Maintaining a coral reef within an aquarium environment is a fine balancing act. So how did the operators of Townsville's Reef HQ Aquarium cutting energy use by 50 per cent while keeping the award-winning research and visitor centre operational? Sean McGowan finds out.

REEF-URBISHMENT

Reef HQ in Townsville is the world's largest living reef aquarium.

Featuring more than 100 species of fish, 130 types of coral and hundreds of marine invertebrate in 2.5 million litres of temperature-controlled water, Reef HQ Aquarium is the world's largest living reef aquarium.

Bringing the best of the Great Barrier Reef to the centre of Townsville, the award-winning tourist attraction was built as a Bicentennial Commemorative Project in 1987. As the national education centre for the Great Barrier Reef Marine Park Authority (GBRMPA), the facility plays an integral role in reef conservation, education and research.

The aquarium had no formal sustainability strategy during its first 20 years of operation. Yet in 2007 concerns surrounding rising energy costs and climate change resulted in the formation of a small working party to investigate opportunities for energy reductions.

Made up of Reef HQ Aquarium's director, engineering supervisor, technical operations manager and other key technical staff, the group settled on an arbitrary energy-reduction target of 50 per cent.

But with no real strategies or budget to achieve it, an internal audit of infrastructure and processes became the first step on the road to energy efficiency that continues six years on.

"We thought there would be no satisfaction in reaching a mediocre target, so we aimed high," says Reef HQ's technical operations manager Sascha Thyer.

"We found so many issues [from the audit] that could be addressed with minimal funding, that they kept us busy for a while."

Of the many low-hanging fruit highlighted by the audit, issues of staff behaviour, procedures and maintenance stood out.

During the following year, staff were trained to avoid wasting energy by closing doors and turning off unused equipment. An array of air conditioning-related issues was addressed, and window tinting was applied to most windows to provide a level of insulation. Dilapidated skylights were also removed.

Combined, these simple and inexpensive measures resulted in a 13 per cent reduction in energy consumption in the first year.

"We found that as staff members came on board, it was easy to make changes and identify issues," Thyer says. "Having said that, to some extent old habits die hard, and we had to put in place mechanisms and processes to prevent wastage."

One of these was to increase the building's air conditioning set-point from 23°C to 24.5°C.

Despite initially drawing some complaint, both staff and visitors quickly accepted the higher set-point. This was aided by a community-wide engagement drive by local electricity distributor Ergon Energy, which urged homeowners to do similar.

"The outside temperature in a Townsville summer can be 35°C or more," Thyer says. "So 25°C is really quite acceptable as long as you have acceptable airflows."

However, this rise in temperature had an adverse effect on some aquarium tank temperatures, raising the priority for heat exchangers to be introduced on the exhibit tanks.

THE SECOND STEP

With tangible energy savings under their belt, and a belief that the once-arbitrary 50 per cent reduction target was readily achievable, the second step for Reef HQ was to seek funding for further works.

This required a number of formal audits, the first two of which were coordinated and paid for by the GBRMPA Climate Change Group. Though they did not reveal anything new to the Reef HQ technical team, the audits planted a seed in the GBRMPA management team. The team realised that some serious funding would be required to make the desired infrastructure changes.

A strategic infrastructure plan by a specialist aquarium consultant followed.

"This was a very important tool in securing significant federal government funds," Thyer says. "It emphasised the long-term outlook for the aquarium as a business, and reviewed the business model."

The space limitations of the aquarium made installation quite difficult.

Installation of the water-cooled chillers.

The plan also identified many new ideas and strategies to increase efficiencies within the aquarium filtration systems.

Around this time, Ergon Energy was seeking partners to minimise peak demand on the electricity network through its Network Demand Management pilot project in Townsville. Reef HQ was approached and became integral to the program achieving its 20MW demand reduction.

"We looked at a range of diversified businesses – large and small, government and non-government – to find a range of energy management solutions that could be implemented to achieve these goals," says Ian McGregor, Ergon Energy's development manager of large customer demand.

In partnering with the aquarium, Ergon Energy helped cover the cost of two further energy audits to Level 2 standard. The first of these was an important catalyst for a demand-reduction agreement between the two organisations.

It also facilitated the introduction of McClintock Engineering to the project.

"We simply did not have the expertise in-house to make any further efficiency gains with regards to the chiller systems," says Thyer. "Craig McClintock brought a level of expertise, innovation and strategy that was well beyond our expectations."

As well as being sensitive to the aquarium's needs, McClintock, an AIRAH member, presented a master plan that was pivotal in Reef HQ Aquarium achieving its 50 per cent energy-reduction target, and resulted in securing the necessary funding to upgrade the chilling system.

