Resident experiences using load management devices in an Australian monitored low-energy housing development

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Abstract

This paper reports on resident experiences with a simple load management feature in dwellings within an eco-friendly and comprehensively monitored Australian housing development. The 80 houses in Lochiel Park (South Australia) are designed to reduce energy use, and incorporate high performance building envelope, energy efficient appliances, gas-boosted solar hot water systems, and a grid-connected photovoltaic system. Each house is also fitted with a monitoring system that provides residents with real-time feedback regarding household electricity, gas and water usage.

The monitoring system includes a customizable load management system, which can deactivate high-powered electrical appliances or circuits when household electricity demand exceeds a specified set point. The use of this load management feature is voluntary and is seldom used. The reasons include the inappropriate choice of interruptible appliances, lack of incentives, practical limitations (caused by installation issues) and lack of perceived benefits for those living within a low-energy housing estate.

Load management systems may become important if South Australia moves towards peak electricity tariffs, hence it is important to address the real and perceived deficiencies of these. The paper also examines the potential to reduce household peak demand and any cost savings achieved using load management systems at various demand thresholds, using monitored power and energy usage data.

Introduction

Modern electricity networks, often with intermittent generation sources, have the ongoing challenge of matching highly variable supply and demand within the distribution system’s capacity. In particular, the challenge of managing short periods of peak demand is a significant problem [1, 2], with human thermal comfort at its root. The use of air conditioning (AC) is growing fast and is already a major contributor to summer peak demand in Mediterranean countries [3]. In similar climates such as in Adelaide, South Australia, where over 90% of households have an air-conditioner for summer cooling, the peak load can be 70% higher on hot days compared to typical network load on days of moderate conditions. In cooler climates such as the United Kingdom and New Zealand, residential peak demand occurs in the mornings and evenings during the winter months, coinciding with breakfast and dinner times, and is mostly related to space heating, water heating, cooking, and lighting [4].

For locations with a summer peak demand, an increase in solar photovoltaic generation may reduce the amplitude of the peak, but may increase the peakiness of electricity demand for the grid [5]. For example, during daylight hours conventional generation is replaced by supply from solar generation resources, but as the sun sets starting around 4:00pm other generation must be dispatched to meet the daily peak. Reducing peak electricity demand reduces overall distribution costs and therefore electricity prices through the deferral of capital expenditure [6].

Managing demand through the implementation of peak demand reduction strategies is critically important to reduce the overall cost of providing electricity. Electricity demand management uses a range of strategies to modify the level and timing of demand, including energy efficiency measures and energy saving technologies / practices such as: insulation; passive design; and automated control systems. Load management initiatives may also shift the timing of loads, or call on energy storage to reduce local demand, without reducing the provision of energy services. These measures can reduce the difference between peak and off-peak demand, and hence reduce the need for network augmentation with peak generation or energy storage equipment.

This paper documents the trialing of a load management system installed in 80 homes within Lochiel Park Green Village, in South Australia. It explores resident responses to voluntarily reducing their impact to network peak load, and the potential financial benefit at various demand set points.

Literature Review

Peak load drivers

Electricity networks are a complex interaction between generation, transmission and distribution systems and the demand for energy. The load on a particular electrical grid varies daily and seasonally, peaking during periods of extreme climatic conditions, whilst simultaneously growing as new energy services are added to the system. In Australia, both the average demand and peak demand are expected to grow rapidly at about 20 per cent and 30 per cent respectively for the period 2010 to 2020 [7], although the impact of the recent increase in the uptake of building rooftop photovoltaics may moderate this growth [8, 9].

The difference between managing a peak daily demand on a mild day and the peak demand during extreme climatic conditions, such as a summer heatwave, represents a substantial investment in energy supply infrastructure which is used infrequently. In South Australia, data from the electrical network utility shows that one third of the required capacity is needed for just 3% of the year [10]. For example: in 2004, the load for an extreme 38°C day in South Australian was over 1,000MW higher than an average 24°C summer's day, representing a 70 per cent increase in power demand [2]. Similarly in New South Wales, it was found that at least 10% of New South Wales' generating capacity is needed for just 1% of the time, and it was suggested that with predicted residential air-conditioning penetration, this will rise to 20% of generating capacity [1].

Recent evidence from South Australia is demonstrating that residential rooftop photovoltaic generation can lessen heatwave related peak electricity demand on the local energy grid, reducing some of the need for additional electrical infrastructure [9], although the Californian experience suggests that an increase in solar photovoltaic generation may increase the overall peakiness of electricity demand for the grid [5].

The market value of electricity increases appreciably when demand approaches the maximum supply capacity [11]. The analysis noted that peak demand periods accounting for only 3.2% of the annual market were responsible for 36% of total market costs. In Australia, summer peak loads are increasing electricity costs to consumers and leading to inappropriate over-investments in energy infrastructure [12], and infrastructure unreliability [13].

