

Report

CR001

2015

Enhancing household energy efficiency in central Australia: Analysis of the Alice Solar City initiative

Lisa Havas

Digby Race



Australian Government
Department of Industry and Science

Business
Cooperative Research
Centres Programme



Citation

Havas L and Race D. 2015. *Enhancing household energy efficiency in central Australia: Analysis of the Alice Solar City initiative*. CRC-REP Research Report CR001. Ninti One Limited, Alice Springs.

About the authors

Based in Darwin, Lisa Havas is a Research Fellow on the Climate Change Adaptation and Energy Futures project with the CRC-REP and Charles Darwin University. Lisa's research interests are in understanding the drivers and the effective mechanisms to ensure efficient uptake of energy-efficient and renewable energy technologies.

When based in Alice Springs, Digby Race was a Principal Research Leader with the CRC-REP. Digby's research interests relate to the socio-economic dimensions of development for rural and remote communities.

Acknowledgement

The authors would like to thank the following people for their contributions to the research on which this report draws and/or their comments on a draft version of this report:

- Chris Penna, formerly Alice Solar City and Alice Springs Town Council
- Sam Latz, formerly Alice Solar City and Alice Springs Town Council
- Mike Rowell, Alice Springs Town Council
- Julie Ballweg, Charles Darwin University.

The Cooperative Research Centre for Remote Economic Participation receives funding through the Australian Government Cooperative Research Centres Program. The views expressed herein do not necessarily represent the views of CRC-REP or its Participants.

For additional information please contact

Ninti One Limited
Communications Manager
PO Box 3971
Alice Springs NT 0871
Australia

Telephone: +61 8 8959 6000 Fax: +61 8 8959 6048 Email: communications@nintione.com.au

www.nintione.com.au

© Ninti One Limited 2015. Information contained in this publication may be copied or reproduced for study, research, information or educational purposes, subject to inclusion of an acknowledgement of the source.

**Enhancing household energy efficiency in
central Australia:
Analysis of the Alice Solar City initiative**

Lisa Havas

Digby Race

Contents

Executive summary.....	v
1. Introduction.....	1
1.1 Adoption of RE technologies by households.....	1
1.2 The National Solar Cities program	3
2. Enhancing household energy efficiency in central Australia.....	4
2.1 Adapting to the future	5
2.2 Predicted changes to the climate	5
2.3 Economic framework.....	5
2.4 Improving the comfort of homes	7
3. The Alice Solar City Initiative.....	8
3.1 Households participating in the Alice Solar City initiative	10
3.2 Photovoltaic installations	11
3.3 Solar hot water	12
3.4 Energy efficiency measures	12
3.5 Alice Springs electricity usage during the ASC program	12
3.5.1 Trends in electricity usage in the Alice Springs control group.....	14
4. Research results	15
4.1 Socio-economic and demographic characteristics of PV adopters in the ASC.....	15
4.1.1 Income.....	16
4.1.2 House style and size	18
4.1.3 Household composition	20
4.1.4 Level of highest educational attainment in the household	21
4.1.5 Energy consumption and production	22
4.2 Financial effectiveness of the adoption of EEMs	22
4.2.1 Methodology – calculating financial effectiveness.....	23
4.2.2 Results – payback periods and IRR	24
4.2.3 Discussion – payback periods and IRR.....	29
4.3 Change in electricity usage for the adoption of RE technologies and EEMs	30
4.3.1 Study sample	31
4.3.2 Data analyses	31
4.3.3 Short-term change in electricity usage.....	32
4.3.4 Long-term change in electricity usage	33
4.3.5 Long-term predictors of greatest household electricity reduction	34
4.3.6 Discussion – change in electricity usage.....	34
5. Summary	37
Appendix 1: EEV adoption and expenditure	40
Appendix 2: Summary of kWh and GHG savings by EEMs supported by EEVs in ASC	41
References.....	42

Tables

Table 1: Profile of participant households in ASC	10
Table 2: Solar hot water summary	12
Table 3: Summary of EEVs issued and used in the ASC program	13
Table 4: Tariff changes that occurred throughout the ASC program.....	14
Table 5: Binary logistic regression results	16
Table 6: Annual household income	16
Table 7: Family and household composition for different populations	21
Table 8: Daily average energy consumption and production (kWh)	22
Table 9: Adoption of EEMs summary	25
Table 10: Short-term change in electricity usage.....	33
Table 11: Long-term change in electricity usage.....	33

Figures

Figure 1: Locations of the Solar City initiatives	4
Figure 2: Flowchart of ASC's residential component.....	9
Figure 3: Timeline of household participation in ASC	10
Figure 4: Histogram of appliance data	11
Figure 5: Timeline of ASC PV installations	11
Figure 6: Electricity demand of Alice Springs residential households, excluding ASC customers (rolling yearly average of ADC of control group throughout the ASC program)	14
Figure 7: Annual household income	16
Figure 8: Likelihood of PV early adopter by income band.....	17
Figure 9: House style	18
Figure 10: Likelihood of PV early adopter by house style	19
Figure 11: Likelihood of PV early adopter by number of bedrooms.....	20
Figure 12: Likelihood of PV early adopter by level of highest educational attainment	21
Figure 13: Energy consumption and production of PV early adopters	22
Figure 14: Product life and unincentivised and incentivised payback periods	26
Figure 15: Unincentivised and incentivised IRR	27
Figure 16: IRR vs. adoption of EEMs.....	28
Figure 17: IRR vs. net household expenditure on EEMs.....	28

Shortened forms

ADC	average daily consumption
ASC	Alice Solar City
CDU	Charles Darwin University
EEM	energy efficiency measures
EEV	energy efficiency vouchers
GHG	greenhouse gas
IRR	internal rate of return
LGA	Local Government Area
NPV	net present value
NT	Northern Territory
PWC	Power and Water Corporation
PV	photovoltaic
RE	renewable energy
SHW	solar hot water

Executive summary

This research study has analysed the implementation of energy efficiency measures (EEMs), solar renewable energy (RE) technologies and behaviour change initiatives brought about by the Alice Solar City (ASC) initiative. ASC was part of the Australian Government's Solar Cities program, which trialled a range of innovative and sustainable energy solutions between 2008 and 2013.

Households that registered for ASC received a home energy audit, from which a number of EEMs were recommended. Some of the EEMs were financially incentivised by ASC through energy efficiency vouchers (EEVs), which contributed to the cost of, among other things, households adopting photovoltaic (PV) technology or a solar hot water (SHW) system. Demographic information and data about household energy consumption were collected from participating households during their involvement in the program.

This study analysed the database repository of this information to discover the characteristics of ASC participants and what effects their participation in ASC and the EEMs they adopted had on their long-term energy use. The study found that households in freestanding houses, with fewer bedrooms, were more likely to be PV early adopters. The next strongest predictor of PV adoption was education level, with higher levels more likely to take up the technology. Demographic variables such as Aboriginal or Torres Strait Islander status, number of residents and the presence of children or the elderly in the household were only weakly correlated with PV adoption. There was a weak trend of increasing PV adoption with increasing income, which indicates that policy is best directed to the larger middle-income groups, which are only slightly less likely to take up PV energy, but who still have a greater effect on the total energy system.

The most heavily adopted EEV was SHW, with 908 participating households taking up the incentive from ASC and this resulting in a 10% fall in their energy use across the time they were in the program and over the longer term. The incentive for the PV was capped at 277 households, and that number was reached. This measure resulted in a net fall in electricity use of 34% for those households while they were in the program; this fall was also sustained over the longer term. The net change in energy use due to the PV system can be split into its components of energy production and energy consumption; in the long term, households increased their energy consumption by 6%, which was more than offset by the energy their PV system produced. This rebound effect of 15% observed for PV adopters (where a decrease in price results in an increase of consumption) is at the smaller range of rebounds observed in other studies. No rebound effect was observed for SHW adopters.

Economic analysis conducted showed that adoption of EEMs was not based on economic rational principles, with some heavily adopted EEMs having very long payback periods or negative internal rate of return. However, some EEMs were highly financially effective, if targeted to the appropriate households. The range of investment returns and the popularity of different incentivised EEMs offered through the program clearly indicate that economic effectiveness is only one consideration in EEM adoption. Other important considerations are popularity of product, perceived improvement in comfort, absolute up-front cost and support provided for the EEM adoption.

There was no statistically significant impact on electricity usage due to either the customer signing up to the ASC program or obtaining a personalised home energy audit. Overall, long-term change in energy use due to the ASC program was a net fall of 10%; a significant component of this is the adoption of PV and SHW. When these two items are excluded, the net fall in energy use due to participation in the ASC was

3%. While this 3% fall is not statistically significant when taken overall, some of the EEM-only adopters did have statistically significant reductions in energy use.

It is because these significant reductions are possible at the individual level that the program found that enhancing the ‘energy intelligence’ of motivated residents appears to be a critical prerequisite in the process of increasing energy efficiency of households. Carefully designing a package of small yet complementary changes can be an effective adaptation to improve the overall liveability for people in central Australia, particularly those living in remote communities. Understanding what drives different households to adopt RE technology will better inform strategies to ensure greater precision, and therefore effectiveness, in the targeting of future programs.

1. Introduction

Adoption of renewable energy (RE) technologies and energy-efficient products and practices by households has been widely promoted by Australian governments during the past decade as a means of reducing reliance on grid-supplied energy and shifting energy use outside peak periods. Widespread adoption of RE technology by Australian households would ease pressure on existing energy infrastructure, reduce carbon emissions and reduce household energy costs. However, there is limited understanding of the adoption of RE technology and the extent to which this technology has altered and led to sustained reductions in energy consumption. The Alice Solar City (ASC) initiative was an important investment by the Australian Government and partner organisations during 2008–2013 to promote innovative and sustainable energy technology among urban households.

The Cooperative Research Centre for Remote Economic Participation (CRC-REP), in partnership with Charles Darwin University (CDU), undertook an in-depth analysis of the implementation of energy efficiency measures (EEMs), solar RE technologies and behaviour change initiatives brought about by the ASC initiative. As part of its normal operations, the ASC assembled a comprehensive database on the energy technology and usage of its ~2800 participating households (approximately 30% of households in Alice Springs), yet did not have the resources or expertise to fully analyse the database during its period of operation. The CRC-REP and CDU have worked cooperatively with the Alice Springs Town Council to analyse the ASC database, which is documented in this report.

1.1 Adoption of RE technologies by households

Recent research has revealed a strong correlation between socio-economic and demographic characteristics with household energy usage. That is, higher household income, larger houses (floor size) and fewer household members correlate with higher energy use per capita (Lenzen et al. 2006, Newton & Meyer 2012). For example, higher income households are likely to contain more appliances than households with lower incomes, with one study showing that there has been a substantial increase in energy consumption due to the increasing use of a range of home entertainment and kitchen appliances (Taylor et al. 2010). However, households with young children (<5 years of age) and older members also correlate with higher energy use (Brooks & Yusuf 2009).

The predictors of adopting RE systems or undertaking EEMs have been extensively studied; however, no definitive predictors have been identified. The literature on residential energy efficiency and RE adoption tends to focus on household behaviour (Abrahamse et al. 2005), economics (Howarth et al. 2000), or policy (Levine et al. 1995, Varone & Aebischer 2001). An earlier study into demographic characteristics found that adopters of solar energy systems were younger and more highly educated, with higher incomes (Labay & Kinnear 1981). This finding is consistent with more recent studies that found that home owners and people with higher incomes and homes with a pool were more likely to adopt EEMs and RE technologies (Sdiras & Koukios 2004, Kaldellis et al. 2005, Mills & Schleich 2009). However, another study found that there is a weak relationship between the adoption of RE technologies or EEMs and income and education levels of households (Mills & Schleich 2008). Others have reported that the type of engagement, goal setting and feedback on performance has an effect on short-term change in energy use (Harding & Hsiaw 2012). Providing information alone to households is rarely an effective strategy (Van Houwelingen & Van Raaij 1989). This study observed no change in energy usage by participating households after program sign-up or energy audits. This is similar to a study of Canadian households in the ENEVERSAVE program, which found that when one group of participants received tailored information

and another group received general advice, there was no difference in energy usage after two years (McDougall et al. 1983). Other studies have found that household audits had mixed results, with some households using more energy after the audit (McMakin et al. 2002), or there being no effect from a program from the initial sign-up stage (Abrahamse et al. 2005).

A challenge for policymakers and researchers is to better understand the drivers that influence the adoption of RE technologies and changes in behaviour leading to energy efficiency. There is also uncertainty about the link between pro-environmental attitudes and beliefs and subsequent changes in household behaviour that lead to reduced use of grid-supplied energy. Understanding the particular drivers for different socio-economic groups of households will inform strategies to promote and support adoption of appropriate technology and changes in behaviour. For instance, some of the complexity of this topic is that provision of credible information tends to result in higher levels of knowledge, but this does not necessarily translate into behavioural changes towards energy efficiency. Also, financial rewards and incentives generally lead to energy conservation, but tend to be short-lived. Personalised regular feedback on household energy usage has been found to be valuable in shifting household behaviour towards greater energy efficiency (Abrahamse et al. 2007).

Some of the important drivers to encourage households to become more energy conscious identified in the literature are given below:

- A core component to conserving energy is the individual's beliefs in the importance of energy conservation and the belief that they can make a difference (Abrahamse & Steg 2009, Gadenne et al. 2011). A significant constraint, even if the belief or attitude is positive or can be changed to positive, is changing household habits (De Vries et al. 2011).
- Households may not be aware of the implications of their behaviour on their energy use, and information or knowledge can bring about a reduction in energy use if there are no other barriers to change (Gatersleben et al. 2002, CSIRO 2009, Akter & Bennett 2011, Heinzle & Wüstenhagen 2012). However, the literature says that while information will increase knowledge, information on its own may not bring about the desired reduction in energy usage if other barriers exist.
- General monetary incentives have been found to result in a reduction in energy usage. However, the major criticism is that the change in behaviour can tend to be short-lived (Abrahamse et al. 2007). Another way to create efficiencies across the system and result in less need for infrastructure is to have users change the time they use electricity, without requiring an overall reduction in use. A shift in pattern of energy use can be generated by monetary incentives (Gottwalt et al. 2011).
- Household energy conservation is constrained by the lack of awareness around the use of electricity in the home. By providing feedback and increasing awareness of actual use and cost of electricity, energy conservation can be increased. In-house meters increase awareness in a continuous and frequent manner (Hargreaves et al. 2010, Willis et al. 2010, Paetz et al. 2012).
- Prevailing social norms and community views are an important foundation for sustained community-wide adoption of increased energy efficiency behaviour.

A combination of policies and investments to encourage adoption of RE technologies and EEMs is one strategy to encourage behavioural changes in households. Studies found that a policy instrument is likely to be adopted if administration exists to help minimise costs of implementation, the policy targets appropriate groups willing to implement changes, and the technology and market structure exist for implementation (Varone & Aebischer 2001). Energy efficiency programs with high levels of public engagement tend to provide households with goal setting, information, rewards and feedback (Abrahamse

et al. 2005, Harding & Hsiaw 2012). Households are more likely to engage with energy efficiency programs if they have identified environmental concerns and ‘green living’ among their energy goals (Harding & Hsiaw 2013). Smaller, more educated households are more likely to opt-in to energy efficiency programs, but the key to long-term participation for these households appears to be identifying non-binding, realistic goals (Abrahamse et al. 2005, Harding & Hsiaw 2012). So, while household size and income level may be useful guides to spontaneous (unassisted) adoption of energy efficiency practices by households, these factors may become less important if well-designed household engagement strategies are followed and retail energy prices are causing cost-of-living pressure.

This research in part sought to explore the extent to which the findings published in the literature were consistent with the experience of the ASC.

1.2 The National Solar Cities program

The Australian Government initiated a major investment in RE and energy efficiency in June 2004, through the national Solar Cities program (Zahedi 2010). This program generated combined investment of \$280 million through national, local and consortium members into a program that covered seven locations across Australia. Solar Cities was administered by the former Department of Climate Change and Energy Efficiency, with seven locations selected for the program: Adelaide, Alice Springs, Blacktown, Central Victoria, Moreland, Perth and Townsville (Figure 1). The individual projects trialled a mix of technologies, including solar hot water (SHW) and photovoltaic (PV) technology, energy efficiency, load management, smart meters and cost-reflective pricing in large-scale grid-connected urban sites (ASC 2014).

The objectives were to support communities to rethink the way they produce and use energy (Wyld Group 2011) and to:

1. demonstrate the economic and environmental impacts of integrating cost-reflective pricing with the concentrated uptake of solar, energy efficiency and smart metering technologies
2. identify and implement options for addressing barriers to distributed solar generation, energy efficiency and electricity demand management for grid-connected urban areas.



Figure 1: Locations of the Solar City initiatives

Source: Solar Cities 2009

2. Enhancing household energy efficiency in central Australia

Central Australia is a unique place, combining an extraordinary climate with special landscapes, diverse peoples with rich cultures and remoteness from major cities. It is the traditional country to many Aboriginal peoples. The Northern Territory (NT) has a population of 230,000 that is spread over 1,350,000 square kilometres, an area over five times larger than the United Kingdom. The NT consists of two regions: a tropical Top End and a dry Central Australian region where Alice Springs is located. Alice Springs is at the geographic centre of Australia. It is a remote town (>1400 kilometres to a major city of >100,000 people), with a population of 25,186 people and 9163 households (ABS 2011).

Alice Springs has a diverse economy (e.g. 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 semi-arid, with hot summer temperatures (e.g. an average of 89 days per year above 35°C up to 2003, but projected to increase to more than 108 days per year by 2080; Suppiah et al. 2007). There are also predicted changes to the cost of conventional energy and the implications for communities in central Australia when this is linked with the projected change in climate (Stafford Smith & Cribb 2009, Maru et al. 2012). Understanding the nature of these interconnected changes will be critical to identifying strategies to reduce the intensity of climate change impacts and maintaining liveability in central Australia.

The sole provider of electricity in Alice Springs is Power and Water Corporation (PWC), and 38% of the total electricity demand for Alice Springs is residential (ASC 2013a). This remote community was a good location for a pilot trial exploring residential efficiency and RE technology adoption.

2.1 Adapting to the future

Effective adaptation to climate change implies making adjustments or changes to our lives that are sustained for a relatively long-term period or are permanent (Palutikof et al. 2013). Although making a number of small changes can often be easier for people than making a few large changes, it is uncertain whether this will be sufficient for people to maintain liveability in central Australia given the projected climate change. Even if a package of small changes leads to effective adaptation, we need to understand how the changes improve people's lives over the longer term (Maru et al. 2014) and whether people will be motivated to sustain the changes as part of their everyday lives.

Also, making a number of changes to the way people live and work in central Australia can be complex, because some of the changes may require purchasing expensive new appliances for homes (e.g. an energy-efficient fridge) or equipment for work (e.g. solar-powered water pumps), and so each change needs to be carefully assessed to ensure it provides the anticipated benefits and is positive to overall livelihoods. There is also a need to consider the accumulative effects of many small changes, to ensure small individual changes are complementary to other changes and lead to enhanced liveability (Adger et al. 2009, Grothmann & Patt 2005). For example, if a household installs several new air conditioners to cool their home on hot summer days, the daytime air temperature in the home may be more comfortable, but the household's electricity bills may increase. Exploring alternate and cheaper options to cool homes is likely to be a more effective adaptation to very hot weather, hence the interest and role of the ASC initiative.

