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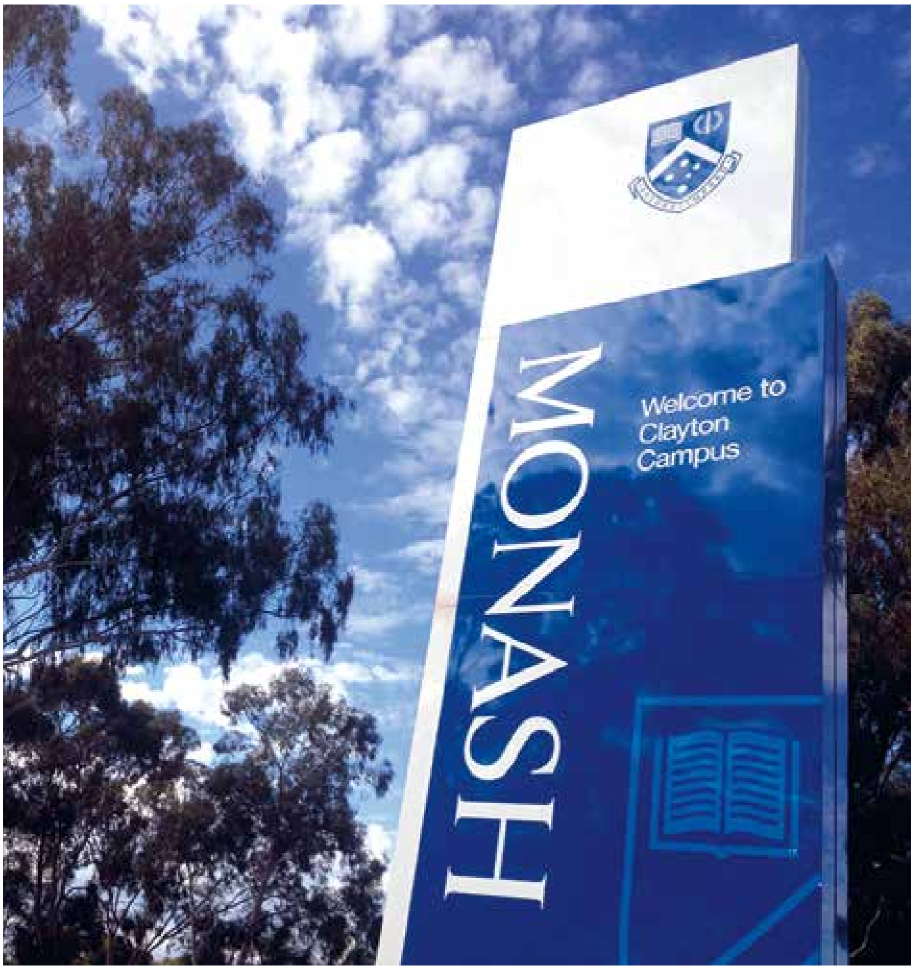


Down on the (solar) farm

To achieve net zero emissions by 2030, Monash University has utilised the latest in solar technology to provide preheating to a low-load boiler serving a campus-wide high-temperature hot water system. **Sean McGowan** reports.

Images: Simon Witt, M.AIRAH

Like many other university campuses in the southern states of Australia, Monash University's Clayton campus relies heavily on natural gas to meet the demand for high-temperature hot water (HTHW).

As one of Australia's largest university campuses, Clayton features 100 buildings, accommodates eight faculties and educates over 30,000 students.

The university's campus-wide HTHW system consists of a gas-fired boiler plant connected to a network of pipes that deliver high-temperature hot water around the campus for process (absorption) cooling as well as heating hot water applications.

Such is the system's size, that gas represents approximately half of the campus' total energy consumption. And although the university is seeking to transition to 100 per cent renewable energy, it could find few viable alternatives to eliminate its reliance on natural gas to meet its HTHW demands.

In 2013, this conundrum led to discussions between Monash University's engineering and sustainability manager Dr Rob Brimblecombe and Simon Witts, M.AIRAH, principal engineer with the engineering consultancy LCI, about alternative energy solutions that could work in a suburban environment such as Clayton.

Among the solutions that they discussed was the incorporation of a solar evacuated tube field – a technology that had matured considerably in recent years, and that can achieve high temperatures. Soon after, the concept of a solar farm to supplement the university's HTHW system was born.

"The latest series of evacuated tubes have a higher collection efficiency and higher operating temperatures than the previous versions," says Witts.

"We saw the opportunity to integrate this product into a high-temperature hot water environment, which prior had not been commercially possible."

But despite the promise of the system, funding constraints saw the project parked in the short term.