A key factor driving the summer peak energy demand is the use of domestic air conditioning [13, 14]. It was noted that although air-conditioning is responsible for only around 6% of residential energy use, it is responsible for about 40% of residential peak demand [14]. Energy Efficient Strategies (2004) calculated a temperature sensitive load in Melbourne of over 2,000MW during the summer of 2002/03 (from a base of 6,000MW), which was almost entirely due to the use of residential air-conditioning. This means that considerable savings can be achieved in avoided capital and maintenance expenditure on the electrical network by reducing demand during extreme climatic conditions such as summer heatwaves [7, 15].

Household energy end-use reductions, across both the average load and during peak demand times, plus domestic-scale on-site generation of electricity, can combine to reduce the need for new large-scale generation infrastructure and enhancements to electricity supply networks [7, 13, 14, 16-18].

Load management solutions

There are a number of strategies typically used to reduce the level and shift the timing of demand, to reduce the overall size of network peak demand. In particular, direct load control strategies allow network providers to eliminate some of the load for a specific period. Critical peak pricing and other voluntary load control measures can provide an incentive for electricity users to shift or curtail demand during periods of peak network demand. Also, energy storage may play a role in substituting for network supply during periods of peak demand.

Direct Load Control

Direct load control strategies allow network providers to eliminate a part of the load for a specific period. Trials in South Australia [6] and Western Australia [19] have given aspects of control of residential air-conditioners to the network providers to periodically change function from reverse-cycle cooling (compressor operating) to fan only provision, often only for 15 minute periods per each hour of use. The result of this process is the elimination of almost one quarter of air-conditioning energy demand for the household sample. Although there were differences in how the trials were conducted and the technology employed, both trials noted that the majority of customers did not experience any adverse impact on their comfort levels.

Critical Peak Pricing

Critical peak pricing is based on the concept that households exhibit a price elasticity of demand for various energy services that are used during peak network demand periods. Often critical peak pricing is conducted in conjunction with an in-home display to provide consumers with all the information they need to make a choice about energy use and potential savings. In some trials the households agreed to automated particular price sensitive energy service use strategies which are then automated.

In locations with a summer peak load, the electricity tariff may be temporarily increased during certain hours (time of use tariffs) within designated hot days to dissuade householders from switching on their air-conditioning, and therefore help keep aggregate load within manageable limits [1]. A case study in Australia involving 756 residential customers noted that while many other electricity-using practices were shifted to lower cost times of the day in response to critical peak pricing events (e.g. laundry, cooking, vacuuming, clothes drying and ironing), thermal comfort (cooling) practices were less often shifted [20].

In New Zealand a trial was conducted to encourage residential customers to voluntarily move some thermal loads to off-peak periods. Participants were found to forego heat for some time, however they were less willing to forego a cup of tea / coffee. Overall, the trial found that there was a willingness for delaying the use of some energy services such as washing machines, clothes dryers and dish washers during periods of peak network demand [4].

The Californian experience of critical peak pricing shows that some discretionary loads can be moved to lower cost periods, although beyond the initial set of actions further curtailment becomes increasingly price inelastic [21]. The wider American experience has included trials that take the consumer out of the day-to-day response equation by automating the response to price signals [22]. Given householder's inherent desire for thermal comfort, it is not surprising that it was found that technology to automate response to price signals increased peak load related savings compared to direct consumer response to price signals [22]. With a vision to the future of household energy use, [23] suggest that personal electric vehicles may become the largest discretionary load that may be shifted by time of use pricing.

Additional supply from energy storage

Energy storage may play a role in the reduction of peak demand through two main mechanisms: (a) the use of thermal storage to shift electrical demand to off-peak times; and (b) the use of electrical storage to meet localized demand for energy services. These strategies can be operated through either direct storage control, whereby the network provider chooses to remotely operate the energy storage system, or via a market mechanism whereby the end-user chooses to utilize local energy storage, e.g. when the cost of operating the storage is lower than the network price.

Recent studies have found that due to the high cost of battery storage relative to other strategies, this is not a cost effective option, although with increased production of electrical storage there will likely be a time whereby batteries can play a role in reducing peak network demand [24]. In addition to building related battery packs, remote management of distributed energy storage from plug-in electric vehicles may play an important role in the future management of peak network loads [23].

Case study

The Lochiel Park Green Village is purpose built low energy residential development, designed to significantly reduce energy use and associated greenhouse gas emissions [25]. All Lochiel Park homes include solar photovoltaic systems, solar hot water systems, relatively high levels of passive thermal comfort design, water and energy efficient appliances and equipment, and other technologies designed to reduce both annual and peak energy demand.