2.2 Predicted changes to the climate

Climate scientists continue to report that much of Australia should expect a more extreme climate during this century (CSIRO & Bureau of Meteorology 2014). Climate research indicates that it is likely to become hotter in central Australia, and coastal northern Australia is likely to experience more intense storms (Climate Commission 2013). While researchers are not sure about the exact impacts of climate change on people living and working in remote areas of central and northern Australia, there are indications that heat stress and its flow-on effects will become more common, with symptoms being particularly severe for young children and elderly people (Addison 2013). Also, more intense storms are anticipated to cause flooding, increased illness and injury among residents; damage to infrastructure and housing; restricted road access; and degraded telecommunication, placing increased pressure on remote communities to be self-reliant for power and other essential resources.

2.3 Economic framework

In an economically rational framework, investment in EEMs by residential households requires, like all investment decisions, that householders balance the up-front costs against the potential future gains (Jaffe et al. 2004). Rising energy prices and increasing concern for energy security and global climate change has meant that energy efficiency programs for households have become a significant part of government policy (Prime Minister's Task Group on Energy Efficiency 2010). Australians have one of the highest levels of energy use per capita in the world (World Bank 2012). Much of the energy for households is derived from fossil fuels; Australian households therefore have a relatively high carbon footprint given current energy consumption, with CO₂ kg per capita emissions due to energy use by Australians (17,432) more than three times the world average (4504) (and much higher than the OECD average of 9948) (IEA 2013). Yet it is clear that residential households may not act within an economically rational framework (Bruderer Enzler et al. 2014, Levine et al. 1995, Sanstad & Howarth 1994, Scott 1997, Stephenson et al. 2010), making it

challenging to know how best to incentivise households to adopt EEMs. Given financial limitations faced by most governments, acquiring a better understanding of how residential households make their investment decisions in regard to EEMs should assist, refine and target current policies and future programs.

At the household level, energy prices are steadily increasing and adding considerable pressure to the cost of living. It is well established in the literature that socio-demographic variables are strong determinants of the level of energy use; however, this relationship has not been shown to hold for changes in energy use or the adoption of energy-efficient technologies (Brandon & Lewis 1999, Gatersleben et al. 2002). It is therefore important to further explore the drivers of energy use change and understand the outcomes of energy policies.

Despite a large range of energy-efficient products and opportunities for consumers to both reduce energy use and save money, adoption of energy efficiency options has been shown extensively in the literature to suffer from market inefficiencies (Levine et al. 1995, Jaffe et al. 2004, Mundaca et al. 2010). The literature discusses market failures in energy efficiency markets and how good policy can improve economic and energy efficiency. These market failures can be attributed partly to lack of information about, or good understanding of, the potential benefits and savings for consumers (Jakob 2006) and partly to uncertainty, which consequently leads to a demand for very high investment returns before energy-efficient products are adopted (Dubin & McFadden 1984).

Residential solar energy has experienced rapid growth in Australia over recent years due to supportive government policies and reductions in the costs of technologies. Like other RE 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 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 (De Vries 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 & 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 (Faier & Neame 2006, Niemeyer 2010, Drury et al. 2012).

A key economic consideration is the electricity tariff. The total cost of electricity to the household is an important determining factor in consumer behaviour towards RE and energy efficiency programs (Howarth & Andersson 1993, IEA 1997, Scott 1997, Bor 2008). Economic theory suggests that the demand for electricity is related to the total cost of electricity to the householder (Sandstand & Howarth 1994, Poortinga et al. 2003, Oikonomou et al. 2009). In simple terms, the total cost of electricity is determined by several factors, including 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). The work described here 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 consumption patterns of electricity 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.

2.4 Improving the comfort of homes

The level of physical and emotional comfort people have within their home closely corresponds to their personal health and ability to stay engaged in education and employment (Addison 2013, Nguyen & Cairney 2013). A lot of research has been done over recent years to design houses that better suit the climate of central Australia (ASC 2013b, Martel & Horne 2012, CAT 2013). Important aspects of a house design are ensuring it:

- reflects the needs of the occupants (e.g. appropriate number of bedrooms and bathrooms, adequate kitchen space and storage)
- is constructed and oriented to minimise the impacts of extreme weather (e.g. maximise insulation in roof and walls, shading from the afternoon sun during summer)
- is cost-effective to build and operate (e.g. recycled materials used where possible, windows can be opened for ventilation, secure screens used on doors and windows that allow people to feel safe yet allow for ventilation, minimise the energy costs for adequate cooling, heating and lighting)
- is linked to appropriate use of the surrounding yard and environment (e.g. shade trees planted to provide shelter from afternoon sun in summer, sufficient water tanks and taps to allow people to have ornamental and vegetable gardens).

Typical adaptation in remote communities in central and northern Australia is to rely on air conditioners during hot weather (Horne et al. 2013), or drive to distant locations to live with family before severe storms arrive (Mommott et al. 2013). However, the sharply increasing cost over the past decade for electricity (ABS 2013) has made these responses much more difficult for families. Businesses in central Australia are also heavily dependent on diesel and gas to generate electricity. People are therefore considering ways to improve the energy efficiency of homes and businesses and explore options for using RE (e.g. solar generated electricity). Some households and businesses that participated in the ASC initiative reported reducing their electricity consumption by 20% (ASC 2013b, Havas et al. 2015) and so were able to considerably reduce their operating costs – estimated to be a saving of \$300–400 per year for the average home in Alice Springs.

3. The Alice Solar City Initiative

Through the Solar Cities program, the ASC program was launched in March 2008 and was based in Alice Springs. This remote location gives us the ability to undertake the first comprehensive study in Australia of this kind. Alice Springs has the key attribute such a study requires, namely, an extensive government-incentivised energy efficiency program.

The ASC program had funding of \$42 million and operated from March 2008 to June 2013 (ASC 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 program, as well as financial and in-kind contributions from a consortium of public and private organisations. ASC's overarching goals were to explore how solar power, energy-efficient technologies and new approaches to electricity supply and pricing can encourage the residents of Alice Springs to become 'energy champions' and develop a sustainable energy future. The ASC support for residential (household) buildings included three main elements: solar RE technologies, 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, \$14m was spent across the RE technologies and EEMs on offer. This was subsidised 35% by the ASC program. A list of RE technologies and EEMs offered by the program is given in Appendix 1. RE technologies formed the major component (87%) of the financial expenditure.

The research undertaken by the CRC-REP and CDU was framed by the key research questions:

- What are the characteristics of participants in the ASC (for the different ASC technology options)?
- How effective in reducing reliance on grid-supplied power are the different renewable technologies or EEMs adopted via the ASC?
- To what extent has the ASC led to changes among the ASC participants?
- How transferrable is the ASC to populations beyond the Alice Springs urban area?

ASC was focused on changing energy production and use across the three key programs: residential, commercial and iconic buildings. The analysis conducted by the CRC-REP focused on the data from the residential component of the ASC initiative, which had approximately 2800 participating households, representing about 30% of Alice Springs households. On becoming an ASC participant, a household had a home energy audit, which, along with identifying energy-saving potentials, collected socio-economic and demographic data from the household. ASC staff identified specific EEMs that each household could undertake and provided financial incentives for these, as well as ongoing advice and general information for the life of the ASC. The ASC database recorded this household data, along with incentive uptake and energy use, and this formed the main data source for this research.

Figure 2 below is a high-level schematic description of the services offered to residential customers of the ASC. It also identifies some of the data collected by ASC which was subsequently used for analysis.

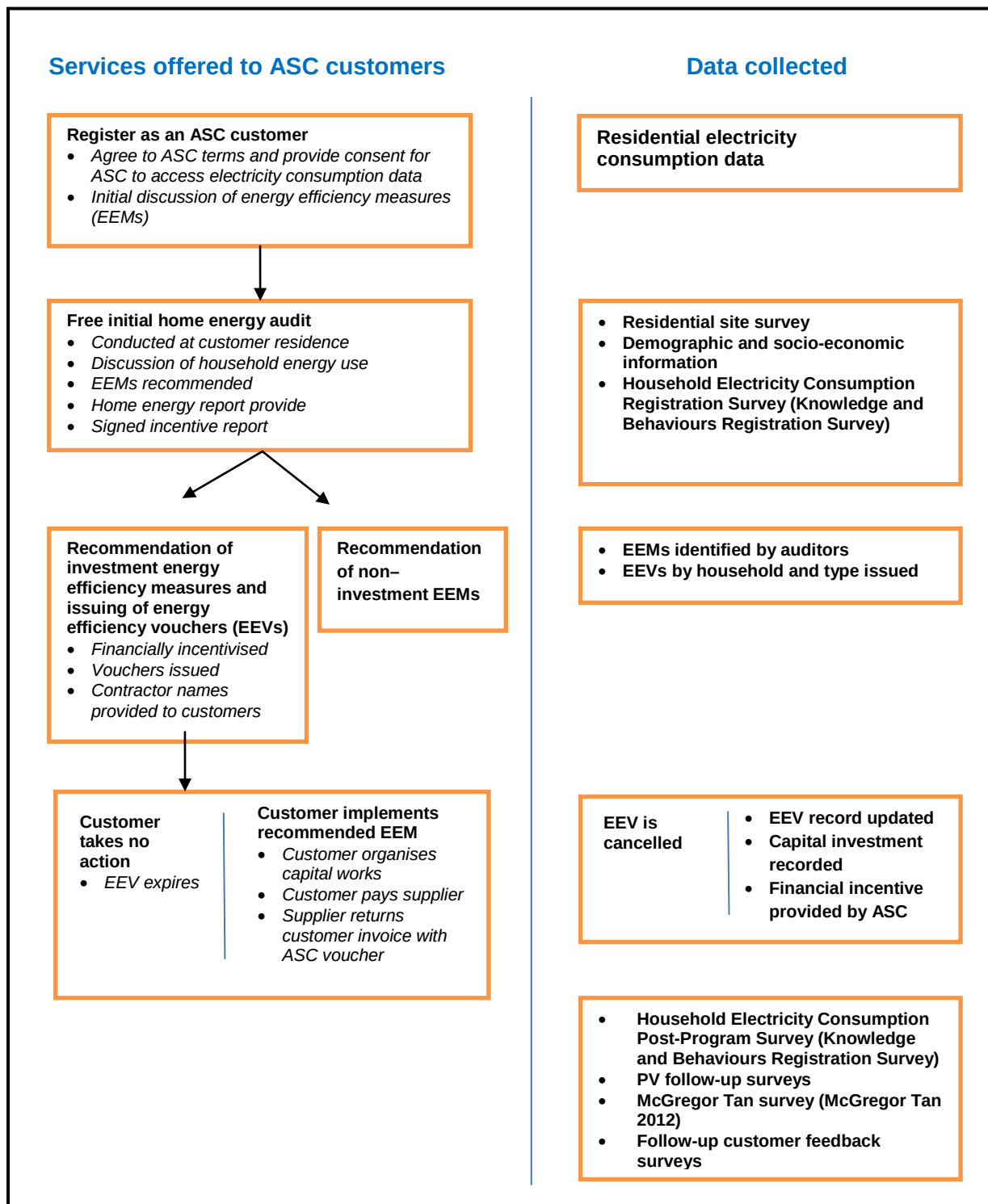


Figure 2: Flowchart of ASC's residential component

3.1 Households participating in the Alice Solar City initiative

A total of 2856 households registered as customers with ASC, representing about 30% of households in the Alice Springs Local Government Area (LGA). Alice Springs LGA has a population of 25,186 and has 9163 households (ABS 2011). A profile of participating households is presented below (Table 1). There was a marked increase in participation by households in the ASC from early 2009 to March 2010, with participation numbers continuing to rise through to September 2012 (Figure 3, below).

Table 1: Profile of participant households in ASC

Total registrations in program	2,856	
Landlords	158	6%
Owner–Occupier	2,504	88%
Rental tenant	194	7%
Home energy audit	2,687	94%
Offered EEV	2,489	87%
Adopted EEV	1,946	68%
Terminated	840	29%

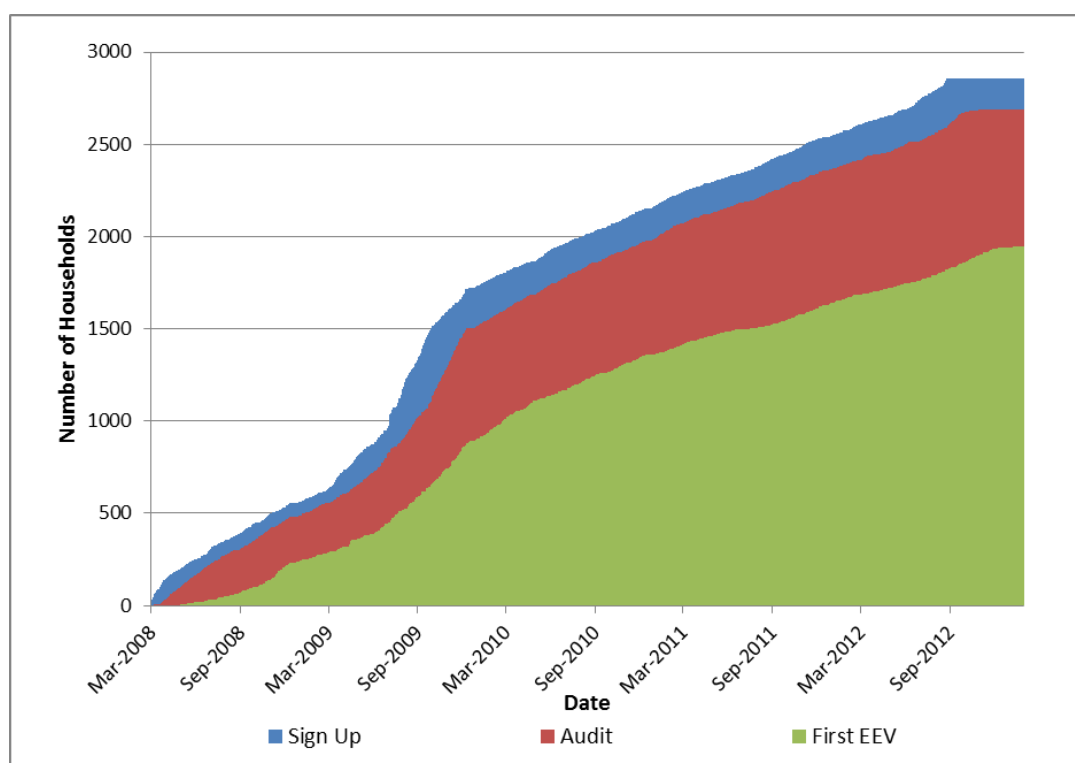


Figure 3: Timeline of household participation in ASC

Part of the data collected by ASC was comprehensive appliance data in the home. This appliance data is a comprehensive record of all energy-using appliances owned by the household, ranging from numbers of refrigerators, types and numbers of air conditioners to numbers of computers and laptops owned. Of the 2856 households, 88% (2525) had appliance data recorded. This comprehensive database of appliance data

can be explored further to understand the relationship of appliance ownership with energy use and changes in energy use.

A short summary of the data is provided here. A total of 91,288 appliances were recorded with a range of 5–109 appliances and a mean of 36. A histogram of the appliance count is shown below:

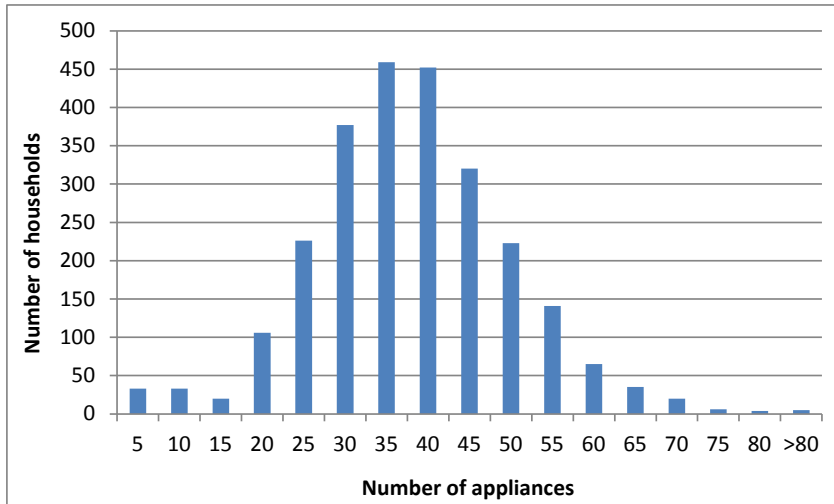


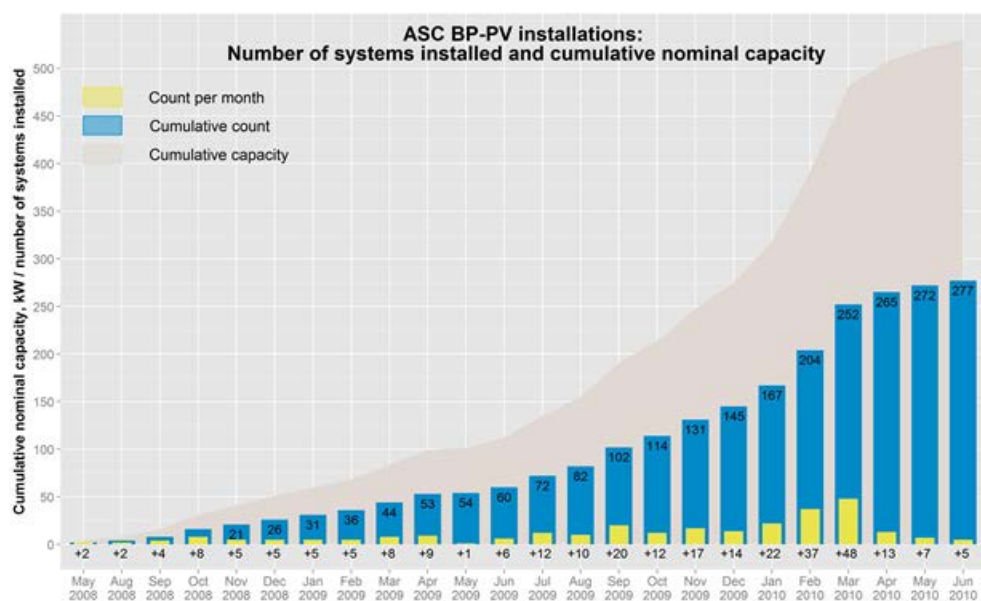
Figure 4: Histogram of appliance data

3.2 Photovoltaic installations

A cornerstone of the ASC residential program was incentivising PV installations on home rooftops. This component was the largest spend of the program, with ASC incentives totalling \$2.3 million of the \$6 million in total costs of installed PV.

The cumulative installations and capacity installed are shown below. The capacity of 531 kW is approximately 1% of the peak load experienced in Alice Springs at the time of mid-2010 (Figure 5).

Figure 5: Timeline of ASC PV installations



Source: ASC (2012)

Using baseline figures applied by the Australian Government's Office of Renewable Energy Regulator to calculate the generation amounts for Alice Springs, the annual generation of the 277 installations will be 860,844 kWh/yr, with 585,374 kg/yr of greenhouse gas emission reduction from the adopted rooftop PVs – equivalent to a total saving of \$233,547 per year, or about \$840 per year for each installation.

