Fairwater Living Laboratory Milestone 3
University of Technology Sydney Research Report – Highlights

Outcomes for Energy, Network Demand, Resident Experience, Community Resilience, Urban Heat Effects and Commerciality, prepared for ARENA and Climate-KIC Australia.

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Opened in 2016, Fairwater was heralded as one of the country’s most progressive, environmentally-friendly community developments: 800 homes set in a landscape including wetlands, and with the largest geothermal heating and cooling system in the southern hemisphere. To gauge whether Fairwater delivers predicted sustainability, resilience, wellbeing and commerciality benefits, the University of Technology Sydney has collaborated with Climate-KIC Australia and research partner Curtin University to establish the Fairwater Living Laboratory in 2019, with funding from ARENA with additional financial support from Frasers Property Australia and NSW Department of Planning Industry and Environment (NSW DPIE) (formerly NSW Office of Environment and Heritage).

The full report details the multidisciplinary research led by the University of Technology Sydney and outcomes achieved in Year 2 of the Fairwater Living Laboratory project (through 2020). The analysis draws on detailed monitoring of energy and environmental conditions and occupant studies in 40 recruited individual households as well as aggregate and precinct level data for network demand, environmental parameters and urban heat. In 2020, in addition to developing and administering two household surveys relating to satisfaction and everyday practices for summer and winter, co-designed with the research team at Curtin University, UTS also implemented a suite of other observation and feedback studies. These included unique snapshot SMS surveys about coping with extreme weather and associated practices, a series of walking track monitoring studies, and phenocam studies of local greenery.

The UTS report details the energy and networks outcomes with respect to the study homes and through a comparative analysis of Fairwater Estate and North Kellyville (a suburb with comparable housing efficiency and high penetration of conventional air-conditioning). It also details the outcomes for Fairwater residents & community resilience through analysis the qualitative and monitored data. In addition, mid project outcomes are presented for our urban heat and commerciality studies.

Highlights of the study are provided below.
ENERGY OUTCOMES AND INSIGHTS

The quantitative and qualitative analysis of data collected for the 40 study homes has yielded a number of interesting insights that are linked to the interrelationship between design of the homes, their performance, as well as occupant preferences and behaviour.

The occupant satisfaction with houses as designed was remarkably high for the overall design of the houses, interior layout and appearance, outlook and connection with the outdoors and suitability for their needs before and during COVID-19 lockdown, and to a lesser extent with respect to privacy and the provision of usable private outdoor space or backyard space. High satisfaction for overall comfort was accompanied by positive feedback for natural and artificial lighting, as well as airflow and air quality. On the other hand, concerns in relation to noise and acoustic quality were linked to noise between rooms and floor and adjoining properties. Occupants found the houses to be very comfortable in the mid-season, with varied responses in relation to summer and winter.

From an overall thermal performance perspective, it is clear from our analysis of the non air-conditioned data that in extreme conditions the building fabric is able to maintain indoor conditions at least around 10-15 C less than peak summer temperatures and around 7C-12C higher than peak winter temperatures. Nevertheless, around 30% expressed dissatisfaction with the thermal conditions in summer and winter in the absence of air-conditioning. Moreover, our analysis shows all homes relied on air-conditioning to a greater if not to some extent in summer and winter. The utilisation of air-conditioning varies widely and is as much as 18-76% of a home’s electricity consumption in summer. Our emerging analysis of monitored data, corroborated through the snapshot SMS surveys, reveals the importance of user preferences and behaviour alongside indoor and outdoor temperature and occupancy. Most households resort to AC only after adjusting clothing and switching on ceiling fans. Some reluctance to open windows when the weather was appropriate was evident and attributed to noise, dust and security concerns. Our findings to date suggest that some households consistently control their homes to a fixed temperature range and condition their homes to a greater extent even in mid-season months, whereas others adopt a more climate responsive approach in sync with outdoor temperature. The results also suggest a cautionary lesson where the tendency to have AC ‘on-tap’ can lead to some level of indiscriminate air-conditioning and also incur electricity consumption for standby power. These aspects will be investigated further for Milestone 4.

The satisfaction with regard to effectiveness of the AC system for heating and cooling was remarkably high at 85-87%. The system that had been sized to cope with demand in the two zones of the house for roughly 80% of the year raised some concerns regarding the inability to maintain desired temperatures during extreme conditions across the year and the system struggling to cope when AC was switched to both zones. Although approximately 60% believed the system had met or exceeded their expectations, some households were less convinced, with 20% unsure of the effectiveness, cost savings and maintenance needs.

