The Landcare Research building: Sustainable performance in practice

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ABSTRACT: Landcare Research, one of New Zealand's Crown Research Institutes, has won recognition and awards for its use of techniques such as triple-bottom-line reporting in its annual report, in an attempt to make sustainability issues more mainstream. When the organisation needed to build a new building for about 90 staff, the decision was made to make the building as sustainable as possible without exceeding the budget for a conventional building. This aim was complicated by the fact that the required building comprised four components: research laboratories; offices; archival collections of insect and fungal specimens and climate-controlled greenhouses The paper describes the outcomes of the design and decision-making processes in terms of the planning of the building on the site and the choice of systems (structural, mechanical, water, etc.) within it. These systems range from the relatively simple – high-mass insulated construction; to the relatively complex – heat recovery from laboratory fume cabinets; and from the conventional – high-efficiency lighting; to the highly unusual – waterless toilets. One of the intentions was that the building would be monitored over time to see if its environmental performance measured up to the designers' intentions. In the paper, operational measurements of the building are provided to demonstrate what has been achieved, and how the building's performance compares with national and international performance targets.

Keywords: sustainability; energy consumption; water consumption

1. INTRODUCTION

Manaaki Whenua Landcare Research is one of the Crown Research Institutes formed when New Zealand's government research organisations were restructured into Government owned companies in the early 1990s. Landcare Research is the CRI that is primarily concerned with New Zealand's terrestrial environment and sustainable development. When Landcare Research decided to move to a site on the University of Auckland's campus at Tamaki, the staff wanted to demonstrate how it might be possible to make a building much more environmentally friendly than normal, but for the same budget as a conventional building. This was a complex task because Landcare Research needed a building that was far more complex than any normal commercial building. It needed to house not only offices, but also research laboratories, controlled-climate greenhouses and the national collections of insects and fungi, comprising over six million specimens.

The Tamaki building has been widely acknowledged as New Zealand's leading example of a sustainable commercial building. In May 2005 it won the Energy Efficiency and Conservation Authority's Energy-Wise Commercial Building Award, and it also received the Green Ribbon Award conferred by the Environment Minister on "environmental heroes".

Architects Chow:Hill and engineers Connell Mott MacDonald worked with Landcare Research to design the Tamaki building to reduce demands for energy and water, to reduce its impact in terms of stormwater and sewage, and also to make use of more sustainable materials and finishes.

2. ENERGY CONSERVATION

The goal of the energy design is to maximise passive climate control so that pleasant conditions are maintained throughout the building with minimum use of energy. Instead of the constant temperature of a typical office building, in the Tamaki building temperatures are designed to range between 17–25^{o}C between winter and summer, when external temperatures will be between 6–27^{o}C. The building's energy strategy comprises both design – the use of design features that reduce the need for heating and cooling, and technology - the recovery and reuse of waste heat.

2.1 Building Fabric

The external shell of the building is multi-layered to limit heat gains and losses. The innermost layer is a 200 mm thick concrete block wall which places the thermal mass of the concrete on the inside of the building. This is wrapped with R4 fibreglass batts with timber or metal cladding on the outside. Internally, exposed concrete has been used extensively in floors, walls and ceilings to increase the thermal storage capacity of the building. The roof has R5 insulation. The windows are double glazed, but not in thermally-broken frames.

2.2 Ventilation & Controlled Environments
Instead of the typical approach of air conditioning the whole building, in the Tamaki building each room was assessed separately and then provided with appropriate systems. The goal is to use natural ventilation wherever practicable, and to use low-impact technology to provide the controlled environments needed in some areas. The majority of offices face the atrium, landscaped with native plants, at the heart of the building, with desks and work stations within five metres of an opening window, double-glazed to ensure good insulation. On the north side of the atrium, sun-screens shade the offices from direct sunlight in summer; similar shades protect the laboratories on the north side facing Morrin Road. Laboratory areas have tempered air supply or in some cases, full air conditioning where specific equipment requirements exist.

2.3 Fume Cupboards
The various laboratories and preparation rooms have a total of 11 fume cupboards. Fume cupboards (the equivalent of a very powerful extractor fan in an enclosed space) are used when handling chemicals or organisms that could irritate if inhaled. The huge amount of air extracted from the building by these fume cupboards has to be replaced with outside air, which is often too cold or too hot. The fume cupboards represent the heaviest energy use for the whole building. To recover waste heat energy before the air is discharged to the outside, selected fume cupboard exhaust is circulated through a sealed heat-exchanger in the two rooftop 'Eco-Air units'. Outdoor air is also drawn in through these units, and is warmed / cooled and partially dehumidified by the recycled heat from the outgoing air.