3.3 Solar hot water

SHW was the most heavily adopted EEV and contributes the largest kWh and greenhouse gas (GHG) reduction. There were 908 participating households that took up the SHW incentives from ASC, which covered approximately one-third of the cost. A short summary is provided below:

Table 2: Solar hot water summary

Number of systems installed	908
Total capacity – litres	267,105
Total cost \$	\$5,268,778
ASC cost \$ (percentage of total cost)	\$1,684,402 (32%)
Estimated electricity savings kWh/year	1,848,100
Estimated GHG reductions kg/year	1,256,708
Estimated financial savings/year	\$500,000

See additional details in Appendix 2

3.4 Energy efficiency measures

At the initial home energy audit provided by ASC, the auditor educated the householder about a range of EEMs that could be undertaken; many of these measures were not financially incentivised by ASC. Additionally, a range of EEMs were accompanied by a financial incentive, an EEV, which the ASC offered to participating households and which provided a discount on the purchase/installation of an approved EEM. A detailed list of the range of EEVs offered, used and the total cost involved is provided below in Table 3.

An estimation of the amount of energy saved by each of the EEVs on offer has been made (see Appendix 2). From this estimate we can extrapolate the kWh and GHG emissions that will be saved by the adoption of the EEMs. The EEMs supported by the ASC, using the EEVs listed above, have the potential to reduce residential electricity consumption by approximately 818,760 kWh/year (equivalent to a saving of \$222,130¹ per year by the participating households) and, in doing so, decrease GHG emissions by 556,757 kg/year, with these calculations presented in Appendix 2 (note: this analysis excludes PV and SHW installations, which are detailed separately).

3.5 Alice Springs electricity usage during the ASC program

It is important to understand the factors independent of the ASC program that were impacting on householders both within and outside the ASC program. To control for changes in electricity usage due to other influences, such as price and weather, the electricity usage of non-ASC households was recorded.

¹ Based on NT Power and Water Corporation's Domestic Standard Meter of \$0.2713 per kWh (without the fixed charge of 50.48 cents/day), applicable >1 January 2014.

Table 3: Summary of EEVs issued and used in the ASC program

EEV groups	Maximum incentive (\$)	EEVs issued	EEVs used	% converted	ASC incentive (\$)	Total cost (\$)	ASC contribution
Paint roof white	750	707	218	31%	122,934	362,759	34%
Replace old roof with new white roof sheeting	2,500	90	33	37%	62,134	215,555	29%
Install roof ventilation device	300	228	67	29%	12,857	37,688	34%
Install ceiling insulation – batts	750	241	39	16%	26,442	86,396	31%
Install ceiling insulation – loose fibre	1,500	5	2	40%	2,541	7,260	35%
Replace ceiling insulation – batts	1,000	34	4	12%	2,655	8,192	32%
Install bulk floor insulation	1,000	1	1	100%	750	5,214	14%
Retrofit insulation into walls	1,500	7	1	14%	1,478	4,224	35%
Replace high energy usage lighting with energy-efficient lighting	200	1,165	208	18%	11,663	45,097	26%
Replace 12V Halogen downlight system with low-energy option	350	427	112	26%	24,954	86,579	29%
Install motion sensors on external lighting	150	58	10	17%	855	2,908	29%
Tint windows	700	126	68	54%	26,219	76,832	34%
Install double-glazed windows (Insulated Glazed Units)	3,500	26	12	46%	23,386	76,982	30%
Installation of 'one shot' relay for SHW systems	150	296	111	38%	12,446	39,203	32%
Service of SHW system	200	435	210	48%	38,389	137,972	28%
Replacement of perished fridge/freezer seals	100	95	23	24%	1,677	5,125	33%
Service of evaporative A/C	100	741	411	55%	40,018	152,774	26%
Install external shading on walls/windows	1,000	397	181	46%	137,389	485,955	28%
Purchase swimming pool cover	350	407	234	57%	62,828	205,688	31%
Install thermal 'skin' over external walls	1,000	14	3	21%	2,424	9,543	25%
Supply and install variable speed pool pump	400*	85	51	60%	19,150	64,855	30%
Replace old refrigerator with a new, energy-efficient model	400*	92	53	58%	26,180	110,842	24%
Replace old freezer with a new, energy-efficient model	400*	11	8	73%	3,048	9,427	32%
Surrender old refrigerator or freezer	100*	58	50	86%	9,847	9,847	100%
Purchase swimming pool cover roller	150	77	44	57%	8,153	26,742	30%
<i>SHW</i>		1,294	908	69%	1,684,402	5,268,778	32%
<i>Solar PV</i>		300	277	92%	2,334,065	6,008,967	39%
Smart meter and In-house display for cost-reflective tariff		522	522		180,500	180,500	100%
10:10/20:20		339	339		39,623	39,623	100%
Totals		8,674	4,580	53%	4,919,007	13,771,527	36%

* ASC also organised and paid for de-gas and disposal of replaced and surrendered refrigerators/freezers, at a cost of \$108 per unit, which is included in EEM incentive for the total cost of the EEM to the ASC.

The NT's dominant power provider – Power and Water Corporation (PWC) – provided de-identified utility electricity consumption data for all residential households in Alice Springs, excluding ASC customers (that is, the electricity consumption of approximately 6800 households), over the period July 2006 to December 2012. There was some slight adoption of RE technologies in the control group, but the numbers are small enough to discount its impact on this study.

The data provided by PWC was the number of households, total number of days of electricity usage and total electricity usage. PWC also provided historical tariffs for Alice Springs.

The monthly electricity consumption data of the control group was converted to average daily consumption (ADC) per month, and a rolling yearly average was calculated. The rolling yearly averages created a series of control periods which were matched to each ASC customer individually. The control periods matched to the individual study samples act as a control for variations that occurred in Alice Springs due to tariff changes or weather conditions.

3.5.1 Trends in electricity usage in the Alice Springs control group

The rolling yearly average ADC for the control group is shown in Figure 6. Table 4 summarises the tariff changes that occurred for Alice Springs households during the life of the ASC program. These results show that the Alice Springs control group had sensitivity to electricity price. Over the period of the ASC program there was a downward trend in electricity usage from 24.71 kWh/day to 23.31 kWh/day, a fall of 5.7%. Over this time there was a total tariff rise of 44%. Notably there was a large fall in electricity usage in July 2009 following the largest incremental tariff increase of 2.79c/kWh (18%), and similarly following the July 2012 increase of 1c/kWh (10%).

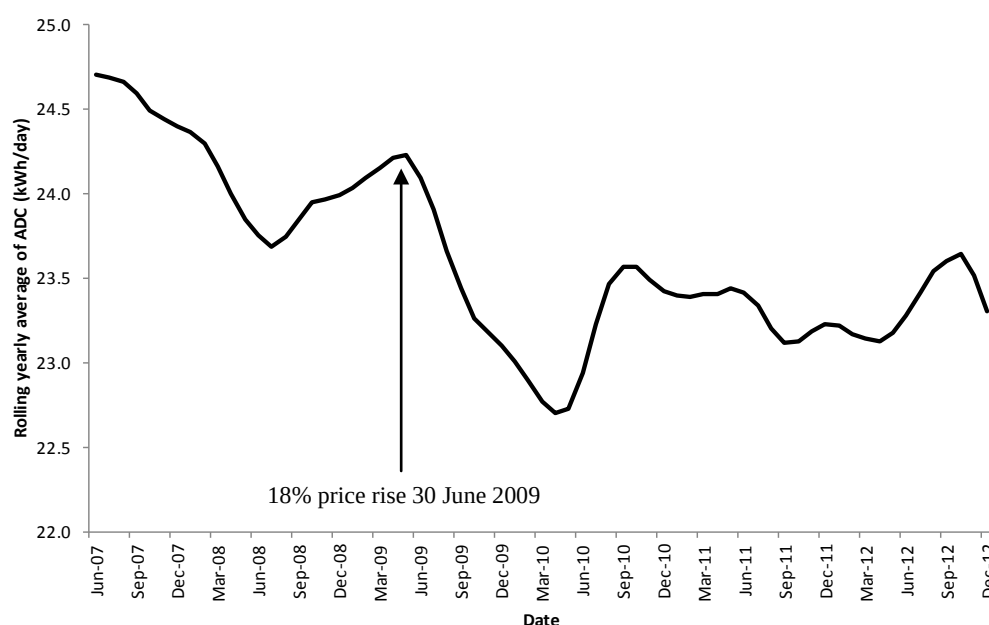


Figure 6: Electricity demand of Alice Springs residential households, excluding ASC customers (rolling yearly average of ADC of control group throughout the ASC program)

Table 4: Tariff changes that occurred throughout the ASC program

	July 2007 – June 2008	July 2008 – June 2009	July 2009 – June 2010	July 2010 – June 2011	July 2011 – June 2012	July 2012 – Dec 2012
Flat-rate tariff c/kWh	15.1	15.52	18.31	19.23	19.77	21.77
Incremental tariff rises		2.8%	18%	5%	2.8%	10%

4. Research results

The data analysis examined the following:

1. socio-economic and demographic characteristics of households that adopted PV through the ASC program
2. financial effectiveness of the adoption of EEMs
3. change in electricity usage after the adoption of RE technologies and EEMs.

4.1 Socio-economic and demographic characteristics of PV adopters in the ASC

The ASC collected socio-economic and demographic data from all its customers during a household energy audit. Up to 30 June 2012, ASC had 2043 households participating in their program (including those who dropped out – not shown on Figure 3). ‘Early adopter’ incentives were given to the first 277 households to install PV on their roof; this number was reached in the two years between June 2008 and June 2010. Nine of these 277 households have been excluded from the analyses due to missing socio-economic and demographic data. Additionally, customers of ASC granted permission to ASC to access their metering data; these data were used when analysing household energy consumption and production.

ASC also recruited a control group of households for the purposes of analysis and comparison. The control group was selected using two methods:

1. advertising, through which 59 households were attained
2. selection of a further 110 households who were ASC customers who did not partake further in the program after initial enrolment.

ASC collected the socio-economic and demographic data from the control group. Of the 169 households in the control group, 6 households were excluded from the analysis due to missing socio-economic and demographic data. The analysis may be biased by the second method of selecting the control group; they may have been pro-environmental households by virtue of enrolling in the ASC program and may not be representative of Alice Springs households. As an internal check of the control group data, the attributes in the control group were compared to the general Alice Springs LGA population for income groups and house style ($\chi^2=4.547$, $p=0.2082$, $\chi^2=0.6397$, $p=0.7263$). The control group and the general population did not differ in these attributes.

Australian Bureau of Statistics data from the 2011 census were used for descriptive statistics and comparative purposes. The census geographical area of Alice Springs LGA was used (ABS 2011). Descriptive statistics were used to summarise and cross-tabulate data for χ^2 tests of independence. Data were further analysed using the statistical software GenStat (VSN-International 2012). Because the response variable (adoption of PV or not) follows the binomial distribution, we modelled the socio-economic and demographic attributes of early PV adoption using a generalised linear model with a logit link function (i.e. logistic regression). The latter analyses compared the attributes of the 268 PV early-adopter households with the collected control group of 163 households.

Predictor variables were selected based on a review of the literature and also included the most useful variables for policy development. The predictor variables used were household income, level of highest educational attainment, house style, number of bedrooms, Aboriginal or Torres Strait Islander status,

number of residents and the presence of children or the elderly in the household. The full model (including all predictor variables as fixed affects) fitted well ($F_{13,345} = 3.670$; $p < 0.001$; see Table 5, below).

Table 5: Binary logistic regression results

Predictor variable	Wald statistic	chi. pr.
House style	19.961	<0.001
Level of highest educational attainment	5.028	0.081
Number of bedrooms	7.199	0.126
Aboriginal and Torres Strait Islander status	1.620	0.203
Income band	1.365	0.243

4.1.1 Income

Income was grouped into categories of annual household income (see Table 6, below).

Table 6: Annual household income

Annual household income (\$)	PV early adopter	Control group	Alice Springs LGA
0–50,000	7% (19)	20% (32)	24% (2220)
50,001–100,000	46% (122)	33% (53)	28% (2536)
100,001–150,000	31% (82)	27% (44)	21% (1910)
150,001+	12% (32)	12% (20)	12% (1125)
Unknown	5% (13)	9% (14)	15% (1372)
Total	100% (268)	100% (163)	100% (9163)

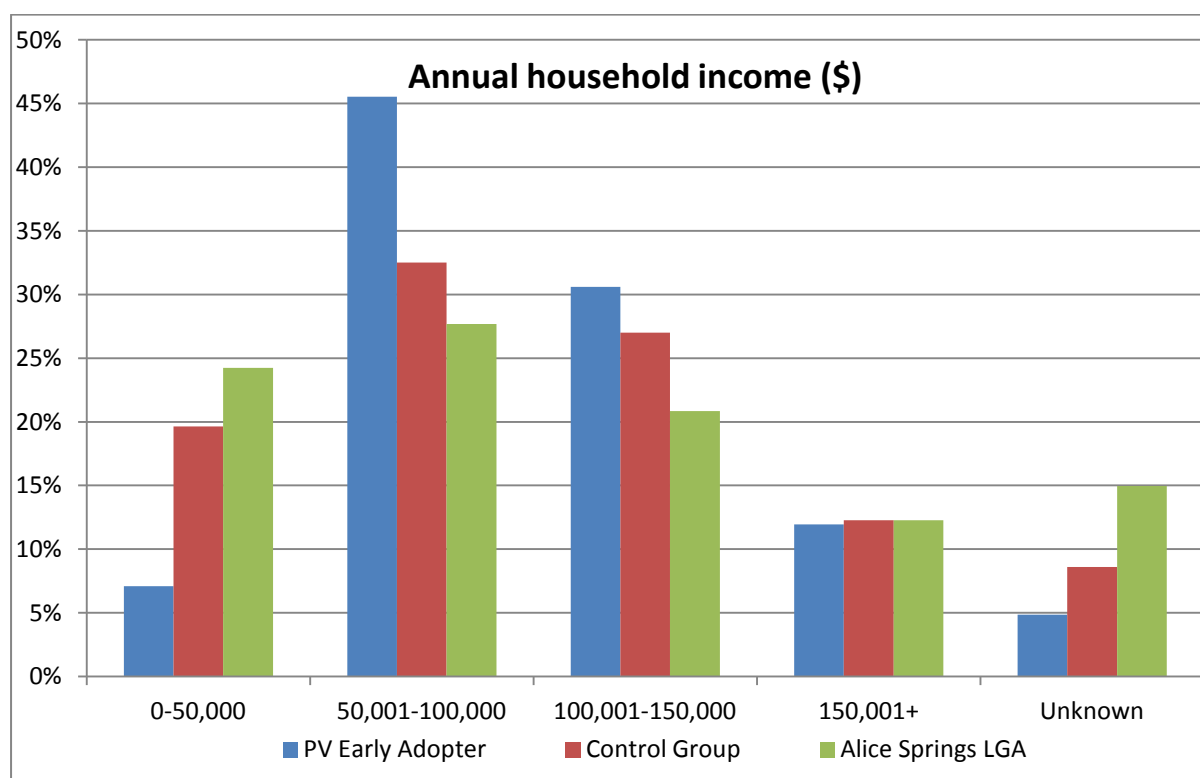


Figure 7: Annual household income

There was a significant difference in income categories between the PV early adopters and the control group ($p < 0.001$) and Alice Springs LGA ($p < 0.0001$). There was no statistical difference between the

income categories of the control group and the wider Alice Springs population. The lowest income group was significantly under-represented by PV early adopters, and the \$50,001–\$100,000 income group is well represented (Figure 7). The middle-income categories (\$50,001–\$150,000) had more PV early adopters than either the control group or Alice Springs LGA. Nevertheless, household income was not a strong predictor of early adoption of PV (Figure 8, below), and there was a weak trend only of increasing adoption with increasing income.

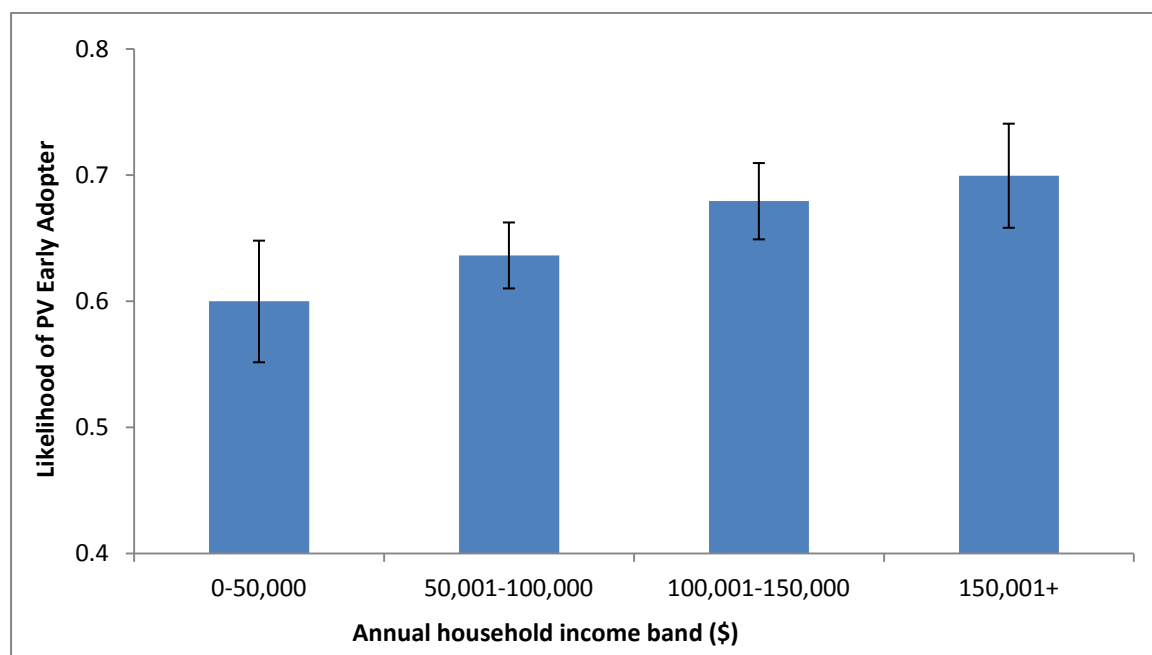


Figure 8: Likelihood of PV early adopter by income band

This result is interesting from a program perspective as it is somewhat counterintuitive. The gross expenditure on PV systems generated by the ASC trial was ~\$6 million. ASC provided direct cash subsidies of ~\$2.3 million to households, leaving a total aggregated investment by customers of ~\$3.7 million. This averages out at a cost per household of ~\$9000 (after netting off the value of Renewable Energy Certificates). This is a sizeable investment for households, and it is noteworthy that it is not highly dependent on income. A follow-up survey conducted by ASC in October 2011, where 37% of PV early adopters responded, found that only 31% had borrowed more than 30% of the value of their PV investment.

In general, higher income is strongly correlated with higher energy use (Lenzen et al. 2006, Newton & Meyer 2012). Higher income earners could be expected to more readily adopt RE options because there is more scope for adoption as they:

1. tend to be higher energy users
2. have sufficient disposable income to invest in RE technology.