In 2006, the state government owned land developer (Land Management Corporation) approached the electricity network provider (ETSA Utilities) with a view to applying load limitation at Lochiel Park. The proposed system allowed an agreed preset maximum demand of up to 6 kVA per allotment and to actively monitor this demand; this was based on evaporative air conditioners limited to 2kVA. If the preset level was breached, then the system would automatically turn off householder selected, non-essential electrical appliances/circuits in order to avoid the peak demand level being exceeded. A tariff was developed to incentivize customers to voluntarily limit their demand to 6kVA or less [6]. However the air conditioning specifications changed and were based on the house size [6] and were limited to 4kVA, as mentioned in the development's urban design guidelines [6]. The distributor estimated the after diversity maximum demand of this development as per normal precincts which is described in their Technical Standard TS-100 [26], i.e. 4, 6, 8 and 10kVA for houses with average dwelling sizes of 110m^2, 100-185m^2, 185-280m^2, and above 280m^2 respectively.

Each house in Lochiel Park is fitted with an 'EcoVision' brand monitoring system, which includes an in-home feedback display, a programmable logic controller (PLC), and a variety of intelligent meters and sensors [27, 28]. One feature of this is the customizable load management system (LMS) that can interrupt power to certain power circuits by controlling up to 6 contactors if a power set point of 3, 4 or 5kW was exceed for a 30-minute period. The contactors are typically wired to high-powered appliances including reverse-cycle air conditioners; pool or spa pumps; ovens and dishwashers; and laundry and kitchen power circuits, as specified in the electrical installation guidelines [29].

The LMS is designed to continue interrupting power to circuits until the electrical demand falls below the set point. Due to safety reasons, circuits are not automatically re-energized once interrupted; this must be manually undertaken by the resident by interacting with the LMS. An example of two in-home display load management system pages is shown in Figure 1 (a) and (b), where (b) highlights which power circuits / appliances have their supply of power interrupted.

Figure 1: Load management system screens of two in-home displays for set points of (a) 5kW and (b) 3kW. Subfigure (b) highlights the power circuits that have had power interrupted.

Installation Issues and Limitations

Although the electrical installation guidelines [29] specified that circuits powering refrigerators, lights or telecommunication devices should not be interruptible, many electrical subcontractors did not obey this, particularly regarding refrigerators which were in a number of cases wired to kitchen appliances circuit, rendering this unsuitable for inclusion in the load management system. Similarly, a small number of air conditioners could not be included in the list of interruptible appliances as the selected contactors were rated at 25A, whilst corresponding circuit breakers were rated at 30A.

The load management feature is voluntary, and to encourage initial uptake the electrical retailer initially offered a small financial incentive (AU$60/quarter) to residents who maintained a 3kW limit. However, this incentive was discontinued by the retailer following a lack of consumer interest.

Methodology

Interviews

The residents of 15 Lochiel Park households were recently interviewed about many aspects of living within a low-energy housing estate, during which they were asked to comment on their experiences, and those they might have heard, regarding their perceptions and (intentional or otherwise) utilization of their LMS. They were also asked to comment on other residents' positive or negative experiences, and which appliances / electrical circuits they believed should be controlled and those that should remain powered at all times. These 15 interviews supplemented those conducted in 2012-13.

Monitored Load Management Data and Simulated Economic Improvement Analysis

Individual household energy, power and LMS data, collected each minute was collected and collated for up to 71 households over a monitoring period spanning 7 years, i.e. 2010 - 2017. Each of the 3,955 monthly files were processed to determine the amount of time each LMS was used (if at all), along with set point (threshold) levels, and whether or not these interrupted power and to what extent.

Economic Analysis: Peak Tariff and Mandatory Load Management System

The potential to save money by moving to peak tariffs was explored, by firstly simulating individual household electricity bills using current 2015 tariffs, and comparing these to currently accessible peak tariffs. This was carried out in two stages for 47 households in 2015 using Microsoft Excel, as these had complete data sets for the 2015 calendar year. First, the uptake of LMS was replicated as monitored in 2015 (referred to as a load management setting of 'as is'), and second, the effect of mandating LMS utilization in each house and at each of the available set points, i.e. 3, 4 and 5kW, was simulated. It was assumed that the energy purchased from the grid remained unchanged, whilst the peak power demand during the 'peak window', i.e. 4-9pm daily, was limited to each set point.

Table 1 summarizes the components of the current 2015 and peak tariffs [30]. Compared to the current 2015 tariff, the main differences in the peak tariff include: a reduced daily connection charge; additional monthly meter reading charge; additional peak summer and winter charges (based on the monthly peak power demanded in the peak window); and only one energy charge rate used for each month of the year. For the purpose of the analyses presented here it is assumed that the solar feed-in tariff (credit) remains unchanged, as this will remain in place until June 2028 providing the residents do not increase their PV system size beyond that previously approved by the distributor [31].

Table 1: Summary of Current 2015 and Peak tariff components, in AU$ [30].