2.4 Air Conditioning
Some office and laboratory areas required individual air-conditioning. In these areas, highly-efficient reverse heat-cycle heat pumps with variable refrigerant volume (VRV) technology have been used.

2.5 Controlled Environments for the Collections
The New Zealand Arthropod Collection (1 million dried insects, spiders and relatives plus 5 million specimens in ethanol), the Fungal Collection (72,000 specimens) and the International Collection of Micro-organisms from Plants (11,000 strains) are designated as 'Nationally Significant'. It is essential that they are maintained under cool, dry conditions of about 18^{o}C with 45% relative humidity. The ethanol room is maintained at 10–12^{o}C. The location of the collections on the south side of the building, out of the sun, and with no glazing, combined with very high levels of insulation plus the thermal mass of the building helps reduce the energy needed to maintain these conditions. The refrigeration system provides energy-efficient dehumidification with waste heat available for heating offices. Chilled-water cooling systems provide a backup to the refrigeration system.

Associated with the Collections are two freezer/chiller rooms, which are used as an alternative to methyl bromide treatment to control possible contamination of the specimens. The refrigeration technology uses a centralised system using R 404A refrigerant, which was the most energy- and greenhouse gas-friendly, and ozone-friendly refrigerant available. Waste heat from the compressors is re-used for piped base-board heating in the offices.

2.6 Solar panels
Two solar panels on the roof provide the energy needed for the hot water used in the laboratories. The cafeteria and the washbasins in the toilets have a separate solar hot water system. A gas fired booster system supplements, when needed, the recovered heat and solar heating systems.

2.7 Lighting
Lighting is supplied as far a possible by daylight, supplemented with high-efficiency fluorescent lighting. Emergency lighting uses ultra-low-energy light-emitting diodes.

3. WATER CONSERVATION

As well as saving energy, the Tamaki building was designed to reduce its demand on the mains water system.

3.1 Rainwater Harvesting
Instead of rainwater running into the city's stormwater system, as much as possible is collected and stored on site for use in urinals (manual flushing), ground floor toilets, and for irrigating gardens and glasshouses. A mains backup is available during dry spells. Rainwater is fed by a syphonic drainage system from the roof to three interconnected 25,000 litre tanks near the glasshouses. Water is pumped from the storage tanks up to the roof header tank using electricity supplied by a small 400 Watt wind turbine. Overflow from the rainwater tanks flows into the raingarden at the main entrance to the building. The effect of the raingarden, which also receives run-off from the carpark, is to remove most of the contaminants from the stormwater, and to allow much of it to drain away into the soil. Any excess stormwater will still enter the municipal stormwater system but the volume is drastically reduced compared to conventional situations. The costs of the tanks and wind turbine generator were offset by not needing to run downpipes to the ground and connecting them to underground stormwater systems, and by savings in water charges.

3.2 Mains Water for Basins and Drinking
Hand basins use mains water but have low-volume water-saving taps to prevent unnecessary wastage of water, including the hot water heated by solar panels.

3.3 Purified Water for Laboratories
Reverse osmosis is used to provide pure water to those laboratories with specialist requirements for slide preparation and uncontaminated glassware. A reverse osmosis machine is a large consumer of water as only a small proportion of the water (maximum 30%) flowing through the machine actually

passes through the filter. The system has been configured so that the reject water can be collected for re-use in urinals and for garden irrigation, i.e. the reject water is incorporated in the stormwater management system. There is the option of using either rainwater off the roof or mains water in the reverse osmosis machine. However, using recovered rainwater may extend the life of the reverse osmosis resin filter

3.4 Runoff from the Car Park
The carpark has been constructed with a permeable gravel surface allowing rainwater to infiltrate the surface. During storms, excess water, beyond what the soil can normally retain, flows through a planted swale and then under the building to the raingarden area at the front.

4. REDUCING SEWAGE

One of the design goals was to minimise the load that 90 staff, visitors and laboratory usage place on the city's sewer and wastewater system. The key to achieving this goal is using low-impact alternatives that meet all health and waste discharge requirements.

4.1 Ground floor Conventional Toilets
Low water-use flush toilets have been installed on the ground floor. The rainwater collected and stored on site is used for flushing these toilets plus the urinals on all floors.

