CASE STUDY 04/09

Energy team keeps Te Papa cool and comfortable

TE PAPA, WELLINGTON

Te Papa's energy management team has cut energy costs while taking care of a huge open-plan building with constantly changing uses and ever-expanding operating hours.

THE **MARAE** AT **MUSEUM OF NEW ZEALAND TE PAPA TONGAREWA**.

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1 THE **TIME WARP** INTERACTIVE EXHIBIT – RESPONSIBLE FOR **2%** OF TE PAPA'S ENERGY USE.

TE PAPA, WELLINGTON

About Our Place

Construction began in 1994.

Opened 14 February 1998.

Cost $317 million.

Architect: Jasmax.

Floor area: 40,000 square metres.

Contains 80,000 cubic metres of concrete.

Stands on New Zealand-invented earthquake insulating bearings.

Clad with 14,500 decorative concrete panels.

How do you preserve treasures ranging from Pacific masks to reptiles, in a vast space that hosts after-hours parties and events and accommodates more than a million visitors a year?

Te Papa is an increasingly popular venue for entertainment functions and their associated catering. The activity can start as early as 6am and finish as late as 2am.

The price of popularity is an unpredictable energy-use pattern.

Each new exhibition has its own requirements. An upcoming collection of the Queen's paintings, *From Holbein to Hockney*, needs a tight temperature range of 19 to 21 degrees and relative humidity between 50% and 55%.

Conservators log the number of hours precious objects are exposed to light and put them back into storage before they exceed the permitted dose.

Behind the scenes, the back-of-house storage and service areas have different requirements.

This all has to be achieved in a space that centres on one vast 20,000m^2 room, with doors open to the outside.

Despite these challenges Te Papa has managed to significantly reduce its energy use.

Treasures top priority

Te Papa's main site is the Jasmax-designed landmark between Wellington's waterfront and Cable St.

Also under the team's care is the former Wellington City Council Works Depot in Tory Street, a facility used mostly to store collections of fish, birds, reptiles, molluscs and other creatures and objects. It is not generally open to the public and uses only 10% of the energy of the Cable St site.

The top priority for Te Papa's original design was to keep the temperature and humidity correct for the collections of objects the museum houses, of which only 10% might be on display at any given time. Te Papa's founding Act specifies the care, maintenance and accessibility of its collections as required functions.

A 50% increase in the use of the building for private functions has presented challenges for the energy management team.

Converting a store and library into an extra 5000m^2 of full-time air conditioned public galleries in 2001 caused a blip in the steady progress the team was making in its downward energy-cost trend.

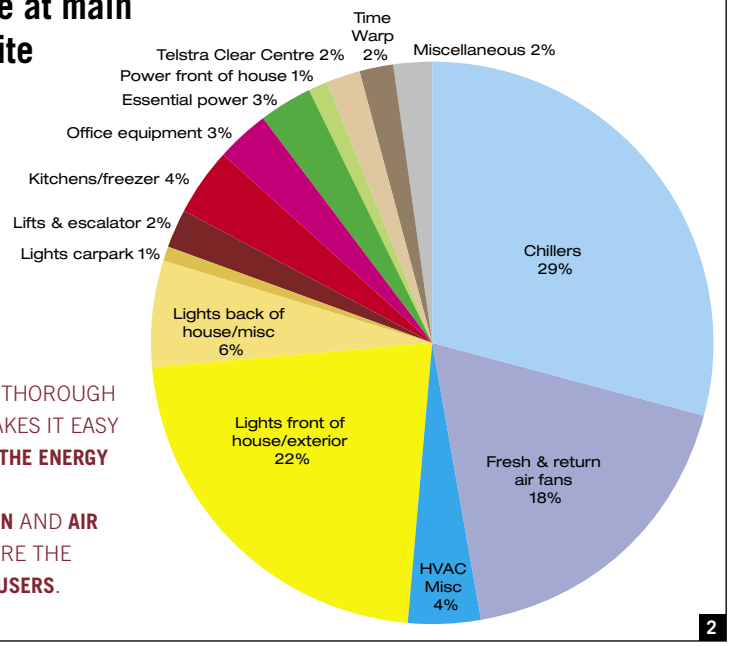
It had cut electricity usage by one-third and its gas usage by even more, but the extra air conditioning increased energy demand.

Team talk

Te Papa's energy management team, headed by building operations manager Mike Anthony with support from manager of planned maintenance Ian Williams and ex-Te Papa energy manager Sandy Winterton, now working independently as Energy Advantage Ltd, is well set up to cope with most things thrown at it.

