Fairwater Living Laboratory – Implications for Networks

UNIVERSITY OF TECHNOLOGY SYDNEY REPORT

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[i] This research was undertaken by researchers at the University of Technology Sydney as part of the Fairwater Living Laboratory. Publication of these findings must include the attribution: *Thomas, L., Wilkinson, S, Wyndham J, Huete, A., Biloria N., Woods, A., Kalali, P., Powles, R., Srivastava, A., Liu, Y., Bulut, M., Dritsa, D., Runck, M., Dwyer, S., 2022, Fairwater Living Laboratory Milestone 4 Report Summary: Outcomes for Energy, Network Demand, Residents and Community, Resilience, Urban Heat Effects and Commerciality, prepared for ARENA and Climate KIC.*

INTRODUCTION

The Fairwater Living Laboratory project aimed to assess the performance of renewable thermal energy heat pumps into homes at the Frasers Property Fairwater development in Blacktown, NSW. Research undertaken by the University of Technology Sydney (UTS) has successfully delivered on the project objectives, including demonstrating reduced peak demand and total consumption for grid energy; and quantified actual energy performance of the Ground Source Heat Pump (GSHP) systems. Additionally, the study has shown the reduced cost of living for residents (compared to business as usual) as well as the economic benefits to the developer, residents and the distribution network service providers. Improved urban heat island outcomes compared against a similar nearby site have been demonstrated. In doing so it has delivered a technical and commercial evidence base to show the potential for reduction in electricity network augmentation and the commercial merits of industry-wide adoption of GSHP technologies and systems approaches in residential precinct developments.

Importantly, through its use of the living laboratory framework that engages multi-scalar and multidisciplinary approaches to interrogating performance in practice, the study also reveals the importance of an integrated approach to decarbonising precincts. The study findings emphasise the importance of thermally efficient climate responsive building design, a better understanding of occupant behaviour and energy consequences, precinct-based approaches that encompass technology innovation for a decarbonised future as well as well-designed infrastructure to support the health, wellbeing and resilience of the resident population.

Ground source heat pump (GSHP) or geothermal air-conditioning (or) systems such as those installed at Fairwater, harness the stable ground temperatures for heat exchange while heating or cooling a building. Such systems would be expected to perform better than conventional air-conditioning systems that rely on heat exchange with ambient air which can be more inefficient when temperatures are extreme. However, little was known about the monitored performance of GSHP in practice in an Australian context, and especially the impact of geothermal air-conditioning to network demand and savings.

DIRECT BENEFITS FOR THE NETWORK

- Fairwater Estate GSHP houses were found to consistently demand less power than North Kellyville houses with conventional air-conditioning when ambient (external) temperatures deviate from the comfortable range.
- Our statistical modelling of smart-meter data indicates that for every degree that outdoor air temperature moves away from the comfortable range, electricity power 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. On the other hand, geothermal 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 electrical kW when temperatures are extreme, but also differ depending on time of day.
- In terms of greenhouse gas emissions, the savings for a more compact home combined with geothermal air-conditioning as seen at Fairwater represents 2.18 tonnes of CO2 e (scope 1, 2 and 3) on average per home per annum, and across an 800-home estate could result in 1,746 tonnes of CO2e emissions per annum.

UTS has also conducted an in-depth analysis to establish network benefits and value of geothermal air-conditioning for a number of scenarios.

- Reliability and Emergency Reserve Trader (RERT) Events: For instance, the utilization of GSHP air-conditioningduring a single RERT event such as the one on 4 January 2020 that lasted 3.42 hours implies a saving of $323 per home or $258,400 for an 800-house estate.
- Deferral of Network Augmentation: Depending on location within the network, and assuming a power savings rate of 3kW per household at peak demand, a geothermal home could see deferral values between $347-$2773 which equates to $277,600 to $2,218,400 over 800 homes.
- Exceedance of Local Distribution Network Peaks: Based on power consumption savings of around 3kW per home at peak times in summer, a conglomerate of 800 homes would save around $26,400 in exceedance ($11/kW) in a hot month if they were required to pay demand charges similar to businesses.

These benefits are all the more relevant in current scenarios of warming temperatures, increasing housing demand and urbanisation in western Sydney and other locations around Australia.