ON THE PATH TO EFFICIENCY

"Deciding where to start is not simple, even if the big offenders are clear," says Thyer. "The decision is governed by the ability to implement the change."

With good in-house expertise available, and baseline and cost-benefit analysis complete, a lighting upgrade became the next step. All general area downlights were changed from dichroic to compact fluorescent lighting, which were later changed again to LED downlights.

Additionally, trials were conducted on different types of exhibit lighting.

With spectrum quality important for the health of aquarium coral, Reef HQ imported and installed the first plasma light in Australia, as well as installing a number of natural solatubes. These have virtually eliminated the need for lighting maintenance on these exhibits.

The overall payback period for general lighting initiatives was two and a half years. It means Reef HQ is now more than $10,000 ahead, and overall energy consumption resulting from the lighting upgrade was reduced by 3.1 per cent.

With pumps and filtration systems also areas of strong expertise among Reef HQ staff, pumping issues were identified early on in the project.

"It wasn't difficult to secure funding for filtration pumping changes, as the payback times were very short," says Thyer.

In one example, the change of a large pump's motor (at a cost of $1,500) resulted in an annual energy cost saving of $10,000. Additionally, a cost benefit analysis of the smaller pumps revealed that the cheap "pump of choice" was costing $20,000 per year more to run than the most expensive pump on the market.

The main difficulty, however, was that these changes were both complex and relatively labour intensive. They required careful planning to maximise the outcomes, minimise exhibit down time, and minimise risk during installations.

Submersible pumps in the main reef tank were deemed inefficient, unreliable and expensive to maintain. These were replaced with new innovative, efficient, low-voltage pumps constructed from carbon fibre and plastic.

About $120,000 was spent over three years, delivering a 55 per cent reduction in pumping energy demand and a $270,000 return on investment.

CHILLERS DELIVER

These upgrades led the project to its greatest challenge: the upgrade of the facility's large chilled-water system.

The old system had continued to perform poorly. Issues included poor air circulation around the 600kWr air-cooled chiller; a corrosive environment (salt water); and poor hydronic system configuration that has fixed and modulating-field chilled-water bypass valves.

The aquarium's inefficient air-cooled system was replaced by a water-cooled solution.

The audits had also identified poor air-side systems, with some air-handling units operating at 30 per cent of the design values. An air-purge system, manually forced on, was also causing the building to operate under negative pressure.

"Data loggers were installed on the existing system to log the system performance," says McClintock, director of McClintock Engineering Group.

"The average system COP (coefficient of performance) is 2.4, with more than 20 starts in one night-time period (10 hours). The total system was out of tune with the building loads and functional use."

Having already reduced building heat loads through window tinting, the application of reflective roof coatings and rectification of building air leaks, the chiller upgrade began with an overhaul of the existing air handling. Coils were also cleaned and fan pulleys upgraded to achieve air figures that McClintock determined by engineered heat loads.

The building air balance was corrected, with the end result that the building was put under positive pressure. The water side was corrected, and all existing two-way and three-way valves were replaced by two-way valves. The fixed-field bypasses were also closed and recommissioned.

Air-cooled and water-cooled plant was compared through energy modelling in a number of configurations. A high-efficiency water-cooled solution was ultimately selected.

The water-cooled solution provides N+1 redundancy, has a long life-cycle, and efficiency approximately 1.7 times better than air-cooled. These benefits will provide the aquarium with life-cycle cost savings of approximately $4.8 million over 25 years.

This solution also addressed previous noise issues with local residents. By adopting a water-cooled solution, cooling towers could be oversized for redundancy, and have both low fan speeds and less noise.

"Three 250kWr plate heat exchanger chillers were selected, mainly for the short footprint and versatility of being able to move the chiller into the newly constructed plant room without heavy lifting gear," says McClintock.

"Another benefit is the modular-style approach, which meant we could reduce our primarily chilled-water pump flow rates at low-load conditions, with only one chiller running," he says.

"The evaporator plate heat exchanger has a higher water-side pressure drop, which was offset in energy consumption by reduced pumping requirements, with smaller chiller groups."

The selection of these chillers also halved the project lead time to six weeks. The equipment was air freighted to Sydney from the manufacturer in Tokyo, before being road freighted to Townsville, all in the space of just seven days.

In addition to this high-efficiency plant, a base-load 20kL thermal energy storage (TES) tank was selected. This was used to decouple the primary pumping groups from the secondary pumping groups, providing around five hours of thermal storage in the cooling day-time run periods and holding the chillers off during winter at night time.