In analysing the energy usage and demand for the study houses, we found air-conditioning to be, on average, 42% of the annual household electricity usage of 4846kWh per annum (daily average 13.2kWh) for this cohort. AC was found to be a key driver of the summer consumption with the cumulative peak seen in the late evening. Twin peaks in electricity demand occur in the early morning and late evening in winter and are influenced by both AC and uptake of other appliances and plug loads. Subsequent analysis once the gas loggers are installed and data is available will be used alongside PV generation data to get a complete picture of total energy.
consumption and greenhouse gas emissions of these homes.

**NETWORK SAVINGS AND BENEFITS**

Within the terms of the study, UTS has completed its deliverable towards the Network Objective: To test and quantify the (presumed) reduced local network peak demand and reliability especially on hot summer days, tracking house energy and substation level data.

Geothermal air-conditioning (or ground source heat pump GSHP) systems such as those installed at Fairwater would be expected to perform better than conventional air-conditioning systems that rely on heat exchange with ambient air, by virtue of harnessing the stable ground temperatures for heat exchange while heating or cooling a building. However, little is known about their performance in practice, and especially the impact of geothermal air-conditioning to network demand and savings. Our study of reveal some interesting findings:

Our statistical modelling of smart-meter data indicates that Fairwater Estate GSHP houses consistently consume less power than North Kellyville houses when ambient temperatures deviate from the comfortable range. For every degree that outdoor air temperature moves away from the comfortable range, demand from conventional air-conditioning (heating and cooling) increases by between 6% and 11% in hot weather and between 3.5% and 9% in cold weather.

GSHP air conditioning reduces this rate to between 4.5% and 9% for hot weather and between 2% and 6% for cold weather. Due to the compounding nature of these rates, savings rapidly increase in terms of kW when temperatures are extreme, but also differ depending on time of day.

UTS has also conducted an in-depth analysis to establish network benefits for a number of scenarios: Reliability and Emergency Reserve Trader Event, Deferral of Network Augmentation, Exceedance of Local Distribution Network Peaks. We focused our comparison on newly developed areas in western Sydney where all homes were developed after the 2010 stringent energy efficiency provisions for building envelope were introduced, and excluded smart meter data of all known solar homes. This approach ensured that the major confounding factors of solar shadow or variability in thermal efficiency often overlooked in many studies are mitigated.

On the matter of house size, another potential confounding factor - our modelling results indicate that the difference between cohort for the compounding rate at which demand increases, the mainstay of our analysis, has a log relationship and is therefore not related to house size, but to efficiency of space conditioning.

However we acknowledge other confounding factors relating to any indeterminable variation between populations for demographics, uptake of other heating systems, or occupied hours may have affected our comparisons.

Towards determining a reduction in electricity consumption, with reference to business as usual, we found that in absolute terms, on average Fairwater Estate Houses consume 37%, or 2303 kWh less electrical energy than the North Kellyville houses between 1 September 2019 and 31 August 2020. Comparing the two smart meter datasets when normalised for house size on average Fairwater Estate Houses consume approximately 22% less electrical energy in comparison to North Kellyville in Summer. The consumption is 17% less in Winter and 19% less (940 kWh) over the year. These results indicate the potential for real saving and reductions in cost of living in comparison with comparable homes with conventional air-conditioning. However
we reiterate that the quantum of savings or energy consumption for air-conditioning is highly variable and dependant on occupant behaviour, preferences for comfort and occupancy.

It should be noted that a full cost-benefit investigation, including the capital costs of systems, installation and maintenance, embodied energy or direct emissions (including global warming potential from possible refrigerant leakage) is outside the scope of the study and could be considered as a next step when commissioning additional research. However, we recommend that larger scale trials be undertaken in future residential developments in which confounding factors may be better eliminated. For example, a single residential development site with 50% conventional and 50% GSHP air conditioners with sub-metered data for both groups would provide an excellent baseline and treatment group comparison.