However, this study found that higher income groups were not significantly more likely to adopt PV energy. This result is informative, as, although tending to be large energy users, high income households are a small group in number and therefore tend to be a small proportion of total energy use. As this group is not significantly more likely to adopt RE technology, this should inform policy when targeting

programs; it suggests that to achieve the greatest level of adoption of RE technology, households in the middle-income classes, representing approximately 50% of households, should be targeted most strongly.

4.1.2 House style and size

House style, as defined by the Australian Bureau of Statistics categories (ABS 2011), was a good predictor of whether a household was an early adopter of PV (Wald = 19.932, $P < 0.001$). PV was adopted mostly for separate houses and least adopted for apartment or semi-detached style houses (Figure 9).

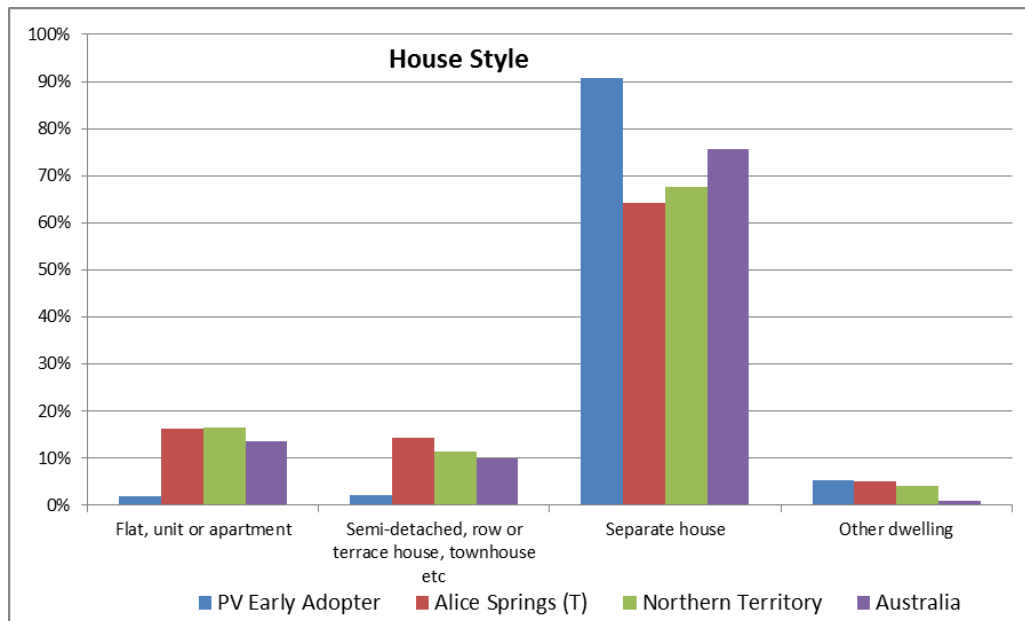


Figure 9: House style

In this analysis it was important to control for whether PV adoption was possible at the household residence. No households were included in the analyses where they were unable to install PV (such as mid-level flats). Households in a separate house were more than twice as likely to install PV as those in a semi-detached style house, which had more than three times the likelihood of PV adoption than eligible flats or apartments (Figure 10).

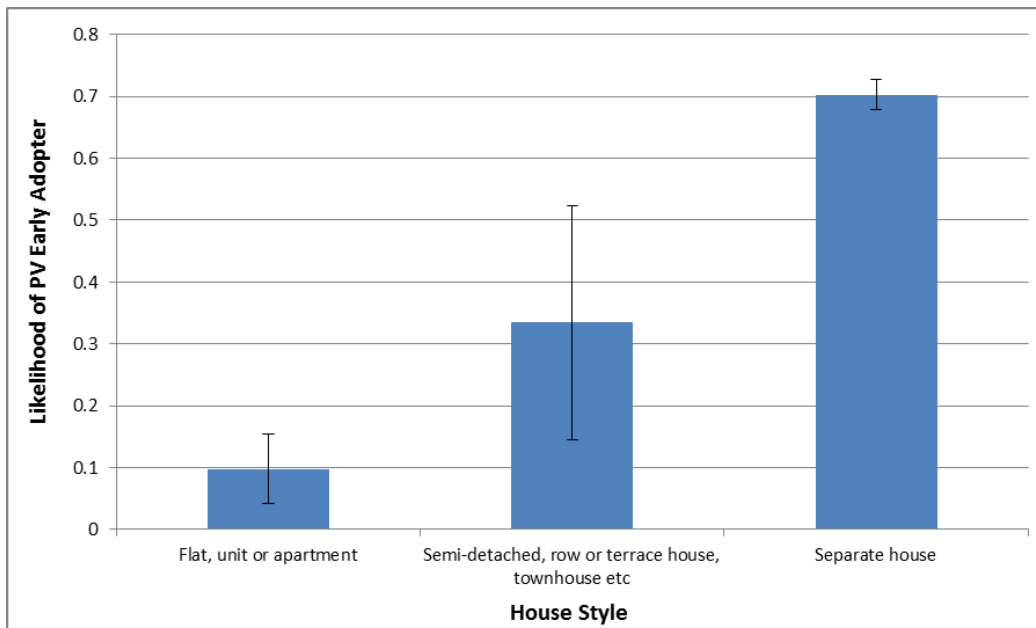


Figure 10: Likelihood of PV early adopter by house style

These ASC data illustrate an important area for reducing barriers to PV installation, because they include several cases of PV installed on apartments or detached houses where the barriers were significant. Considering that ~35% of dwellings in Alice Springs and 25% of dwellings in Australia are not separate houses, a review of the limitations for the other house styles may increase the market for PV installation. Perhaps body corporate or strata issues are a major impediment in apartment-style households to installing PV. While semi-detached or row houses should not encounter these issues, the sharing of roof space may make the coordination of PV installation a challenge.

The number of bedrooms also significantly influenced the likelihood of PV adoption (Figure 11). Households with fewer bedrooms were more likely to be a PV early adopter. This downward trend in PV adoption with increasing house size is contrary to the weak trend in rising income. The latter suggests that the amount of disposable income is an important determinant of early adoption of PV rather than wealth per se. Accordingly, financial incentives and financing options should strongly influence a household's decision to adopt PV.

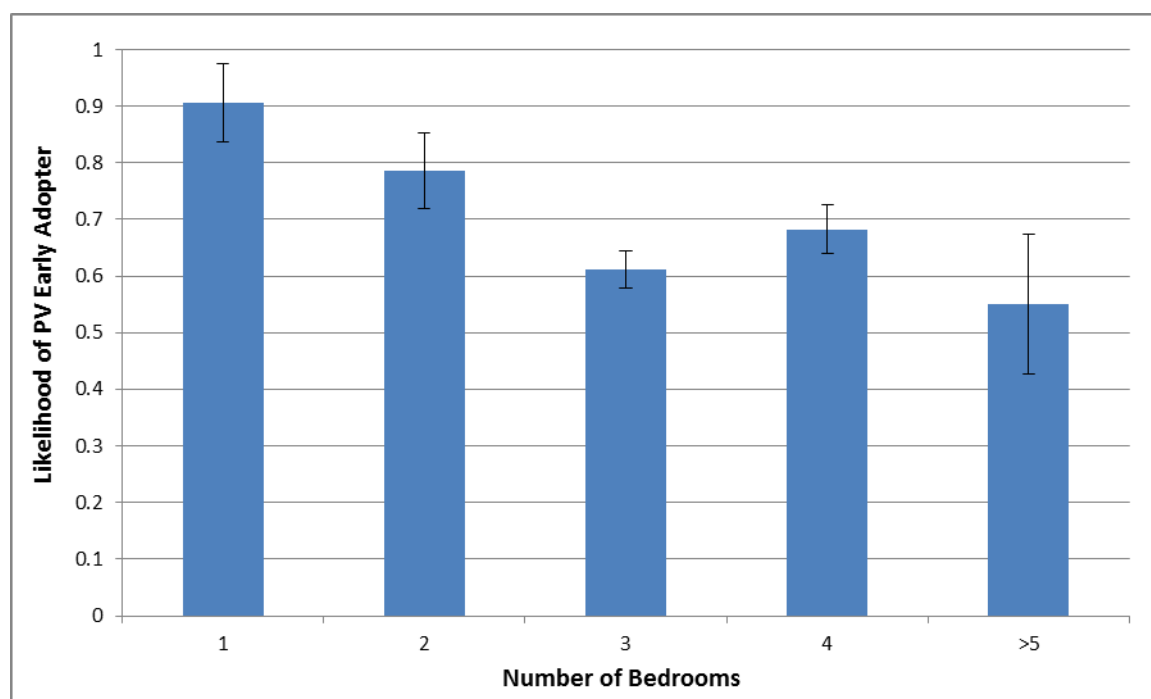


Figure 11: Likelihood of PV early adopter by number of bedrooms

4.1.3 Household composition

Four aspects of household composition were examined in this study:

1. number of residents
2. presence of young children in the household
3. presence of the elderly in the household
4. Aboriginal or Torres Strait Islander status.

Due to the strong associations of household composition with energy use found in the literature, it may be expected that household composition would also be related to PV adoption. This was not found to be the case in this research of ASC data. The number or ages of the household residents were weak predictors of early adoption of PV. In terms of effective use of solar power, this is a disappointing result as the young and elderly are more likely to be at home in the day coincident with the power generation. It is most efficient if the users of electricity are close to where the electricity is generated. Therefore, it is ideal that adopters of PV are at home and using electricity during the day at the place their solar electricity is being produced. Instead, the current grid infrastructure is required to deliver the power from the PV installation on empty homes to the locations of energy use in shops or workplaces. A greater reliance is placed on the existing electricity grid to ensure that the locally generated power can be delivered to the users of that power, with resultant costs associated with modifying the grid to support transport of the solar energy. This highlights a challenging area for policies to encourage adoption of RE technology.

There was a weak indication that non-Aboriginal and Torres Strait Islander households were more likely to adopt PV than Aboriginal and Torres Strait Islander households; however, sample sizes were too small to ensure a reliable result. Household composition was in general not a strong determinant of the early adoption of PV.

The following data indicate that the family and household compositions in the Alice Springs LGA do not differ greatly from the wider NT population, nor the national population (Table 7). The similarity of household composition suggests that there may be potential for the ASC experience to inform what might be possible in households elsewhere in the NT and Australia.

Table 7: Family and household composition for different populations

Family composition	Alice Springs	%	NT	%	Australia	%
Couple family without children	2,117	35.8	16,310	34.0	2,150,299	37.8
Couple family with children	2,656	44.9	22,245	46.3	2,534,397	44.6
One parent family	1,024	17.3	8,610	17.9	901,634	15.9
Other family	120	2.0	866	1.8	97,721	1.7
Household composition	Alice Springs	%	NT	%	Australia	%
Family households	5,716	68.0	44,046	72.3	5,550,611	71.5
Single (or lone) person households	2,143	25.5	13,317	21.9	1,888,697	24.3
Group households	542	6.5	3,528	5.8	321,005	4.1

4.1.4 Level of highest educational attainment in the household

Level of highest educational attainment in the household was a statistically significant predictor of early adoption of PV and the second strongest predictor after household style. Other research on innovation adopters has found that earlier adopters tend to have higher levels of formal education (Farhar & Coburn 2000). Those findings were consistent with this research, and it will be informative to find if this pattern extends to other EEMs too.

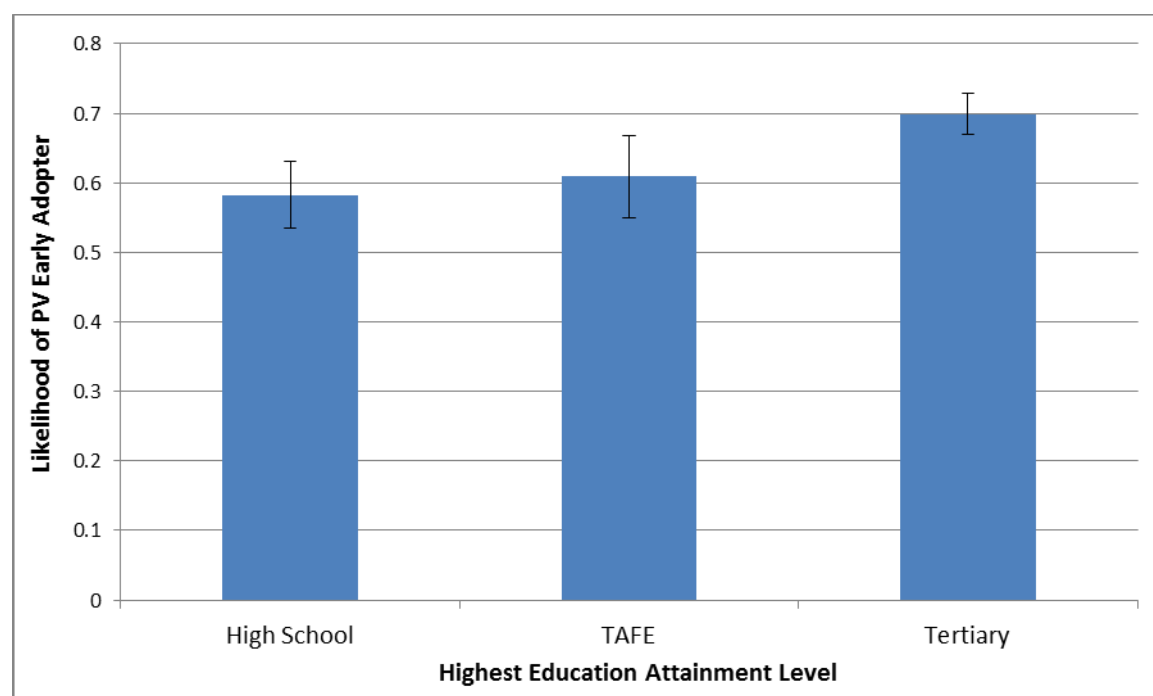


Figure 12: Likelihood of PV early adopter by level of highest educational attainment

4.1.5 Energy consumption and production

In understanding the PV early adopters, it is interesting to examine their energy consumption and production data. The daily average consumption (kWh) for a household was calculated in each of the two years prior to and post the installation of the PV system. Additionally, the amount of power generated by the PV system was estimated using the Clean Energy Regulator's estimate of annual production for Zone 1 regions. This estimate was commensurate with the power generated by the systems installed by the ASC program in Alice Springs (ASC 2012).

Table 8: Daily average energy consumption and production (kWh)

	Mean daily consumption 2 yrs – 1 yr prior	Mean daily consumption 1 yr prior	Mean daily consumption 1 yr post	Mean daily consumption 1 yr – 2 yrs post	Mean daily production	% Production / consumption
1kW PV System	15.2	15.8	15.5	15.7	4.4	28%
1.5kW PV System	17.5	16.1	17.0	16.5	6.7	41%
2kW PV System	24.7	24.3	23.2	22.9	8.9	39%

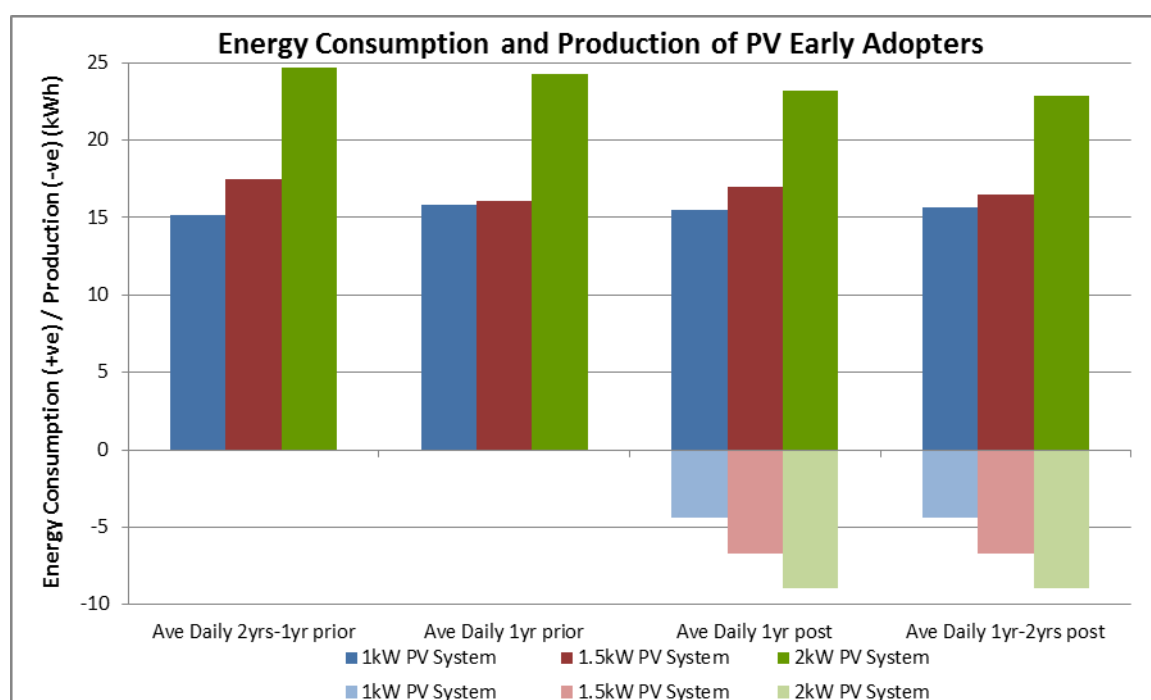


Figure 13: Energy consumption and production of PV early adopters

The size of the different PV installations installed is correlated to the energy consumption of the household. This is an indication that the energy audit led to the correct choice for the subsequent PV installation, with the system producing 28–41% of the household's energy consumption.

4.2 Financial effectiveness of the adoption of EEMs

Secondly, the financial effectiveness of residential EEMs offered through the ASC program is examined. It examines the financially incentivised component and the decision-making and adoption of this part of the program. Payback periods and internal rates of return are calculated. The adoption of the EEMs in relation

to their financial effectiveness and possible drivers for these adoption decisions are discussed. The results are examined in terms of their financial effectiveness as a standalone investment decision within an economically rational framework. Reasons for apparently sub-optimal financial decision-making are explored.

This work adds to the literature by examining whether financial subsidies resulting in economically rational investment opportunities are a strong driver for adoption of these products. In the remote context, where this study was based, this is especially relevant when seeking to alleviate some of the pressure of increasing energy prices. For example, new energy-efficient technology may provide cheaper operating costs than older technology currently in use, yet the up-front capital costs may make new technology unaffordable for lower income households (Rosenow et al. 2013).

4.2.1 Methodology – calculating financial effectiveness

Financial effectiveness with respect to uptake and household expenditure was analysed, using estimates of the kWh/yr reduction per measure and the life of each measure. These estimates are sourced from ASC (2014; Tables 5 and 22). They were made on a conservative basis and used regional and national data coupled with local experience and expertise (the estimates applied in the analysis have been verified by independent experienced energy analysts at the University of South Australia).

The following fields were extracted from the ASC database:

- a record of each EEV cashed per household
- the total incentive paid to each household by ASC per EEV
- the total expenditure by the household on each EEV.