SOLAR REVISITED

In 2016, funding became available for a new boiler, and LCI Consultants was asked by Monash University to review and update the preliminary study from 2013, with a view to progressing to a full project.

"Prior to the project, the boiler house contained three large HTHW boilers, each approximately 8MW," says Witts.

Although adequate at the time, the campus load profile had changed during the life of these boilers.

Consequently, LCI Consultants needed to establish a load profile for the campus, to determine the size of the solar field and the required low-load boiler.

"The university provided us with detailed gas consumption records, and we were able to produce detailed yearly, monthly and daily load profiles," Witts says. "These proved invaluable in the assessment of the boiler capacity,

Getting the most out of the sun: the 400kW solar installation.

and in identifying both the size of the proposed replacement boilers, and the matching solar field."

The daily boiler profile revealed significant variations in the boiler load across the year, as well as during the day. And tellingly, the study revealed that the primary boilers on site were operating at less than 20 per cent load for significant periods of time during the summer months.

"The concept was then developed to incorporate a low-load boiler, with the solar field acting as a preheat/low-demand system," says Witts.

Following consultation, a 4MW low-load fluid heater was selected, which was matched to the 400kW solar field.

SOLAR FARMING

The Monash University Solar Farm project has been designed in two stages.

Stage 1, completed in June 2017, comprises of the 400kW solar field (split into two) installed on the roof of a building, which accommodates the Faculty of Engineering.

Two fields on the same building will form Stage 2 and see the total system capacity expand to around 1MW upon completion.

Rather than water, as is commonly used in solar evacuated tube collectors, LCI Consultants has chosen a proprietary heat-transfer liquid that can not only achieve the high temperatures required, but also run through the system at low pressure.

> "Such is the system's size, that gas represents approximately half of the campus' total energy consumption"

Monash's Faculty of Engineering is now equipped with an extensive array of solar tubes.

The finished platform with solar system pumps, header and HTHW heat exchanger.

> In reality, catching the sun is the easy part. The control of the system is a vital part of the design

The HTHW system serving the campus operates at temperatures ranging between 120°C and 160°C. It is even able to operate at 180°C at a design pressure of 12 bar gauge (1200kPa), Witts says.

Such pressures are beyond the working limit of the solar heaters. With consideration given to the large number of panels (tubes); the rooftop location; maintenance requirements; as well as health and safety issues, alternative fluids needed to be explored.

"Most evacuated tube systems operate well below 120°C, thus not incurring high pressures using water," says Witts. "We are not aware of heat-transfer fluids being routinely used with evacuated tubes, but that's not to say it hasn't been done before."

Several common heat-transfer fluid options were investigated. But most were unable to meet the criteria of the project, such as stability over a wide range of temperatures up to 300°C, usage of non-hazardous and non-toxic materials, and resistance to oxidisation.

After further investigation, a high-performance, efficient and environmentally friendly thermal fluid was identified.

Engineered for applications requiring high-temperature stability to 332°C, it is non-toxic, non-hazardous and non-reportable, and, most importantly, poses no ill effects to worker safety and does not require special handling.

> "The design allows for the entire solar field to be free-floating"

The Monash University Solar Farm has used the thermal fluid to flow to and from the solar field. Heat is transferred to the HTHW system via a shell-and-tube heat exchanger, specifically designed for the project.

The low-load boiler then tops up the heat, if required.

Beyond the challenges of heat transfer, LCI Consultants also had to overcome many other design obstacles, including catering for a highly variable heat source.

"There are only two things we know for certain with the solar field – we don't collect any heat before sunrise, and once the sun is up we can't turn it off," says Witts.

"Therefore, the system had to be designed to cater for a large variance in heat supply from the field without the low-load boiler or the main system seeing any destabilising fluctuations.

"In reality, catching the sun is the easy part. The control of the system is a vital part of the design."

The design team also had to overcome the challenges of thermal expansion and the significant amount of pipework movement in the solar field – a consequence of long pipe runs and regular diurnal temperature swings.

"Some of the pipework in the main field expands and contracts 120mm each day," says Witts. "Expansion and contraction of this nature cannot be easily contained. The design allows for the entire solar field to be free-floating. In this way, anchoring and fixing systems do not have to cater for the expansion loads."

LESSONS FROM THE CONSULTANT

LCI Consultant's principal engineer, Simon Witts, M.AIRAH, offers some of the key considerations when integrating any solar field/system into an existing system or process.

Fully understand the system into which the solar thermal field is integrating.

It would be very easy to oversize a field, which in the case of a non-tracking system such as this, would be a significantly control issue.

