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Research article

Residential consumer perspectives of effective peak electricity demand reduction interventions as an approach for low carbon communities.

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Abstract: Internationally, policy makers have been trying to find ways of changing residential electricity use through improved energy efficiency or by means of behaviour change. Drawing on evidence from an Australian project undertaken in a community of approximately 2200 residents, this paper reviews how a combination of interventions have successfully reduced electricity demand levels to below that of pre-intervention levels. Employing a qualitative methodology and using this successful project as the basis of a case study, this research explores the effectiveness of the electricity demand reduction interventions from the perspective of residents from 22 households. By combining and tailoring interventions to the specific needs and motivations of individual householders, this study demonstrates how a multi-pronged and integrated approach can be effective in addressing the multi-faceted challenge of energy efficiency and behaviour change. The experience with this Australian residential community in achieving an ongoing reduction in electricity use is rare and the findings from the research are internationally relevant in informing policy and practice directions for achieving government-set lower carbon emission targets. This research has important implications for addressing issues related to total consumption and peak demand reduction, both financial and environmental, for the benefit of energy providers and consumers.

Keywords: Residential electricity demand; peak electricity demand; Australia

1. Introduction

Since the 1970s, policy makers internationally have been grappling with finding ways to change consumer behaviour regarding energy consumption. The reduction of energy consumption was based on resource scarcity, but more recently this effort has been based on increasing infrastructure costs

and the desire by governments to reduce emissions from generation fuels and to encourage low carbon communities as part of its climate change commitments [1,2]. While, there have been examples of successful programs that have reduced electricity consumption there have been few studies that have demonstrated continued or sustained successful demand reduction over a longer period [3-5]. Drawing on evidence from an Australian project undertaken in an island community off the Queensland coast with a permanent population of approximately 2200 people, this paper discusses how a combination of intervention efforts have succeeded in making a difference in reducing electricity demand levels. Prior to the implementation of the project in 2008, peak energy demand was growing in the island community to unsustainable levels for existing infrastructure and therefore would require the installation of a third undersea cable to supply peak electricity during summer months. By 2011, the peak electricity demand and total grid supplied consumption had decreased below pre-intervention demand levels. This paper investigates why peak demand reduction occurred within this community through the eyes and words of the people who changed their electricity use over an extended period of time.

1.1. About the project

In early 2000s, the Australian Federal Government launched a solar cities programme to promote trials integrating demand side management measures and distributed solar photovoltaic (PV) generation in regions around Australia. This was at a time when Australia was conscious of meeting international obligations with the Kyoto Protocol, experiencing increasing costs of electricity generation and when solar costs were prohibitive to residential consumers.

Ergon Energy (as part of a consortium including the Townsville City Council) was successful as 1 of 7 areas to receive federal government funds to run a solar city project in Townsville. Ergon decided to invest the project funds on Magnetic Island because it could achieve the federal government program objectives while finding alternatives to costly network augmentation. Magnetic Island network peak demand was growing at a rate that would require a new sea cable (see Figure 1 below).

The peak demand data points on Figure 1 indicate the highest demand kVA level reached during the year. The dark blue line shows the expected growth of peak demand on Magnetic Island, which is similar to peak demand growth in Queensland due to growth in home appliances and as well as population increases, with the sea cable installation planned for 2007 as indicated by the vertical blue line arrow. Ergon forecast that a successfully implemented solar city project, that included using technical, economic and social interventions to reduce peak demand, would flatten the network peak demand at Magnetic Island for 3 years, with peak demand increasing, but at a slightly slower growth rate as indicated by the pink line. This would delay cable installation until 2013 as indicated by the pink vertical arrow.

The green vertical line shows when home energy assessments commenced. The actual result is shown in red. Peak demand growth continued upwards for the first year after the start of home energy assessments and then started to decrease to levels below pre-project implementation. At this time, the planned cable installation has extended out to 2015 and likely beyond. With the cable costing approximately $17M, this represents a saving of over $1.5M per year in interest payments. Previously, Townsville and Magnetic Island network peak demand growth were on similar paths. So the graphs (Figures 2 and 3 below) highlight the impact of the Solar City project on Magnetic Island. The peak demand shown in Figure 3 is the highest daily kW level and highlights the annual peak day.