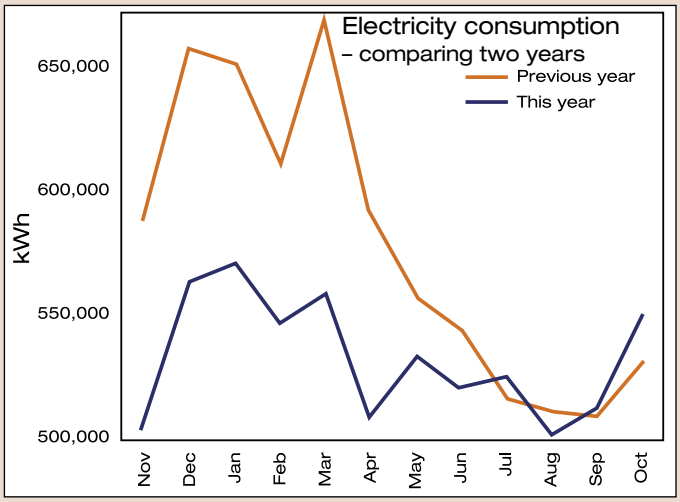
The team includes a representative from controls company Setpoint Solutions Ltd and mechanical engineer Peter Appleby ▶

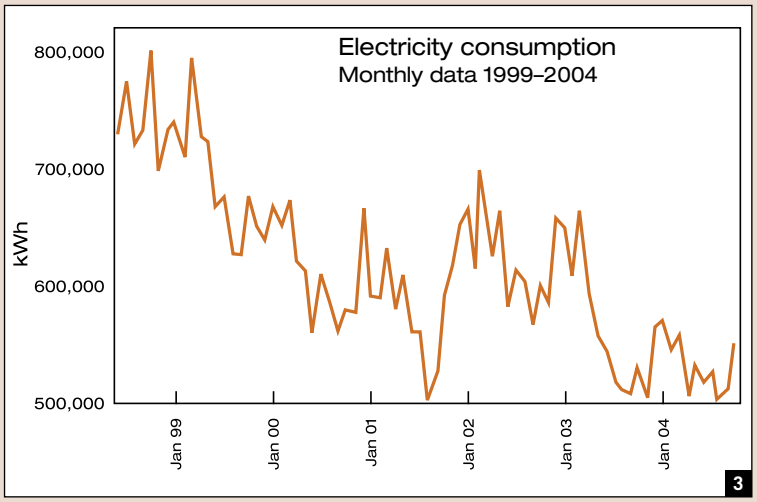
Energy use at main Te Papa site



2 TE PAPA'S THOROUGH **MONITORING** MAKES IT EASY TO SEE **WHERE THE ENERGY IS GOING**.

VENTILATION AND **AIR CONDITIONING** ARE THE **MAJOR ENERGY USERS**.





3 GRAPHS BASED ON THE OUTPUT FROM **ENERGY PRO** ENERGY MANAGEMENT SOFTWARE.

4 **TE PAPA ENERGY TEAM** MEMBERS, LEFT TO RIGHT: **SANDY WINTERTON**, ENERGY ADVANTAGE LTD; **ROB BISHOP**, ENERGY SOLUTIONS LTD; TE PAPA BUILDING OPERATIONS MANAGER **MIKE ANTHONY** AND TE PAPA MANAGER – PLANNED MAINTENANCE **IAN WILLIAMS.** ABSENT: **PETER APPLEBY** AND **MEL JONES**, ABS LTD; AND **GLYNN BENSON**, SETPOINT SOLUTIONS LTD.

5 THE LANDMARK **TE PAPA** BUILDING ON WELLINGTON'S WATERFRONT, VISITED BY **1,289,000 PEOPLE** IN 2003.

TE PAPA, WELLINGTON

The big issues

The energy management team faces several important challenges.

1. **Changes of use** in the building, such as converting back-of-house areas to public galleries, are challenging to accommodate with the large centralised heating, ventilation and air conditioning system.

2. The precise requirements for **temperature and humidity control** for the objects stored and displayed are different from the comfort needs of people attending the functions held at Te Papa, with consequences for energy use and cost.

6 **MADE IN NEW ZEALAND** EXHIBIT: **JEFF THOMSON**'S CORRUGATED CAR.

7 **MIKE ANTHONY** STANDS IN THE **ENORMOUS DUCT** FOR THE RETURN AIR, WHERE ALL THE BUILDING'S AIR IS PULLED DOWN TO BE FILTERED, REHEATED OR COOLED AND MIXED WITH FRESH OUTSIDE AIR TO RE-ENTER THE BUILDING. **PRESSURE SENSORS** CONTROL THE RETURN AIR FANS SO THEY USUALLY OPERATE AT 50% TO 70% OF THEIR CAPACITY. WELL-ADJUSTED CLOSE CONTROL **AVOIDS ENERGY WASTE**.