	Tariff Component	Applies	Current	Peak
Energy ($/kWh)	Summer (First 10.9589 kWh/d)	JAN-MAR	0.32120	-
	Summer balance	JAN-MAR	0.37466	-
	Winter (First 10.9589 kWh/d)	APR-DEC	0.29524	-
	Winter balance	APR-DEC	0.33913	-
	Peak Consumption	JAN-DEC	-	0.26345
Peak ($/kW/d) [min. charge 1.5kW/m]	Summer Demand Peak	NOV-MAR	-	0.54197
	Winter Demand Peak	APR-OCT	-	0.26950
Daily Charge ($/d)	Supply		0.70169	0.40392
	Daily Meter Read		-	0.18030
Solar Credit ($/kWh)	Feed-in Tariff (exported energy)		0.50800	0.50800

Summary of Load Management System Utilization and Power Interruptions

Interview Results

The results from 15 householders that were recently interviewed about the use of their LMS, is summarized in Table 2, which shows the months each household used their LMS and experienced power interruptions. Note that some similar interview responses from [32] are also included. Also note that the number within the curly brackets, e.g. {2} represents the number of months where the data showed that the LMS was used or had interrupted power, however in reality these did not occur as the LMS was not re-commissioned following a monitoring system firmware upgrade.

Despite the general consensus that the LMS were seldom used in the development, the data shows that 5 of the interviewed households used their LMS despite reporting that they did not. This indicates the residents unintentionally activated this, forgot it was on, or were unaware of its function. Further, power was interrupted at least once in 4 households, and in two of these cases, the residents were notified by phone call as they were unaware that power to appliances had been interrupted.

Table 2: Summary of 15 recently interviewed householders showing usage and events. The number or letter within { } indicates data where LMS appears to be used, but was inoperable.

	LMS Used?, according to:		# Months (from data)		
Household	**Interview**	**Data**	**Data**	**Used**	**Power Interruptions**
E	Y	Y	61	57	4
F	N	N	54	0	0
G*	Y	Y	74	2	1
H*	N	Y	67	5 {2}	4 {2}
J*	N	Y	75	3 {1}	0
N*	Y	Y	75	5	1
O	N	N	43	0	0
P	N	Y	46	5	4
Q**	Y	Y	71	44	11
U*	Y	Y	76	13 {6}	2 {2}
Z**	N	Y	61	2 {1}	1
AA	N	Y	60	51	24
BB	N	N	9	0	0
CC*	N	N {Y}	35	28 {28}	8 {8}
DD*	N	Y	68	4	4

* LMS was not re-commissioned after firmware upgrade and no longer functions correctly.

** LMS was re-commissioned after firmware upgraded and is functioning correctly.

Many households thought that the load management feature was no longer operating, whilst others thought the feature was of little value to them for they were already very energy efficient. Household B did not use this feature because they wanted to maintain control of all electrical appliances and equipment. Household E had used the feature but found it *“useless”* after it turned the washing machine off when they needed the clothes washed. Household G attempted to use the feature without success. Household I thought it was *“conceptually fantastic, but not a good feature at the moment”*, and referred to a negative experience of another Lochiel Park household that was not interviewed in this study. Household F was typical of responses to this feature:

> *“[person’s name] did mentioned that and explained it somewhat, but we haven’t sort of run into that territory where we’ve been motivated to need to do it, …”*

Household Q uses the load management system to help know when they were using too much electricity and to track and control air conditioning used by the daughters, but without a high level of success as this caused anger from daughters when the air conditioning stopped. Household Q noted:

> *“… but the rest of the household doesn’t like me using it. They have learnt how to turn it off, so they can get their air conditioning back again.”*

Appliance Control

When asked which appliances should be controlled by the load management system, there was a mixed response from those regarding appliances that are interrupted by default. The majority of interviewees, 8, indicated the air conditioner should be controllable, whilst 1 felt this should remain on in winter and 1 stated that only the compressor should be controllable, i.e. keep air moving but do not interrupt power to the whole system. Residents in 5 households were happy to have their dishwasher interrupted, as were 4 and 3 having their laundry appliances and oven controlled, respectively. Other recommendations made by residents included televisions by 2 households, and 1 household suggested controlling a hairdryer, kettle, computer and electric toothbrushes.

Regarding appliances that should remained powered at all times, 1 household indicated that all should be, whilst the refrigerator was identified by 7 households, followed by the oven in 4 cases. Lighting circuits and water heaters were listed by 2 households, and 1 household wanted clocks, a computer server and water pumps to remained powered at all times. Given that lights, refrigerators, water pumps and general power outlets (other than those in the kitchen or laundry), were wired to remain powered at all times, together with suggestions of low-powered devices, such as electric toothbrushes, televisions and computers, this suggests that the majority of residents generally are not aware of appliance power ratings or how their LMS operates. This is seen in a few cases, where the LMS was used following a firmware upgrade where this was inoperable, refer to { } in Table 2.

Given that the financial incentive to use the LMS was withdrawn by the energy utility before many of the homes were occupied, this feature may have been attractive to more households. However, the tone of most household responses indicates a lack of interest in this method of peak load control.