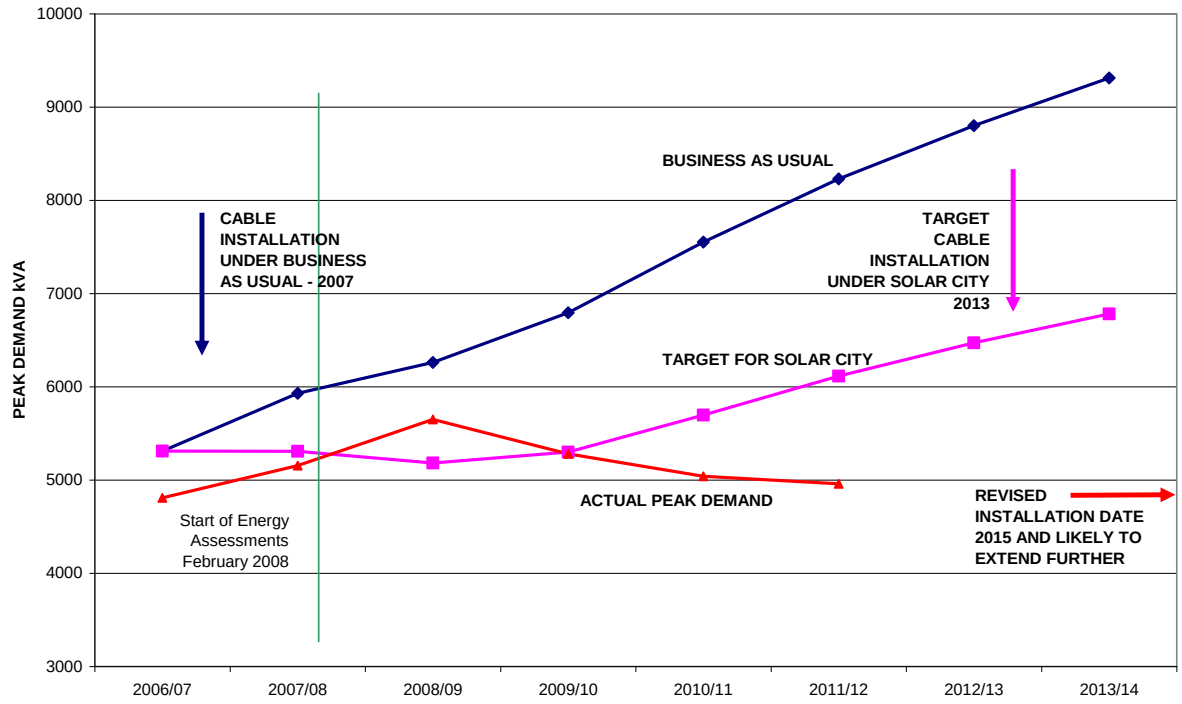

Figure 1. Peak demand—expected versus actual.

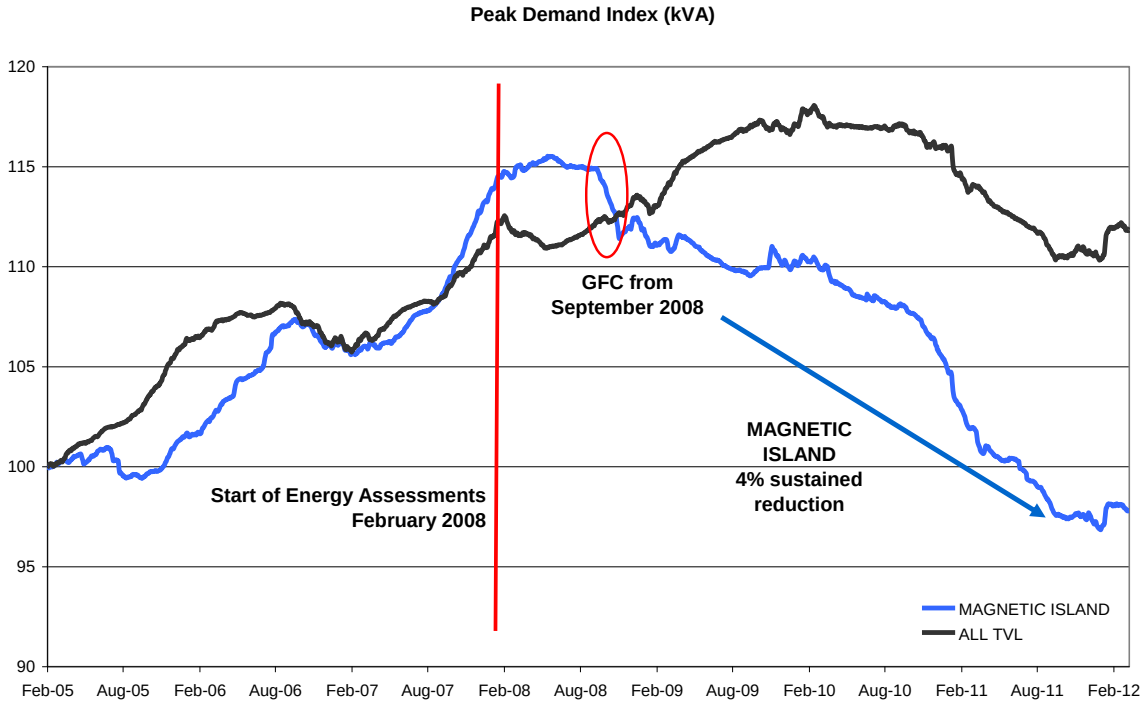

Figure 2. Magnetic Island versus Townsville.

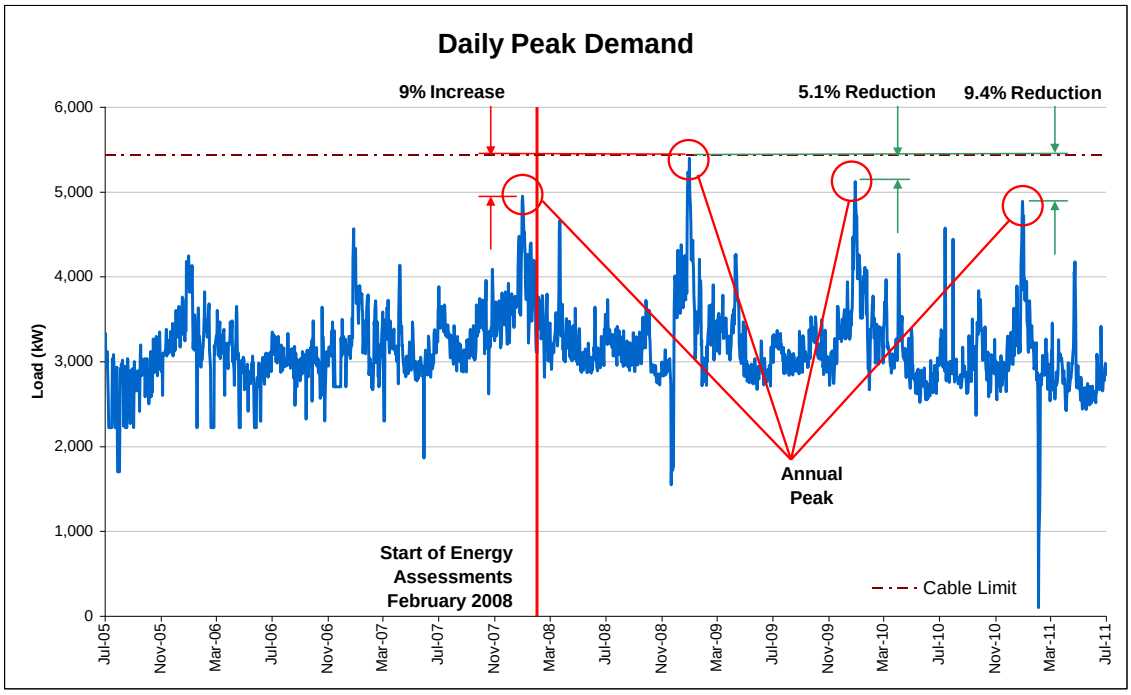

Figure 3. Magnetic Island daily peak demand.

