Brimbank City Council: St Albans Leisure Centre – Carbon Neutral Aquatic Centre Deployment

LESSONS LEARNT REPORT 1
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Acknowledgement and Disclaimer

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EXECUTIVE SUMMARY

Milestone 1 of the Carbon Neutral Aquatic Centre Deployment Project has involved incorporation of the proposed heating, ventilation and air-conditioning (HVAC) system into the overarching Brimbank Aquatic and Wellness Centre project.

This has required a variation costing process with the builder, and a detailed design process to finalise the Construction Issue Design Documents. Both steps are now completed, in line with the project budget and funding requirements.

As per the funding agreement, the final project design reflects a central, whole of facility HVAC system, consisting of a 4-pipe heat pump, thermal recovery and thermal energy storage, a 500 KW solar photovoltaic (PV) array, and a building management system.

In line with the project target of securing all residual electricity from a renewable power purchasing agreement, all Council facilities are now supplied with 100% renewable electricity by the Victorian Energy Collaboration (VECO). Further detail on the VECO initiative can be found here - https://veco.org.au/.

Milestone 1 also required completion of the project's planning and building permits, which have now been approved.

Several knowledge sharing activities have also been initiated, including the establishment of an Industry Roundtable to advance the cause of all-electric aquatic centre design.

The first phase of the project has entailed an in-depth process of knowledge and design development. Several cost considerations have had to be balanced against the project's renewable energy, energy efficiency and environmental objectives.

The following report discusses the heat pump and thermal energy storage options considered as part of the design process and identifies opportunities to improve energy performance and environmental outcomes on future projects.

The learnings and insights provided in this report should be considered preliminary until they can be confirmed by operational data from the built facility.

KEY TERMS

Council – Brimbank City Council (BCC)

Overarching Project – the overarching project is the $60M Brimbank Aquatic and Wellbeing Centre. This state-of-the-art new facility will be a significant new asset for community health and wellbeing in Melbourne's west.

Design and Construction (**D&C) Contract** – the Design and Construction Contract for the Brimbank Aquatic and Wellness Centre.

Heating, Ventilation and Air-Conditioning (HVAC) - Heating ventilation and air conditioning systems account for up to 50% of a commercial building's energy use and dominate peak electricity demand. Capital and maintenance costs for these systems also comprise a high portion of overall building costs. A holistic HVAC strategy relies on an integrated approach to reduce demand, optimise existing systems and upgrade to more efficient systems. Advances in electrically powered HVAC systems, such as heat pumps, can result in significant energy savings and emission reductions.

The Project – the project to develop an all-electric, net-zero greenhouse emissions HVAC system for the Brimbank Aquatic and Wellness Centre. The project includes a central heat pump for heating and cooling with 1200 KW_{th} of heating capacity (at 4 degrees Celsius), an 88 KL thermal energy storage system, 500 KW of rooftop solar PV and a renewable electricity power purchasing agreement. The project design is distinct from the Business as Usual Design (see below) which had been in development as part of the overarching project but was retired following commitment to proceed with the all-electric, ARENA funded design.

Business As Usual (BAU) Design – A 1700 KW_{th} gas boiler heating system, a central chiller and significant number of additional air-conditioning units throughout the facility for cooling (i.e. not a centralised HVAC system). It included 500 KW of rooftop solar PV and a renewable electricity power purchasing agreement. It was costed as part of the original D&C Contract Tender.

Building Management System (BMS) – a digital control system for operation of building services such as HVAC, lighting and security.

Coefficient of Performance (COP) – the coefficient of performance of a heat pump, refrigerator or air conditioning system is a ratio of useful heating or cooling provided to work (energy) required. Higher COPs equate to higher efficiency, lower energy (power) consumption and thus lower operating costs. The COP for a heat pump system can be expressed in the form of a curve, which shows the power consumed to operate the equipment against the amount of heat energy supplied.

Global Warming Potential (GWP) – a measure of how much energy the emissions of 1 tonne of a gas will absorb over a given period of time, relative to the emissions of 1 tonne of carbon dioxide (CO_2).