COVID-19 IMPACTS

With major changes by way of working from home being introduced during the COVID-19 pandemic, 74% of the households reported changes in their routines, with the most meaningful change evident for weekdays with a 50% increase in daytime hours spent at home, and effectively meaning that a total of 23 to 24 hours were spent at home for many residents during the pandemic. The increased occupancy has had a knock-on effect in both electricity use and air-conditioning all round. This is especially evident in the increase in electricity consumption in 2020 for both Kellyville and Fairwater Estate compared to same months in 2019 - around 45% increase in May 2020 and roughly 20% during winter months in 2020.

Beyond offering an explanation for differing patterns in resource consumption over the course of the study, the increased home occupancy raised other lines of inquiry. For instance as many residents have had to adapt their residences to accommodate their working from home, our study revealed people are occupying rooms that may not be designed for habitation (such as setting up workspaces in garages), potentially for extended periods of time. Such spaces not designed for human thermal comfort and are not serviced by the GeoAir air-conditioning system warrant further investigation. Our studies also indicated that many spent 20-24 hours indoors and at homes during that period. Occupant feedback revealed concerns of increased consumption of electricity, particularly for heating and in the mornings while others reported the positive consequences of working from home and not having to travel to work.

ASSESSMENT OF URBAN HEAT EFFECTS AT FAIRWATER

Our Year 1 analysis established the importance of coarser resolution MODIS thermal measurements as a continuous time series baseline of both day and night Surface Urban Heat Island (SUHI), however the 1 km resolution restricted our ability to diagnose heat patterns within residential housing block units. In Year 2 of this study, we have established the value and capability of ‘sharpened’ 30 m thermal imagery from the Landsat satellite to diagnose urban residential heat patterns at the housing block scale. In comparison to our MODIS-based baseline thermal analyses in Year 1, this Landsat-based analyses provided a 1,000-fold increase in resolution and magnification, which enabled us to assess more detailed urban heat effects from vegetation, rooftops, and pavement.

By quantifying these individual effects (green-space and albedo variations) we were able to carry out cross site comparisons with neighbouring precincts. Our analysis in Year 2 has
established lower Surface Urban Heat Island (SUHI) values observed at Fairwater when compared to housing in neighbouring Blacktown and the Ponds area. The **lighter-coloured roofs at Fairwater create a cooling effect** with lower Land Surface Temperature and SUHI values (~1°C), relative to the adjacent mixed darker/lighter roofs present to the west and to the east of the new housing precinct. The **green space effect** was more complex and dependent on vegetation type. Tree cover had a cooling effect while grass cover imparted both cooling and warming (or none) effects with senescent, dry grass not able to cool an area owing to an absence of evaporative cooling (evapotranspiration), while trees were able to reduce SUHI through year-round access to water with their developed and deep rooting systems. Plant phenology and climate stress factors are able to turn on and off, evapotranspiration, and hence influence the magnitude and direction of SUHI.

Through our analysis, we conclude that the lower SUHI observed at Fairwater are driven by energy balance considerations related to albedo and vegetation evaporative cooling (evapotranspiration, latent energy). As a next step, we will aim to ‘normalise’ the Land Surface Temperature (LST) and SUHI values observed to take into account both albedo and green-space variations. Simultaneously our analysis will combine the spatial-temporal fusion of these two sensors in order to make use of the MODIS finer temporal resolution with Landsat’s finer spatial resolution capabilities. It is anticipated that this will provide cross-site comparable SUHI values without the albedo and green-space influences that could enable us to ascertain the role of additional energy conservation methods, such as heat pump usage, towards Milestone 4.

**COMMUNITY OUTCOMES WITH RESPECT TO RESILIENCE INFRASTRUCTURE**

Abundant open space, walking tracks and opportunities for healthy living were some of the important dimensions of the 6 Star Green Star Communities Fairwater development. UTS has completed a unique **monitoring study of Fairwater walkways** at different times of the year to ascertain usage of the park and walking tracks. The observation was conducted using video and image capture and analytics processes. Environmental monitoring datasets were also analysed in order to identify direct and indirect dependencies.

In summary the main findings were that the park and walking track was more activated in the evening and late evening in summer, and in the morning and afternoon in autumn and winter. The **overall activity was generally low** - for instance there no activity in 77% to 90% of the captured frames until the evening in summer and similar levels of inactivity early morning and late evening in Winter. In summer late evening, the maximum possible visitors recorded was 43 with a median of 5, and in winter mornings the maximum possible visitors recorded was 61 with a median of 18 visitors per hour.