8 **ROOFTOP COOLING TOWER**. THE TEAM IS PLANNING A **SMART ENERGY TECHNIQUE** WHERE WATER COLDER THAN THE USUAL 25-26ºC IS SPRAYED THROUGH THE OUTGOING AIR. FOR EACH DEGREE COLDER, **3% LESS COOLING TOWER ENERGY IS NEEDED**.

▶ from ABS Ltd. ABS keeps a representative on site full-time.

Winterton represents energy consultant Energy Solutions Ltd on the team.

The key to Te Papa's successful energy management is the team's disciplined approach, supported by powerful monitoring, control and information systems.

For the last two or three years the team has met every month to work through a formal agenda with action points.

Coming from a construction project management background, Mike Anthony joined Te Papa when the building was still under construction, and stayed on when it was completed.

Winterton worked for Anthony in the facilities team at the old National Museum & Art Gallery and came over to Cable St by 1996.

The building operations team takes care of building services, exhibitions construction, maintenance, cleaning, dockway services and audiovisual services.

It has 17 staff in-house, including electricians, carpenters, and exhibitions and audiovisual technicians on a seven day a week roster, backed up by contractors for many services.

Audit trail

As part of his Diploma in Energy Management from the Central Institute of Technology, Winterton carried out a preliminary energy audit of Te Papa in 2000. This set the course for the energy management programme for the next few years.

Says Winterton: "It threw up things we could do. We worked our way through items and began to look at others: some small, some large, like chiller optimisation. Controls, resets – we're still working through."

Says Anthony: "It showed us where we're using load. We could ask ourselves if there's something we could do about it, or whether we'd just have to learn to put up with it." He says the measures they've taken so far have had a short payback of less than a year.

Energy Solutions Ltd carried out a subsequent audit, which found more projects that could be considered.

Anthony funds the energy efficiency measures from the savings, which means he doesn't have to keep requesting more budget from the finance department.

The audit found areas where heating and cooling were fighting each other, which led to simplifying the controls. Says Energy Solutions consultant Rob Bishop: "The system was really gold-plated. We took off around 60% of the control loops, but it still meets the requirements."

A huge chunk of early energy cost savings came from negotiating the tariffs. Says Anthony: "Our consultants at the outset estimated energy costs would be around $1.2 million a year.

"With electricity we negotiated a very good

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3. The heating, cooling and ventilation plant is all sited in the car park, with **long duct runs** to the area to be conditioned. This means a high initial duct pressure (ie level of energy use) is required to make sure the conditioned air gets to its destination at the right flow rate.

4. Because of the high level of automation and control of lighting and air quality, and the **high baseload** of energy use for air conditioning, the habits of the Te Papa staff in switching off computers or lights have little impact on the facility's overall energy use. The energy management team gets better returns from its technical fixes than from exhorting staff to switch off.

9 PRIME EXHIBIT**: THE BRITTEN MOTORCYCLE**.

10 **MIKE ANTHONY** AND **IAN WILLIAMS** AT THE CONTROLS. THE FIVE SCREENS SHOW (LEFT TO RIGHT) THE **LIGHTING CONTROLS**; THE **TORY ST BMS**; **CABLE ST BMS**; **FIRE SYSTEMS**; AND **LIFTS AND ESCALATOR CONTROLS**.

11 **YORK CHILLING PLANT:** NOTE THE EXTENSIVE **INSULATION.**

rate at the start. That $1.2 million never panned out – it was always $900,000 to $1 million. We saved $200,000 on the tariffs alone.

"The saving in gas was huge, say 50%."

Now the annual energy cost is $700,000 to $750,000.

Cautious tweaking

The team has performance constraints and can't just switch equipment off unthinkingly for quick savings. Says Winterton: "Because we have national collections, the environmental demands are very carefully controlled, so we have to be very cautious. Sometimes we have to put in safety measures so if something goes outside the tolerance band, it's taken care of." However he says they continue to challenge assumptions about how the equipment should be run. "We haven't really believed all we've been told – we've experimented, trialled different things, monitored and logged."

Some of the planned changes require signoff from equipment manufacturers such as York in the USA, because Te Papa's pushing the equipment to operate outside its normal parameters.