Further key findings and implications pertinent to the Networks (and its customers) include:

- Air-conditioning is a substantive component of energy use in a home and key driver of the summer and winter peak electricity demand.
- Our analysis has found that in absolute terms, Fairwater Estate Houses consumed 38% less total electrical energy (average savings of 2,424kWh per annum per household) than the North Kellyville houses (which use conventional air-conditioning) during the 24-month period from 1 Sep 19 to 30 Aug 21.
- Assuming single rate tariff usage rates ranging from 17.51 to 28.85c, the reduced consumption would result in savings between $425 and $699 per annum (average of $557 per annum at 22.96c). These savings include the twin benefits of geothermal air-conditioning and a more compact house at Fairwater.
- As Fairwater Estate houses were smaller than North Kellyville houses, the residual savings more likely to be attributable to take up of heating and cooling were computed by normalising the energy consumptions for house size. Our study indicates that Fairwater homes with geothermal air-conditioning return a saving of 21% of electricity energy consumption compared to homes of a similar size with conventional air-conditioning across the study period.
- Assuming single rate tariff usage rates as before, the normalised reduction in consumption would result in savings for between $181 and $299 per annum (average of $238 per annum).
- Our study has shown that residents in Solar PV houses consumed more electricity and air-conditioning (30% more on average) than those who had never installPV.
- A high take up in roof top solar was accompanied by increased electricity consumption, low self-sufficiency and low self-consumption diminishing the full potential for greenhouse gas reductions from renewable energy.
- Almost all Solar PV Study Houses were found to be NET POSITIVE under the simple definition of Net Zero, even when gas consumption is accounted for; however, assuming the same level of consumption seen in the Solar Homes and current CO_2 emission factors for the NSW grid, the present configuration of PV would barely break-even; leaving no surplus for electric vehicles (EV) and the like.
- From the perspective of developing a sustainable model towards Net Zero homes and precincts, this calls for two-pronged efforts - to mitigate the rebound effect amongst households, and to ensure decarbonisation of electricity grid.

A more strategic approach to energy generation and demand management is recommended at precinct scale.

- Precinct wide approach to space heating and cooling offers a number of opportunities in economies of scale and demand management.

- Where peak loads are due to space conditioning, GSHP is recommended as it reduces peak loads. Solar PV systems installed alongside GSHP must be "right-sized" and aligned to consumption and or storage.
- The study findings emphasise the importance of managing user behaviour and consumption, and also making the right decisions for sustainability and resilience at both household and precinct level. Integration and operation of geothermal air-conditioning goes beyond the technical performance of the system. High performance air-conditioning in and of itself is not a solution in the quest to reducing dependence on air-conditioning, getting to net-zero and maximising sustainability. A suite of measures that influence sustainable practices must be considered.

DIRECTIONS FOR FUTURE RESEARCH AND PARTNERSHIPS

- The study findings indicate that the benefits from the reduction in peak demand and network augmentation enjoyed by the networks are greater in comparison to residential customer energy savings from GSHP. This calls for better partnerships between property developers, consumers and the networks to ensure benefits to the network are also passed on to property developers and consumers.
- Additional opportunities for partnerships include: planning for a diversity of uses whereby retail/commercial/public buildings and residential homes take advantage of shared services for heating and cooling, which could serve to balance power demand between day and night time uses, investment in precinct scale EV infrastructure and installation of other shared infrastructure such as micro grids and shared energy storage.
- The study identified a clear need for benchmarkable energy data to support analysis and comparisons of residential precincts. The solar shadow in current configurations of smart metering makes meaningful research of solar houses very difficult. From a network and customer perspective, detailed submetering of end-uses as deployed in the current study can offer better insight for energy conservation and demand management. Meaningful research also requires important data with respect to demographics and building metrics.
- Consumers will benefit from real-time feedback of electricity and gas consumption by end use within the home, in addition to the import/export information current apps provide. Behaviour and choices can also be influenced if this information is coupled with real-time feedback on indoor and outdoor temperatures as well as weather conditions and forecasts. This offers an opportunity for networks to collaborate with suppliers of smart apps as well as experts on consumer behaviours, and designers and developers of homes and precincts to encourage sustainable practices.
- 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) was outside the scope of the study and could be considered as a next step when commissioning additional research.

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 a third GSHP air-conditioners with refrigerant loop such as the one included in this heat pump study, a third with GSHP air-conditioners with the water loop and a third with conventional reverse cycle air-conditioning and with sub-metered data for all groups would provide an excellent baseline and treatment group comparison.

- Living Laboratory style investigations of performance in practice should be a mandatory test bed for all innovative interventions. The success of the Fairwater Living Laboratory reinforces the value of integrating research and innovation within a user-centred approach encompassing multiple stakeholders.

Please contact Leena Thomas, School of Architecture, University of Technology Sydney or Belinda Whelan, Director Climate-KIC Australia to learn more.

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