Data Analysis of Entire Estate: What really happened?

Table 3 shows the aggregated amount of time (in minutes, and expressed as a percentage) that the load management systems were collectively utilized, at any set point, and had interrupted power to at least one electrical circuit. It is revealed that LMS were set for nearly 13 million (M) of nearly 171M minutes, or 7.60% of the monitoring period. Of which, the LMS were used for 1.36M minutes or 0.80% of the time, without being re-commissioned following firmware upgrades, which rendered this feature inoperable; these numbers are shown hereafter in curly brackets, e.g. {3}. Furthermore, power to circuits was interrupted for about 1.66M {0.343M} minutes which corresponds to 12.80% {2.64%} of the time that the collective LMS were utilized, for about 0.97% {0.20%} of the total monitoring period.

Table 3: Total LMS data available including the amount of times (minutes and percentage) this was utilized and interrupted power. Number in { } indicates data when the LMS was inoperable.

	Utilization		Power Interruptions		
Data (mins)	**Total # mins**	**Percentage**	**Total # mins**	**% of all data**	**% of Utilization**
170,893,866	12,985,557 {1,360,188}	7.60% {0.80%}	1,661,802 {343,369}	0.97% {0.20%}	12.80% {2.64%}

Although the above table gives an overall idea of the amount of times that the LMS was utilized or interrupted power, the data needs to be disaggregated to draw any conclusions from this. Table 4 shows the LMS data disaggregated by the number of households, year, duration of utilization, set point, and priority level; it also indicates the number of monthly data files available. The number shown in each cell represents the number of months corresponding to that respective condition, whilst the number in curly brackets (e.g. {2}) indicates the number of monthly periods the LMS was inoperable as the LMS was not re-commissioned following firmware upgrades, yet appears to have been used or interrupted power. For example, consider the year 2014 where 68 households recorded data for 777 months. Of these, it appears that 15 {2} households utilized their LMS for a total of 81 {16} monthly periods where the monthly maximum set point was 4kW for 29 {5} monthly periods, and in 69 {14} cases the system was used for more than one week, at any set point. Further, power was interrupted to at least one power circuit in 18 {2} monthly periods in 7 {1} households; in 8 of these cases, a maximum priority of 2 was recorded, i.e. 2 power circuits had power interrupted.

Data from 6+ years and 71 individual households has resulted in 3,955 monthly data files, which show that 47 {2} households used their LMS in some capacity for 397 {39} monthly periods. Of this, these were used for less than 1 hour for 63 {5} cases, indicating the residents were likely experimenting with the system. In contrast, there were 310 {33} cases where the LMS were used for more than 1 week in a given month, suggesting the residents likely did not exceed their set point and hence did not have any power interrupted. Further analysis shows that 20 {3} households had power interrupted in 82 {12} months and that in 58 {10} of these cases, 2 or less power circuits were interrupted, suggesting that the LMS achieved its objective of reducing peak power demand. In the remaining 24 {2} cases, the maximum monthly priority reached 6 indicating the LMS was unable to prevent the 30-minute average power demand exceeding the set point and hence did not meet its desired objective.

Table 4: Summary of available data, and a breakdown of the utilization of and power interruptions caused by the load management system, over the 6+ year monitoring period.

			2010	2011	2012	2013	2014	2015	2016	Total
Data	# Months		240	447	668	774	777	765	284	3,955
	# Houses		33	47	63	67	68	68	59	71
Utilization	# Months		32	46	48	71 {1}	81 {16}	86 {13}	33 {9}	397 {39}
	# Houses		19	21	12	14 {1}	15 {2}	11 {2}	10 {4}	47 {2}
	Duration (any set point)*	>0mi, ≤1h	18	16	5	12 {1}	6 {1}	4 {1}	2 {2}	63 {5}
		>1h, ≤1d	2	4	1	1	1	1	0	10
		>1d, ≤1w	3	3	3	0	5 {1}	0	0	14 {1}
		>1w, ≤1m	9	23	39	58	69 {14}	81 {12}	31 {7}	310 {33}
	Set Point	3kW	12	26	11	23 {1}	29 {11}	14 {11}	3 {3}	118 {26}
		4kW	5	8	12	24	29 {5}	24	7	109 {5}
		5kW	15	12	25	24	23	48 {2}	23 {6}	170 {8}
Power Interruptions	# Months		7	16	9	10	18 {2}	18 {8}	4 {2}	82 {12}
	# Houses		6	9	5	4	7 {1}	3 {1}	2 {1}	20 {3}
	Priority **	1	1	5	2	1	2	15 {8}	2	28 {8}
		2	0	3	3	9	8	3	2 {2}	28 {2}
		3	1	1	0	0	0	0	0	2
		4	0	0	0	0	0	0	0	0
		5	0	0	0	0	0	0	0	0
		6	5	7	4	0	8 {2}	0	0	24 {2}

* mi, h, d, w, m represent: minute, hour, day, week and month, respectively.

