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Who pays, who benefits? The financial impacts of solar photovoltaic systems and air-conditioners on Australian households☆

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ABSTRACT

Increasingly, there are calls for the owners of photovoltaic (PV) systems to pay additional charges on the basis that they are not contributing their fair share to network revenue. Air conditioners (A/Cs) are even more widespread than distributed PV systems, and their use has increased demand peaks and the size of networks required to meet them, the cost of which is typically recovered from all customers. There appears to be limited analysis in the literature regarding the impacts of A/C and PV on the electricity bills of customers who do not have these technologies. While the impacts of renewable energy on centralised electricity generation have been explored in the literature, this paper proposes a methodology to estimate the financial impacts of PV and A/C that flow through network operators to other customers. The analysis indicates that, in the datasets used, A/C systems have most likely resulted in significant bill increases for customers who don't have them. In contrast, PV systems have most likely had a minimal financial impact on customers who do not have them. While these analyses were undertaken using Australian data, the method is applicable to most countries with modifications to suit the local regulatory environment.

1. Introduction

Distributed rooftop photovoltaics (PV)[1] is being deployed at an increasing rate worldwide. Falling PV costs mean that even jurisdictions without explicit PV policy support may offer highly attractive commercial returns for the system owner [1]. It is, however, not the only energy technology seeing growing uptake by energy users. Split system air conditioning (A/C) is far more widespread, especially in hot regions, but now also in cooler regions where reverse cycle A/C is commonly used for heating. These two technologies have rather different financial implications for distribution network service providers (DNSPs),[2] and hence all the energy users they serve. Under net metering, self-consumption of PV reduces network revenue under standard volumetric tariffs [2–4], whereas A/C increases it. In terms of network costs, PV can contribute to reducing demand peaks under some circumstances, which in turn may reduce capital expenditure (capex) requirements [3,4]. In contrast, A/C is a major contributor to peak demand and therefore DNSP capex [5]. Australia provides a useful case study of the impacts of PV and A/C as it has likely the highest residential penetration of PV systems in the world (over 15% of Australian households in 2015; [6]) while 75% of Australian households have air-conditioning [7].

All Australian DNSPs are now regulated under a revenue cap, or soon will be,[3] which means that approved expenditure can be recouped through tariff settings that are adjusted if and as revenue rises or falls [8–11]. This situation is similar to that in the US [3] and the EU [2], where most network utilities are subject to some form of revenue cap, although the exact nature of each regulatory environment of course differs, sometimes significantly, with some jurisdictions including aspects of price cap regulation [12,13]. A key implication of revenue cap regulation is that customer actions that decrease or increase their electricity bills, or network costs, may impact on the revenue that will

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[1] The acronyms used is this paper are defined as follows: A/C, air conditioning; ACT, Australian Capital Territory; AER, Australian Energy Regulator; AUD, Australian dollar; CER, Clean Energy Regulator; DNSPs, distribution network service providers; DUOS, Distribution Use of System; ESAA, Energy Supply Association of Australia; GST, Goods and Services Tax; IPART, Independent Pricing and Regulatory Tribunal; kVA, kilovolt amps; kW, kilowatt; kWh, kilowatt hour; LRMC, Long Run Marginal Cost; MWh, megawatt hour; NEM, National Electricity Market; NSW, New South Wales; O&U, overs and unders'; PV, photovoltaics; SWH, solar water heater; TNSPs, transmission network service providers; TOU, time-of-use; TUOS, Transmission Use of System; WAPC, Weighted Average Price Cap.
[2] Also called Distribution Network Operators (DNOs), Electricity Distribution Businesses (EDBs), as well as other similar names in different countries.
[3] With the exception of ActewAGL, which is regulated under an average revenue cap [73].

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be collected from all customers. Thus, although A/C may increase network costs, this cost is spread over a greater sales base. Vice versa for PV, where it may decrease network costs, and this benefit is spread over a smaller sales base.

Network costs and tariffs have received considerable attention in Australia over recent years. Very large increases in network expenditure, argued to be necessary primarily due to peak demand growth, were the main driver of a near doubling in residential tariffs over a period of five years. The role of A/C in this, and the significant subsidies paid by customers without A/C to those that have it, received some attention [14,15]. However, this period also coincided with rapid uptake in net-metered household PV, which reduced DNSP revenue, and the resulting potential cross-subsidy received arguably far greater attention from regulators and DNSPs. This debate focused almost exclusively on direct financial impacts and so ignored the fact that PV can provide indirect benefits to all customers (as discussed in Section 2), whereas A/C provides benefits only to customers who own them.

As discussed in Section 2, there is a large body of work on the social, financial and technical impacts of PV on system owners, utilities and society in general. The equivalent literature on A/C systems is much more limited, despite the fact that A/C may have a more significant impact on other customers than PV. It is this gap that this paper seeks to address.

The paper is organised as follows: Section 2 provides background on the financial analyses reported to date on PV and A/C, with a focus on their impacts on other stakeholders. Section 3 describes in detail the methodological approach used here, including the conceptual framework. Section 4 presents the results for the impacts of A/C and PV, as well as sensitivity analysis of four different variables. Section 5 discusses the results and Section 6 presents the conclusions and policy implications.