During the project, residents were asked to host a solar PV generating system, leasing their roof space for a low or nominal rent. The system would be owned by Ergon and the power would go directly into the grid. The customer would get no direct benefit. Over 200 people hosted systems and only 6% of those with suitable roofs refused to host because there was no monetary gain for them. The 650 kW of power generated reduces the island's dependence on coal fired power, reduces the carbon footprint, but does not directly help with the peak demand that occurs at 7 pm.

By June 2013, the Townsville Solar City Project had conducted 1425 residential energy assessments, out of a total of 1735 households on Magnetic Island, since February 2008, representing greater than 80% of the homes on Magnetic Island. For the home energy assessment, usually two highly trained and accredited energy assessors spent up to two hours in each residential household to provide a detailed and personalised energy assessment. Each assessment highlighted benefits and removed barriers to electricity peak demand reduction, with examples such as prompts to remind the consumer to set air-conditioners to 25 °C or take shorter showers, the installation of energy efficient light bulbs and showerheads, cash-back vouchers for polyester roof insulation, reflective roof paint, upgrading to energy efficient appliances, and the removal of old inefficient appliances from the home. Finally, the residential consumer was asked to sign a document and commit to changing behaviour, with the top three changes being written on a sticker to be placed on the kitchen fridge, as well as a detailed action plan report outlining efficiency and behavioural change signed by the resident confirming the agreement sent later to the residential household.

1.2. Barriers to individual and household behavioural change—Need to combine actions

Different disciplines have discovered a range of barriers to reducing energy demand by individuals and households [6-10]. The barriers identified in studies include, social system barriers of entrenched social practices, common conventions and existing relations and infrastructures [11,12];

economic market failure barriers of a lack of information on the risks and benefits of alternative solutions [13,14] and psychological barriers of feelings of incapacity to make a difference as well as information overload and a lack of direct feedback [15-18]. In addition, human behaviour can be uncertain and complex, requiring a different approach to that based strictly on logic and structure [19,20]. For these reasons, individual discipline approaches and sole policy interventions have been ineffective in reducing household energy consumption [21-23]. Integrated and multi-disciplinary approaches require ongoing improvement to ensure their credibility and to make them a feasible alternative to existing solo or individual intervention and policy alternatives [22].

Recent research has emphasised a multi-disciplinary approach comprising a mix of interventions combining information, incentives, support and persuasion [24,25] involving users and groups in design and providing flexibility in implementing changes at both an individual and community level [11,26-28]. Using data from the most effective documented interventions that did not involve new regulatory measures, Dietz and colleagues [29] categorised these actions into five behaviourally distinct groups. These five categories included, Weatherisation, Energy efficiency, Maintenance, Adjustments and Daily use behaviours. The weatherisation of the residential home represents the increased energy efficiency of the building through design improvements. Weatherising the home involves, for example, shading walls that face west, purchase of fans and information on their strategic use, roof insulation and the like. Actions within the weatherisation categories are one-time investments in making the building more efficient. Plasticity from the most effective documented weatherisation related interventions involved strong social marketing, grants or rebates covering most of the retrofit cost, convenience features (e.g., one-stop shopping) and quality assurance (e.g., credentialing of contractors and inspection of work carried out) [29]. Financial incentives are necessary but insufficient to achieve strong plasticity depending on other elements of their implementation for successful outcomes [6,29].

The behavioural category of energy efficiency involves the replacement of less energy efficient appliances or equipment with more energy efficient ones, e.g., upgrades to inefficient air-conditioners, heating appliances, etc. Within this category, previous studies have shown that the greatest plasticity has been achieved by interventions combining elements of product information for householders and retailers, improved labelling or rating systems, strong social marketing and having financial incentives for the replacement of inefficient appliances with more efficient ones [10,29-31].

Maintenance actions are low-cost activities like changing of air-conditioning filters. Adjustment actions are no-cost activities like tariff change, reducing laundry or hot water system temperatures, re-setting thermostat temperatures on air-conditioners that once done are maintained automatically or by habit. Daily use behaviours are actions like line drying clothes and eliminating standby electricity functions. These functions are frequently repeated habitually or consciously chosen actions [29]. Interventions that had the greatest plasticity for maintenance, adjustment and daily use behaviours involved combining the elements of household and behaviour specific information and communication through individual households, social networks and communities and media messages [3,10,29,31].

What Dietz and colleagues and other researchers [21-23,32] demonstrate is the need for a multipronged and integrated approach to addressing the multi-faceted challenge of behaviour change to achieve energy conservation and peak demand management. An integrated approach can apply specialist discipline expertise while recognising the issue's larger and more complex context [22]. Combining financial incentives with program components like energy assessments, information,

education, appeals, informal social influences, convenience and quality assurance reduce the transaction costs of targeted, desired actions and have shown synergistic effects greater than the additive effects of individual interventions or policy [6-8,10,29].

The current case study is a review of a program of interventions that were exceptionally successful in achieving significant energy conservation and peak energy demand reduction across an entire island community (see Figure 1 above) off the Australian Queensland coast. Examples of successful programs involving an entire community and extending across years are uncommon making this study a valuable contribution to research and policy in energy conservation and peak demand management. This paper explores the interventions used to achieve the reduction in energy demand and the perceptions and experiences of the interventions for residents from 22 island households. The purpose of this paper is to investigate the experience of the residential island consumers and their perceptions of the interventions implemented within the project to provide insight into what interventions or mix of interventions are most effective in achieving energy conservation.

2. Method

This particular article is based on a case study of a highly successful project in one residential community that achieved significant electricity demand reduction over a prolonged period. The research used a phenomenological, qualitative approach, that prioritised participants own words and voices in expressing and understanding their day to day lived experiences, and how they related to the mix of interventions used in the project. In-depth interviews were used for this purpose and gathered specific information on participant descriptions of their everyday household experiences. In-depth insight into issues and topics and an exploration into the social and cultural contexts that affect processes, decisions and events, were explored through the real life experiences of Magnetic Island residential consumers who participated in the Townsville Solar City Project.