** Priority represents the number of electrical circuits that had power interrupted during a given month.

How Were Residents Alerted of Power Interruptions?

It is assumed that residents who had power interrupted to circuits were able to identify and rectify this, as power can only be restored (re-energized) by interacting with the EcoVision monitoring system by nullifying the set point. This appears to have occurred in the majority of cases, however there are a few known exceptions, e.g. in 2 cases, phone calls were made to residents who were unaware of power interruptions. One of these was an elderly couple who did not understand why their air conditioner was not operating during a hot afternoon, and their daughter was grateful to receive the call and instructions how to re-energize the air conditioner; they have not used the LMS since. In the other case, a household was being minded by friends whilst they were overseas and their friends were not aware that power had been interrupted for a total of 22 of 34 months, in 2 separate cases.

In another case one the residents of a newly commissioned house were unable to use their oven for several days. They did not interact with their monitoring system, nor contact either the builder who installed the LMS, or the university who would have immediately suggested inspecting the monitoring system. Instead the resident contacted their preferred electrician who was unaware of the LMS and its functionality, and did not discover the issue for several hours, resulting in an expensive and negative experience. It is thought that a child in the household may have activated this unknowingly.

Finally, the LMS was being used for more than the last 18 consecutive months in 4 households. It is likely that the residents are not aware of their LMS being activated, as power has not been interrupted in any of these households, which would require user intervention to re-energize power circuits.

Peak Demand Analysis and Potential Cost Savings

The demand tariff has had limited uptake since. The analyses presented hereafter hence investigate whether 47 Lochiel Park households, would benefit financially on this tariff, based on data from 2015.

Peak Demand Analysis and Cost using Current Tariff and Load Management System Settings

A detailed list of monthly peak events is shown in Table 5, which summarizes the monthly minimum, average and maximum peak demand together with number of households whose peak occurs within the 4-9pm peak window, shown in [ ]; this occurs in 71% of cases. The table also shows the number of peaks that occur above 1.5, 3, 4 or 5kW, as these represent the monthly minimum charged to the customer and the LMS set points. The data shows that the majority of houses have a monthly peak that exceeds 3kW, during the cooling and heating dominant months (DEC-FEB and JUN-SEP), which is likely caused by using reverse-cycle AC which are limited to 4kVA. Hence using the LMS set to 3 or 4kW would almost guarantee interrupting power to the AC as by default, this is the first appliance to be interrupted; this is less likely yet possible by adjusting the set point to 5kW.

Table 5: Summary of 47 household monthly peak demands in 2015.

	Number of Houses, where monthly					Peak at: All times [during window]		
Month	**Peak in window**	**Peak > 1.5kW**	**Peak > 3kW**	**Peak > 4kW**	**Peak > 5kW**	**Min. (kW)**	**AVG (kW)**	**Max. (kW)**
JAN	31	45 [45]	30 [27]	21 [20]	11 [11]	0.67 [0.67]	3.75 [3.58]	7.09 [7.09]
FEB	37	44 [43]	33 [33]	21 [20]	10 [10]	0.47 [0.47]	3.80 [3.76]	7.13 [7.13]
MAR	35	42 [42]	17 [14]	6 [5]	3 [3]	0.65 [0.17]	2.74 [2.63]	6.17 [6.17]
APR	30	46 [45]	27 [24]	13 [11]	6 [6]	0.80 [0.30]	3.43 [3.19]	7.74 [7.74]
MAY	32	47 [46]	34 [32]	24 [23]	12 [9]	1.69 [0.15]	3.98 [3.79]	7.75 [7.75]
JUN	32	46 [45]	38 [35]	29 [25]	18 [14]	0.43 [0.14]	4.50 [4.25]	8.40 [8.40]
JUL	33	45 [43]	36 [35]	30 [28]	21 [21]	0.20 [0.15]	4.56 [4.39]	8.04 [8.04]
AUG	31	46 [46]	35 [33]	29 [29]	22 [20]	0.16 [0.16]	4.64 [4.42]	9.11 [8.05]
SEP	30	44 [44]	32 [31]	25 [22]	13 [11]	0.32 [0.27]	3.97 [3.81]	7.82 [7.82]
OCT	38	44 [43]	17 [17]	8 [7]	3 [3]	0.51 [0.45]	2.88 [2.78]	6.83 [6.83]
NOV	36	44 [41]	21 [20]	12 [11]	4 [3]	1.17 [1.17]	3.21 [3.02]	7.12 [7.12]
DEC	37	45 [45]	31 [31]	25 [25]	15 [14]	1.34 [1.34]	4.19 [4.06]	8.03 [7.41]

Although the data indicates that the many households could reduce their monthly peak demand by utilizing the LMS, the current tariff offers no financial incentive to do this. To explore the potential to save money by moving to a demand tariff consider Figure 2 which shows the base case electricity bill using the current tariff for 47 households, where the black dot shows the overall cost, whilst the bars breakdown the various charged and credited components. Currently 17 households remain in credit.

