Renewable and Sustainable Energy Reviews 76 (2017) 932–940

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Residential energy efficiency and distributed generation - Natural partners or competition?

Sebastian Oliva H.[a,b,*]

[a] Instituto de Investigación Multidisciplinar en Ciencia y Tecnología, Universidad de La Serena, La Serena 1720170, Chile
[b] University of Technology Sydney, Institute for Sustainable Futures, Sydney, NSW 2007, Australia

ARTICLE INFO

Keywords:
Cost-benefit analysis
Energy policy
Solar photovoltaics
Energy efficiency

ABSTRACT

Residential energy efficiency and distributed generation seem to be natural partners in our journey towards a more sustainable energy future. A growing range of energy efficient consumer technologies and extraordinary declines in photovoltaics system prices has seen household electricity demand fall whilst a growing proportion of the remaining load is provided by household self-generation. Australia is a particularly interesting example of these developments, with around 15% of households now possessing a PV system while per-capita household demand has also fallen markedly. However, existing retail electricity tariffs and regulatory arrangements can create mixed incentives for households contemplating both PV and energy efficiency options and for their network service providers. This is certainly the case in Australia with net metering arrangements that value self-consumption of PV far more than PV exports to the grid. There are also complex benefits for the electricity network created by these household energy resources that can be significant. In this paper we use real household load and PV data from Sydney households to model the potential implications of existing electricity tariff arrangements on the financial attractiveness of PV and energy efficiency. We model these options separately and in combination for both households implementing these options and their network service providers. Our results highlight how inappropriate tariffs may well adversely impact on the value that the combination of energy efficiency and PV offers not only to households, but also to their network service providers, and suggest ways that such impacts might be ameliorated by acknowledging the benefits that these resources can offer to the electricity network.

1. Introduction

Growing concerns about the potentially catastrophic damage of climate change [1–3] and increasing energy security challenges in many jurisdictions around the world [4,5] have pushed governments to find more sustainable ways to generate electricity. Distributed Energy Resources (DE) are modular energy technologies, installed and operated by disperse electricity customers, that can contribute considerably to achieving these goals [6–8]. Typical DE systems include renewable energy technologies and energy efficiency measures. Both offset fossil fuel generation and offer a more flexible and therefore more secure energy supply. Hence, most governments worldwide have designed numerous policies to promote the deployment of DE resources such as distributed photovoltaics (PV) and Energy Efficiency (EE) [9–11]. PV and EE have been seen in this way as key partners for a more sustainable energy future [2,4].

The result of these policy efforts has been the remarkable growth of deployment of distributed PV and EE measures in recent years. PV world capacity has grown from 40 GW in 2010 to 180 GW in 2014 [9] while PV costs have fallen dramatically in the last decade [12–14]. Concurrently, a growing range of EE products have been made available for the residential and the commercial sector. This has driven a large deployment of EE measures including in the building and appliance sector [15]. This sector is key as it accounts for one third of global energy demand mainly in the form of electricity. In particular, significant advances have been achieved in the development of more efficient heating and cooling systems and other household appliances. This has contributed to improving building performance standards and

Abbreviations: ADV, Annual Deferral Value; AEMC, Australian Energy Market Commission; DE, Distributed Energy Resources; DISCOs, Distribution Companies; EE, Energy Efficiency; FiT, Feed-in Tariff; IEA, International Energy Agency; ISF, Institute for Sustainable Futures; LCOE, Levelised Cost of Energy; NEM, Australian National Electricity Market; NM, Net Metering; NSP, Network Service Provider; NOM, Network Opportunity Maps; NSW, New South Wales; PV, Photovoltaics; SR, Support Required; TOU, Time of Use Tariff; US, United States; ZS, Network Zone Substation

* Correspondence address: Instituto de Investigación Multidisciplinar en Ciencia y Tecnología, Universidad de La Serena, La Serena 1720170, Chile
E-mail address: sjolivah@gmail.com.

http://dx.doi.org/10.1016/j.rser.2017.03.083
Received 11 July 2016; Received in revised form 20 January 2017; Accepted 16 March 2017
1364-0321/

to reducing global energy intensity, that is, primary energy consumption per unit of economic output [9,16,17]. In this way, PV and EE have also become competitors over the last decade, as they both offer cost-effective sustainable energy for consumers and governments.

In many jurisdictions this large DE deployment has created significant benefits as well as costs to society and key electricity industry stakeholders. The impacts of PV have been widely studied in the scientific literature [18–21]. We have also explored these PV impacts in the Australia context [22–25]. Examples of the economic benefits that PV and EE can create include avoided energy generation and environmental costs, and avoided network investments from the centralised energy supply. For customers with DE, benefits include lower electricity bills, however this also translates to a revenue reduction for electricity retailers and network businesses. The magnitude of the benefits of PV and EE can differ greatly depending on the specific characteristics of their installation and operation. As such, PV and EE can also be seen as competitors not only from a cost perspective but also from a benefit generation perspective.

