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Assessing the impact of solar PV on domestic electricity consumption: Exploring the prospect of rebound effects

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ABSTRACT

This study examines patterns of electricity use by households in Sydney who have installed solar photovoltaic (PV) technology compared to those who have not in order to assess the impact of government solar incentive schemes, and to identify whether conservation or rebound (increased consumption) effects are associated with rooftop PV. Findings have significance in determining whether a rebound effect needs to be factored into projected energy/carbon savings from solar PV installation. At issue is the robustness of carbon mitigation estimates included in future rounds of international climate change agreements as well as local forecasts of future electricity demand affecting the national grid. Analysis and modelling was undertaken on billing data for the period 2007–2014 on a representative sample of 4819 households. The sample comprised three groups: households who were early adopters and installed PV under a 60 c/kWh gross feed-in tariff scheme, a group who installed under a 20 c/KWh gross feed-in scheme and a control group with no PV. Econometric modelling undertaken on energy consumption behaviour of households with versus without local renewable energy generation revealed that on a kWh basis, the rebound effect is estimated to erode up to one fifth of the carbon benefit of renewable energy generated by solar PV.

1. Introduction

An energy transition is now a clearly established global goal for the 21st century, with the UNFCCc (2016) in collaboration with 197 nations assembled in Paris for COP21, endorsing a framework agreement within which such a transformation is possible. Within this framework, each sovereign nation creates policies designed to significantly reduce their own greenhouse gas (GHG) emissions over the medium and long term. Regular reporting on emissions and actions taken to meet nationally established targets represent an important part of this agreement. In Australia, energy, emissions and climate policy continues to be a fraught area politically, given the strength of the protective regime that has grown up around the country's major fossil fuel related industries since the mid 20th century: coal mining for export and for local power generation. However, the weight of scientific evidence internationally (IPCC, 2013) and within Australia (BoM, 2016) in relation to the future disruptive impacts of climate change is now clear. Also, recent public opinion surveys suggest that three quarters of Australians believe climate change is occurring, with 60% agreeing that climate change is being driven by human induced industrial and urbanisation-related activities which have been rapidly accelerating over the past 70 years (Climate Institute, 2016; Steffen et al., 2015); and 90% indicate that responsibility for policy and action rests primarily with the federal government.

At the UNFCCC's COP21 Conference, Australia confirmed its emissions reduction target of 28% on 2005 levels by 2030 (DEE, 2016). Many countries are developing 2050 plans to help guide long term planning and decision-making by investors and the community, but in Australia only state governments have committed to longer term targets to date; for example, New South Wales, Victorian and South Australian governments have all committed to net zero emissions by 2050.

Renewable energy has a central role to play in this energy transition in Australia, but currently accounts for less than 6% of national energy supply (DIIS, 2016). In an attempt to stimulate supply of clean energy, the Australian government introduced (in 2009) its renewable energy target (RET) of 20% of national electricity generation by 2020 (www.cleanenergyregulator.gov.au) – a significant increase over the initial target of 2% established in 2001. In January 2011 the RET was split into two parts:

- A large scale RET – focused on incentives to establish solar farms, wind farms and hydro-electric power stations; and
- A small scale RET – with incentives for rooftop solar PV, small scale wind, hydro and solar water heating

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Table 1
Representative state government feed-in tariff schemes for domestic small scale solar PV.
Source: www.solarspec.com.au

State	Schemes and dates	FiT rate (cents/kWh)	Duration of scheme
NSW	1/1/2010–31/10/2010	60	31/12/2016
	1/11/2010–28/4/2011	20	31/12/2016
Victoria	1/11/2009–31/12/2011	60	31/12/2024
	1/1/2012–31/12/2012	25	31/12/2016
	1/1/2013–31/12/2015	6.2	31/12/2015
	1/1/2016-	5	Current
Queensland	1/7/2008–9/7/2012	44	1/7/2028
	10/7/2012–30/6/2014	8	From 1/7/2015 succeeded by FiTs offered by retail market

In an attempt to directly stimulate consumer uptake of small scale rooftop solar systems, state governments became active participants in solar incentive schemes directed at households. Here state governments offered purchasers of solar PV units a guaranteed feed-in tariff (FiT) as an incentive payment for electricity fed into the national grid. This marked the emergence of distributed generation as a significant force in the decarbonisation of low density housing in Australian cities (Newton and Newman, 2013).