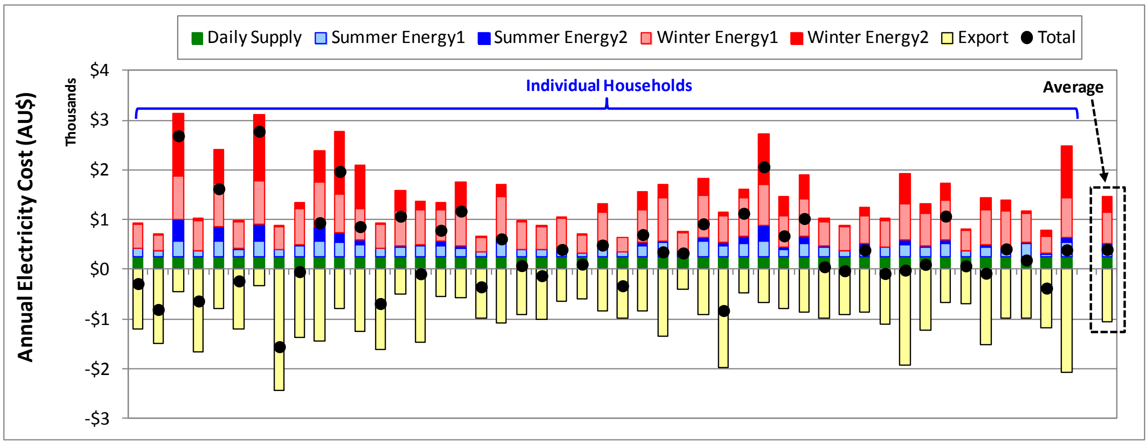

Figure 2: Electricity bill breakdown for 47 households in 2015, using the current tariff.

The result of moving to the demand tariff for each household is shown in Figure 3, which results in a more complex bill overall, as energy, peak demand and meter reading fees are now charged each month (recall Table 1). Despite a reduction in daily connection charges of about $40/year, each house pays more money (or reduces its credit) overall; this is represented by a negative cost saving. Of the

17 houses that were previously in credit, only 9 remain in credit, indicating that they have lost revenue; the other 8 houses are now paying an annual amount, whereas they were in credit.

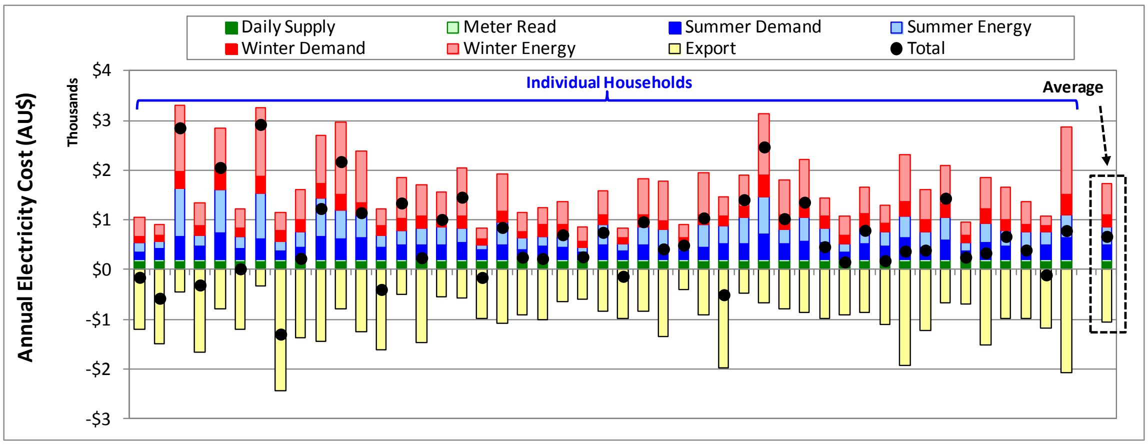

Figure 3: Electricity bill breakdown for 47 households in 2015, using the demand tariff.

Cost and Potential savings Utilizing Load Management Systems on Peak Tariff

The introduction of a demand tariff does not reduce energy bills for the 47 investigated low-energy houses. Unlike standard houses, these have load management systems installed which is designed to limit peak demands, which can offer a cost saving by reducing monthly peak demand components. This is only possible if the LMS is utilized for the entire year, which according to monitored data occurs only very rarely. Nonetheless, the electricity bill for each of the 47 households is now simulated and shown in Figure 4, where the LMS is utilized 'as is' (Figure 3), and for set points for 3, 4 and 5kW.

