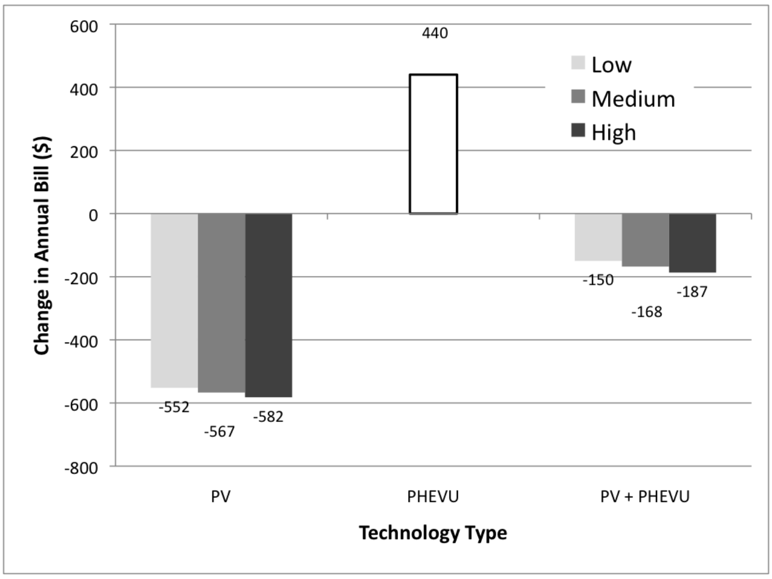

Figure 3. Third Order Impacts of PV and PHEVU on 'Responsible Customers' Annual Electricity Bill, revenue cap regulation

a) Low, Medium and High refer to the amount of PV available during the annual demand peak – see Table 1.

[12] Note that the PHEV and PV systems do not need to be installed on the same house. The impacts are almost identical if they are installed on neighbouring houses, as long as they are on the same local distribution network.

The combined effect of PV + PHEVU for 'Responsible customers' is not the simple addition of PV and PHEVU, with the annual bill being lower than expected. This is because the PHEVU increases the 'Responsible customers' demand and so a greater proportion of their PV electricity is used on-site and so offsets the prevailing tariff (rather than being exported and earning only the assumed 8c/kWh). Similarly, the combined effect of PV + PHEVU on 'Other customers' is not the simple addition of PV and PHEVU. In this case, 'Other customers' bills are slightly higher than would be expected. This is because the greater on-site use of PV electricity by the 'Responsible customer' decreases revenue for TNSPs and DNSPs, and so under the revenue cap scenario they increase their tariffs to compensate.

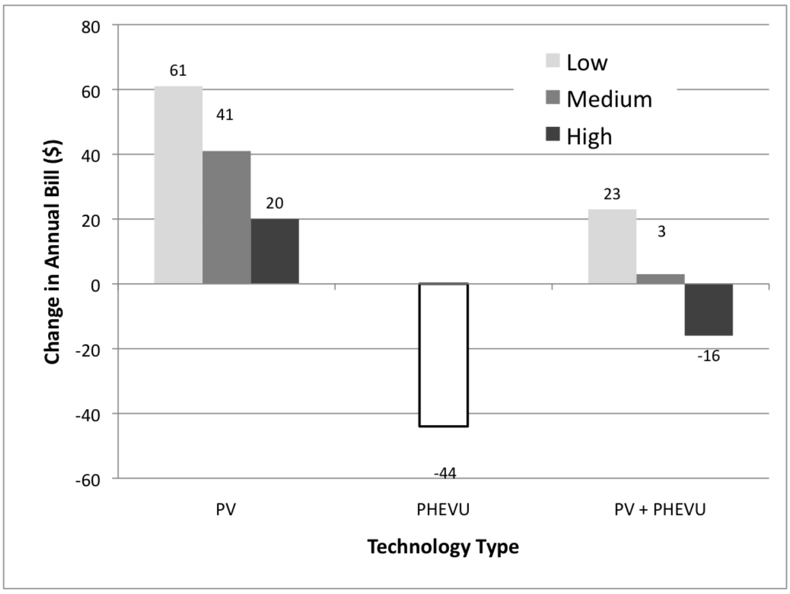

Figure 4. Third Order Impacts of PV and PHEVU on 'Other Customers' Annual Electricity Bill, revenue cap regulation

a) Low, Medium and High refer to the amount of PV available during the annual demand peak – see Table 1.

4. Discussion

Although PV increases 'Other customers' bills slightly under the revenue cap scenario used here, under the WAPC scenario (which is currently the case in all Australian jurisdictions except for Qld), PV generally decreases 'Other customers' bills (Passey and Watt, 2014). This is because when DNSPs are regulated under a WAPC, they do not increase their tariffs to offset losses due to decreased sales, and 'Other customers' benefit from PV's ability to reduce demand peaks. As discussed in Passey and Watt (2014) the ability of a particular PV system to increase 'Other customers' bills is influenced by at least three factors. It is lower if (i) the 'Responsible customer' has lower than average annual electricity use, (ii) they install a larger than average PV system or (iii) the PV system makes a greater contribution to reducing the annual demand peak. Thus, the current trends in Australia of decreasing residential electricity use and larger PV systems will improve the financial outcomes for households that don't have PV systems. PV's correlation with residential demand peaks can be improved by being faced west (Burk, 2014).

Note that the values we have used for PV reducing network costs are based on the cost of augmenting the network. Although demand peaks are forecast to increase over time, they have decreased recently, and have been lower than forecast, although some of that decrease is attributed to PV (AEMO, 2013). If peak demand decreases over time, even if that decrease is in part due to PV, the values used here for avoided network augmentation would most likely be too high. They are based on the levelised cost of annual increases to the size of the network, whereas the financial benefits of absolute reductions in the size of the network would only accrue once components needed replacing: because they had reached the end of their life or if they failed for some other reason.

The modelled PHEV used here reduced costs for 'Other customers' because it resulted in a relatively small increase in the annual demand peak and increased revenue for network operators (and so, under the revenue cap resulted in lower tariffs for all customers). The use of controlled charging and the EV battery in either 'vehicle to grid' or 'vehicle to home' formats to reduce demand peaks would further reduce 'Other customers' costs.

Further work in this area is focussing on the use of different types of tariffs (eg. time of use and demand charge-based tariffs) by both the 'Responsible' and 'Other' customers, to minimise costs for all customers. Given the variation in the size and shape of the load profile of different customers, it is likely that the impacts of the different tariffs and technologies will differ to a similar extent, and so this is also an area of ongoing work, as it could inform policies for low income households or other customer types.

5. Conclusions

The internal structure of electricity tariffs (the level of TUOS, DUOS and retail components), can have a significant impact on how technologies such as PV and PHEV affect the revenue received by TNSPs, DNSPs and retailers. Where either or both the TNSP and DNSP are regulated under a revenue cap, the internal structure of the tariff can also significantly affect the impact that such technologies have on the costs faced by 'Other customers'. To date, PV has most likely had a minimal impact on 'Other customer's bills, but as DNSPs move to revenue cap regulation, PV could result in a slight increase. Future uptake of PHEVs, especially with controlled charging regimes, will most likely decrease 'Other customers' bills.

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