The tank also allowed the team to demand-limit the site.

"Previously, the chilled-water system would cool the building and the 4ML marine aquarium tanks simultaneously and into the night," McClintock says.

"The new chilled-water system cools the building during the day and tops up any spare cooling capacity into the TES tank and marine aquarium tank. Upon completion of the building HVAC systems' daytime duty cycle, the chilled water is redirected to cool the marine aquarium tanks."

The bleaching threshold temperature

Along with helping to reduce Reef HQ's energy consumption by 50 per cent, the chiller upgrade has also assisted the aquarium in avoiding the bleaching threshold temperature.

This is the temperature at which the water becomes too hot for coral, causing its tissue to turn white.

Though this is a naturally occurring phenomenon in the wild, and more recently linked to climate change, it can also occur in aquariums if water temperature is not closely monitored and managed.

"Corals are an animal, usually with a white calcium skeleton that is inhabited by symbiotic algae called zooxanthallae," explains Thyer.

"It is the algae and other pigments that give the corals their beautiful colours. Being a plant, the algae photosynthesise and provide food – carbohydrates and oxygen – for the coral, and in turn the coral tissues provide a safe home and important nutrients for the algae.

"If the water temperature gets too hot, the algae are expelled from the coral, which causes the tissue to look white, hence the term 'coral bleaching'. And without the friendly algae the coral will eventually starve and die."

At Reef HQ, the bleaching threshold is around 29°C, and if this temperature is sustained for a period of days to weeks, the corals housed there suffer lethal or sublethal effects.

By upgrading the chilled-water system, the aquarium water temperatures are now able to be effectively maintained below the bleaching threshold, with a significantly positive effect on aquarium exhibit health.

Reef HQ's efforts in sustainability were recognised when the organisation earned the Qantas Award for Excellence in Sustainable Tourism at the Queensland Tourism Awards in November.

PROJECT AT A GLANCE

The professionals

Client: Reef HQ Aquarium (Great Barrier Reef Marine Park Authority)

Energy partner: Ergon Energy

Mechanical contractor: Peak ARE

Mechanical engineer: McClintock Engineering Group

Equipment at a glance

BMS: Reliable / North Queensland Controls

Cooling towers: Cooling Tower Sales and Service

Metering: Crompton / North Queensland Controls

Thermal energy storage: Rocket Fab Engineering

Water-cooled chillers: Hitachi by Northern Air / Temperzone

Solar PV System: SunPower Corporation

The space limitations of a 25-year-old building presented significant hurdles in the plant's installation. Another challenge was the aquarium's operational requirements; these dictated maximum downtimes of one hour for mains power and three hours for chilling.

To make room for the new plant to be installed, mechanical contractor Peak ARE cut new, temporary chilled-water stubs into the existing system by freezing sections of the existing pipework over a period of short shut-downs. They then ran temporary flex CHW lines, electrical feeds and controls to outside the plant area.

"Once this was set up, we disconnected and craned out the existing chiller and CHW pump to outside the plant area, then connected the temporary lines and electrical feeds to the chiller and pump, and restarted the system within three hours," says Peak ARE's Brad Swaffer.

"This allowed us to build the new plant room and cooling tower platform structure in place while the site was supplied with CHW water from the relocated existing plant."

EFFICIENCY ACHIEVED

A new BMS has also been installed. Selected by Peak ARE, the new system provides the lowest capital cost solution to replacing the existing, aged BMS on site.

It provides networking of all private metering points through native BACnet, and gives the Reef HQ team the ability to see where energy is being used throughout the building at any given time.

McClintock says this will help fine-tune control strategies and improve future designs and engineering modelling and reporting.

With the new chiller system now operating for almost five months, results to date have been impressive. For instance, in October last year, a 56 per cent energy saving and 41 per cent demand saving was achieved.

Although a few abnormalities in the demand response have been found, rectifying these will help the team reach the target power demand reduction of 48 per cent.

"The success of the project has been forged on a number of fronts – from the leadership and motivated hands-on approach of our client Sascha Thyer, the GBRMPA and Reef HQ Aquarium, to the proactive leadership of Ergon Energy and a team approach between everyone employed on the project, including the genuine desire by Peak ARE to deliver a first-class project under some testing conditions," McClintock says.

"We are very pleased with the result for GBRMPA, and early indications show we should exceed our engineering targets."

Overall, Reef HQ Aquarium's arbitrary energy reduction target of 50 per cent is now likely to be exceeded, with the addition of a 153kW peak solar PV system set to make it home to one of the largest rooftop solar PV systems in North Queensland. ▲