Table 6 also summarizes the household minimum, average and maximum savings by moving to the demand tariff and utilizing their LMS at various set points. The table also quantifies the number of households that fall into one of six categories, denoted by three characters made up of either '-' or '+' which represent negative and positive values. The first and second characters represent the costs under the current and peak tariffs, respectively, whilst the third character represents the difference in cost on the peak and current tariffs; the latter is equivalent to the *money* or *cost saved* by moving to the peak tariffs. For example, ' - - - ' indicates that a house was initially and is still in credit, however the credit is now smaller. Similarly, ' - + - ' indicates that a house was initially in credit and is now paying for electricity, which has a negative cost saving. Cases of interest are those ending in a '+' (shaded in Table 6), which indicate that money can be saved by moving to the peak tariff; this only occurs for 2 households when utilizing their LMS at 4kW, or 7 households when set at 3kW.

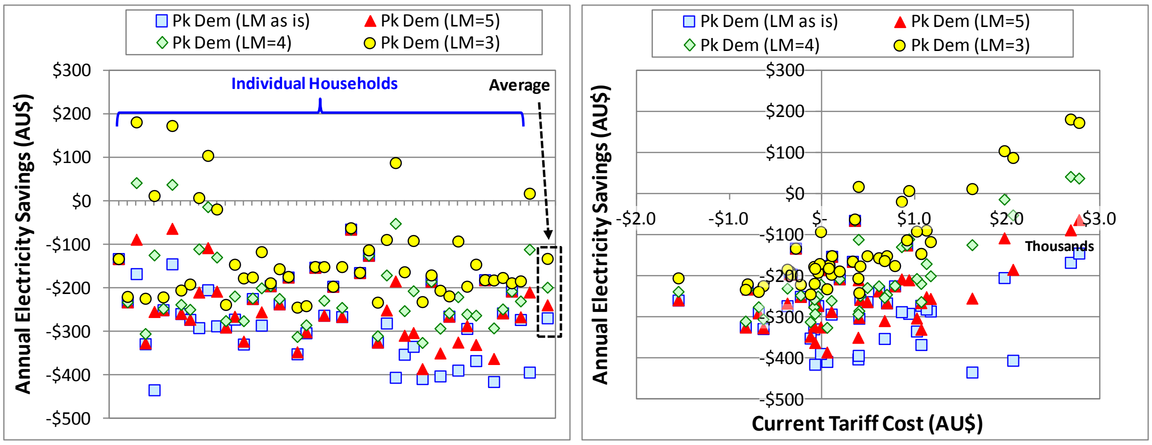

Figure 4: Electricity savings made by moving to demand tariff and utilizing LMS, for (a) individual households, and (b) as a function of respective current tariff costs.

Additional conclusions drawn from the analyses include: i) moving to a demand tariff alone costs the average household an additional $269 annually, ii) if already on a demand tariff, the average household can save $30, $70 and $136 annually, compared to the 'as is' case, by utilizing their LMS at set pints of 5, 4 and 3kW, respectively, and iii) a maximum annual saving of $139.52/peak kW can be made, suggesting that a LMS may be worthwhile if householders are already on a demand tariff.

Table 6: Summary of household savings by moving to demand tariff and utilizing LMS.

LMS Setting	**Annual Electricity Saving (AU$)**			**Number of Houses:**							
				Current Tariff, Peak Tariff, Cost Saved						**Cost Saved**	
	Min.	**Average**	**Max.**	**- - +**	**- - -**	**- + -**	**+ - +**	**+ + +**	**+ + -**	**Y**	**N**
as is	-$434.07	-$268.58	-$64.61	0	9	8	0	0	30	0	47
5kW	-$385.47	-$238.66	-$62.74	0	9	8	0	0	30	0	47
4kW	-$325.25	-$198.14	$42.36	0	9	8	0	2	28	2	45
3kW	-$244.04	-$131.95	$182.14	0	10	7	0	7	23	7	40

Summary and Conclusions

This paper reviewed mechanisms to limit peak demand within the residential sector, and investigated the effectiveness of voluntary load management systems (LMS) within houses inside a low-energy housing development in South Australia. The latter involved interviewing residents, collating and analyzing large volumes of individual household monitoring system data, and simulating the impact of moving to peak tariffs together with utilizing load management systems at set points of 3, 4 and 5kW.

Residents of low-energy houses generally feel they already effectively manage their electricity usage and see no need for automated systems, and some suggested that low-powered appliances should be interruptible. This, together with monitored data, which revealed that i) LMSs were used for nearly 7.5% of the monitoring period, and had interrupted power to circuits for nearly 1% of the total monitoring period, and ii) that most exceeded the minimum LMS set point of 3kW for the majority (58%) of months, indicates the residents are either unaware or didn’t care about the impact of their electricity usage on their own and the network peak demand.

Results of simulations for 47 individual households showed that moving away from current energy-based tariffs towards peak-based tariffs increased the annual cost (or reduced credits) for all houses. Further, only 7 households could save costs on their electricity bills by moving to demand tariffs if their LMS are continuously utilized at a set point of 3kW; this reduces to 2 households for a 4kW set point.

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