The main reason for conducting a single case study was to investigate a unique case, with the advantage of high discoverability [33]. Qualitative research does not suggest generalisation of the results across populations but rather its purpose is to collect data that illuminates the phenomena under study [33]. Thus, a deeper understanding is obtained from the full and meaningful responses provided by the participants [34,35]. In qualitative research, sample size is less important as the priority is the creation of patterns and themes that accurately represent meaning [36]. Qualitative research is an internationally recognised and rigorous social research method that is used to gain in-depth knowledge and understanding of a particular issue or question.

2.1. Case study location

Magnetic Island is eight kilometres off the coast of North Queensland (a 20 minute ferry ride) and is considered a suburb of Townsville with commuting workers, as well as being a desirable retirement location and popular holiday destination with 300 days of sunshine a year. See Figure 4 below for a map of the island in relation to Townsville. The permanent population is approximately 2200, although this fluctuates in holiday times. The majority of customers (more than 99%) on Magnetic Island are non-market customers who are charged regulated residential electricity prices set by the Queensland Competition Authority under their delegated powers from the Queensland Government.

Figure 4. Magnetic Island location near Townsville, Queensland.

Magnetic Island has clear geographical and electricity network boundaries that make it an easily definable region for research and analysis purposes. Magnetic Island was selected as the site for the Townsville Solar City Project because of the need for a third undersea cable, within the immediate planning horizon, due to increasing peak electricity demand forecasts. The Townsville Solar City Project was part of the Australian Government National Solar Cities Partnership between all levels of government, industry, business and local communities to trial sustainable energy solutions and to rethink the way Australia produces, consumes and conserves electricity.

2.2. Participants

A total of 30 participants (18 Females and 12 Males) from 22 Magnetic Island households were selected from local community sources including a local resident data base, energy utility customer database and local contacts. Participants were all house owners. Household size varied from one resident to seven residents, with the majority being two residents per household. Participants were selected to include key community resident types including single working people (four), working couples (ten), house share (one), retirees (five) and families with children (two). Ages ranged from early 30's to late 70's with most of the participants being in the 45 to 65 age range. All participants were permanent residents of Magnetic Island. Nearly two thirds were employed full time either on the Island or in nearly Townsville. The Queensland University of Technology Human Ethics Committee granted ethics approval for interviews to take place, with written consent obtained from each participant.

2.3. Procedure

Interviews gathered data about the participants' initial experiences and ongoing family

adaptations to changing behaviour for electricity use. The semi-structured interview format enabled residents to provide an in-depth understanding of their experiences from their perception. The interviews were conducted in participant homes or at a convenient location and lasted approximately 60–90 minutes. All interviews were digitally recorded and later transcribed verbatim into text for analysis, thereby capturing participant views and experiences in their own words.

The interviews explored the key themes of participation in Townsville Solar City Project, individual awareness, behaviour change in electricity use, expectation of electricity bill, impact on community, benefits and barriers to peak electricity demand reduction, and transferability to other regions. These topics were the focus in all interviews, which in turn led to other themes emerging as a consequence of the semi-structured nature of the interviews and the open-ended questioning used. All interviews were conducted by the one researcher.

2.4. Analysis

Transcribed interviews were analysed qualitatively in order to determine patterns or themes pertaining to life or living behaviour [37]. Thematic analysis identified the major issues and topics that emerged from the data. An iterative process was used with the transcripts being read and re-read in order to code the data and identify emerging themes and meaningful categories. The data was manually coded with key themes and sub-themes highlighted, grouped and labelled to enable the creation of a comprehensive observation of how and why Magnetic Island residents changed their household use of electricity.

3. Results

The case study project implemented a multi-faceted approach to successfully promote peak demand and total residential consumption reduction. The results below report the major themes identified within the data of participants' perceptions of the interventions implemented and the behavioural changes that they adopted. The themes are reported with examples of comments made by particular participants that represent the data from the participants. The thematically analysed data indicate that there were interventions that acted as facilitating factors and thus were important in obtaining commitment from residents and the community more broadly to behavioural change and the adoption and altered use of technologies in pursuit of reducing peak demand and total energy consumption. The analysed and themed results also indicate that there were interventions that participants found had minimal influence on affecting behavioural change. The data shows that the facilitating factors enabled strategies targeting behavioural change. The change targeted was most clearly identified in the data within the major theme areas of weatherisation, energy efficiency, maintenance, adjustment and daily use. These are categories that have previously been identified by Dietz and colleagues [29] and they serve as a useful way to explore the data as they exemplify major themes within the data of the adopted approach.

3.1. Facilitating factors

3.1.1. Home energy assessments and incentives

Home energy assessments and incentives were identified by participants as the major

facilitating factors in reducing general consumption as well as peak electricity demand. With rising electricity bills due to fuel and infrastructure costs, the consumer cost of living is increasing. Without knowledge of electricity used in the home, the residential consumer can have little understanding on how to effectively reduce their consumption. The impact of advice given by the project team of home energy assessors was greater knowledge and awareness of electricity use in the residential home and ways to reduce consumption and costs to the consumer. Without this knowledge and awareness consumers feel powerless to reduce consumption.

> *"If you sort of said to a bunch of people, you are worried about your bill, people probably feel powerless about what they can do … "Well, what can you actually do in your own home?"* House5

A major theme identified in the analysis of the data regarding home energy assessments was the connection with the project team through the assessment that seemed to create ease of communication between residents and the utility and resulted in an action-orientated community for electricity demand reduction.

> *"Yes, they came* [to do the home energy assessment]. *They were absolutely marvellous. They explained how to - if I had my pool filter put onto a different tariff, how much I would save, and that's true. They changed the lights… But it made me aware…So we have just been so much more careful."* House15

The use of incentives was also identified as a strong theme in the data. Understanding high energy use appliances may sometimes be assisted by a form of incentive. The case study project ran a competition with incentive payments to households able to reduce electricity use by more than 15% or 25% during the billing cycle. The competition encouraged some participants to change electricity use behaviour, with substantial savings as an outcome.