Although our study of participating households found residents to be very positive about the precinct and connection to greenery etc, the results suggest that many residents seem to only appreciate the park as an element to be viewed from their homes.

The research confirms a **clear relationship between usage of the park and ambient environmental conditions** with greatest utilisation in summer between 20-25°C. While the increased usage of the park in winter months especially in the mornings coincided with the Covid-19 lockdown when residents were working from home, it does appear that the walking tracks remain underutilised. This is reinforced in the Extreme Weather SMS surveys of the
residents, where the Fairwater parklands were ranked third as the destination where time was spent outdoors - after one's backyard and outdoor public spaces outside of Fairwater. Moving to the final stage of the study, the above insights will inform the design of the community survey to ascertain a wider perspective in relation to urban heat and resilience infrastructure. In addition the present findings will sharpen analytical processes, to include spring 2020 data, real time environmental data from external sensors and collaborative work with the Faculty of Science team to link with UHI effects, and analysis with reference to Household Surveys 2 and 3.

**Household feedback to community and resilience infrastructure:** The second household survey completed by 38 study households in December 2020 covered household feedback in relation to community infrastructure and amenities, motivation for purchase, transport, and health and wellbeing. This aspect of the study develops the deeper interrelationships between design, operation and maintenance of sustainability, well-being and resilience. Detailed analysis is underway and further investigation will occur through community survey targeting all residents in the precinct and workshops planned for 2021 that was delayed due to COVID-19 pandemic and other project priorities in 2020.

Emerging findings indicated that all the Fairwater Study Households are highly satisfied with their experience of living at Fairwater as a **6 Star Green Star community development**. They believed that the Fairwater residential precinct encourages and supports community features and lifestyle, especially by providing access to the public open spaces, connection to the natural environment, social interaction with other community members, active and environmentally friendly lifestyle with these aspects gaining 85-95% satisfaction. Likewise, the evaluation of households’ health conditions showed that the vast majority of households were satisfied with their **health conditions** in their Fairwater homes and with respect to living in the Fairwater precinct. However, there were concerns in terms of safety, privacy, and easy access to public transport which will be investigated further.

**COMMERCIALITY**

Towards the identification of commercial benefits of the Project compared to a business-as-usual development, a hedonic pricing analysis to understand how different attributes impact property prices in Blacktown LGA and if there was a premium associated with Fairwater properties has been completed. Our analysis reveals that **Fairwater properties attract a premium** of 62871 AUD compared to non-Fairwater properties of a similar attributes (including age and size) located in Blacktown. This premium is 8.2 % of the median price of a non-Fairwater property included in the analysis and suggests that Fairwater yields a higher return on investment compared to a traditional development. As discussed above, a conservative estimate suggests that Fairwater homes on average use 19% less electricity than comparable non - geothermal AC homes.

We have begun to ascertain the costs (construction, maintenance and operation) and benefits (property value, Frasers Property Australia brand value, ROI) of the Fairwater Development to determine commercial viability. The cost benefit analysis for developer and residents is ongoing and will seek additional information regarding conventional development costs from Frasers Property Australia.

In addition, we have ascertained the **motivation for purchase**, and sought and gained feedback on householder's perspective of savings achieved and expectations met. Our analysis of survey findings show that like most buyers, almost all Fairwater Study Households emphasise basic
attributes factors such as location, house features and house price, when buying a home. Additionally many prioritise sustainability aspects, but nominated different aspects. While most nominated the community and outdoor facilities at Fairwater and the 6 Star Green Star Communities credentials for Fairwater, energy savings was ranked 12th out of 13 criteria.

Interestingly when asked to nominate **priorities for future house purchases**, energy savings climbed to rank 8th demonstrating a shift in importance amongst these participants. This would suggest a better appreciation for the actual attributes and outcomes at Fairwater even while typical priorities for location, features, and price of the house took precedence.

The research to date has identified a framework for a scorecard for evaluation of development which will seek to address sustainability, wellbeing, commerciality and community development and resilience by including objectives, measures and initiatives that could be followed up.

**IN CONCLUSION:** Notwithstanding some delays and headwinds outside the control of the UTS research team, in this second year of the project we have established a number of tangible outcomes, and pathways for further investigation in relation to the Fairwater Living Laboratory. In the absence of any unforeseen impediments to the project, we believe we are on track to meeting our final project objectives. Our findings to date indicate that the completed analysis by the end of the project will produce the qualitative, technical and commercial evidence base for future projects seeking to implement GSHP technologies and other sustainability initiatives incorporated at Fairwater.

