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Power to change: Analysis of household participation in a renewable energy and energy efficiency programme in Central Australia

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HIGHLIGHTS

- Households adopting solar hot water systems reduced total electricity usage by 10%.
- Households adopting photovoltaic systems reduced total electricity usage by 34%.
- 15% rebound effect in electricity usage by adopters of photovoltaic systems.
- Excluding renewable energy no significant reduction in average electricity use.

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ABSTRACT

The Australian government funded a national Solar City program (2008–2013) to support communities to increase adoption of energy efficiency measures and renewable energy technology. One community was Alice Springs, a town with about 9000 households in the geographic centre of Australia. The programme offered a package of support: free energy audits, discounts for the purchase of renewable energy technology and energy efficiency measures, and ongoing information. Households that adopted solar hot water and photovoltaic systems reduced their electricity usage immediately after adoption by 10% and 34% respectively, and this was maintained in the long term. A small rebound effect of 15% was observed in the photovoltaic adopters. It was observed that, on average, households that adopted only energy efficiency measures did not have a significant reduction in their electricity usage over the long term. However, consistent with expectations, this study did show that there was a significant correlation between the number of energy efficiency measures adopted and the greatest household reduction in electricity usage. These contrary results indicate that there are additional factors involved. The connection between the effective use of measures, coincident behavioural change or increased energy awareness and greater energy reduction is discussed.

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1. Introduction

Access to affordable energy is central to maintaining a functioning economy and standard of living. In the five years from 2007 to 2012, the average electricity price to households in Australia increased by 60%, although this trend moderated during the most recent years (Australian Electricity Market Commission, 2014). The cost of energy infrastructure was viewed as the primary reason for price increases in Australia (CSIRO, 2013). Increasing the efficiency of Australia's use of energy and developing sustainable sources of renewable energy are viewed as important strategies for safeguarding energy supplies for households (PM Task Group on Energy Efficiency, 2010). Australia has one of the most carbon-intensive economies in the world (PM Task Group on Energy Efficiency, 2010, p. 15); electricity generation alone (mainly from the combustion of coal and natural gas) comprises 33% of Australia's greenhouse gas emissions (Department of Environment, 2014). Therefore, Australian energy prices are highly sensitive to any

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policy changes to limit or price carbon emissions – both domestically and internationally.

Residential energy efficiency has been a topic of interest since the energy crisis in the 1970s. Despite the technological innovations and education programmes, household energy use continues to rise in developing countries (IEA, 2007). This is in contrast to recent experience in Australia, where a decline in electricity consumption has been observed, a trend which is forecast to continue (or be stable) over the next few years (Australian Electricity Market Commission, 2014). Today the common concern is energy generation, and its contribution to climate change and threats to biodiversity (Gardner and Stern, 2002). Therefore, the use of energy within the household, particularly enhancing energy efficiency, remains an important area of public policy.

In light of the importance of energy conservation, the Australian government initiated a major investment in renewable energy and energy efficiency in June 2004, through the national Solar Cities program (Zahedi, 2010). Through national, local and consortium members, this programme generated combined investment of A$280 million into a programme that covered seven cities across Australia, with the objective of supporting communities to rethink the way in which they produce and use energy (Wyld Group, 2011). Alice Springs, a town in the Northern Territory (NT) which is at the geographic centre of Australia, is one such city. In March 2008 the Alice Solar City (ASC) program was launched and based there. The ASC program had funding of A$42 million and operated from March 2008 to June 2013 (Alice Solar City, 2014). ASC received financial support through a funding agreement between Alice Springs Town Council and the Australian Government as part of the national Solar Cities programme, as well as financial and in-kind contributions from a consortium of public and private organisations. ASC was focused on changing energy production and use across three types of buildings: residential, commercial and iconic. The ASC support for residential (household) buildings included three main elements: solar renewable energy (RE) technologies, energy efficiency measures (EEMs) and load management measures. ASC sought to address these elements through a variety of methods, including energy audits, education, financial incentives, rewards for participation and community engagement. In total, A$14m was spent across the RE technologies and EEMs on offer. This was subsidised 35% by the ASC programme. A list of RE technologies and EEMs offered by the programme is listed in Appendix 1. RE technologies formed the major component (87%) of the financial expenditure.