Lesson Learnt No. 1: Comparison between LCA Heat Pumps and HFO Heat Pumps

Category: Commercial / Risk

Objective: Demonstrate the commercial feasibility of a renewable energy powered heat pump solution for aquatic centres.

Detail: The project's initial concept design nominated a 4-pipe low charge ammonia (LCA) heat pump system, but this was changed to a 4-pipe Hydrofluro-Olefins (HFO) heat pump system during the procurement process. Both options have been assessed as being capable of providing the facility's year-round heating and cooling requirements without resort to back-up gas boilers.

Energy Efficiency and Environmental Performance Comparison

The initial choice of utilising a LCA heat pump was based on energy efficiency and environmental performance. The below table provides the annual electricity consumption for each option as per the project's energy model.

	LCA option	HFO option
Annual electricity for water and space heating/cooling (KWh)	1,308,808	1,450,120

Based on its COP curve the HFO option is expected to have higher annual power consumption than the LCA option. The higher consumption will require approximately $15,000 - $20,000 in additional electricity costs per year. This is modelled on an electricity price reflecting both the solar PV and grid sourced electricity from which the additional demand will be drawn. If the additional demand was to be sourced purely from the grid, the extra annual costs would be in the order of $25,000 - $30,000.

The refrigerants used for HFO heat pumps are also less environmentally friendly compared to LCA heat pumps. The synthetic refrigerant used for HFO is called R513a and has a GWP of 631, while the LCA heat pumps use natural ammonia refrigerant, which has a GWP of 0.

That said, given that the most commonly used heat pump refrigerant, R410a, has a GWP of 2088, the adoption of R513a refrigerant with GWP of 631 represents a significant improvement. R513a also has a significantly lower volumetric requirement than R410a to achieve equivalent thermal transfer. Taking into account these parameters, R513a results in a 90% improvement in GWP relative to R410a.

The LCA vs HFO consideration also took into account incorporation of a refrigerant leak detection system in the HFO design which generates BMS alerts when any change in refrigerant volume is detected. This will help achieve negligible leaking of refrigerant gas to the atmosphere over the course of the heat pump's operations. The gas will also be made inert as part of the heat pump's end of life decommissioning.

A leak of all R513a refrigerant would result in the release of approximately 12 tonnes of CO_2-e in the atmosphere which is equivalent to the annual greenhouse gas emissions of an average Australian household. By comparison, the estimated greenhouse gas emissions of the BAU gas boiler-based design over the facility's design life (60 years) would be in the order of 60,000 tonnes CO_2-e.

Capital Costs Comparison

The table below provides cost range estimates that future projects can expect to encounter for HFO and LCA systems respectively. The estimates are for a system with heating capacity of 1200 KW_{th} at 4.0 degrees Celsius. The core heat pump costs, and potentially some of the total overall costs, could be higher or lower depending on the required heating capacity.

	HFO	LCA
Core heat pump units and associated equipment*	$0.5M -$0.7M	$1.3M - $1.5M
Total overall supply and construction cost**	$1.35M - $1.55M	$3.0M - $3.2M

*Associated pumps, heat absorption/rejection units, plus a small additional heat pump for domestic hot water temperature top-up in the case of the HFO system.

**Inclusive of design, installation and supporting materials and equipment costs.

The decision to proceed with the HFO heat pump option was based primarily on budgetary grounds given the lower capital cost associated with this type of heat pump. The decision also took into account the HFO option's energy efficiency and performance capabilities. Although the HFO efficiency and performance is lower compared to the LCA option, its parameters are still sufficient to meet the project's overarching objective of an all-electric, net-zero greenhouse emissions aquatic centre.

Implications for future projects:

LCA heat pump technology appears to have a considerably higher capital requirement than HFO, although its capital premium for this project was likely exacerbated by design and procurement complexities resulting from the contract variation nature of the procurement process.