Please contact Leena Thomas, Professor School of Architecture, UTS or Belinda Whelan, Director Climate-KIC Australia to learn more.
Milestone 3 Report Summary | Fairwater Living Lab

**Fairwater Living Laboratory Milestone 3**
**Curtin University Research Report - Highlights**

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The Milestone 3 report provides an overview of the work Curtin University is conducting to provide insights into the objectives: house performance, solar PV use, use of the Ground Source Heat Pump connected to the GeoAir system and the overall home system of practice. The results from this analysis provides preliminary insights into the Fairwater project. As the project continues and more data is collected, these insights will be more robust and provide a detailed picture of energy use in the Fairwater precinct.

The Curtin analysis was undertaken via a K-means clustering technique and machine learning to identify routines in household energy and water use over the seasons to evaluate the performance of the residences. These energy profiles provided insight into the practices and routines of the residents by analysing the timing and magnitude of the peaks in these profiles. The timing and magnitude characteristics are important when discussing the impacts to the distribution network and the amount of stress applied to this network. Fairwater homes following the same daily energy profile results in aggregation subjecting the network to heavy stress loads. Thus, this analysis identified the different energy profiles that the Fairwater homes followed, and efforts were made to explain when these profiles were observed during the year.

**HOUSEHOLD TIME OF USE ENERGY PROFILES**

The temporal characteristics of energy consumption is important when considering the distribution network and the effectiveness of a renewable energy system such as solar PV. The higher the utilisation of PV systems in the Fairwater precinct will mean less energy is being required from the grid, reducing the carbon footprint of households. The utilisation of these systems correlates with the temporal profile of energy consumption as without battery technology, these systems can only provide energy during the day. This is a major limitation of the technology and occupants must adjust their schedule and routines to align with this power generation.

The results demonstrated that households typically followed four different daily energy profiles. These were identified through a machine learning algorithm evaluating patterns in the energy data for each household. These four clusters had distinct peak characteristics. Some clusters observed a sharp morning and afternoon peak while others showed broad peaks over a longer period. From this analysis, seven Fairwater daily energy profiles were identified, and each household was assigned to these profiles depending on their individual profiles. This outlines the households that followed similar energy consumption throughout the day with the timing of peaks aligning between these households. These groupings provided insight into the practices and routines of each group and the similarities of these routines between households. Furthermore, the number of households assigned to each cluster reinforces how common that profile is in the Fairwater precinct and indicates the impact of each cluster to the distribution network. The more households that followed a specific energy profile, the more the accumulation effect will be on the grid. This accumulation effect is the aggregation of the energy consumption over the grid area resulting in high and sharp peak demand periods. The less
assigned homes to a cluster will result in a reduced impact to the network as the accumulation effect is much smaller with reduced number of homes aligning their consumption. This provides valuable insight into the grid management and how to reduce the impact of peak demand on the distribution network by trying to encourage households to follow a different energy profile.

**TIME OF USE OF SOLAR PV SYSTEMS**

Time of use profiles were also identified for the households with solar PV systems to evaluate the use of these systems and the benefits they provide households. Households that receive the most benefit from their solar PV systems are those that do not observe sharp peaks in the early morning and late evening. Instead, they have higher energy consumption during the day with a broad midday to afternoon peak, consuming energy when it is being provided by the solar PV systems.

Not all homes with solar PV systems followed these beneficial patterns of energy consumption. This implies that some solar power homes consume energy at poor times of the day that does not utilise their PV system. Further investigation into the reason why these homes do not follow the optimal clusters demonstrated restrictions in their lifestyle resulting in being locked into their current routines. Their working lifestyle is a key variable that impacts how they consume energy. The majority of individuals work during the day when peak solar power is generated and these people cannot consume this energy. The development of technology may allow these locked in households to increase their solar power consumption by allowing them to consume energy during the day when the occupants are not home. This reinforces the importance of flexibility within the household when needing to adjust energy consuming activities however, some occupants may find this harder to change. Further investigation in the effectiveness of this technology will be discussed in Milestone 4.