The system should be designed to be failsafe.

Any issue with the solar field itself should not affect the operation of the main system.

Control.

The success and payback of the system ultimately comes down to very good and very clear control.

COMMISSIONING

As well as matching the solar field and low-load boiler to modifications made to the existing controls, significant effort was made during the commissioning process to remove moisture from the system.

Witts says that any pipe work system – especially those installed in the humid Melbourne climate – will be subject to moisture in the system, including in the major items of plant.

"Once the system was filled with the thermal fluid, the moisture in the system had to be given time to boil off," he says.

"This process had to be completed slowly by gently raising the temperature of the boiler, and venting the steam vapour at the highest point of the system."

Since reaching completion, the solar yield from the system has been relatively low given that the solar field installation is optimised for summer collection.

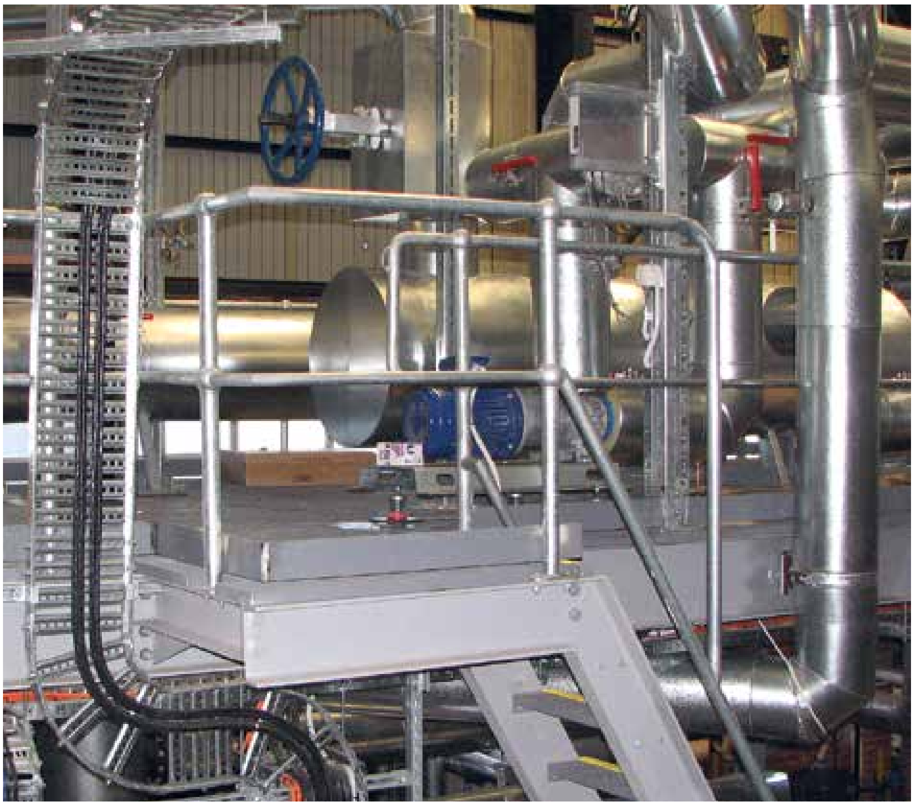
Ahead of the system's first summer of operation, this has provided an opportunity to complete the initial tuning and integration into the main campus HTHW system.

"We have a 24-month tuning program because we are reliant on the seasons," Witts says. "Experience on another project has shown us that once we go through two cycles of seasons, most of the hard tuning will be finished."

Although the full cost of the project remains undisclosed, a payback period of eight years (calculated at current gas prices) is expected once its second stage is completed.

"This will hopefully be a test case that will allow us to eliminate our dependence on natural gas," says Dr Brimblecombe.

"Perhaps more importantly, we treat Monash University campuses as living laboratories. We feed the research into the practice that we do, and hopefully we will find solutions that can be rolled out across our campuses and out into the world."



The solar heat exchanger and header system on the platform, during install.

PROJECT AT A GLANCE

The personnel

- **Client:** Monash University
- **Consulting engineer:** LCI Consultants
- **Mechanical services contractor:** Fraser and Mountain
- **Solar installation:** GreenLand Systems
- **Controls:** Alerton

The equipment

- **Boiler:** Consolidated Fire & Steam
- **Heat exchanger:** Consolidated Fire & Steam
- **Pumps:** Consolidated Fire & Steam
- **Solar evacuated tube collectors:** GreenLand Systems
- **Thermal fluid:** Duratherm

(Source: LCI Consultants)

Would you like to know more?

To find out more about the project, watch the video at www.youtube.com/watch?v=oiW9TjfaX-U