There was initial uncertainty at what level the FiT should be set. This is illustrated in Table 1, where the initial FiTs in all states were set as mandatory government rates at what could be classed as premium or subsidy levels. The rationale for subsidies in this context has been advanced by Loynes (2014) as:

- Compensating for the higher prices of solar PV that operated at the time
- Growing a local PV industry
- Encouraging electricity consumers to be more energy conserving and reduce carbon emissions
- Promote diversification and decentralisation of energy production

Government reviews after the first 12–18 months of operation of the 'solar bonus' schemes resulted in significant reductions in subsidised FiTs, followed shortly thereafter with shifts of all FiTs for new PV installations to market rates offered by electricity retailers.

The impact of these government incentives for installing rooftop solar were dramatic, as Fig. 1 illustrates.

The most recent report from the Clean Energy Council of Australia (2016) reveals that small scale (< 100 kW) rooftop solar installations rose from 3500 units nationally in 2007 to a peak of over 350,000 in both 2011 and 2012; creating a total installed capacity of over 4000 MW, and representing 16% of total clean energy generated in Australia in 2015.

With a reduction and subsequent removal of government subsidies in this area, annual levels of new PV installation have declined(in the state of New South Wales that includes Sydney, from *a* peak of 80,000 systems in 2011 to 30,000 in 2016; Clean Energy Council, 2017). This is at a stage when governments overseas and in Australia are setting long term (commonly 2050) targets for net zero emissions, in line with UNFCCC objectives. To achieve this level of decarbonisation will require a cocktail of policies ranging from replacement of coal-fired power stations by a mix of gas, wind farms and solar thermal plants, realising significant energy efficiencies in electrical products, buildings, transport and city design, and endeavouring to instill persistent energy conservation behaviours in the general population. Each sector of the economy needs to develop a roadmap for transitioning to net zero emissions that embraces these key elements (ASBEC, 2012; Berry and Davidson, 2015). A roadmap for decarbonising the Australian housing sector has been articulated by Newton and Tucker (2011) and is represented diagrammatically in Fig. 2. The modelling underpinning this study underlines the critical importance of an above average energy efficient building shell (a minimum 5 star rating in the Australian Building Code – below which progression to a zero carbon dwelling was found to be unattainable) and energy efficient built-in appliances in providing the necessary platform for achieving net zero emissions. They are not of themselves sufficient, however. Solar PV represents the second critical contextual element for decarbonised housing. Energy conservation behaviour on the part of dwelling occupants cannot be relied upon in contemporary consumerist high income societies to deliver emissions reductions, given the size of the attitude-action gap that currently exists in the population (Newton and Meyer, 2013, 2016).

With the future trajectory of rooftop solar PV diffusion uncertain, given the removal of what have been considered to be generous direct government incentives to consumers (GSES, 2016), it is important to understand the impact that installation of PV up until 2015 has had on electricity demand as well as in emissions reduction. The take-up and use of solar PV needs to be understood in terms of the behavioural response of households in relation to electricity consumption. Rebound has been found to be associated with all energy efficiency innovations to date, and the question that this study explores is whether a rebound effect is associated with households that install solar PV (in this case, under government subsidised feed-in tariff schemes).

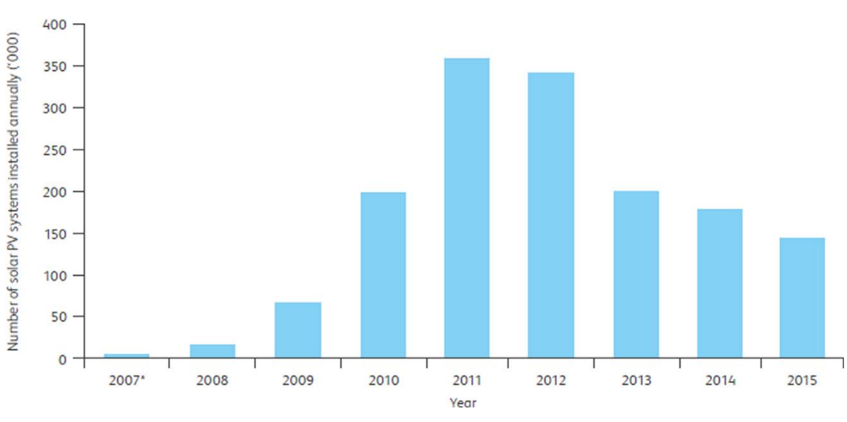

Fig. 1. Annual solar PV installations, Australia 2007–2015; Source: Clean Energy Council of Australia (2016).