These data were used to collate the total number of EEVs redeemed per EEM and to calculate the average total expenditure and average incentive per household.

The average simple payback period is a commonly used method in determining the acceptability of energy efficiency projects (Mott 1990, Santamouris 2001, Wada et al. 2012). The average simple payback periods for each EEM were calculated, for both the unincentivised and the incentivised costs. This calculation is made by taking the initial investment cost of the EEM and dividing it by (annual electricity saving × the residential electricity price). In the NT, the residential electricity price was \$0.2591/kWh (as at 1 July 2013). Payback period has been shown to be an important, popular, primary and traditional method for assessing the viability of investments; however, it does not measure the profitability but rather indicates how quickly the investment cost will be recovered (Lefley 1996). This provides a good indicative tool of the likely profitability of each EEM when compared to the expected product life; however, this calculation does not take into account the time value of money nor the potential changes in electricity prices relative to inflation.

Economic efficiency means earning the greatest net revenue or benefit. Choosing between or ranking investments requires establishing measures of net revenue as a decision criterion. Three criteria traditionally used to rank investments are: net present value (NPV), benefit/cost ratio (B/C) and internal rate of return (IRR). All of these methods use compound interest to adjust for costs and revenues occurring at different points in time. NPV is the sum of discounted revenues less the sum of the discounted costs over a defined period. NPV is sensitive to the interest rate used for analysis. B/C indicates the amount of present value revenue per unit of present value cost by dividing the sum of discounted revenues by the sum of discounted costs. B/C ratio is an index measuring the relative productivity of each dollar spent (Mishan

1972). IRR is a unique characteristic of an investment and does not require a guiding interest rate for calculation; it is measured by the rate the investment actually earns. Some analysts prefer NPV to evaluate the profitability of an investment but IRR is more commonly used and, in uncomplicated investments, produces similar results to NPV (DeCanio 1998). The EEMs presented in this study are uncomplicated investments as they involve an up-front cost, followed by positive net revenues as electricity savings are realised. Therefore IRR is a good method to compare the financial effectiveness of the various EEMs.

The IRR was calculated for both the unincentivised and incentivised EEMs. The IRR is calculated using the following general equation (Osborne 2010):

$$-I_0 + \sum_{i=1}^n \frac{c_i}{(1+R)^i} = 0$$

The IRR is the rate (R) that makes the sum of the initial investment outlay (I_0) and the NPV over the product life in years (n) of all future cash flows (c_i) equal to zero. This was calculated based on the average investment cost and savings for each household. In this case, I_0 is the initial incentivised or unincentivised cost and c_i is the yearly electricity savings to the householder generated by investing in the EEM. The equation is then solved for R, which is the resulting IRR. Thus, it is the effective yield earned by investing in each particular EEM. IRR does not take into account potential changes in electricity prices relative to inflation. However, it is a good financial tool for comparing each of the different EEMs offered against each of the other EEMs and also against other investments and current market interest rates on deposits. The higher the IRR, the higher the return on investment.

An absolute measure of financial effectiveness is not defined as this depends on a range of factors, not simply the payback period and IRR. This paper provides a relative ranking of each EEM's financial effectiveness in relation to the other EEMs. It categorises as low financial effectiveness measures where the payback period is longer than the expected life of the product, since they are unlikely to provide a positive financial investment return.

4.2.2 Results – payback periods and IRR

Extracts of data from the ASC database reveal that in total, 2154 EEVs were redeemed across 1253 unique households. The total expenditure was \$2.3m, with the vouchers provided by ASC accounting for \$0.7m or 30% of the total expenditure. The 10 most frequently adopted measures accounted for 84% of the total number of EEVs redeemed and 72% of total incentive expenditure. Most products had a similarly proportional financial incentive provided by ASC of around one-third. There were some notable exceptions, such as the surrendering of a fridge or freezer which was fully paid for by ASC and the installation of floor insulation which was only incentivised to 14%. All other measures had incentive ratios ranging from 24% to 35% (refer to Table 9 for further details).

Table 9: Adoption of EEMs summary

Energy efficiency measure	Number of EEMs redeemed	Total EEM expenditure across ASC (\$)	Average net spend per household (\$)	Yearly estimated electricity reduction (kWh/yr)	Expected EEM product life (years)	Lifetime kWh savings per household (kWh)	Yearly saving @25.91c/kWh (\$)	Lifetime savings per household (\$)	Incentivised IRR
Install external shading on walls/windows	181	485,955	1,926	300	15	4,500	78	1,166	-6%
Paint roof white	218	362,759	1,100	200	10	2,000	52	518	-12%
Replace roof with new white roof sheeting	33	215,555	4,649	200	25	5,000	52	1,296	-8%
Purchase swimming pool cover	234	205,688	611	600	5	3,000	155	777	9%
Service evaporative air conditioner	411	152,774	274	150	1	150	39	39	-86%
Service SHW system	210	137,972	474	900	5	4,500	233	1,166	40%
Replace old refrigerator with a new, energy-efficient model	53	110,842	1,597	300	10	3,000	78	777	-11%
Replace 12V halogen system with low-energy option	112	86,579	550	400	10	4,000	104	1,036	14%
Install ceiling insulation (batts)	39	86,396	1,537	350	25	8,750	91	2,267	3%
Install double-glazed windows	12	76,982	4,466	200	25	5,000	52	1,296	-8%
Tint windows	68	76,832	744	200	15	3,000	52	777	1%
Install variable speed pool pump	51	64,855	896	1,200	7	8,400	311	2,176	29%
Replace high energy usage lighting with energy-efficient lighting	208	45,097	161	400	5	2,000	104	518	58%
Install one-shot relay for SHW system	111	39,203	241	250	10	2,500	65	648	24%
Install roof ventilation device	67	37,688	371	20	15	300	5	78	-15%
Purchase swimming pool cover roller	44	26,742	422	600	5	3,000	155	777	24%
Surrender old refrigerator or freezer	50	9,847	-	500	5	2,500	130	648	N/A
Install thermal 'skin' over external walls	3	9,543	2,373	350	25	8,750	91	2,267	0%
Replace old freezer with a new, energy-efficient model	8	9,427	797	300	10	3,000	78	777	0%
Replace ceiling insulation (batts)	4	8,192	1,384	230	25	5,750	60	1,490	1%
Install ceiling insulation (loose fibre)	2	7,260	2,360	350	25	8,750	91	2,267	0%
Install bulk floor insulation	1	5,214	4,464	150	25	3,750	39	972	-9%
Replace perished fridge/freezer seals	23	5,125	150	100	5	500	26	130	-5%
Retrofit insulation into walls	1	4,224	2,746	200	25	5,000	52	1,296	-5%
Install motion sensors on external lighting	10	2,908	205	25	5	125	6	32	-41%

The estimated annual electricity savings of the EEMs offered ranged from 20 kWh/yr to 1200 kWh/yr. The installation of a variable speed pool pump offered the largest electricity saving followed by the servicing of a SHW system. Based on the then current electricity price in the NT of \$0.2591/kWh, the range represents annual savings that vary from \$5 to \$311, with a mean saving of \$88. EEM lifetime electricity savings per household varied from 125 kWh/lifetime to 8750 kWh/lifetime. At this electricity price this is a total financial saving ranging from \$32 to \$2267.

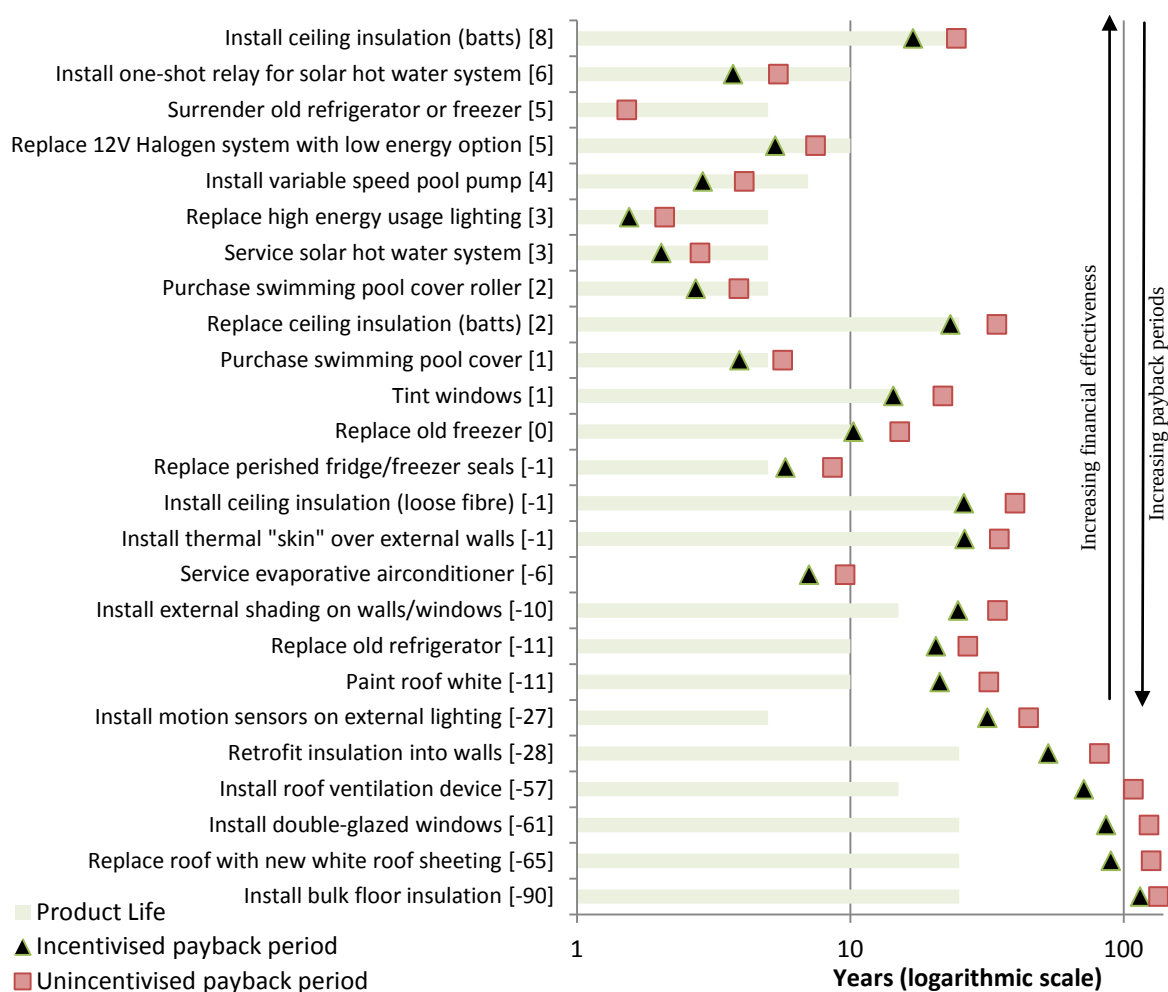


Figure 14: Product life and unincentivised and incentivised payback periods

In Figure 14, for convenience, the difference in years between the product life and the incentivised payback period follows the product name in parentheses. The relative payback periods for the unincentivised and incentivised EEMs to their expected product life are shown. Eight of the 25 measures offered by ASC had payback periods that were less than the expected life of the product, even prior to any financial incentives. When considering the incentives provided by ASC, only three more measures had payback periods less than the expected life of the product. An additional four products had payback periods just outside the expected lifetime (1.5 years or less) when incentivised. The remaining 10 products had very long payback periods, with a median payback period of 37 years and ranging from 6 to 90 years longer than the expected life of the product. It is unlikely that they would be considered economically viable without persistent increases in power prices. The three products that had the largest dollar

expenditure all had long payback periods: installing external shading on windows/walls (25 years), painting the roof white (21 years) and replacing roof with new white roof sheeting (90 years).

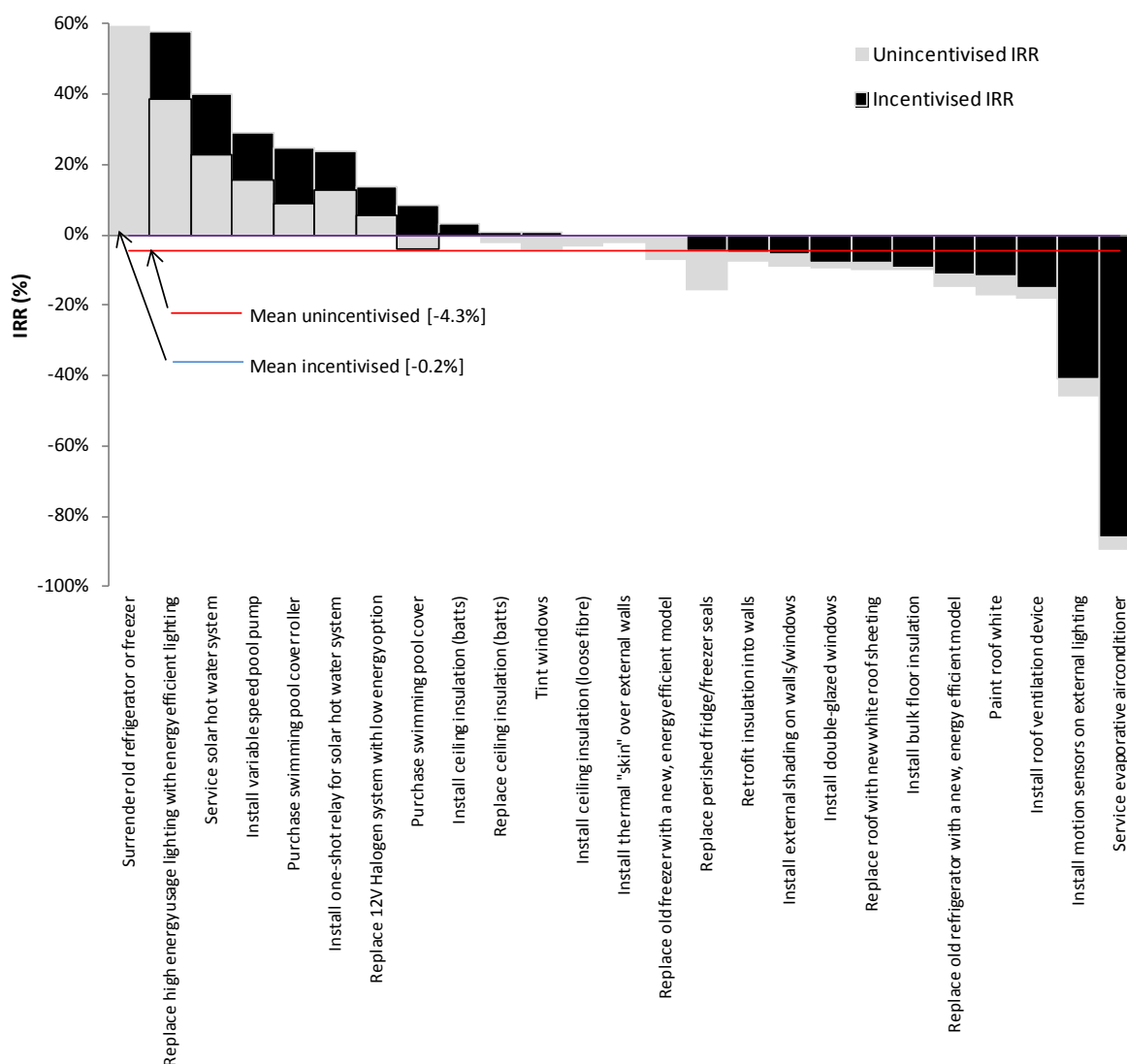


Figure 15: Unincentivised and incentivised IRR

The mean underlying unincentivised IRR for the products offered was -4.3% and ranged from +59% to -90%. Allowing for incentives and ignoring the surrendering of the fridge/freezer (which was at no cost to the household), the mean IRR to the household was -0.2% and ranged from +58% to -86%. Once incentivised, there were 10 products with a positive IRR. Three products (purchasing a swimming pool cover, replacing ceiling insulation and tinting windows) switched from negative to positive IRR after incentivisation and hence were only economically beneficial to the household if purchased through the ASC program.

Finally, there was no evidence of any relationship between the frequency of uptake or up-front dollar expenditure by household on each EEM and IRR. The scatter plot in Figure 16 shows the lack of relationship between frequency of uptake and IRR, and there is also a very low correlation coefficient (-0.18) between these variables. Figure 16 shows that two of the most frequently adopted EEMs had strongly negative IRRs: servicing of evaporative air conditioner (-86%) and painting the roof white

(-12%). The scatter plot in Figure 17 exhibits a similar lack of relationship between up-front dollar expenditure by household and IRR. There is also a very low correlation coefficient (-0.13) between these variables. Figure 17 illustrates that none of the eight most expensive products had positive IRRs and, likewise, all these EEMs had very long payback periods.

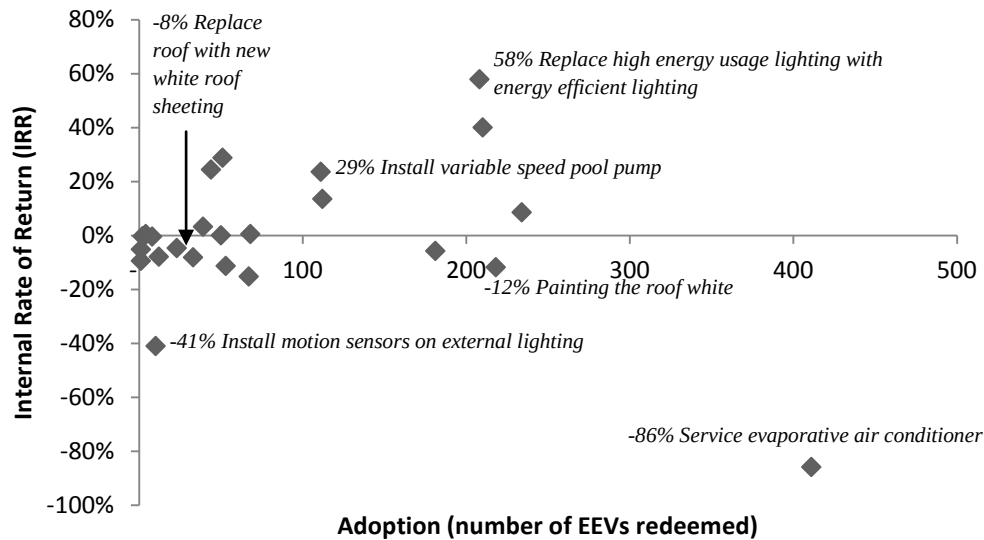


Figure 16: IRR vs. adoption of EEMs

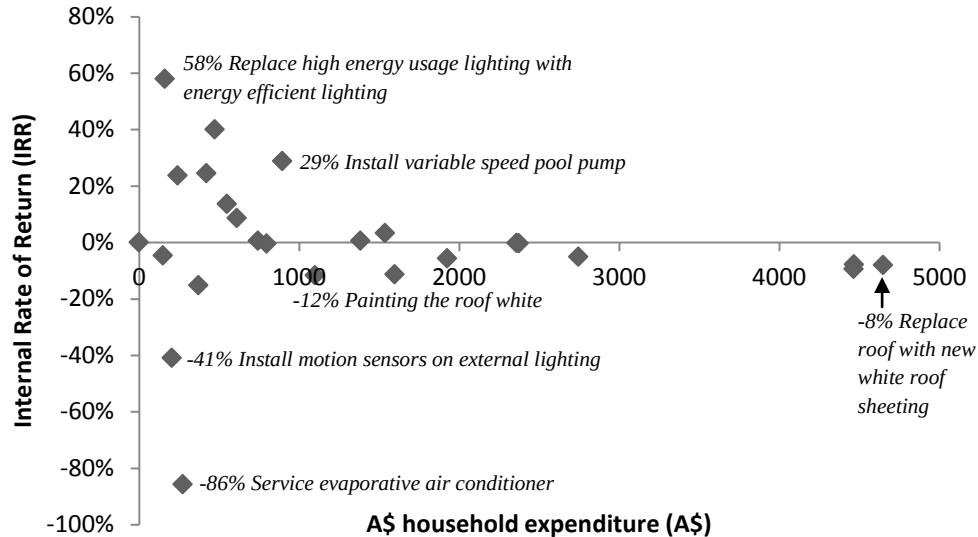


Figure 17: IRR vs. net household expenditure on EEMs

4.2.3 Discussion – payback periods and IRR

The decision to invest in an EEM is based on a range of variables. The literature discusses a wide range of potential impacts on the decision to purchase energy-efficient products (Gamtessa 2013, de la Rue du Can et al. 2014). Payback periods and returns on investment are potential variables in this decision.