The location of this programme, Alice Springs, is a remote town (>1400 km from a major city of $>100{,}000$ people) with a population of 25,186 people and 9163 households (ABS, 2011). It has a diverse economy (for example, government support services, mining, tourism) and is a major service town for many small, remote communities and settlements (<1000 people) within a 500 km radius. The climate is reflective of semi-arid conditions with hot summer temperatures: it has a mean daily maximum temperature above 30 °C for six months of the year (Bureau of Meteorology). Not surprisingly, household electricity consumption is cooling dominated as people rely heavily on air-conditioners to cool indoor temperatures during the extended summer period. There is a sole provider of electricity in Alice Springs, Power and Water Corporation (PWC), and 38% of the total electricity demand for Alice Springs is residential (Alice Solar City, 2013a). This remote community was a good location for a pilot trial exploring residential efficiency and RE technology adoption. This paper explores the programme's effect on electricity usage from the utility provided mains grid. It explores the adoption of RE technologies in detail and also examines the impact of other aspects of the programme (including informational and adoption of EEMs).It examines the impact of adopting RE technology over the short and long term, and the economic parameters involved. The paper also explores the characteristics of households that did not adopt RE technology and the predictors of the greatest change in electricity usage.

Residential solar energy has experienced rapid growth in Australia over recent years due to reductions in the costs of technologies and supportive government policies. Like other renewable energy generation, solar energy generation benefits from fiscal and regulatory incentives; including tax credits, feed-in-tariffs, low cost loans and subsidies. The increase in adoption of solar energy technology in Australia is reflected internationally, as the global photovoltaic (PV) capacity increased from 1.4 GW in 2000 to 40 GW in 2010, with an average annual growth rate of around 49% (Timilsina et al., 2012). The growth of solar technologies is attributed to policy support in Germany, Italy, United States, Japan and China (DeVries et al., 2007). Despite the increasing rate of PV adoption, there is often a mix of barriers to its widespread adoption (technical, economic and institutional). Technical limitations include low conversion efficiencies and storage issues (IEA, 2006). Economic barriers relate to initial system costs, financing, uncertainty about ongoing payments for electricity, and potential charges for PV systems to export electricity produced. Institutional barriers refer to existing laws and regulations, metering and billing issues, availability of trained people to install systems, and public misperceptions, knowledge and attitudes (Jacobson and Johnson, 2000; Goldman et al., 2005). Studies have found that reducing these barriers will increase the adoption of RE technologies by more of the population and across demographics (Drury et al., 2012; Faiers and Neame, 2006; Niemeyer, 2010).

A key economic consideration is the electricity tariff. The total cost of electricity to the household is an important determining factor in consumer behaviour toward renewable energy and energy efficiency programmes (Bor, 2008; Howarth and Andersson, 1993; IEA, 1997; Scott, 1997). Economic theory suggests that the demand for electricity is related to the total cost of electricity to the householder (Oikonoumou et al., 2009; Poortinga et al., 2003; Sandstad and Howarth, 1994). In simple terms, the total cost of electricity is determined by several factors, including fixed supply and demand related charges together with unit cost (tariff), volume consumed and volume generated by the household. According to conventional economic logic, electricity demand will fall as electricity prices increase if other factors are constant.

However, adoption of RE technology can confound consumer behaviour, such as when a rebound effect occurs as households increase electricity usage due to the electricity savings made from adopting RE technologies-which may have been promoted to reduce household electricity consumption (Berkhout et al., 2000). This paper applies the calculation of a direct rebound as described by Berkhout; that is, the percentage of energy saving improvement initiated by the technological improvement that is offset by increased energy consumption. The direct rebound effect is caused by income and substitution effects. Income effects are caused by energy efficiency improvements that lower the household electricity bill, increase the real income of the household and permit increased consumption of all goods and services. The substitution effect examines how households may shift their financial consumption patterns of electricity from other non-energy activities when the relative cost of electricity has decreased, even if their real income is constant. (Oikonomou et al., 2009). Greening and Greene (1998) reviewed 75 studies of the rebound effect. They found consumers adopting EEMs experienced the following rebound effects: space cooling devices, 0–50%; residential lighting, 5–12%; and water heating, 10–40%. This indicates the rebound effect can be quite pronounced.

The predictors of adopting renewable energy systems or undertaking EEMs have been extensively studied; however, no definitive predictors have been identified. The literature on residential energy efficiency and renewable energy adoption tends to focus on

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