In addition to analysing the time of use of solar PV systems, the Curtin analyse also examined the amount of solar PV electricity generation was used by the house or exported to the grid. The self-consumption and self-sufficiency ratios were calculated for each household to evaluate the actual usage of their system and identified variation across the households. Additionally, these values indicate the extent each household still rely on the distribution network for energy and the extent of independence achieved. The natural rhythms of the occupants resulted in poor mismatch between energy demand and solar power generation resulting in Fairwater homes achieving poor performance from their solar PV systems. This relates to the routines and system of practices of each occupant within the home which was discussed in this report. Further work needs to be conducted to evaluate strategies, interventions and new technologies that can be utilised to shift these energy profiles to align with solar power generation.
WATER CONSUMPTION ANALYSIS

The water consumption analysis provided insight into the house performance and the system of practice for each Fairwater home. The daily water consumption profile identifies the routines of the individuals and evaluates when they perform water consuming practices. For this study, the practices that were evaluated through the summer survey included when households ran the dishwasher and clothes washing appliances and when the occupants have a shower. These are the major water consuming practices within a household related to the routines of the occupants.

The survey asked the residents about the timing of their water practices to gain insight into the perspective of the residents towards their water consumption. The responses provided the time of use for their showering and washing practices, and this was matched with the quantitative data. The aggregation of the responses over the 40 homes indicated the peak periods should occur in the morning and afternoon. Across the study homes, the popular times to perform these activities were in the morning and late evening, and when residents are at home. The timing of the peaks occur during the same time of the day reinforces the water behaviors are consistent all year round. The quantitative data displayed peaks during these times demonstrating a match between self-reported water consumption and actual consumption. This indicates the Fairwater residents are aware of their water consumption. Being aware of consumption is the first step to understanding how residents can reduce and time-shift their consumption.

In terms of utilising technology, the survey showed the 13 out of 40 households used the timer function on their washing or dishwasher machines, allowing them to achieve flexibility in their water and energy consumption. This was usually run during the day when the occupants were at work.

USE OF THE GEOAIR SYSTEM

The clustering analysis was used to assess the performance of the GeoAir system in the Fairwater homes. It is important to map the timing of use of the GeoAir system as this contributes a significant amount of energy to the overall household consumption. The analysis revealed the variation in heating and cooling practices between the study homes. Additionally, the Fairwater homes were grouped into high, medium and low users based on their GeoAir usage. These groupings showed which Fairwater homes relied on their GeoAir system to achieve thermal comfort and the additional stress the home put on the distribution network.

Overall, the Fairwater homes synchronise their GeoAir system usage between each other resulting in peak periods. These peak periods occur due to the heating and cooling practices of the Fairwater residents. This observation demonstrates that the heating and cooling practices are similar between the households. The peak usage of the GeoAir system occurs in the morning and afternoon when the household is usually occupied. The analysis continued at a deeper level to identify the acute variation between GeoAir usage between the Fairwater homes.

Firstly, the correlation between the NatHERS rating of the home and the AC circuit consumption data was conducted. The expected result was that lower rated homes would observe higher energy consumption due to poor house performance resulting in indoor conditions being impacted by outdoor conditions. However, the results observed minimal differences between
the consumption from high and low rated homes. The summer period observed homes with higher than 5 stars rating would consume more energy compared to homes with 5 or less stars rating. For the winter period, the 5 star rated homes generally showed a reduction in energy consumption compared to the homes with 5 or less rating. The higher rated homes had a reduced peak magnitude of 17% compared to the other homes. Contradictory, the winter season in 2019 observed the higher rated homes having an increase in peak magnitude in the afternoon. The performance of these homes did not seem to correlate with the NatHERS rating of the homes. Further investigation into this performance will be conducted and reported in Milestone 4.

The K-means clustering technique was utilised for the AC consumption data to identify variation in the way residents heat and cool their home. Firstly, this analysis identified three groups of Fairwater homes in terms of their AC usage: high, medium and low users. These groups were separated, and the house characteristics and survey responses were used to explain why some households were in the high user category and others in the low category. This analysis demonstrates the house characteristics did not explain this difference in regard to the home’s NatHERS rating, number of residents, internal area and self-reported thermostat setting. Thus, the analysis moved to studying the self-reported practices and motivations from the survey responses to identify variation in the heating and cooling practices. There was no correlation between the presence of additional heating and cooling devices in the homes and the groupings of the households. With high and low users having a similar number of additional heating and cooling devices. Additionally, the self-reported prioritisation of how residents achieve thermal comfort did not explain the clustering. Further analysis into the home system of practice and house performance will be conducted and reported in Milestone 4.