Based on the cost insights and experience from this project, future projects are encouraged to prioritise an all-electric, natural refrigerant design from the outset. Early prioritisation would stand to achieve a more cost competitive outcome for LCA heat pump technology, however the capital premium will need to be reduced considerably before the technology can be considered competitive with HFO on purely financial grounds.

Based on LCA technology's superior energy and environmental performance, future aquatic centre project's seeking to achieve an all-electric outcome should continue to consider LCA heat pump options, alongside HFO options, as part of their design and procurement strategy.

Lesson Learnt No. 2: Optimisation of Thermal Energy Storage Costs and Benefits

Category: Commercial / Risk

Objective: Demonstrate the commercial feasibility of a renewable energy powered heat pump solution for aquatic centres.

Detail Learning: The project's feasibility analysis identified thermal energy storage (TES) as an effective complementary technology for the centralised heat pump based heating and cooling system. Further energy modelling indicated that incorporation of a TES system with volume of 100 KL would enable the following benefits:

A) A reduction in the heat pump's peak heating output requirement from 1700 KW_{th} to 1200 KW_{th} (at 4 degrees Celsius), leading to a significant reduction in heat pump capital costs.
B) Load shifting to daylight hours during periods of 'free' excess solar PV generation. This has the added benefit of optimising operation of the heat pump, thereby increasing the heat pump's average coefficient of performance (COP).

For this project the TES volume/capacity consideration was largely determined by the amount of excess generation available from the 500 KW solar PV system (as per the energy model) that was already part of the overarching project. Theoretically, more solar PV, and therefore more TES capacity, could have been considered. However by the time the TES load shifting feature was being seriously considered, budgetary and time pressures drove a pragmatic decision to simply work with the existing solar PV capacity.

On this basis, the design brief for the design variation costing process nominated a thermal energy storage volume of 100 KL but was non-prescriptive on how that needed to be achieved in terms of an above ground or underground approach. In response, the builder proposed an above ground insulated stainless steel tank solution with a volume of 88 KL. This solution was accepted and its cost was approximately double compared to what was expected from the project's background cost estimates for TES.

Insights on the feasibility and costs of an underground concrete option are not provided in the report, because this information was not disclosed by the builder.

Prior to the variation process, quotes for an underground concrete tank solution were obtained by the Council as background knowledge. Based on this information, it is reasonable to expect that an equivalent, or even larger volume of underground thermal energy storage capacity could potentially be implemented in future projects with a significantly lower cost compared to the above ground solution.

Despite the unexpectedly high cost of the above ground TES solution, Council decided to proceed with this approach based on its commitment to demonstrate the energy productivity and renewable energy benefits of integrating heat pumps with solar PV and TES.

Based on the final heat pump costs, the TES enabled reduction in heat pump capacity from 1700 KW_{th} to 1200 KW_{th} does appear to have achieved a significant reduction in heat pump costs. However, this saving was offset by a higher cost to implement the TES.

Despite the less than ideal cost outcome, the TES is expected to add operational savings of around $10,000-$15,000 per year, which is sufficient to return on the additional investment needed in due course.

Implications for future projects:

Optimisation of TES design and costs will be an important area of innovation and focus on future projects, given the capital and operational cost benefits that its integration into all-electric aquatic centre designs can achieve.

From its experience on this Project, Council believes that the cost effectiveness of TES can be considerably improved for future projects. As long as the TES implementation costs do not exceed the correlating heat pump cost reductions, then a net capital cost benefit can be achieved.

Consideration of underground concrete tank solutions early in the design and procurement process is likely the best way to achieve this.

Cost effective TES will allow consideration of even larger TES volume and capacity than what was included in this project. Larger TES capacity could potentially facilitate even greater reductions in heat pump peak heating output requirements, resulting in significant capital cost reductions. By including sufficient excess of solar PV generation to charge these larger volumes of TES, operational costs and grid reliance can also be reduced further.

Future projects are encouraged to undertake solar PV and TES sizing analysis much earlier in the design process, and in more depth, with a focus on maximising the benefits of incorporating solar PV and TES with heat pumps.