Analysis of the payback period is a quick and intuitive calculation for gaining an insight into the financial effectiveness of a particular investment. Very long absolute payback periods or payback periods longer than product life would tend to be a large deterrent against the adoption of EEMs, if based on cost-effectiveness alone. However, this was not observed in the case of the EEMs in the ASC program. These results reveal a disconnect between the adoption of specific EEMs and the financial payback period, suggesting households are misinformed about the cost-effectiveness of specific EEMs and/or do not place a high priority on the economic rationale for the adoption of EEMs. The three products that had the largest dollar expenditure all had very long payback periods compared to the range of EEMs offered, and on none was it expected there would be payback of the initial investment until at least 10 years beyond the expected product life. As discussed above, applying a simple payback calculation does not take into account rising electricity prices versus inflation, so if there were a strong belief that electricity prices were going to rise exorbitantly this could affect this financial investment decision. However, the magnitude of these results indicates an alternative factor is driving the investment decisions made by households participating in the ASC program. The likely main consideration is positive externalities encouraging their investment in specific EEMs, rather than the payback period calculated from the energy savings alone.

Similarly to the observations on payback period, there was a lack of relationship between IRR and the adoption of EEMs. This lack of relationship could have several explanations. Firstly, the data certainly indicate that a large proportion of adoption decisions are not based on economic maximising principles. This could be explained by the fact that in the ASC energy efficiency program, financial optimisation was not the most important decision criterion. The fact that potential additional benefits are not valued in the calculation of each EEM's IRR may offer some explanation. It is difficult to objectively assess the monetary value of co-benefits of adopting an EEM; therefore, co-benefits such as increased living comfort, operating ease or improved leasing potential are rarely expressed in monetary terms when examining energy efficiency investments (Jakob 2006).

Monetarily quantifying the co-benefits of adopting an EEM could be a point of further study as it may explain the high adoption rates of servicing the evaporative air conditioner (IRR = -86%) or painting the roof white (IRR = -12%) which, from a financial assessment, on expected cashflow only, are very unattractive investments. The low financial returns on these EEMs are explained by the fact that the servicing of the evaporative air conditioner has an expected life of only one year and that painting the roof white has only a low energy-saving estimate. The servicing of the evaporative air conditioner warrants closer inspection, as it was the most popular energy efficiency product adopted but had an IRR of -86%. The main explanation for this is the non-monetary value placed on servicing, that is, the increase in air quality and, potentially, health in the home. The estimate of one-year product life for servicing the air conditioner is a conservative estimate but was made due to local factors. The water quality in Alice Springs dictates that regular servicing of air conditioners is required to avert much larger and more costly repair requirements. The likely reduction in future repair costs on the air conditioner has not been monetarily quantified but would increase the financial effectiveness of this EEM if included. This EEM also has likely elements of the free-rider effect in that many households felt they should service their air conditioner and may have done so without the program (Gillingham et al. 2006). However, it may have taken the reduction in cost offered by the incentive to motivate them to do so, hence reducing the free-rider effect.

The IRR of the EEMs on offer were calculated based on the average investment cost per household and the average investment savings. Thus, it is the IRR earned by the householder that invested the average amount in the EEM and earned the expected average energy savings. This is a good description of the IRR from a program-wide perspective, but it does mean that any individual household could have a significantly better or worse IRR than the average. The data showed that for some products the investment amounts per household were highly variable around the average, but it would be expected that the average energy savings would be highly correlated with this variability. This should have been supported by the ASC program policy that dictated that in order to receive an EEV the householder must undertake an ASC tailored audit. In this process the auditor advised the householder on the best potential EEMs for adoption in addition to a consideration of any EEMs the householder was interested in. Although this process did not formally estimate financial effectiveness nor provide the householder with IRR or payback information, the auditor may have advised or encouraged the householder to adopt products that for their particular residence had a higher IRR than the average. The variability in energy users' expenditure is considered as an explanation of market failures (Jaffe et al. 2004).

With an incentive program that increases IRR on a range of products it would be expected that householders would be attracted to ones that offered a higher relative financial incentive; that is, the more appealing measures will be those that are not financially effective without an incentive but become financially effective once the incentive has been provided. This was shown to be a factor in the ASC program: the second most heavily adopted EEM, purchasing a swimming pool cover, had an unincentivised IRR of -4% and an incentivised IRR of +9%. Purchasing a swimming pool cover in fact had a very high adoption rate, as only 30% of ASC households had pools and hence it was not an option for many households. The high adoption rate of this product is consistent with economic rational theory as the households have effectively identified a good deal, whereby they are making a profit and good rate of return due to the financial incentive available.

Payback period and IRR are potential factors, but other factors commonly cited in the literature include popularity of a particular product; absolute cost of the product; comfort improvements provided by the product; and, potentially, household characteristics such as income, energy use, educational level or other socio-demographic characteristics such as lifestyle and cultural factors. For some investments economic utility maximisation is the basis for investment decisions, whereas with energy-related decisions this is only one of a great variety of determinants (Mundaca et al. 2010). In theory, in an efficient economy the high IRRs demanded for investment in an energy-efficient product reflect the risk taken by and preferences of the investor. The range of IRRs and the divergent investment choices made in the ASC program support the notion that a decision to invest in energy efficiency products is a complex one. Decision-making has a range of determining factors, and economic effectiveness is clearly not the only deciding factor. Subsequent research is planned to explore the relative importance of different factors that appeared influential in the adoption of EEMs in the ASC program.

4.3 Change in electricity usage for the adoption of RE technologies and EEMs

Finally, the adoption of RE technology and EEMs by households participating in an energy efficiency program in central Australia and the impact on household electricity consumption are examined. The research explored the program'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 program (including informational and adoption of EEMs). It examines the impact of adopting RE technology over

the short and long terms and the economic parameters involved. The characteristics of households that did not adopt RE technology and the predictors of the greatest change in electricity usage are also explored. This analysis can contribute to the design of effective RE and energy efficiency programs targeting residential households.

4.3.1 Study sample

This group was selected based on the following criteria: they had to have been with the ASC program for at least two years and they had to have at least three years of uninterrupted, error-free electricity usage data. This identified 545 ASC customers. An additional exclusion was applied to this group relating to a problem with faulty adoptions of SHW. Towards the end of the program it was identified that 289 SHW adoptions may have been installed incorrectly: it may have been functioning as an electric water heater and not achieving the energy benefit expected. In our sample of 545 ASC customers, 49 potentially had this problem and therefore were removed from this study. The final study sample contained 496 households.

Through the compulsory personalised home energy audit, a substantial amount of customer information was gathered and recorded. ASC maintained a large database on all its customers. It recorded demographic information; program participation events; information such as date, quantity, expenditure on any financial incentives taken up; and electricity usage records. The electricity usage records were recorded in two ways: utility consumption data were recorded with quarterly billing records and PV production data were recorded in half-hour intervals. All customers had their quarterly billing data recorded, from at least one year prior to sign-up until termination of involvement in the program or the end of the program. Customers who had a PV system installed on their roof had their electricity production data recorded in half-hour intervals. Due to the PV installations being among the first in Alice Springs (prior to the program there was only one PV installation) there were some initial data collection issues for PV production. In some cases the collection and storage of the data were delayed. On average, data collection was correctly done within 62 days of PV installation, but in some cases it was delayed by from six months to one year. This means that the results understated the immediate impact of PV but were corrected for the long-term calculations.

The following fields were extracted from the ASC database:

- sign-up date
- audit date
- income
- electricity usage prior to program entry
- number of EEMs adopted during the program
- total expenditure by the household on EEMs
- if installed SHW, date of installation
- if installed PV, date of installation
- average daily consumption (ADC) data for the household over the program period
- PV production data post-installation

4.3.2 Data analyses

4.3.2.1 Change in electricity usage

The percent change in electricity usage from the year prior to sign-up to the program to the year post each treatment event was analysed. This was calculated by calculating each participant's average yearly ADC prior to sign-up. Each participant's average yearly ADC post each treatment effect was also calculated.

The events occurred on different dates for each member of the sample study. Therefore, the matching control period for each member of the sample study was identified for both the pre- and post-treatment periods. The change in ADC for each individual study sample was then calculated relative to the matched control period ADCs.

The short-term treatment effects were:

- sign-up
- personalised home energy audit
- adoption of SHW
- adoption of PV.

The long-term treatment effects examined change in electricity usage from the year prior to program sign-up to the electricity usage over the calendar year 2012, that is, the average yearly ADC prior to sign-up relative to the average yearly ADC over the calendar year 2012, adjusted by the matched control period ADCs. The long-term treatment effect was calculated for the whole study sample and for different sub-groups of the study, namely, whether a household did or did not adopt SHW or PV.

For the households that adopted PV, data for both household utility electricity usage and household generation were available. Therefore, the same analysis on net utility electricity usage of the household was performed. In addition, it was possible to examine the change in gross electricity usage, prior to consumption of electricity produced by the PV system.

T-tests were performed to determine the statistical significance of changes in ADC pre- and post-treatment effect.

4.3.2.2 Predictors of greatest household electricity reduction

The households were grouped in quartiles based on the change in long-term electricity usage. The households in the top quartile were compared to remaining program participants to determine common factors in households that had the greatest reductions in electricity usage.

A logistic regression analysis to predict households in the top quartile was performed using SPSS version 22. A comprehensive survey of methods in energy efficiency studies concluded that logistic models were the best approach for constructing a model of predictor values (Klein & Spady 1993, Hannemann & Kanninen 1996, Scott 1997). The dependent variable was defined as the probability that a household was in the top 25% of ASC program participants in terms of long-term change in electricity usage. The dependent variable was then regressed on a vector of predictor variables from the survey data. The predictor variables were selected based on a review of the literature and also included the most useful variables for policy development. Before building the logistic regression model, the variables were tested to determine multicollinearity. There was no correlation between any of the variables. The variables were added to the model using forward stepwise selection.

4.3.3 Short-term change in electricity usage

The resultant changes in short-term electricity usage are summarised in Table 10. There was no statistically significant impact on electricity usage due to the customer either signing up to the program or obtaining a personalised home energy audit. On average, audits occurred 65 days after sign-up.

There was a short-term, immediately post-adoption, statistically significant impact on electricity usage due to the customer adopting SHW. Likewise, there was a statistically significant impact on net electricity

usage when the customer adopted PV. On average SHW adoption occurred 360 days after sign-up and PV adoption occurred 228 days after sign-up.

Table 10: Short-term change in electricity usage

Treatment effect	Group	Number of households	% Change in electricity usage
Sign-up	All	496	-2.3%
Audit	All	496	-2.5%
Adoption of SHW	Adopted SHW	118	-10%**
Adoption of PV	Adopted PV	76	-34%** (net electricity usage)

**p<0.01, *p<0.05, otherwise not statistically significant

4.3.4 Long-term change in electricity usage

The long-term results were analysed, on average, 3.5 years after sign-up, ranging from 2.5 to 4.8 years. The results are shown in Table 11. Overall, there was a statistically significant impact on long-term electricity usage for the entire study group.

The group of participants (302 households) who did not adopt SHW or PV did not have a statistically significant fall in electricity usage relative to the control group. This group adopted a total of 483 EEMs, with a gross expenditure of \$339,005 and a net household expenditure of \$207,198 or an average of \$686 per household.

SHW adopters' long-term use was analysed, on average, 2.6 years after adoption. The results showed a statistically significant sustained fall in electricity usage (-9%), consistent with the short-term results (-10%).

The data for the PV adopters allowed more detailed analysis, as we have figures for net electricity usage and electricity generated in the home. PV adopters' long-term use was analysed, on average, 3.1 years after adoption. The results showed a statistically significant sustained fall in net electricity usage (-35%), consistent with the short-term results (-34%). However, over gross household usage there was a statistically significant increase of 6% for the period from adoption to 3.1 years later. Note that the net electricity usage did not exhibit this 6% increase because of increased PV production figures; the PV production figure accounts for 41% of electricity used. As discussed in 4.3.1, data collection, there were some limitations in gathering the PV production data immediately post-adoption and therefore the short-term PV production data is understated; this is rectified in the longer term PV production figures and hence explains the increase in PV production. The rebound effect is calculated as 6% of 41%, which gives a rebound effect of 15%.

Table 11: Long-term change in electricity usage

Group	Number of households	% change in electricity usage
All	496	-10%**
Households that did not adopt PV or SHW	302	-3%
Households that adopted SHW	118	-9%*
Households that adopted PV – net electricity usage from the utility	76	-35%**
Households that adopted PV – gross electricity usage	76	+6%*

**p<0.01, *p<0.05, otherwise not statistically significant

4.3.5 Long-term predictors of greatest household electricity reduction

The factors that were significant in predicting greatest household electricity reduction were adoption of PV and the number of EEMs adopted. The other factors (income level, electricity usage prior to program entry, total expenditure by the household on program EEMs and adoption of SHW) were not predictive.

The likelihood of a household being in the top quartile of electricity reduction was modelled using demographic and program variables. The model fitted well. The Hosmer and Lemeshow goodness-of-fit test has a significance of .640, meaning the model is a good fit. Nagelkerke's R^2 of .338 indicates a moderate relationship between prediction and grouping. The model was correctly able to classify 81% of the households. The Wald test demonstrated that adoption of PV and the number of EEMs adopted made a significant contribution to prediction. The logistic coefficients are 2.328 for adoption of PV and .114 for the number of EEMs adopted, and the constant is -1.820. The average EEMs adopted were 2.6 for the top quartile, compared to 1.8 for the remaining quartiles.

4.3.6 Discussion – change in electricity usage

The trend data of electricity usage shown in Figure 6 illustrates that Alice Springs households are sensitive to the price of electricity. The retail price of electricity charged by PWC during the study period increased by 44%, as PWC moved towards a cost-reflective tariff for provision of electricity with the removal of external funding and cross-subsidies within PWC's overall business. It can be observed that demand is responsive to the larger price changes in July 2009 and July 2012. The demand response of households to an increase in electricity price is consistent with economic theory and suggests that households in Alice Springs may suffer from the rebound effect after making savings on their electricity costs.

The ASC was a voluntary program that included a compulsory home energy audit that was conducted soon after sign-up. It could be expected that the households that signed up had an interest in improving their energy efficiency and therefore reducing their electricity usage. Additionally, the compulsory home energy audit provided tailored information to the household and included specific recommendations. A potential advantage of this approach is that households received relevant information rather than an overload of general recommendations. The results show that the act of joining the ASC program, which indicates a likely positive attitude towards electricity conservation in itself, did not result in a reduction in electricity. Likewise, having an energy audit performed did not result in an immediate reduction in electricity usage. Our results showed there was no substantive behavioural change on sign-up or the initial energy audit among participants in the ASC program. This adds to the body of literature that indicates that provision of information alone does not necessarily result in a reduction in electricity usage.

The two solar RE technologies available in the ASC program, the SHW and PV systems, were both expected to lead to a significant reduction in overall electricity usage (a 25% [ASC 2013c] and a 36% [ASC 2013d] reduction respectively). SHW and PV are both large, purpose-built technologies that require no behavioural change for the household to achieve a reduction in electricity usage. Statistically significant reductions in electricity usage were observed immediately post-adoption by households in the ASC program for both RE technologies: 10% for SHW and 34% for PV. The reduction of 10% in electricity usage by households that adopted SHW is notably less than expected, while the reduction for PV adopters is in line with expectations. The unexpected result for SHW warrants further investigation. The result in this study sample of 10% electricity saving by households adopting SHW is in line with ASC results conducted on a larger sample of its customers. The ASC results (ASC 2013c) indicate an average 13% reduction post-adoption of SHW, although this result is not adjusted for the fall in use occurring within the control group and so is expected to be higher than this study's result. The reason for the figures observed

in the ASC program is that there were two main types of systems being replaced by the adoption of SHW: either an electric storage hot water system or a faulty electric boost SHW system. In our study sample, these groups had a 13% and a 6% fall in electricity usage respectively. Although a faulty system was replaced only if deemed not to be working, this result suggests that some faulty systems were still operating, albeit at a sub-optimal level; hence the savings achieved were reduced. The result is less than was expected by the program but is broadly in line with an IPART study indicating that a fall of 1400 kWh, or a reduction of approximately 15% of electricity usage, could be expected for replacing an electric storage hot water system (IPART 2011).

The electricity usage savings experienced immediately after the adoption of the RE technology would have had a direct impact on the quarterly bill for these households. The SHW saving was a reduction in electricity usage, which would have had a corresponding reduction in the bill provided the saving was greater than the tariff increases. The PV adoption resulted in electricity generation for which PWC provided an elevated gross feed-in tariff. This resulted in the PV adopters receiving approximately 2.5 times the flat-rate tariff for electricity produced throughout the program. The gross feed-in tariff increased in line with consumption tariff increases shown in Table 4. The combination of the large electricity production of the PV installations and the elevated gross feed-in tariff meant that these households had greatly reduced electricity bills. The additional income available to the household could therefore be spent on other consumables or they could increase their electricity usage. When the SHW adopters were analysed again 2.6 years after adoption, it was observed that there had been no direct rebound effect. When the PV adopters were analysed again 3.1 years after adoption, it was observed that there had been a 6% increase in electricity usage within the household, although net consumption remained reduced. This implies a direct rebound effect of 15%. This is at the lower end of the range of rebounds observed in other studies (e.g. Greening & Greene 1998).