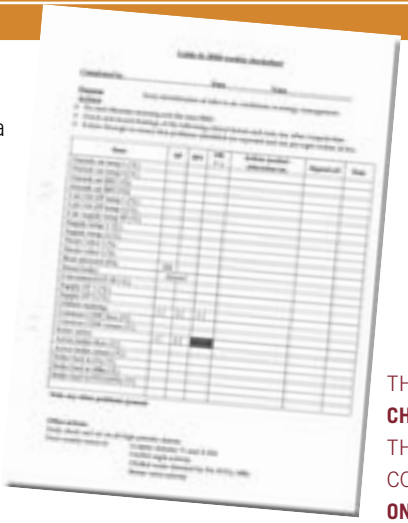
Although the plant was set up to operate around the clock, Winterton began experimenting with switching off the air conditioning for periods at night, extending the duration until it stretched all through the night.

"Most of the things done at Te Papa cost money. Our energy management team saves money!" – Te Papa manager planned maintenance, Ian Williams.

Regular as clockwork

To combat the tendency to deal with only urgent matters, Te Papa has a structured routine to make sure the important basics are covered.

1. An **energy management group meeting** once a month with actions to be completed, and previous actions chased up.
2. A **monthly walk-through** at night to check for anomalies.
3. A **Building Management System checklist** is completed weekly, on paper, and recommended actions must be taken within 24 hours.
4. **Weekly report** on relative humidity and temperature of six selected areas, night activity of the fresh air and return air; the amount of chilled water needed; and the steam valve activity.



THE **BMS CHECKLIST** THAT GETS COMPLETED **ONCE A WEEK**.

"We put in check points sampling temperature and humidity – if it went outside the limits, the plant would start up again. We still run that today."

He was able to rely on the thermal mass of the immense concrete structure to maintain even conditions.

One unwanted consequence of switching off the air conditioning is that when it comes on again, there's a "slug" of dead warmer air in the ducts that causes a spike in power usage when it puffs out, because the temperature sensor tells the system it needs extra cooling to come down to the setpoint.

And the increased number of out-of-hours functions has thrown a spanner in the works. Large parties of guests and their catering equipment generate heat that can't be eliminated by air changes alone – the central cooling plant has to be run to keep the space comfortable for them.

When Te Papa hosts a dinner for 500 guests in one of its exhibition spaces, the central air conditioning system must supply fresh air at the right temperature to the whole space.

For smaller parties and shorter events, it's adequate to heat or cool recirculated air with local fan coil units. This avoids switching on the main air conditioning plant for fresh air, although the boilers and chillers still operate. Carbon dioxide sensors detect whether more fresh air is needed.

The filters in the return air ducts clog up more quickly with the extra load put on them. At $100,000 for a changeover that's scheduled for once a year, a more frequent filter change is an invisible cost of increased catering.

Although the unpredictable timing of the functions makes it difficult to maintain stable energy-use patterns, Anthony and Winterton accept that this burgeoning role for Te Papa is part of the business plan and something they have to deal with.

Unexpected impact

Not all energy-saving measures go according to plan.

Turning heat-exchanging boilers off at night saved an impressive amount of gas, but because the pipes had junctions of two metals with different coefficients of expansion, water escaped through gaps formed when they cooled down. The heat-exchangers had been designed to run continuously and stay warm. Fitting a better seal will fix that problem.

Because of its assiduous record-keeping, the energy management team learns from its experiences and doesn't need to keep repeating its less successful ideas. The flipside is that good ideas can be revisited when conditions suit, and historical records can be consulted to investigate anomalies.

Winterton investigated an expensive jump in the cost of gas used for heating in winter 2004. Investigating the records and correlating them with climate data from NIWA, he found August was a particularly cold, dry month with southerly winds. So the extra gas use on certain days explained why penalty costs had been incurred even though overall gas use had remained similar to 2003.

Good bones

Winterton says a big plus is that the building was well equipped from the outset. "It's easy to monitor and log."

Apart from adding variable-speed drives to cooling tower fans at a cost of $13,500, it's difficult at this early stage to justify improving efficiency by replacing the equipment.

Lighting, whose energy use is secondary to the air quality systems, is generally energy-efficient fluorescents with good controls. The displays require dimmable theatre-style lighting, which is less efficient.

Occupancy sensors switch the lights on only when needed, in lobbies, toilets and other areas that are sporadically occupied.

In the back-of-house corridors, two separate circuits have been installed instead of a single circuit, so that when the lights are switched off, one in four double-lamp fittings stays on as emergency and navigation lighting.

Coming up

Energy Solutions' Rob Bishop is keen to introduce the concept of "continuous commissioning" where the mechanical systems are continually tuned.

Says Williams: "It's sort of what we've been doing – answering questions like, how much air do we need, how cold, are the boilers and chillers running at the same time; similarly are we humidifying and dehumidifying?"