> *"When we had this competition, she stopped using the dryer and she saved $600 in a quarter. I knew all the time that she shouldn't be using the dryer and that would be a direct benefit, but she needed the incentive of the competition and she had the biggest reduction in the bill out of their group*[1]*. It was an insane amount of money."* House3

The incentive of exchanging and installing efficient lighting for free during the free home energy assessment was clearly identified by participants as an attractive option to the community and as such, a facilitating factor. This indicates that at least some households saw the offer as a strong incentive to agree to home energy assessments.

> *"Solar Cities, Ergon, did go round and change everyone's light bulb. So it was something for nothing. You know, that really worked really well."* House1

> *"But I think consistent messaging and definitely real carrots, visible carrots; whether that's, "We will come and change your light globes and we will come and do you a household* [energy assessment]*"—that is incredibly intensive. If you can go to that level of intensity, great."* House10

[1] The competition was run across 4 groups each representing a Magnetic Island town area (Picnic Bay, Nelly Bay, Arcadia and Horseshoe Bay)

"Going into the home was an assessment and it was "we will come around and give you something for nothing". And that goes down really well in this community. It doesn't mean you change anything; it means you put your hand up." House9

3.1.2. Setting goals and obtaining consumer commitment

This facilitating factor was also clearly identified by participants. At the completion of each energy assessment, the consumer was asked to sign a document committing to efficiency and behavioural changes with the top three items listed on a sticker and placed on the kitchen fridge. This provided a goal and commitment for the household that was visible to all household members.

"…We had the visit from the energy [assessor]. *My* [commitment sticker] *is still stuck on the side of the fridge."* House10

3.1.3. Sharing success with the community

Another major theme was the sharing of success within the community. Electricity use behaviour was part of the community conversation and the sharing of success within the community was beneficial in keeping electricity demand reduction in the front of people's thoughts. It was important for locals to know that reduction of electricity bills is possible and this became an effective advertisement within the community for the initiative.

"We do talk about power usage with people here on the island; it is a topic of conversation." House11 Participants
"They [another resident] *had an* [energy assessment] *to see what they could do and they cut their power consumption in half."* House6
"Yes, the pool, putting it on at different times [tariff]. *That saved them* [another resident] *money." House6*

3.2. Factors of minimal influence

3.2.1. Electricity bill

Many of the current interventions used by the electricity industry are information based on personal use or education outlining ways to reduce electricity demand in the home. The regular bill is used extensively for this purpose and is generally the only correspondence between the utility and the consumer. The majority of the participants in the interviews highlighted issues with this approach, with householders not seeing the utility bill as an opportunity to learn.

"Even though we sort of considered ourselves to be very educated about energy efficiency and keeping our footprint on the earth small, I never really looked twice at the electricity bill because you just get your electricity bill and it goes in the big pile of bills." House20

Receiving energy efficiency information on a quarterly bill is only beneficial if the consumer is ready to accept the information and consider it. Only then is positive action possible.

"Even if we got sent things in the mail, you have got to be receptive to read it. … It depends on what you are looking for and how receptive you are. If you are not really thinking about

"saving money on electricity", no matter how many papers come through, you are probably going to throw them all out." House6

3.2.2. In-home displays

This lack of attention and responsiveness to a traditional method of information broadcast by the electricity industry creates missed opportunity for electricity demand reduction. With the technological advancement and reduced costs of smart metering for residential households, the electricity industry is hopeful that information available on In-Home Displays (IHD) will be used extensively to reduce demand. The IHD information is considered a major step forward in presenting personal electricity use information because of the real time data, and as such, gives visibility to electricity use at an appliance level. However, a major theme identified by participants interviewed was the long term value of the IHD, believing that it had a limited use after the new knowledge of electricity use in the home was understood.

"So after 48 hours, the interest in it had just diminished completely… everyone who was given a Smart meter, who allowed them in their homes; how many people are still using it? And I reckon you would get less than 5 per cent." House21

In general, the participants stopped using the IHD quickly.

*"Maybe we didn't pump it [*IHD*] and use it for as much as what it's capable of. But I think we certainly didn't live by it. We sort of lived by common sense than the smart meter, itself."* House20

3.3. The action/behavioural approach

The facilitating factors identified as major themes in the data allowed an approach targeting action/behavioural change identified within the categories of weatherisation, energy efficiency, maintenance, adjustment and daily use.

3.3.1. Weatherisation

As part of the home assessments performed at Magnetic Island, the residential consumers were given advice, specific to their home, to increase energy efficiency. The advice often involved action that was low or no cost with simple design modifications, directly relevant to the house, resulting in an improvement in comfort achieved with little effort. Such advice was well received by householders and persuasive in terms of adopting the action in terms of active behaviour in making the recommended alterations/modifications.

"[The] *thing we were told, which ... was quite useful, was to put a fan at a low level in the kitchen … it can get fiercely hot in the kitchen, especially a western facing kitchen like ours and a fan at floor level is so much better than a fan at shoulder level."* House22

Reflective roof paint was a clearly identified theme in the data under weatherisation as a popular modification with the interview participants who undertook this design improvement advice. The roof paint was successful at reducing the temperature of the residential homes. It was so successful that other insulation products were thought to be unnecessary by the residents

"Oh, yes, that's what else we got a rebate for…, the roof paint … that paint is so effective … I reckon it would be a good few degrees, maybe more, in the extreme." House5

"We had the roof painted and the house cooled down by 3 degrees instantly. And I didn't need to do the roof [insulation]*."* House12

3.3.2. Energy efficiency

Energy efficient appliances are one of the best methods to reduce electricity demand without any change to electricity use habits [5]. Once purchased, the efficiency gains continue for the life of the product. The issue with replacement is the upfront costs involved with the purchase, and the difficulty of residential consumers factoring the life costs of the appliance in evaluating the option. One method used by the case study project, as part of the home assessment, was to offer incentives or rebates to help with the initial investment required. This approach proved attractive to many of the participant interviewees on a variety of home appliances.