The demonstration of price sensitivity in the control group implies that there should be some direct rebound effect following the adoption of RE technology. The solar RE technologies are the most likely product within the ASC program to be characterised by rebound due to the large impact they would have on total electricity cost and the lack of any behavioural change required to achieve this (Greening et al. 2000). However, it was observed that no rebound occurred in the case of SHW, and only a relatively small rebound was observed for PV. The major differences between these two RE technologies are that SHW adopters had a reduction in cost of producing hot water for the household, but the overall cost of electricity usage remained fairly constant due to the tariff increase. The SHW adopters were relatively better off than those that did not adopt SHW, but they did not experience any large reductions in total electricity cost. Our results show that this relative saving did not result in increased electricity usage. The PV adopters experienced a tangible reduction in the cost of electricity to the household. The rebound effect observed in the adopters of PV generated a substitution effect which resulted in more electricity being consumed by the household. The rebound effect could be due to several factors: the large value of investment required; the large volume of energy produced, and consequently large financial savings gained; or the fact that PV actually generated income for the household which was distinct from SHW, which provided only relative savings. These differences could account for the rebound effect occurring for PV adopters rather than SHW adopters. These findings highlight an area of potential future study to better understand the behaviour of RE technology adopters. For example, the distribution of savings among RE technology adopters could be examined, and follow-up surveys and interviews could identify influences, attitudes and reasons behind change in electricity usage.

The ASC program successfully reduced the barriers for RE technology adoption in the remote town of Alice Springs. Prior to the program there was only one PV installation; this program greatly decreased the

technical and institutional barriers experienced in this remote location. The economic barriers were decreased by the specific incentives available for the early adopters of PV. Due to the successful reduction in technical and institutional barriers, later adopters were able to exploit the coincident reduction in PV prices. The ASC program was a valuable initiative to test and refine approaches to promote the adoption of RE technology and EEMs by households in a remote location. Analysis of the popularity of specific technologies and EEMs offered through the ASC program and the subsequent reductions in electricity consumption by households, as presented in this paper, can assist policymakers and program managers in designing a follow-up program.

The average electricity usage by the control group fell by 5.7% over the study period. The result for 61% of households in the study sample that did not adopt SHW or PV showed no statistically significant reduction in household electricity usage relative to the control group, even though 483 EEMs were adopted. This is despite an average adoption of 1.6 EEMs and \$686 net expenditure per household. The results are not what was expected, and it is difficult to ascertain why there was not a significant reduction in electricity usage in this sample. The adoption of EEMs in isolation should have led to a reduction in electricity usage. Explanations for why this did not occur could be that the EEMs were not used or were not used correctly; adoption of similar EEMs or RE technologies was occurring outside this program; or there was a coincident relative increase in usage of electricity which masked the savings produced by the EEMs. The ASC program had education measures in place to try to mitigate the misuse of EEMs, but possibly a greater focus on follow-up and EEM use was required.

Furthermore, the ASC program achieved high uptake within the community, engaging 30% of Alice Springs households, and greatly increased the awareness, availability and knowledge of energy efficiency and RE technologies. As can be observed from Figure 6, the program also occurred during a period of high increases in electricity cost, which would have impacted both participants and non-participants in the program. The price signals provided to householders may have led those both within and outside the program to take measures to reduce their electricity usage. This would indicate that the price signals themselves were stronger than the support offered by the ASC program as households in both groups reduced their electricity usage similarly. In the ASC program a large range of EEMs were offered and adopted, with a large variation in cost and expected electricity savings. The cost of EEMs was significantly lower than that of the RE technologies, which made the incentive provided by ASC less important in the rising tariff environment. EEM adoption may have increased across the community, but the explicit incentives did not have a statistically significant impact. Future analysis on the costs and savings generated by the ASC program is warranted. Another possible hypothesis is that ASC program participants experienced a rebound effect over the period due to the electricity savings made. That could explain the results, although it seems unlikely due to the fact that no rebound effect was observed for the SHW adopters.

The final results explored who were the greatest reducers of electricity usage. The results showed that income level, electricity usage prior to program entry, total expenditure by the household on program EEMs and adoption of SHW were not good predictors of being reducers in electricity usage. This program engaged with households across the demographic spectrum. This is important policy information, as it makes clear that energy efficiency programs should be targeting the broad community, not a particular demographic group. The results found that the two most important predictors of energy use change were adoption of PV and the number of EEMs adopted by households – the more EEMs adopted by the household, the more likely they were to have a reduction in electricity usage. The result is as would be expected, but in conjunction with the surprising lack of reduction in average long-term electricity usage for the EEM adopters, this result is informative. It is also important to note that the level of investment in the

program was not a predictor of being a larger electricity reducer, but the actual number of EEMs was. This indicates that there are different responses to the adoption of EEMs. The higher reducers must use the EEMs more, use the EEMs more effectively, or have relative coincidental behavioural change accompanying the adoption of the EEMs. Possibly it requires a combination of these three factors, with an adoption of a greater number of EEMs showing greater commitment, involvement and engagement in the program, in other words, repeated action, repeated communication with the program and repeated interventions in the household. This could ensure both greater and more correct use of the adopted EEMs, and may be correlated with behavioural change.

5. Summary

The ASC initiative that operated in Alice Springs during 2008–13 engaged with a diverse cross-section of households, with about 30% of households participating in some form. The program had a wide impact on this remote regional community, and the RE technology landscape changed dramatically over the period of the program. Significant changes to the use of RE technology were happening globally, but this program played a role in the ability of this remote location to have expertise and to adopt these technologies.

The RE technology adoption (PV and SHW) of the residential component of the ASC program (comprising 87% of expenditure) was far reaching. It was observed that the program successfully achieved appropriate technology installation, and the consequent electricity savings were in line with the technology adopted.

Installation of RE technology, such as SHW units and rooftop PVs, were popular ways for households participating in the ASC to reduce the reliance on conventional power supplies and save money. The results of the study show that reductions in electricity usage can be achieved by the adoption of RE technology. The analysis showed that these systems successfully reduced reliance on the mains grid, reducing electricity usage by 10% and 34% respectively. These technologies achieved electricity usage reductions in line with expectations, but with PV adopters having a 15% rebound effect. While this observed rebound effect is relatively low, it suggests that policies need to be adopted to deter a rebound in energy use when a program is offering an RE technology that is likely to produce a large reduction in energy cost for the household.

Analysis showed that demographic variables that were good predictors of PV adoption were house style and house size, with separate houses with fewer bedrooms more likely to be PV early adopters. Demographic variables such as Aboriginal or Torres Strait Islander status, number of residents and the presence of children or the elderly in the household were only weakly correlated with PV adoption. There was a weak trend of increasing PV adoption with increasing income, which indicates that policy is best directed to the larger middle-income groups, which are only slightly less likely to take up PV energy, but who still collectively have a greater effect on the total energy system.

Analysis of EEMs adopted by households participating in the ASC program indicates that adoption of specific EEMs is not always driven by rational economic logic, in that many households are willing to invest in EEMs despite unfavourable payback periods and investment returns. Additionally, the analysis showed that ASC participants that only adopted EEMs on average had no statistically significant reduction in electricity usage over and above the non-participants in Alice Springs. This analysis indicates that a refinement of the EEM component of the residential program is warranted. This component of the program was only a small component of expenditure (13%), and the results indicate that this part of the program warrants further focus.

The results show that, while there was a strong statistical correlation between large reductions in household electricity usage and the number of RE technologies and EEMs adopted, there was no correlation between the level of household financial investment in the same RE technologies and EEMs and electricity reduction; that is, the level of financial investment by households in RE technologies and EEMs as part of the ASC program in central Australia was not a good predictor of eventual reduction in electricity usage by participating households. As such, we believe that this indicates that active engagement of households in energy conservation programs is more important than attempting to maximise household investment in RE technologies and EEMs.

Total household energy use is highly dependent on the number of household residents and the proportion of time the house is occupied (Lenzen et al. 2006, Newton & Meyer 2012). The ASC database recorded these variables only at the point of sign-up to the program. While this study's dataset excluded houses where there was a change in the individual or family residing at the household, the occupancy rate or number of permanently residing household members could have either increased or decreased, which would be expected to have a significant impact on electricity usage. Therefore, it is possible that changes in electricity usage were confounded by changes in household occupancy over the life of the program. However, there is no reason to suggest that there would be a bias towards change in household occupancy for those groups we found to be associated with having a change in their electricity usage.

Policymakers should consider methods to maintain the ongoing engagement of households in these programs. This could include measures such as requiring repeated program participation in order to access higher value financial incentives, staggered access to individual products, or additional support. Our findings suggest these measures could result in greater reduction in electricity usage for a given cost to the program. Additionally, this would allow the program to interact with the householder about products previously adopted, ensuring they are being used and are being used correctly.

The adoption of RE technologies does not require a change in household behaviour or create a visible change in housing comfort for electricity savings to occur. However, adoption of EEMs often requires, or creates, a change in household behaviour (e.g. altered lighting, altered setting for air conditioners). As such, adoption and sustained use of a relatively high number of EEMs is likely to be by households that are highly motivated to achieve substantive reductions in electricity usage. Policymakers should consider low-cost options for supporting households that have adopted a high number of EEMs so that sustained lower energy consumption becomes an entrenched pattern of behaviour and a core feature of Australia's future households.

Another challenge for researchers and policymakers is to further understand both the drivers that influence the adoption of RE technologies and the key changes in behaviour that lead to greater energy efficiency. Understanding the particular drivers of adoption of RE technology for different socio-economic groups of households will better inform strategies to ensure greater precision, and therefore effectiveness, in the targeting of future programs.

Some areas of potential further research to more fully inform future policy makers have been identified. Firstly, research could examine the delivery method that achieves the highest economic return on a household basis. This ASC program provided tailored energy audits, and it would be valuable to establish whether these audits successfully ensured that householders with higher potential savings were directed to the appropriate EEMs. If this were the case, the IRRs achieved on average and by each household would have higher financial effectiveness than calculated in this paper. Secondly, developing a method to quantify the co-benefits of adopting EEMs would be a valuable tool to improve the size of any financial incentive. Monetarily quantifying the co-benefits of adopting an EEM would allow policymakers to more

equitably direct financial incentives and thereby allow more efficient use of scarce funds. Thirdly, the value in quantifying the synergies that can arise from the adoption of a combination of EEMs by a household is highlighted by this work. The EEMs offered through this program were independent of each other, but superior energy savings may be achieved by the adoption of a combination of EEMs. Future research could model the additional value of adopting multiple EEMs together. This could then inform future programs to provide combination incentives to achieve overall superior outcomes. Additionally, quantifying the impact of the adoption of individual EEMs or particular types of EEMs (such as cooling or refrigeration) would be informative. The ASC program data did not allow meaningful analysis of the impact of individual EEMs due to the ongoing working nature of the program and the limited monitoring and evaluation framework possible for this aspect of the program. There were many different EEMs available that were adopted over a period of five years, and in many cases several EEMs were adopted at similar times by different households. The results found here show that the number of EEMs adopted, as distinct from the total expenditure on EEMs, indicates that there is an engagement component to the reduction in electricity. However, to expand this hypothesis further a greater analysis of the quantitative impact of each EEM would need to be established.

The results presented also raise questions about the nature and scale of support offered to households to adopt EEMs. For example, it appears questionable whether financial incentives should be offered to households to adopt EEMs that have very long payback periods, particularly if there are other EEMs with much shorter payback periods that could feasibly be adopted. While the experience from the ASC program indicates that external support for households to adopt EEMs is necessary in the prevailing social and economic context, careful consideration of the role and emphasis of financial incentives is important when designing a package of support. Adoption may find stronger appeal if increased reliability of supply is achieved (for example, fewer breakdowns or blackouts), especially for remote communities (McKenzie 2013), or if it is understood that greater energy efficiency does not equate to lower comfort or liveability but in fact can add value to the preferred lifestyle of the household (Mallaburn & Eyre 2014).

The work supports the established view that residential investment in energy efficiency does not follow economic rational principles. The relationship between uptake, payback periods and IRR calculations clearly indicates this. These tools could be used in the development of future policy program areas, both in Australia and more generally.

Some changes required by communities and business that enable them to adapt to climate change will be expensive, such as upgrading housing, energy supplies and transport infrastructure. Other changes that can improve the energy efficiency of households and businesses are underpinned by changing behaviour, so can be relatively inexpensive options for adapting to climate change. The careful design of a package of small yet complementary changes can be an effective adaptation to improve the overall liveability for people in central Australia, particularly those living in remote communities. Promotion of energy efficiency to households needs to encompass more than simply a strong economic rationale. Strategies to improve the energy efficiency of households need to be tailored to suit the specific situation of individuals, families and communities, and businesses – there is not a fixed ‘recipe’ for adaptation that will suit everyone. Active communication of options and strong coordination of changes will be essential so that all the desired changes – large and small – are complementary and enhance the liveability of central Australia (Bedsted & Gram 2013, Liverman 2013, Maru et al. 2014). As such, a lot more work is required to design the most appropriate support package to help households adopt EEMs and increase their own power generation – to appeal to the wide range of households with varying socio-economic characteristics across Australia’s different climate zones.

Appendix 1: EEV adoption and expenditure

EEV groups	Financial incentive (\$)	EEVs issued	EEVs cashed	% converted	ASC incentive (\$)	Total invoice (\$)	% ASC contribution
Paint roof white	750	707	218	31%	122,934	362,759	34%
Replace old roof with new white roof sheeting	2,500 (materials only)	90	33	37%	62,134	215,555	29%
Install roof ventilation device	300	228	67	29%	12,857	37,688	34%
Install or replace ceiling or floor insulation	750–1,500	281	46	16%	32,388	107,062	30%
Retrofit insulation into walls	1,500	7	1	14%	1,478	4,224	35%
Replace high energy usage lighting with energy-efficient lighting	200 (min. purchase 50)	1,165	208	18%	11,663	45,097	26%
Replace 12V halogen downlight system with low-energy option	350	427	112	26%	24,954	86,579	29%
Install motion sensors on external lighting	150	58	10	17%	855	2,908	29%
Tint windows	700	126	68	54%	26,219	76,832	34%
Install double-glazed windows (IGUs)	3,500	26	12	46%	23,386	76,982	30%
Installation of 'one shot' relay for SHW systems	150	296	111	38%	12,446	39,203	32%
Service of SHW system	200	435	210	48%	38,389	137,972	28%
Replacement of perished fridge/freezer seals	100	95	23	24%	1,677	5,125	33%
Service of evaporative air conditioner	100	741	411	55%	40,018	152,774	26%
Install external shading on walls/windows	1,000	397	181	46%	137,389	485,955	28%
Purchase swimming pool cover		407	234	57%	62,828	205,688	31%
Install thermal 'skin' over external walls	1,000	14	3	21%	2,424	9,543	25%
Install heat pump hot water system	1,000	14	10	71%	10,000	48,790	20%
Supply and install variable speed pool pump	400	85	51	60%	19,150	64,855	30%
Replace old refrigerator or freezer with a new, energy-efficient model	400	103	61	59%	29,228	120,269	24%
Surrender old refrigerator or freezer	100	58	50	86%	9,847	9,847	100%
Purchase swimming pool cover roller	150	77	44	57%	8,153	26,742	30%
Standby for a SHW system		2	0	0%	-	-	
Totals		5,839	2,164	37%	690,417	2,322,449	30%

Appendix 2: Summary of kWh and GHG savings by EEMs supported by EEVs in ASC

				Total savings per year		Cost \$		Cost per year of life per kWh saved		Cost per year of life per kg GHG saved	
EEV groups	EEVs used	kWh/yr savings	Life yrs	kWh/yr	GHG kg/yr	Total	ASC	Total	ASC	Total	ASC
Paint roof white	218	200	10	43,600	29,648	362,759	122,934	0.83	0.28	1.22	0.41
Replace old roof with new white roof sheeting	33	200	25	6,600	4,488	215,555	62,134	1.31	0.38	1.92	0.55
Install roof ventilation device	67	20	15	1,340	911.20	37,688	12,857	1.88	0.64	2.76	0.94
Install ceiling insulation – batts	39	350	25	13,650	9,282	86,396	26,442	0.25	0.08	0.37	0.11
Install ceiling insulation – loose fibre	2	350	25	700	476	7,260	2,541	0.41	0.15	0.61	0.21
Replace ceiling insulation – batts	4	230	25	920	625.60	8,192	2,655	0.36	0.12	0.52	0.17
Install bulk floor insulation	1	150	25	150	102	5,214	750	1.39	0.20	2.04	0.29
Retrofit insulation into walls	1	200	25	200	136	4,224	1,478	0.84	0.30	1.24	0.43
Replace high energy usage lighting with energy-efficient lighting	208	400	5	83,200	56,576	45,097	11,663	0.11	0.03	0.16	0.04
Replace 12V halogen downlight system with low-energy option	112	400	10	44,800	30,464	86,579	24,954	0.19	0.06	0.28	0.08
Install motion sensors on external lighting	10	25	5	250	170	2,908	855	2.33	0.68	3.42	1.01
Tint windows	68	200	15	13,600	9,248	76,832	26,219	0.38	0.13	0.55	0.19
Install double-glazed windows (IGUs)	12	200	25	2,400	1,632	76,982	23,386	1.28	0.39	1.89	0.57
Installation of 'one shot' relay for SHW systems	111	250	10	27,750	18,870	39,203	12,446	0.14	0.04	0.21	0.07
Service of SHW system	210	900	5	189,000	128,520	137,972	38,389	0.15	0.04	0.21	0.06
Replacement of perished fridge/freezer seals	23	100	5	2,300	1,564	5,125	1,677	0.45	0.15	0.66	0.21
Service of evaporative air conditioner	411	150	1	61,650	41,922	152,774	40,018	2.48	0.65	3.64	0.95
Install external shading on walls/windows	181	300	15	54,300	36,924	485,955	137,389	0.60	0.17	0.88	0.25
Install thermal 'skin' over external walls	3	350	25	1,050	714	9,543	2,424	0.36	0.09	0.53	0.14
Purchase swimming pool cover	234	600	5	140,400	95,472	205,688	62,828	0.29	0.09	0.43	0.13
Purchase swimming pool cover roller	44	600	5	26,400	17,952	26,742	8,153	0.20	0.06	0.30	0.09
Supply and install variable speed pool pump	51	1,200	7	61,200	41,616	64,855	19,150	0.15	0.04	0.22	0.07
Replace old refrigerator with a new, energy-efficient model	53	300	10	15,900	10,812	110,842	26,180	0.70	0.16	1.03	0.24
Replace old freezer with a new, energy-efficient model	8	300	10	2,400	1,632	9,427	3,048	0.39	0.13	0.58	0.19
Surrender old refrigerator or freezer	50	500	5	25,000	17,000	9,847	9,847	0.08	0.08	0.12	0.12
Totals	2,154			818,760	556,757	2,273,658	680,417				

References

- Abrahamse W and Steg L. 2009. How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? *Journal of Economic Psychology* 30, 711–720.
- Abrahamse W, Steg L, Vlek C and Rotherngatter T. 2005. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* 25(3), 273–291.
- Abrahamse W, Steg L, Vlek C and Rothengatter T. 2007. The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. *Journal of Environmental Psychology* 27(4), 265–276.
- ABS (Australian Bureau of Statistics). 2011. *Alice Springs Statistical Local Area – all people, usual residents*. ABS Census QuickStats, code LGA70200. www.abs.gov.au.
- ABS (Australian Bureau of Statistics). 2013. *Information Paper: Towards the Australian Environmental-Economic Accounts, 2013: Chapter 3 Energy*. Report code: 4655.0.55.002. www.abs.gov.au.
- Addison J. 2013. *Impact of climate change on health and wellbeing in remote Australian communities: a review of literature and scoping of adaptation options*. CRC-REP Working Paper CW014. Ninti One Limited. Alice Springs. Available from http://www.crc-rep.com.au/resource/CW014_ImpactClimateChangeHealthWellbeing.pdf.
- Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J and Wreford A. 2009. Are there social limits to adaptation to climate change? *Climatic Change* 93, 335–354.
- Akter S and Bennett J. 2011. Household perceptions of climate change and preferences for mitigation action: the case of the Carbon Pollution Reduction Scheme in Australia. *Climatic Change* 109, 417–436.
- ASC (Alice Solar City). 2012. *ASC-DCEE Key Results Reporting 2011*. Residential PV Systems Interim Report, February 2012.
- ASC (Alice Solar City). 2013a. Alice Solar City web site. Available at <http://www.alicesolarcity.com.au/facts/solar>. (accessed 20 December 2013).
- ASC (Alice Solar City). 2013b. *Residential Energy Efficiency Measures, Final Report*. Alice Springs Town Council. Alice Springs. http://www.alicesolarcity.com.au/sites/default/files/ASC_KRR_Res-EEMs_For-www.pdf.
- ASC (Alice Solar City). 2013c. *Residential Solar Hot Water, Final Report*. http://www.alicesolarcity.com.au/sites/default/files/ASC_KRR_Res-SHW_For-www.pdf.
- ASC (Alice Solar City). 2013d. *Residential Photovoltaic Systems, Final Report*. http://www.alicesolarcity.com.au/sites/default/files/ASC_KRR_Res-PV%2BApp_For-www.pdf.
- ASC (Alice Solar City). 2014. *Alice Solar City 2008–2013 Report, Final Report*. http://www.alicesolarcity.com.au/sites/default/files/Alice_Solar_City_Report_2008-2013%20FINAL%20for%20web.pdf.