The continuous commissioning will be expensive to set up.

Much of the adjustment involves re-programming the control systems, a task carried out by Setpoint Solutions Ltd working from ideas and feedback based on data logged by the rest of the team.

A project currently underway is to make the chiller control more sophisticated. Previously, the chillers were sequenced on and off depending on the rate of flow of

Monitoring and control

Energy auditor Rob Bishop from Energy Solutions Ltd says Te Papa is one of the most closely-monitored buildings he's ever seen. The tools include:

1. **EnergyPro energy management software** for tracking energy and water consumption against invoices. This allows the true cost per kilowatt-hour to be calculated, shows trends and makes comparisons.

2. **Siemens Desigo Building Management System (BMS)**. A sophisticated system customised for Te Papa.

3. **Ambus datalogging system**, with 10 points around the building that meter and record each hour, and provide raw data for spreadsheets.

4. **Stream software** that feeds the Cable St building's electricity-use data to a server that displays it in various formats on a secure website.

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chilled water. This sometimes caused them to start and stop frequently. The controls are being modified so that both the flow rate and the temperature difference between the incoming and outgoing water determines the chilled water set point. This allows for the chillers to run only when necessary. During warmer periods when there is only a low demand for cooling, the demand for the chiller can be reduced by increasing the temperature setting for the outgoing chiller water. This saves around 4% of power for each degree C of temperature increase.

Another idea is to use water colder than the standard temperature in the cooling tower.

Typically, the water sprayed through outgoing air in a cooling tower is around 25-26 degrees. If colder water is used, say in winter, it saves 3% of energy for each degree. It's possible to use water as cold as 10 degrees, but a more realistic figure in practice is 19 degrees. Says Winterton: "That should be a real major [energy saving]."

Says Williams: "There are risks involved, you don't want to blow up the chiller."

The upcoming measures are more expensive than earlier ones, "but can save heaps".

Avoiding complacency

With so much information available from the building management system (BMS), it would be easy to get complacent and not really pay attention to what's going on.

To make the BMS interface more user-friendly, the highest-priority items, such as an alert to show if the air conditioning plant switched on during the previous night, appear on the first few screens.

To ensure that checking the BMS isn't just a cursory affair, Winterton has designed a printed checklist that gets filled in each Monday morning and filed near the BMS.

The person checking the items has to fill in the setpoint and the measured value for 25 items, including the outside air temperature and relative humidity and the condition of the boiler (see picture opposite). Tory St and Cable St have separate checksheets.

There's a column for any actions needed, and this gets signed off and dated. The protocol requires problems identified to be reported and put right within 24 hours.

Each day, staff check and act on all high priority alarms identified by the BMS.

Once a week they print out reports on the relative humidity and temperature of six "safety stations" (key indicators that act as a safety valve); night activity of the fresh air and return air; the amount of chilled water demanded by fresh air and the fan coil units; and the steam valve activity.

Once a month, Winterton walks through Te Papa at night to check BMS activity and how things are running. "You can make amazing discoveries."

Long-term relationships

The long tenure of key staff (10 years each for Winterton and Anthony) and contractors has built up a valuable institutional memory and store of experience. They know what works and what doesn't, and have the information to revisit a project that was ahead of its time when first conceived.

To preserve the knowledge and prepare for staff changes, they have extensive documentation and good systems.

Says Williams: "We're very very fortunate to have these two [Anthony and Winterton] as part of our team. It's not easy to find the right people to do it. It's a big part of our success."

Winterton left in January 2003 to become an independent auditor. Instead of replacing him, Anthony assigned his work to the energy management team, which includes Winterton as a representative of Energy Solutions Ltd.

Is the energy management team's goldmine of expertise and enthusiasm appreciated?

Anthony says his highly commended placing as energy manager in the 2004 EnergyWise Awards, and Sandy Winterton's finalist placing in 2001, have brought their achievements to the management's attention.

"They do notice. When we got the award, the boss [chief executive Seddon Bennington] was very quick to come and compliment us. He also sent an email to me personally, but I took it as something the team did. It wouldn't happen without the guys – you couldn't do it on your own."

Says Williams: "Most of the things done at Te Papa cost money. Our energy management team saves money!"

CREDITS

Building operations manager Mike Anthony

Manager – planned maintenance Ian Williams

Energy consultant Rob Bishop, Energy Solutions Ltd and Sandy Winterton, Energy Solutions/Energy Advantage Ltd

Building management system controls Setpoint Solutions Ltd

Mechanical engineering consultant Peter Appleby and Mel Jones, ABS Ltd

EECA Emprove account manager Dan Coffey

Case study author Cathy Sheehan