Each individual Fairwater home was analysed in terms of their daily consumption profile for their AC circuit. This demonstrated the variation in the heating and cooling practices and how each home uses their GeoAir system. This analysis outlined the difference between GeoAir usage in the winter and summer. The summer observed a single afternoon when the home is exposed to the hot temperatures during the day and the residents return from work in the afternoon. Alternatively, the winter saw a dual-peak daily consumption profile with peaks in the morning and afternoon. The GeoAir system has a higher usage in the winter due to the dual-peak profile outlining the variation in the heating and cooling practices of the Fairwater residents. This variation was observed for every Fairwater home outlining how the residents share the same routines and perform the same practices to achieve thermal comfort. The synchronisation of these routines across the Fairwater homes is not ideal for the distribution network as this will result in peak demand and high stress in the morning and afternoon during the winter, and in the afternoon for summer.

In terms of the distribution network, this analysis provided insight into the aggregation effect across the Fairwater precinct. The aggregation effect is the accumulation of demand across multiple households and reveals how this subjects the network to high demand and stress. The aggregation of peaks from individual daily energy profiles occurs when the home system of practice is similar between these homes. This analysis evaluated how the home system of practice varies between the Fairwater homes and identified the profiles that would benefit the distribution network and a solar PV system.

THE HOME SYSTEM OF PRACTICE

The principles of the home system of practice can be utilised to improve the performance of the
distribution network and renewable technologies. The analysis in the report outlines the strategies that can be implemented to reduce the stress from the residential sector.

Understanding the way people consume energy is important when developing these strategies and identify interventions that can effectively change the way people live. The choice of clustering technique allowed insights to be made in the routines of each Fairwater home. This analysis identified a repetitive nature in the way the residents consume energy throughout the year. This repetition can be used to develop energy management systems on a precinct level to optimise energy consumption. The inclusion of the home system of practice can allow the system to understand when the household will consume a lot of energy. Additionally, the system will be able to predict the timing of the peak consumption periods of the day from the home and adjust their management to suit fit. On a precinct scale, the management system can ingest and predict the timing of peak periods from each household and manage the production of energy to ensure reliable supply.

CONCLUSION

The development of distributed renewable energy systems has revealed new objectives of home energy management systems. Ideally, homes can reduce their reliance on the distribution network by consuming solar energy. These management systems can share the solar energy generated in a precinct to the relevant households that consume energy during the day. This will increase the utilisation of renewable energy systems on a larger scale and reduce the stress on the network. Additionally, the system can provide feedback to encourage the residents to shift their consumption and follow a daily profile that utilises solar energy. Referring to smart grids, this solar energy can be generated by another household in the precinct that is exported to the grid as the household is not consuming this energy. This introduces the topic of peer-to-peer sharing of resources on a community scale that can significantly increase the consumption of solar power and reduce the reliance on the carbon-intensive distribution network.

Finally, the introduction of automation within the household can assist in time-shifting consumption to optimal times of the day. This report continuously implies the consumption of resources within the home highly depend on the occupancy pattern of that home. The occupancy pattern is related to the working lifestyle and contextual factors of the residents. The idea of separating energy consumption and occupancy is important when assessing the possibility of moving consumption to during the day when the house is not occupied. The development of automation systems can achieve this and be used in parallel with an energy management system. These two systems can work together on an individual and precinct level to optimise energy consumption. This can increase renewable energy systems across the suburb through optimised peer-to-peer energy trading. Such automation systems can be as simple as timer-equipped appliances (e.g. washing machines) to allow the appliance to be loaded but consume energy at a different time. This can more complex by identifying surplus solar power generation and preparing the home for residents through turning the AC on before they return from work. This will allow the occupants to achieve thermal comfort while consuming solar energy and reducing the need to use the AC system later in the afternoon when solar energy is not generated.

The report provides preliminary insight into these systems and principles regarding the timing of energy consumption and increasing the utilisation of solar PV systems. Further data and work is
required to provide more in-depth analysis of how these systems can be effective at Fairwater. This analysis and discussion will be reported in Milestone 4.

Please contact Troy Malatesta, Dr Jessica Breadsell, School of Design and the Built Environment, Faculty of Humanities, Curtin University Sustainability Policy Institute or Belinda Whelan, Director Climate-KIC Australia to learn more.