- Bedsted B and Gram S. 2013. Participatory climate change adaptation in Kalundborg, Denmark (Chapter 2). In P Schmidt-Thomé & J Klein (eds). *Climate Change Adaptation in Practice: From strategy development to implementation*. Wiley-Blackwell, UK. pp. 11–23.
- Berkhout PHG, Muskens JC and Velthuisen JW. 2000. Defining the rebound effect. *Energy Policy* 28, 425–432. [https://doi.org/10.1016/S0301-4215\(00\)00022-7](https://doi.org/10.1016/S0301-4215(00)00022-7).
- Bor YJ. 2008. Consistent multi-level energy efficiency indicators and their policy implications. *Energy Economics* 30(5), 2401–2419.
- Brandon G and Lewis A. 1999. Reducing household energy consumption: a qualitative and quantitative field study. *Journal of Environmental Psychology* 19(1), 75–85. <https://doi.org/10.1006/jevp.1998.0105>.
- Brooks G and Yusuf F. 2009. Household expenditure on domestic fuel and power in New South Wales, Australia. *European Journal of Management* 9, 91+. <http://www.freepatentsonline.com/article/European-Journal-Management/260874451.html>.
- Bruderer Enzler H, Diekmann A and Meyer R. 2014. Subjective discount rates in the general population and their predictive power for energy saving behavior. *Energy Policy* 65, 524–540.
- CAT (Centre for Appropriate Technology). 2013. *Housing Experience: Post-Occupancy Evaluation of Alice Springs Town Camp Housing 2008-2011*. Final Report by CAT for Tangentyere Council, Alice Springs, NT.
- Climate Commission. 2013. *The Critical Decade: Australia's future – solar energy*. Climate Commission Secretariat. Available from <http://www.climatecouncil.org.au/uploads/497bcd1f058be45028e3df9d020ed561.pdf>.
- CSIRO. 2009. *The CSIRO Home Energy Saving Handbook: How to save energy, save money and reduce your carbon footprint*. Pan Macmillan Australia, Sydney, NSW.
- CSIRO and Bureau of Meteorology. 2014. *State of the Climate 2014*. CSIRO and Bureau of Meteorology, Australian Government. Available from http://www.bom.gov.au/state-of-the-climate/documents/state-of-the-climate-2014_low-res.pdf?ref=button.
- De la Rue du Can S, Leventis G, Phadke A and Gopal A. 2014. Design of incentive programs for accelerating penetration of energy-efficient appliances. *Energy Policy* 72, 56–66. <https://doi.org/10.1016/j.enpol.2014.04.035>.
- De Vries P, Aarts H and Midden CJH. 2011. Changing simple energy-related consumer behaviors – how the enactment of intentions is thwarted by acting and non-acting habits. *Environment and Behavior* 57, 1353–1357.
- De Vries B, Van Vuuren D and Hoogwijk M. 2007. Renewable energy sources: their global potential for the first-half of the 21st century at a global level: an integrated approach. *Energy Policy* 35, 2590–2610.
- DeCanio SJ. 1998. The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments. *Energy Policy* 26(5), 441–454.
- Drury E, Miller M, Macal C, Graziano D, Heimiller D, Ozik J and Perry T. 2012. The transformation of southern California's residential photovoltaics market through third-party ownership. *Energy Policy* 42, 681–690.

- Dubin JA and McFadden DL. 1984. An econometric analysis of residential electric appliance holdings and consumption. *Econometrica* 52(2), 345–362.
- Faiers A and Neame C. 2006. Consumer attitudes towards domestic solar power systems. *Energy Policy* 34, 1797–1806.
- Farhar B and Coburn T. 2000. *A Market Assessment of Residential Grid-Tied PV Systems in Colorado (Technical Report No. NREL/TP-550-25283)*. National Renewable Energy Laboratory, Colorado.
- Gadenne D, Sharma B, Kerr D and Smith T. 2011. The influence of consumers' environmental beliefs and attitudes on energy saving behaviours. *Energy Policy* 39, 7684–7694.
- Gamtesa SF. 2013. An explanation of residential energy-efficiency retrofit behavior in Canada. *Energy Build* 57, 155–164.
- Gatersleben B, Steg L and Vlek C. 2002. Measurement and determinants of environmentally significant consumer behavior. *Environment and Behavior* 34(3), 335–362.
- Gillingham K, Newell R and Palmer K. 2006. Energy efficiency policies: a retrospective examination. *Annual Review of Environment and Resources* 31, 161–192.
- Goldman D, McKenna J and Murphy L. 2005. *Financing projects that use clean-energy technologies: an overview of barriers and opportunities*. National Renewable Energy Laboratory. Golden, CO. NREL/TP-600-38723.
- Gottwalt S, Ketter W, Block C, Collins J and Weinhardt C. 2011. Demand side management – A simulation of household behavior under variable prices. *Energy Policy* 39(12), 8163–8174.
- Greening LA and Greene DL. 1998. *Energy use, technical efficiency and the rebound effect: a review of the literature*. Report to the US Department of Energy, Hagler Bailly and Co., Denver.
- Greening LA, Greene DL and Difiglio C. 2000. Energy efficiency and consumption – the rebound effect – a survey. *Energy Policy* 28, 389–401. [https://dx.doi.org/10.1016/S0301-4215\(00\)00021-5](https://dx.doi.org/10.1016/S0301-4215(00)00021-5).
- Grothmann T and Patt A. 2005. Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change* 15 (3), 199–213.
- Hannemann WM and Kanninen B. 1996. *The statistical analysis of discrete-response CV data*. Working paper number 798. Department of Agricultural and Resource Economics, University of California, Berkley.
- Harding M and Hsiaw A. 2012. *Goal setting and energy efficiency*. Working Paper. Department of Economics, Stanford University, Stanford.
- Harding M and Hsiaw A. 2013. Goal-setting and self-control. *Journal of Economic Theory* 148(2), 601–626.
- Hargreaves T, Nye M and Burgess J. 2010. Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy* 38(10), 6111–6119.
- Havas L, Ballweg J, Penna C and Race D. 2015. Energising households: a financial analysis of incentivised energy efficiency measures in remote Australia. *Energy Efficiency*. <http://dx.doi.org/10.1007/s12053-015-9326-6>.

- Heinzle SL and Wüstenhagen R. 2012. Dynamic adjustment of eco-labeling schemes and consumer choice – the revision of the EU energy label as a missed opportunity? *Business Strategy and the Environment* 21(1), 60–70.
- Horne R, Martel A, Arcari P, Foster D and McCormack A. 2013. *Living change: adaptive housing responses to climate change in the town camps of Alice Springs*. Final Report. RMIT University, Tangentyere Council & NCCARF. Gold Coast.
- Howarth R and Andersson B. 1993. Market barriers to energy efficiency. *Energy Economics* 15(4), 262–272.
- Howarth R, Haddad BM and Paton B. 2000. The economics of energy efficiency: insights from voluntary participation programs. *Energy Policy* 28, 477–486.
- IEA (International Energy Agency). 1997. *Indicators of energy use and efficiency: Understanding the link between energy and human activity*. OECD/IEA. Paris.
- IEA (International Energy Agency). 2006. *Barriers to technology diffusion: the case of solar thermal technologies*. OECD/IEA. Paris.
- IEA (International Energy Agency). 2013. *CO₂ emissions from fuel combustion*. Edition released on 19 November 2013. doi:[10.5257/iea/co2/2013](https://doi.org/10.5257/iea/co2/2013).
- IPART. 2011. *Determinants of residential energy and water consumption in Sydney and surrounds, Regression analysis of the 2008 and 2010 IPART household survey data*. Independent Pricing and Regulatory Tribunal of New South Wales, Sydney.
- Jacobson S and Johnson A. 2000. The diffusion of RE technology: an analytical framework and key issues for research. *Energy Policy* 28(9), 625–640.
- Jaffe AB, Newell RG and Stavins RN. 2004. Economics of Energy Efficiency, in Cleveland CJ (Ed.), *Encyclopedia of Energy*. Elsevier, New York, pp. 79–90.
- Jakob M. 2006. Marginal costs and co-benefits of energy efficiency investments: The case of the Swiss residential sector. *Energy Policy* 34(2), 172–187.
- Kaldellis J, Kavadias K and Spyropoulos G. 2005. Investigating the real situation of Greek solar water heating market. *Renewable and Sustainable Energy Review* 9(5), 499–520.
- Klein RW and Spady R H. 1993. An efficient semiparametric estimator for binary response vehicles. *Econometrica* 61, 387–421.
- Labay D and Kinnear T. 1981. Exploring the consumer decision process in the adoption of solar energy systems. *Journal of Consumer Research* 8(3), 271–278.
- Lefley F. 1996. The payback method of investment appraisal: A review and synthesis. *International Journal of Production Economics* 44(3), 207–224.
- Lenzen M, Wier M, Cohen C, Hayami H, Pachauri S and Schaeffer R. 2006. A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan. *Energy* 31, 181–207.
- Levine MD, Koomey JG, McMahon JE, Sanstad AH and Hirst E. 1995. Energy Efficiency Policy and Market Failures. *Annual Review of Energy and the Environment*, 20, 535–555.

- Liverman DM. 2013. Bridging the science-policy interface: informing climate governance in the USA (Chapter 9). In J Palutikof, SL Boulter, AJ Ash, M Stafford Smith, M Parry, M Waschka and D Guitart (eds), *Climate Adaptation Futures*. Wiley-Blackwell, UK. pp. 103–110.
- Mallaburn PS and Eyre N. 2014. Lessons from energy efficiency policy and programmes in the UK from 1973 to 2013. *Energy Efficiency* 7(1), 23–41.
- Martel A and Horne R. 2012. *Thermal comfort modelling of Top End remote Indigenous housing in the Northern Territory*. More Than a Roof Overhead Working Paper #2. RMIT University, Melbourne.
- Maru YT, Fletcher CS and Chewings VH. 2012. A synthesis of current approaches to traps is useful but needs rethinking for Indigenous disadvantage and poverty research. *Ecology and Society* 17(2), Art. 7.
- Maru YT, Stafford Smith M, Sparrow A, Pincho PF and Dube OP. 2014. A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Global Environmental Change* 28, 337–350
<http://www.sciencedirect.com/science/article/pii/S0959378013002379>.
- McDougall G, Claxton J and Ritchie J. 1983. Residential home audits: an empirical analysis of the ENEVERSAVE program. *Journal of Environmental Systems* 12(3), 265–278.
- McGregor Tan Research. 2012. *Alice Solar City Community Survey Report*.
<http://www.alicesolarcity.com.au/sites/default/files/McGregor%20Tan%20Community%20Survey%20Report%20Summary%20-%20July%202012.pdf>.
- McKenzie M. 2013. *Pre-Payment Meters and Energy Efficiency in Indigenous Households*. Report by Bushlight, Centre for Appropriate Technology, Alice Springs.
- McMakin A, Malone E and Lundgren R. 2002. Motivating residents to conserve energy without financial incentives. *Environment and Behavior* 34(6), 848–863.
- Memmott P, Reser J, Head B, Davidson J, Nash D, O'Rourke T, Gamage H, Suliman S, Lowry A and Marshall K. 2013. *Aboriginal responses to climate change in arid zone Australia: regional understandings and capacity building for adaptation*. NCCARF & the University of Queensland. Gold Coast.
- Mills B and Schleich J. 2008. Why don't households see the light? Explaining the diffusion of compact fluorescent lamps. In: paper presented at the 16th Annual Conference of the European Association of Environmental and Resource Economists. June 25–28, Gothenburg, Sweden.
- Mills B and Schleich J. 2009. Profits or preferences? Assessing the adoption of residential solar thermal technologies. *Energy Policy* 37(10), 4145–4154. <https://doi.org/10.1016/j.enpol.2009.05.014>.
- Mishan EJ. 1972. *Elements of cost-benefit analysis*. Allen and Unwin, London.
- Mott G. 1990. *Investment appraisal for managers*. Gower Publishing Co. Ltd. England.
- Mundaca L, Neij L, Worrell E and McNeil M. 2010. Evaluating energy efficiency policies with energy-economy models. *Annual Review of Environment and Resources* 35, 305–344.
- Newton P and Meyer D. 2012. The determinants of urban resource consumption. *Environment and Behavior* 44, 107–135. <http://dx.doi.org/10.1177/0013916510390494>.
- Nguyen O and Cairney S. 2013. *Literature review of the interplay between education, employment, health and wellbeing for Aboriginal and Torres Strait Islander people in remote areas: working towards an*

- Aboriginal and Torres Strait Islander wellbeing framework*. CRC-REP Working Paper CW013. Ninti One Limited. Alice Springs.
- Niemeyer S. 2010. Consumer voices: adoption of residential energy-efficient practices. *International Journal of Consumer Studies* 34(2), 140–145.
- Oikonomou V, Becchis F, Steg L and Russolillo D. 2009. Energy saving and energy efficiency concepts for policy making. *Energy Policy* 37, 4787–4796.
- Osborne MJ. 2010. A resolution to the NPV–IRR debate? *The Quarterly Review of Economics and Finance* 50(2), 234–239.
- Paetz AG, Dütschke E and Fichtner W. 2012. Smart homes as a means to sustainable energy consumption: A study of consumer perceptions. *Journal of Consumer Policy* 35, 23–41.
- Palutikof J, Boulter SL, Ash AJ, Stafford Smith M, Parry M, Waschka M and Guitart D. 2013. The past, present and future of adaptation: setting the context and naming the challenges (Chapter 1). In J Palutikof, SL Boulter, AJ Ash, M Stafford Smith, M Parry, M Waschka and D Guitart (eds), *Climate Adaptation Futures*. Wiley-Blackwell, UK. pp. 3–29.
- Poortinga W, Steg L, Vlek C and Weirsmas G. 2003. Household preferences for energy saving measures: a conjoint analysis. *Journal of Economic Psychology* 24, 49–64.
- Prime Minister’s Task Group on Energy Efficiency. 2010. *Report of the Prime Minister’s Task Group on Energy Efficiency*. Australian Government, Canberra.
- Rosenow J, Platt R and Flanagan B. 2013. Fuel poverty and energy efficiency obligations – A critical assessment of the supplier obligation in the UK. *Energy Policy* 62, 1194–1203.
- Sanstad AH and Howarth RB. 1994. Consumer rationality and energy efficiency. *ACEEE Summer Study on Energy Efficiency in Buildings*, 175–183. Available from http://aceee.org/files/proceedings/1994/data/papers/SS94_Panel1_Paper21.pdf.
- Santamouris M. 2001. Euroclass: a European method for the experimental evaluation and classification of residential buildings. In: *Proceedings of the Presentation of SAVE Project on Energy Legislation in the Building Sector*. 25 July, Athens, Greece.
- Scott S. 1997. Household energy efficiency in Ireland: A replication study of ownership of energy saving items. *Energy Economics* 19(2), 187–208.
- Sidiras D and Koukios E. 2004. Solar systems diffusion in local markets. *Energy Policy* 32, 2007–2018.
- Solar Cities. 2009. *Solar Cities – Fact Sheet 1*, Australian Government. <http://www.townsvillesolarcity.com/portals/0/pdf/factsheet1-final.pdf>
- Stafford Smith M and Cribb J. 2009. *Dry Times: Blueprint for a red land*. CSIRO Publishing. Melbourne.
- Stephenson J, Barton B, Carrington G, Gnoth D, Lawson R and Thorsnes P. 2010. Energy cultures: A framework for understanding energy behaviours. *Energy Policy* 38(10), 6120–6129.
- Suppiah R, Hennessy KJ, Whetton PH, McInnes K, Macadam I, Bathols J, Ricketts J and Page CM. 2007. Australian climate change projections derived from simulations performed for the IPCC 4th Assessment Report. *Australian Meteorological Magazine*. 56, 131–152.
- Taylor PG, d’Ortigue OL, Francoeur M and Trudeau N. 2010. Final energy use in IEA countries: The role of energy efficiency. *Energy Policy* 38(11), 6463–6474.

- Timilsina G, Kurdgelashvili L and Narbel P. 2012. Solar energy: markets, economics and policy. *Renewable and Sustainable Energy Reviews* 16, 449–465.
<http://dx.doi.org/10.1016/j.rser.2011.08.009>.
- Van Houwelingen J and Van Raaij F. 1989. The effect of goal-setting and daily electronic feedback on in-home energy use. *Journal of Consumer Research* 16, 98–105.
- Varone F and Aebischer B. 2001. Energy efficiency: the challenges of policy design. *Energy Policy* 29, 615–629.
- VSN-International. 2012. ‘GenStat for Windows’. VSN International, Hemel Hempstead, UK.
GenStat.co.uk.
- Wada K, Akimoto K, Sano F, Oda J and Homma T. 2012. Energy efficiency opportunities in the residential sector and their feasibility. *Energy* 48, 5–10.
- Willis RM, Stewart RA, Panuwatwanich K, Jones S and Kyriakides A. 2010. Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households. *Resources, Conservation and Recycling* 54 (12), 1117–1127.
- World Bank. 2012. ‘World Bank. 2009–2012. Energy use (kg of oil equivalent per capita)’. Data retrieved 21 February 2014 from World Bank: World Development Indicators database.
<http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE>.
- Wyld Group. 2011. *Mid-Term Review of the Solar Cities Program*. Prepared for the Australian Government, Department of Climate Change and Energy Efficiency. Cape Schanck, Vic.
- Zahedi A. 2010. Australian renewable energy progress. *Renewable & Sustainable Energy Reviews* 14(8), 2208–2213.

PARTNERS IN THE CRC FOR REMOTE ECONOMIC PARTICIPATION

Principal Partners



Project Partners