"People who can't live without air-conditioning were definitely changing their air-conditioners for more efficient air-conditioners … "come and get your rebate, if you are handing in your old top-loading washing machine and get a front-loading, more efficient one"." House13

A clearly identified topic that emerged from the thematic analysis of the data was the value of energy efficient products given away for free and installed in the home as part of the home assessment. This approach avoided the distribution of products without their installation or use being certain.

"They came round - I think they changed the energy saving bulbs and showerheads." House8

By making energy efficient products more easily accessible to residential consumers, greater understanding of the benefits occurs. Confidence in the products capability and value improves to a level that makes energy efficient products more likely to be purchased when next required.

"Once you have got one of those [energy efficient] *globes, you just buy them next time because you know what to get."* House10

The success of the case study project saw one participant interviewee take advantage of all possible efficiency improvements and incentives put forward at the home assessment.

"We basically went and did everything that they recommended, where we could. We moved out all the old air-cons [air-conditioners] *and things down the house, there were a couple of old fridges and everything left and I have got to say the bonus payment made it a whole lot easier to do that sort of thing. They recommended various reverse cycle heat pumps and everything for water heating. We followed everything that they got."* House18

3.3.3. Maintenance

While consideration can be given to maintenance as a cheap method to improve efficiency and avoid deterioration of service of current appliances, most modern appliances are designed to be maintenance free. The greatest maintenance potential regarding electricity appliances identified by

the thematic analysis was air-conditioners.

> *"…changing the schedule for maintenance of air-conditioners can make a difference; make them work more efficiently."* House13

3.3.4. Adjustments

Adjustments, unlike energy efficiency behaviours above, do not consist of providing the same service using less energy. Instead, an adjustment is based on a scarcity principle where behaviour is modified, whether through comfort or convenience levels, to reduce electricity use. Adjustments are attractive for intervention designers due to the low or no cost attached to the behaviour change. Instead, the residential consumer only needs to be convinced that the trade-off in comfort or convenience is not large enough to affect acceptance of the change. Lifestyle is only slightly affected, but the resultant electricity use reduction provides a positive outcome.

One of the adjustments promoted in the home energy audit was changing the set points at which appliances operate. Participants identified that the major appliances targeted with this approach was hot water systems and air-conditioning, given they both substantially contribute to residential electricity demand. By setting hot water temperatures at a low level and air-conditioners at a high temperature for cooling, electricity consumption by these appliances is greatly reduced.

> *"Our air-conditioner is set at 26, our hot water is set at a fairly low* [temperature]. *I can basically hold my hand under the hottest* [water]*."* House8

Adjustments can be done once and not changed after that time, therefore avoiding becoming a behaviour that can rebound after a period of time. This is especially true with one of the intervention adjustments promoted by the case study project—use of tariffs. Tariffs will interrupt electricity supply to appliances during set times, most likely during system peak demand. Due to the need for an electrician to connect the appliance to the correct electrical metering system, this electricity supply interruption during these set times would require an electrician to reverse the tariff connection. The use of tariffs can be widespread in the residential household once an understanding of the process and routine, and an acceptance of the change to service is made by the household. Participants in the study who understood the process and routine identified their application of the different tariffs available to them and their savings.

> *We weighed up anything that was going to be higher consumption and realistically, other than the hot water, we just put - our air-cons were on tariff 33* [2]*, which was fine. So it really didn't make a huge difference to our day-to-day living, if you like."* House8
>
> *"I have cut down my use. I changed my tariff 11* [3] *bill. I put the bulk on tariff 33. I have got: Pool pump it's on tariff 33. My air-cons are on tariff 33. My fridge and freezer are on tariff 33."* House14

The tariff structure can provide substantial discounts for avoiding peak demand and for having a

[2] Tariff 33 is a controlled supply economy tariff hardwired to nominated appliances with electricity usually available outside of peak. Tariff 33 is unlike time-of-use tariffs as the price is the same at all times and does not require a behaviour change to receive the price.

[3] Tariff 11 is a general supply tariff designed for general usage

flexible load pattern.

> *"The prices have gone up and I am still using less dollar value…mainly because of tariff 33 … that's a huge saving, just moving those off that tariff."* House14

3.3.5. Daily use

The theme of daily use, which like adjustments is based on using less energy by limiting electricity use, or modifying behaviour on a daily basis. Participants identified the enterprising energy saving behaviours within this theme including the useful strategy for reducing energy demand by drying clothes without a dryer involving the clever use of air-conditioner outlets.

> *"I put the clothesline next to where* [the air-conditioner] *outlets were; which is a good idea … The two* [air-conditioner] *outlets are at the back of the house, so the clothesline is at the back of the house, attached to the house. So they just blow the clothes dry." House1*

Participants identified within this theme one of the behaviours targeted in the case study project during the home assessment that involved eliminating standby on household appliances. This approach does not limit the use of the appliance in its normal daily manner, but reduces electricity consumed when the appliance is not being used.

> *"When I am going out for a while and I don't need them, I flick it off, so I'm in the using—even though it's an LED monitor, I'm not using that. I have got a laser printer which tends to draw a bit of current, so it's switched off when not in use. So basically try and save as much as possible there. So I lose the standby there."* House4

A challenge to daily use behaviour change and this may also occur with adjustments identified by participants, wais the need to deal with other members of the household. Without autonomy, it is necessary to consider others in the household, with behaviour change requiring evaluation of household tension against the benefits received.

