Fairwater Living Laboratory – Implications for Customers

CURTIN UNIVERSITY REPORT

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INTRODUCTION

The Fairwater Living Laboratory project aimed to understand the sustainability, resilience, well-being and commercial benefits of the precinct scale development of renewable thermal energy heat pumps, coupled with PV and demand management, in a master-planned residential community. This community was one of Australia's first communities to incorporate up-front deployment of these ground source heat pumps in each lot. The performance of these heat pumps at this scale and understanding how occupants will utilise these systems was untested and unproven. Hence, this living laboratory provided information regarding the user experience and performance to inform further development and deployment of this renewable technology.

Curtin University developed a machine learning algorithm to identify energy and water consumption patterns and related them to occupant practices and habits. This is important to assessing how effective this technology is and whether it is achieving the expected reductions in energy consumption. Households with solar PV and battery systems and changes during the COVID-19 lockdowns were also assessed.

The key takeaway from this research for customers is identifying the energy savings associated with the ground source heat pumps, coupled with utilising solar PV energy produced during the day. This enabled people in the homes to remain thermally comfortable with minimal additional cost and impact on the grid. However, if homes are not using the self-generated energy, or their energy intensive appliances outside of times of renewable energy generation, this will still have impacts on the grid. Health and comfort are primary drivers behind people's energy use and the routine nature with which daily practices are performed can be difficult to change. The increase of home energy management systems and building automation systems will optmise the timing of energy use in homes whilst minimising grid impacts if implemented with an understanding of the drivers behind people's everyday practices.

RESULTS SUMMARY

ENERGY USAGE PATTERNS

The objective of the house design in the Fairwater precinct was to increase the thermal performance of the home to reduce the need for energy intensive interventions to achieve thermal comfort within the home. Research has continually shown a gap between expected performance and actual performance in homes, including those designed with higher NatHERS ratings[1]. This is explained by the impact of occupancy compared to when the house is modelled where the practices and habits impact the temperatures and comfort levels of the home. Additionally, this study analyzed the variation between households on what is the ideal indoor temperature. People set their thermostats at different temperatures (18-25 degrees Celsius) suggesting thermal comfort is achieved differently across homes. Furthermore, two similar homes with the same NatHERS rating and number of residents can observe different energy

[1] Nationwide House Energy Rating Scheme (NatHERS) measures a home's energy efficiency

consumption profiles, where one home relied on the air-conditioning more to achieve thermal comfort.

COVID-19 restrictions impacted the timing of energy practices and the consumption of energy generated by the solar PV systems in many of the Fairwater homes. Most homes observed an increase in energy consumption during the day as people were now home. This resulted in the consumption of energy from the solar PV systems, which had not been seen in pre-lockdown practices. This peak was observed as a result of using air-conditioning systems, cooking, cleaning or entertainment practices being conducted during times when the occupants are usually not at home. These peaks occurred at three times in the day, morning (5-9am), midday (11am-2pm) and evening (4-11pm). Pre-lockdown, these peaks were much smaller, although they had similar times of their occurrence. This indicates that people are still performing energy consuming practices at a similar time, however the magnitude of the energy use is increased. The impact of the lockdown on household energy use can be scaled up to the precinct and community level where many occupants are utilising on their own home energy systems during the day more. For homes that have solar PV systems, this results in less energy being exported to the grid during the middle of the day, reducing the stress on the distribution network. However, the greater evening peak negates the benefits of consuming renewable energy during the day as this energy is sourced from the grid during that time.

WATER USE PATTERNS

Similar to energy consumption, a household's water consumption can provide insight into the practices and habits of the occupants. These results are significantly different to the analysis conducted for the energy data. There is less variation in water consumption compared to energy consumption throughout the study year. Each cluster showed an early morning peak, a morning peak and a late afternoon peak. The early morning peak is consistent for all the clusters implying that some households synchronise with each other and perform water practices early in the morning. However, the morning and late afternoon peaks correlate with the peaks observed in the energy data for the winter profiles. This confirms the occupancy patterns of the home that majority of fairwater residents occupy the home in the morning and late afternoon. There is minimal different in the timing of water use throughout the year, with winter having only a slightly higher consumption per day peak than summer. This may be explained through longer showers being taken during winter when temperatures are colder as a way to keep comfortable.

PEOPLE'S PRACTICES

This study investigated social and psychological theories to explain why energy is consumed by the Fairwater homes. These theories identify the practices, routines and habits of individuals that can explain the nature of energy consumption. This is important when discussing the implications to the public. The energy transition requires action from the public and they have an important role to drive this change.

The analysis observed people consuming energy differently across different Fairwater homes. The report discusses the influence of personal context on people's lifestyles and attitudes.

Research has observed how attitudes and values can impact the way individuals consume energy and respond to efforts to change this behaviour.

One common theme found in research is that energy is invisible in households with occupants being unaware of their energy consumption. This is a challenge that needs to be overcome as knowledge and awareness are important when trying to spark change. If people do not understand how their energy consumption is impacting the environment and this energy transition, then there will be little motivation for them to change. The development of HEMS (home energy management systems) offers a potential solution to this challenge by interacting with the occupants and providing information and feedback about the household's energy consumption.

Another challenge relates to the people who do not follow pro-environmental values and attitudes, hence, will not respond to policies and interventions that are focused on the environmental benefit. Hedonistic people value and pursue comfort within the home over anything else. These people will not respond to environmentally driven behaviour-change programs. A common observation found throughout the Fairwater project is that people try to reduce their consumption and reliance on the air conditioning systems in order to save money on energy bills. This identifies a strategy that can be used to encourage behaviour change for people who do not value environmental impact. Advertising the potential cost savings by increasing reliance on renewable energy systems and adjusting the way they consume energy can achieve behaviour change.