2. Background

There are many studies in the literature that assess the value of a PV system to its owner and hence commercial attractiveness (e.g. [16–18]), and other studies assess such aspects as PV's wholesale value [19] and potential impact on wholesale market prices [20–24], technical impacts on the electricity network [25,26] and market operation [27,28], the lifecycle impacts on society in general [29], the generation capacity value of PV [30,31], and the broader societal value of avoided conventional electricity generation, avoided line losses, reduced emissions and employment and health benefits [21,32–37].

The literature on the financial impacts of A/C has tended to focus on electricity costs for owners, their contribution to network demand peaks and hence network investment, and how to reduce such impacts (for example [38–46]), and the environmental impacts of A/C and possible mechanisms to minimise them (for example [47,48,39]).

2.1. Impacts of PV and A/C on other customers

As PV uptake has increased, it has started to negatively impact the revenue of utilities in a number of countries: for example in the United States [49–51,3], throughout Europe [52,53,2] and in Australia [54]. These impacts vary by regulatory and market arrangements, and the nature of any PV policy support. Of particular focus in our study are network revenue impacts associated with net-metering of PV rather than arrangements where utilities are providing explicit support to PV systems through special FiTs or equivalent.

In Australia there has been widespread calls by DNSPs and some regulators that owners of PV systems should pay a 'self-consumption' charge or 'solar tax' because owners of PV systems are not paying their fair share of network charges [55–57]. Even while network operators were regulated under a weighted average price cap (WAPC, explained in more detail in Section 3.5), and so could not increase tariffs to recoup income lost because of PV during the current regulatory period, they still claimed that PV was increasing costs for other customers [58]. As an increasing number of studies focus on the impacts of PV on utilities, some have also taken the step of considering how these impacts then impact on utility customers. Key work most relevant to this paper is summarised below.

Oliva and MacGill [59] assess the value of PV electricity to owners, retailers[4] and DNSPs, and Borlick and Wood [50] estimate the difference between the PV customer benefits and utility costs, however neither assess the subsequent impacts on other customers. Wang et al. [18] assess the financial impact of distributed energy resources (DER) owned by commercial customers on what they term Load Serving Entities (LSE), that both sell electricity and operate the network. Although they assess the impact of DER on the LSE's wholesale purchase costs, they do not include any benefits from reduced network peaks, and again do not convert this into an impact on other customers. Cai et al. [60] use an approach that is similar to that reported here in that they calculate the cost to utilities of reduced revenue due to PV adoption, and include a method to incorporate this impact into the size of retail tariffs required to maintain utility revenue. However, they do not allow for any peak load reduction benefits of PV nor do they convert the revenue impacts on utilities into an annual bill impact for customers, but instead calculate how the tariff changes affect the rate of adoption of PV.

The papers that do assess the impact of PV on the broader customer base would seem to use quite approximate methods to estimate these impacts. Eid et al. [2] approximate the impacts on all customers of 20% of customers installing PV systems by simply dividing the reduced income to networks by the total number of customers, which does not account for the diverse impact on different types of customers nor the impacts that PV can have on network costs. Satchwell et al. [3,4] reports on what appears to be the most detailed attempt to quantify the impact of PV on utilities and therefore on customers. Their focus is primarily on the impact on utilities and their shareholders and so they use a sophisticated utility model derived from the Benefits Calculator that was originally constructed for the National Action Plan on Energy Efficiency. However, the model has limited granularity when assessing the impact of PV uptake on customers. It performs all calculations at the total utility level, and does not differentiate among rate classes or between customers with and without PV. This means it cannot assess the impact on different types of customers, nor the level of cross subsidisation between customers. The impact of PV was based on an annual generation figure multiplied by a percentage uptake, and PV's ability to reduce demand peaks was incorporated through an assumed percentage reduction at the network-wide level, with no financial value assigned to peak demand reduction (e.g. $/kW). The model was also limited to a single type of tariff.

Estimates of the impacts of A/C on all customers are scarce in the academic and broader industry literature. This is certainly the case in Australia, despite the fact that network expenditure accounted for about 50% of electricity price increases in Australia from 2007 to 2012,[5] with the bulk of the increased network expenditure being attributed to A/C [61,5]. The exceptions to this are by the Productivity Commission (an Australian Government body, [14]), the Energy Supply Association of Australia, ESAA) [55] and a report by the authors of this paper [62].[6]

The work presented here presents a framework for assessing PV, and other customer choices such as A/C, on an equivalent basis with regard

[4] The term retailers in Australia is broadly equivalent to suppliers in the European context

[5] In Australia, residential electricity prices increased by 70% in real terms between 2007 and 2012 [14,15]. Over the following two years prices increased further, in part due to the introduction of a price on carbon, and have moderated since then [5]. Electricity prices also increased in European countries, although by much less than in Australia, with the average increase from 2009 to 2011 for the EU-27 being 12.2% (households) and 8.7% (industry) [84]. Average electricity prices in the United States over the same period increased very little, with residential increasing by 2.7% and commercial by 1.9% [85].

[6] This paper is based on the methodology developed for this report.