Australia has the highest per-capita deployment of distributed PV in the world [26]. In Australia, generous feed-in tariffs (FiT), in conjunction with Federal Government support and falling PV prices, led to the deployment of around 5 GW of small-scale distributed PV [27,28]. As a result, 15% of Australian households currently own a PV system [29,30]. A significant proportion of this PV deployment has been undertaken under net metering (NM) arrangements and Time-of-Use (TOU) tariffs, where households first self-consume the PV generation and then export any excess to the grid.

Research has proven that this PV deployment under NM has created significant benefits and costs to Australian electricity customers and to the monopoly regulated Network Service Providers (NSPs) – known as DISCOs or DSOs in other industries – [31–35]. A particularly concerning impact of PV deployment has been noted on the NSP's reduced ability to recover regulatory revenue as a result of declining electricity sales. As a result, this revenue fall is finally recovered from electricity tariff increases which ultimately increase the cost of electricity for customer. This issue has also been experienced in other jurisdictions with high PV penetration including the US, Spain and South Africa [21,36–39]. This issue is exacerbated by EE, which also reduces demand for electricity. However, it has been argued that these negative impacts are not caused by DE itself and are rather symptoms of a bigger issue, which is highly simplified volumetric electricity tariffs that do not reflect the time and location-varying cost of electricity supply [38,40,41].

There are potentially strong financial interactions between PV and EE from a household and NSP perspective, which are closely linked, and which have not been studied in the past. With NM, Australian households value self-consumption of PV far more than PV exports to the grid [25]. Thus, adding EE resources to reduce household demand can potentially lower the household PV revenue. This is a clear threat to the PV return and therefore can be strong space of competition. From the NSP perspective, it is relevant to study not only the revenue fall from lower electricity sales, but also the potentially significant value that PV and EE could provide to defer or avoid network investments.

The expenditure of the electricity network has been a topic of great concern in Australia in recent years. Investments in the Australian National Electricity Market (NEM) for the sole purpose of managing the network peak demand rose to around $75 billion in the last decade. This has more than doubled electricity bills for consumers [42]. In this period, demand peaked and then declined in part due to the deployment of DE. In response, a series of policy reforms have been proposed recently to promote more optimal DE deployment that helps to manage the peak demand [43]. They include the amendment to the 'Distribution Network Pricing Arrangements' which will require NSPs to develop more cost-reflective network prices based on their long run marginal cost [44]. Another policy is the 'Demand Management Incentive Scheme' which aims to reward NSPs that implement efficient demand management [45]. These reforms are still under development and the way they will be implemented will be key to achieve their policy goals [42].

In summary, there are important financial interactions between residential PV and EE that have not been studied in the past and therefore are not well understood. There are also complex links between the benefits and costs of PV and EE for the households installing them and their NSPs. In this article, we study specifically two key financial impacts of household PV and EE resources that are strongly linked: 1) the impact on the operational short-term revenue for households and NSPs, and 2) the NSP financial savings as a result of deferred network investments. Other areas of value of PV and EE, such as the avoided wholesale energy and environmental costs of centralised fossil fuel plants, are not addressed in this article.

The organisation of the paper is as follows: In Section 2, we review existing research assessing the value of PV and EE and their possible interactions. The methodology used for our study is presented in Section 3, and the data we used is outlined in Section 4. Section 5 presents the combined revenue impacts of PV and EE whilst Section 6 shows the deferral value of PV and EE. Finally, Section 7 presents some conclusions of the study and thoughts on future work.

2. Previous research on the value of PV and EE energy resources

The simplest way to assess the competition between PV and EE energy resources is to compare their costs. Works such as [46,47] have assessed the Levelised Cost of Energy (LCOE) of different energy technologies including PV and EE, and have shown that the LCOE of EE is generally around half the LCOE of PV. However, LCOE is a limited metric since it does not capture the time and location-varying benefits that DE resources can create for both society and industry stakeholders [12,48–50]. Thus, more sophisticated and granular methodologies have been developed that capture the diverse values of DE.

Many existing granular studies have estimated the social and private value of distributed PV systems. Societal valuations have estimated diverse social benefits such as avoided wholesale energy, power losses and environmental costs, and deferred network investments [24,51–53]. They have shown that benefits can be significant and very context-specific. Private valuations have assessed the value of PV for customers investing in PV under different net metering arrangements, tariff structures and metering technology, for the residential and the commercial sector [19,25,54–64].

Far less research has investigated the financial value of EE investments. Diederen et al. [65], Papadopoulos et al. [66], Adan and Fuerst [67] and Choi et al. [68] have assessed the value of EE in the context of building renovations and other industrial applications. However, we have not found granular economic modelling of efficient residential appliances in the existing literature.

A small body of important recent literature assessing the impacts of DE deployment on NSPs was found. Satchwell et al. [21] estimated the revenue fall from PV deployment for electricity utilities in the US and found modest tariff increases for all customers. However, Satchwell et al. [21] also shows that the impacts vary considerably depending on the specific operating and regulatory environment of each utility. In a second work, Satchwell et al. [36] explores different possible measures to mitigate this revenue fall and concludes that they involve significant trade-offs between industry stakeholders and other policy goals. Blackburn et al. [39], Eid et al. [37] and Mayr et al. [38] have also found significant revenue fall for electricity utilities and have proposed diverse solutions. Eid et al. [37] shows that in Spain the revenue fall is