RECOMMENDATIONS

LOAD SHIFTING

The idea of load shifting for residential households is to reduce the impact of peak energy demand on the distribution network and to consume energy when energy prices are lower (based off a tariff system). The performance of the network can reduce when the demand for energy is high and can result in major problems. These peaks in the energy profile are due to the synchronisation of occupant's lifestyles and their practices being similar between households, which is evident in the energy and water data for this Fairwater project. The analysis identified when these practices synchronized, typically in the morning and the afternoon. Even with the impact of COVID-19 lockdown restrictions and work from home practices, people performed similar daily practices in the morning and afternoon that aligned across many households.

People often follow routines because they feel comfortable in doing so and it fits with their commitments, any change to their normal lifestyle can result in discomfort. This idea of comfort can explain why people follow such a routine lifestyle as seen in the energy and water data. There are slight differences between the weekend and weekday with more differences in energy profiles between winter and summer. This difference between winter and summer can be explained by a different type of comfort being sort at these times. Thermal comfort is often achieved by people through energy-intensive means such as air-conditioning. The feeling of

being too hot or too cold can feel uncomfortable for residents when they are home. This impacts on the idea of the home as it is often considered the place of comfort for people hence, air conditioning is relied on to achieve thermal comfort. These different types of comfort results in people being locked into their energy and water practices. Hence, it is difficult to achieve load shifting within households as this can impact one or two of these comforts.

An additional purpose of load shifting is to increase household's utilisation of solar power generated onsite. The natural rhythms of everyday life often constrain the use of solar power. This misalignment between natural rhythms of people and the sun demonstrates the need for load shifting to move energy consumption to times where solar power is produced. The major problem for this objective is the natural occupancy patterns of households resulting in the household being empty during the day. However, the impact of COVID-19 restrictions and how people's working lives are changing to rely on working from home more often presents an opportunity to utilise solar PV systems better. This can allow residents to shift their energy practices to during the day without the need for any complex home energy management systems or home automation. Home energy management systems and automation can assist in people shifting the timing of their practices to those that align with renewable energy generation to reduce the load on the energy grid.

CONSUMER PARTICIPATION AND ENGAGEMENT

The role of the consumer is very important to consider during this energy transition. Residential energy demand is created by the consumer's energy practices and habits within the home. These habits were discussed in this report to explain the energy patterns identified in the energy data of the Fairwater home. To change the way energy is consumed and achieve load shifting within the home the consumer must align with this goal.

The first step of encouraging people to align with this energy transition is to understand the attitudes and beliefs of the consumer. Pro-environmental values can motivate some people to change some of their energy or water consuming practices, while other people are motivated by cost. It is important to develop policies and technologies that can be utilized by a range of people with varying attitudes and beliefs. People may sacrifice certain practices and routines knowing that this will reduce their environmental impact or achieve significant cost savings however, others may be locked into their lifestyle or resist changes to their routines. This requires innovation for technology to maintain people's lifestyle by have a reduced environmental impact. The extent the consumer wants to engage with this energy transition can vary and will impact the effectiveness of new policies and technologies.

The second step is to make energy visible for residents as research often has demonstrated occupants rarely understand the timing and extent of their own energy and water practices. When turning appliances on, the energy consumed is hidden and people cannot see it. This results in a lack of awareness and understanding of people's own energy behaviors. This issue is compounded with the inclusion of residential solar PV technology with residents not knowing when they are consuming solar power and when they are drawing from the grid. This requires

consumer engagement through policies and information system to educate households on their consumption so they can self-assess whether they can optimise their own routines to achieve better performance from their PV systems. Furthermore, this allows consumers to actively participate in this energy transition and understand how changing their lifestyles or investing in technology can achieve energy reduction and cost savings.

IMPLICATIONS

Practices and habits are ingrained in people's lives and often form routines within the household. As discussed previously, these routines create typical daily energy profiles that draw energy from the network. The implication of this research outlines the role of the consumer in this energy transition.

Literature has discussed how energy is invisible and people are not engaged with how they consume energy and water within the home. This lack of knowledge can result in sub-optimal routines that do not benefit the user nor the distribution network. People are often focused on their lives and do not think about their energy and water consumption practices unless the bills are significant to their lifestyle. Australian energy and water are relatively cheap compared to normal lifestyles therefore, people do not worry about their consumption. This results in bad habits and inefficient use of energy and water which develop routines that are ingrained in people's lives. There is a shift to increase awareness of how much people consume energy and water however, these routines are still being followed as people are used to it.

The first challenge is to increase the awareness and knowledge of energy and water consumption within the home. This requires engagement and participation from the users to monitor their practices. The development of technologies and smart software allow for this engagement to occur easily through smart apps and interaction with smart devices installed within the home. Similar to the algorithm used in this research, the software can utilise prediction and pattern recognition software to analyse the energy and water use in the home and provide a summary and feedback to the user. This can educate the user on energy and can encourage them to consider how they consume energy in the future. This can make energy and water use visible and increase awareness.

Policy makers want to implement interventions and programs that educate individuals on how their practices impact the environment. This is important to develop knowledge on this impact as it can create motivation for people to change. Education is crucial to developing positive energy and water practices and achieving optimal consumption within the home. This will require changes in people's routines which can cause discomfort and hence will require motivation to overcome this barrier initially. Once new routines with positive energy and water practices are developed then people can feel comfortable in following these routines.

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