> *Oh, yeah. They suggested that I turn it off at the* [wall socket] *and at the time I said, "Look, I am prepared to pay the little bit extra power that I am using because of convenience with my wife," but then I thought I would have a look at it. Looked at how much was on standby power and I thought, "No, we will go down that road and turn those off."* House14

4. Discussion

This article presents a qualitative investigation of a case study of a successful residential electricity demand reduction project within an Australian suburban community. The success of this project is evidenced by the reduction in residential electricity demand, both peak and total consumption over an extended timeframe from 2007/08 to current day. By 2011, peak demand had reduced to below pre-intervention levels (see Figure 1 above). The knowledge gained from this case study cannot be formally generalised to other communities, however, this case does add validity to existing theory on behavioural change for energy reduction and provides valuable concrete, practical knowledge. The findings from this case study research demonstrate the importance of facilitating factors in delivering a tailored mix of interventions, for which residential consumers are prepared to make alterations to their homes and behaviour to reduce their energy demand. Analysis of the

interview data have shown how the interventions were mixed and personalised to individual households. Similar to previous findings [29], the results in this study suggest that the combination of interventions employed in the Magnetic Island project had a potentially greater affect than the simple addition of separate interventions. This section discusses the interventions employed by the project under the headings of Information, Incentives and Support and includes the factors for success identified in the combining of interventions that were persuasive in this study, by enabling behaviour change at both an individual and community level. These same categories have been previously identified in recent research as effective for reducing residential energy consumption [24,25,29].

4.1. Information—it's all about personalising

Much daily activity electricity use (e.g., washing, cooking, cleaning, entertainment, etc) is often habitual and invisible being undertaken without much conscious thought [16,38,39]. Information on personal use of energy can highlight the consumption being undertaken and provide the knowledge to assist in efficiency improvements and behaviour change [38,40]. While information generally does not create a motivation for change, personalised information can provide a tangible value [41,42] as illustrated by one of the participants in the case of appliances on standby. In this example, a recommendation to turn off their stand-by power forced the recognition of the behaviour as convenient and habitual and made them aware of the cost involved in such activity. This information allowed them to make an informed decision to change their behaviour and switch off all their stand-by power.

With the limits to the information that consumers can process in the digital age [43], personalising the information to each household can substantially decrease the knowledge necessary to that which is most relevant to individuals. The energy assessments provided to Magnetic Island residents were perfect examples of the provision of tailored information on efficiency and curtailment options based on the current situation that included advice on maintenance of air-conditioners (maintenance), lowering thermostat settings or applying a different tariff (adjustment actions) or applying insulation (weatherisation). In regard to improved energy efficiency, one of the participants described how placement of a fan at ground level, pointed out by the energy assessor, greatly increased comfort (weatherisation), while another suggested using the exhaust fan of the air-conditioner for drying clothes (daily use). These no cost steps improve the efficiency of the house, appliances and daily behaviour and would not have been possible without individual household knowledge. Customised information and advice, as found by other researchers, appears to be important for the information and advice to be effective [3,31,44].

In the current study, each household energy assessment included a free in-home display device designed to provide detailed feedback on electricity use within the home. These in-home displays were automated, concrete signals designed to provide real-time feedback to the householders. While advantages of electronic device feedback have been widely reported in terms of flexibility and presenting actual consumption data [40,45,46], participants overwhelmingly reported that they did not find the in-home device helpful or of any real assistance, particularly beyond the lessons learnt in the first two days. Participants also reported that their electricity bill was similarly ineffective as a means of reducing their electricity demand.

4.2. Incentives

Informational campaigns can increase knowledge but the action required for change by some residential consumers is assisted by making this step more financially attractive [7]. Some participants suggested that it is possible that knowledge of electricity use and potential savings is enough for behaviour change to occur. While for others, the financial carrot of rebates for energy efficiency improvements was necessary to fully embrace immediate demand reduction strategies.

While consumers may be unwilling to sacrifice certain comforts in the home, e.g., the use of air-conditioners, incentives for switching to more efficient appliances (energy efficiency) that deliver the same or improved comfort levels can also contribute to lowering energy use. In the current case study, residents were offered various rebates to improve the energy efficiency within their home either through weatherisation actions like insulation or through upgrading appliances, e.g., air-conditioners and washing machines (energy efficiency). As part of the energy assessment, assessors were able to physically inspect appliances and understand their use from observing their operation and from discussions with householders. The assessor was then able to provide the financial benefits to residents of upgrading which would include the value of the rebate and the improved efficiency of the upgraded appliance. Energy efficient products were also given away for free and installed in the home as part of the home assessment. This approach avoided the distribution of products without their installation or use being certain. It was also considered by participants to be an attractive inducement to request a free home energy assessment which was such an effective facilitating factor.

The results show that one of the values of the incentives occurred when individual household energy reduction became a conversation in the community thus keeping electricity demand reduction in the front of people's minds. This has been recognised by Ehrhardt-Martinez and colleagues [47] as leading to increasing focus by members of the community. Incentives provided the necessary motivation and impetus for Magnetic Island residents to try and use new energy efficient technology. Most residential consumers often understand efficiency appliances but are unclear of the true difference between products [31]. When a product such as reflective roof paint (weatherisation) was incentivised, it gave some potential for the early adopters at Magnetic Island to experiment. Once the product was deemed successful by the early adopters and with electricity use being a topic of conversation in the community, local support was an effective advertisement for the new technology. The discussion helped transmit incentive information, with the acceptance of some community members creating its own momentum. This phenomenon has been previously recognised by Sundramoorthy and colleagues [31].

4.3. Support

Offering practical, tangible support to householders is an enabling action for energy conservation [48]. Support provided by the utility made the information and incentives more effective by removing barriers and achieving the desired energy conserving behaviour. For example, the utility provided support by taking responsibility for the removal and disposal of old inefficient refrigerators and other appliances (adjustment). Another act of support used by the utility in conjunction with information and incentives was the physical no-cost replacement of inefficient lighting with energy efficient lighting (energy efficiency) for each house receiving an energy assessment. As mentioned above, some participants indicated that it was this lighting replacement

service that acted as the motivation they needed to sign up for an energy assessment. These types of support complimented the other interventions of information and incentives encouraging residents to make their house more energy efficient.

This support by the utility in helping residential consumers accept new technology and make their home more efficient could also been viewed as a successful incentive given the number of participants highlighting the attractiveness of the offers of free efficient lighting and removal and disposal of old unwanted appliances. With the large number of households requesting energy assessments, the utility had an excellent opportunity to engage in energy related communications making the information and incentives more personalised, relevant and vivid. Support, in conjunction with the other interventions, was an important contributor to success of the project.

4.4. Combining interventions—factors for success

The project appears to have been effective, in part, because of the cooperation that was established between the utility and residential consumers. Some participants outlined the ease of communication with the utility, constant awareness generated around demand reduction and how electricity use became a topic of conversation in the community. A persuasive factor of success was when another community member positively reinforced energy efficiency and behaviour change. The implied acceptance of change was shown in a request for a home energy assessment,

The assessors were well trained and provided a package of interventions that were able to be tailored to the needs and motivations of individual households. Conversations during the home energy assessment allowed the building of a bridge to understanding individual motivation, and thus knowing the approach and advice required to different consumers. The energy efficiency and energy saving information and advice provided was highly detailed, vivid and personalised and successful in having residents accept and commit to a range of efficiency and behavioural changes that they signed in a document with the top three action items put on a sticker and placed on the kitchen fridge. These results corroborate findings by Gonzales and colleagues [49] who found households receiving energy assessments by assessors using vivid, personalised information reportedly had a significantly greater likelihood of making the recommended changes.

Similar to findings identified by McMakin and colleagues [20], this study found that an integral reason for the effectiveness of the program was that intervention efforts explicitly included the characteristics of the householders and their living environment. The fact that the assessors conducted the energy assessment at each household site, were able to view each appliance, find out more about the design of the house, the operation of the household as well as analyse each household's energy consumption behaviour enabled them to give detailed, personalised and tailored advice thus creating customer trust and confidence. This process helped overcome the invisibility of the impacts of residents' energy consumption patterns and provide insight into the types of behaviours necessary for changes in energy use. Most importantly though, the energy assessment allowed for an understanding of what the residential consumer wished to achieve with their energy reduction and therefore put forward suggestions that would help increase likelihood of electricity demand reduction.

The mix of interventions employed in the project had an obvious impact as residents altered their houses and behaviour according to the advice given, availed themselves of the subsidies and rebates for more efficient appliances and the pick-up and disposal service of old and inefficient appliances. The approach used appears to have encouraged householders to adopt relatively easy to

change behaviours. The program focused on promoting behaviour changes by residents themselves, emphasising no-cost and low-cost actions (in terms of effort, convenience and time) as recommended by McMakin and colleagues such as thermostat setting (adjustment), the efficient use of appliances (maintenance and daily use), simple shade covers on western aspects (weatherisation) and the like. By providing tailored recommendations regarding options of possible actions to reduce waste and to save energy, residents were empowered to choose which actions to take as well as the scope of behaviours available.

4.5. Implications for policy

Policy development can only be improved when it is based on knowledge developed in the field, investigating successful interventions with everyday consumers in a community. The economic models have had difficulty with predicting residential response to incentives, while information has been seen to increase knowledge and change attitudes without transforming the knowledge into action. This paper reviews a successful community based electricity demand reduction project through the eyes of the people who made it successful. The findings highlight the need for policy makers to seek out, understand and incorporate consumers' views and interests in new policy developed to fully achieve the potential of wide-ranging and long-lasting energy efficiency improvements and behavioural change. The Magnetic Island experience is important because of its success in electricity demand reduction and lowering carbon emissions in a practical real-life setting over an extended period. The array of interventions available and the opportunity to mix and personalise the interventions through each energy assessment was important. Eliciting interest from over 80 per cent of the island household population and delivering a quality energy assessment to each and every household who requested one was critical to the success of the project and its outcomes. The challenge for policy makers going forward will be how to duplicate this experience and get into everyone's homes. From this position, the industry can listen to the consumer and together find opportunities to create low carbon communities that are of interest to policy-makers internationally.

5. Conclusion

This research highlighted the reduction of residential peak demand and total grid supplied electricity consumption in our case study region over a multi-year period. This demand reduction by residential consumers over a prolonged period of time is uncommon and with the qualitative case study research methodology, this article adds validity to existing theory on behavioural change for energy reduction and illuminates the important factors involved with interventions for improved energy efficiency and behaviour change. This paper highlights the need for and value in a multi-disciplinary approach to reducing peak electricity demand. The use of both economic, such as financial incentives, and non-economic, such as support and information interventions, when personalised, provide the opportunity for a flexible mix of approaches well suited to the variances and complexities of residential households. The combination of information, goal setting, commitment, financial incentives and information and advice tailored for individual households was especially successful in reducing electricity demand across an entire community by allowing residents to achieve greater insight into the possible ways to reduce energy use.

While the current study reports on the experiences of a small number of household residents

living in one suburban area, thereby precluding formal generalisation of its findings, it provides valuable concrete, practical knowledge capturing the local reality of everyday energy use and conservation for this group of residents. The study provides insight into their lived experience in reducing electricity demand. Their experiences with the project and the interventions are likely to have relevance to other residential community contexts elsewhere without having to discount for local differences. This is because the participants' reasons for action across a wide range of action contexts clarifies the nature of their knowledge and experience, which it is reasonable to assume, extends beyond this particular community to other residents elsewhere. To further develop this current study, additional research is needed that explores, in depth, how residents use electricity and respond to utilities and interventions designed to achieve energy conservation. This research is grounded in local reality and highlights pertinent challenges involved with electricity demand reduction in a residential consumer environment for policy and planning action. Formal generalising of this particular case can be made if further research is carried out, so that judgements of the typical nature of these results can justifiably be made.

Residential consumer electricity demand substantially contributes to energy grid infrastructure costs and emissions. While engaging the vast number of residential consumers is challenging, the impact of individual homes to reduction of infrastructure costs and emissions seems negligible. However, when substantial numbers in a community respond and accept energy efficiency and behaviour change, the resultant reductions are significant and can create momentum for change. Successful implementation across a wider community base would address objectives regarding rising costs of infrastructure to produce and supply electricity, lowering cost of living for residential consumers, and would help address emission targets set by governments. Considerable synergy between the residential consumer, the electricity industry and the government is possible, with low carbon communities being an achievable outcome.

Conflict of interest

The authors declare there is no conflict of interest.

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