4.2 Composting Toilets on Levels 1 & 2
The first and second floors have waterless composting toilets with seven individual toilet pedestals feeding two large Clivus Multrum composting tanks. These are located behind windows on the north wall so that the sun can help to keep the composting tanks warm for optimal functioning, and the tank area has external access to make servicing easier when it comes time to remove the finished compost. Waterless toilets were not suitable for the ground floor because the hole that would have needed to be excavated for the composting tanks would have been below flood level, and would have had to be excavated in rock. The system conforms to the Australian standard for composting toilets, and the New Zealand standard for on-site wastewater disposal. This means the finished compost can go onto the surrounding gardens.

4.3 Greywater
The small amount of liquid from the waterless toilets drains direct to the city sewer system, as do the urinals and washbasin wastewater. Wastewater from the laboratories goes via local sediment / dilution traps to a 1,000 litre detention/dilution tank, and then into the sewer system. The load being placed on the city's sewer system is markedly smaller than for a conventional building of similar size and function.

5. MATERIALS AND FINISHES

The Tamaki building uses a range of simple materials, wood, concrete and steel, chosen to minimise as far as possible their environmental impacts, but with the need to be cost-effective. Internal finishes include water-based paints, linoleum flooring (made from linseed oil and jute) and loose-laid carpet tiles made of recycled plastics. Much of the existing furniture from the former Mount Albert building was re-used at Tamaki, making a significant difference in the "embodied energy" due to the furnishings.

6. MONITORING

Landcare Research is a Research Institute, and the Tamaki building forms an essential part of its research activity. The energy and water consumption of the building are being measured, and the stormwater is being assessed to see what effect the swale and raingarden are having on the removal of pollutants. Even the composition of the compost from the toilets is being analysed. The findings from this research not only help to ensure that the building is operating as intended, and help to guide possible improvements, but also feed into future sustainable building projects elsewhere in New Zealand, and in other parts of the world.

7. BENCHMARKING AND PERFORMANCE

It is difficult to say if the Tamaki building is performing well or poorly without some sort of benchmark against which to assess it. Because it is a complex building, comprising laboratories, offices and archival collections, its performance in use cannot be assessed against the performance of a conventional building

7.1 Energy
Data on the energy consumption of commercial buildings in New Zealand are limited. The Energy Efficiency and Conservation Authority quotes an annual figure of 186 kWh/m^2 (EECA 2000, p46). On the other hand, the Property Council of New Zealand gives an average value of 269 kWh/m^2 of net lettable area (Property Council of New Zealand, 2000, Fig 109, p 475). Laboratories are even more of a problem, as data from comparable laboratories in New Zealand are not available. Sartor et al in the United States claim

"Buildings with cleanrooms and laboratories are growing in terms of total floor area and energy intensity... These buildings, with high ventilation rates and special environmental considerations, consume from 4 to 100 times more energy per square foot than conventional commercial buildings." (Sartor et al, 2000, p1).

This implies that laboratory spaces could be expected at the very least to have an energy consumption of between 750 and 1,100 kWh/m^2. The United States Environmental Protection Agency reported on the energy performance of their 29 laboratories in 2004, and showed a target value of 275,000 BtU/ft^2 (EPA, 2006), which is 816 kWh/m^2, a good correlation with the values from Sartor et al.

Measured data from the Australian Greenhouse Office for energy consumption in the Commonwealth's buildings are shown in Table 1, and provide a useful range of building types to compare with the activities that take place in the Tamaki building.

Table 1: Australian Commonwealth building consumption data 1999-2000

Building type	*kWh/m^2/annum*
offices (tenant light and power)	130*
offices (central services)	126
offices total	256
climate controlled stores (inc. archives)	194
laboratories	291

(compiled from data in Australian Greenhouse Office 2000, Table 10, p 12)
(* original data in MJ/person converted on the basis of assumed space standard of 25m^2 per person)

It can be seen that the measured laboratory average energy consumption figure is much lower than those measured in the United States. Given the greater similarity between New Zealand and Australia, as opposed to the United States, it may be appropriate to use the AGO figures as a guide to benchmarking. Considering the figures above, it would appear that it could be proposed that average energy consumption values for the building types that comprise the Tamaki building might be as shown in Table 2 below.

Table 2: Benchmark values for assessing the Tamaki building

Building type	*kWh/m^2/annum*
Laboratories	300 kWh/m^2/year
Offices	250 kWh/m^2/year
Archives	200 kWh/m^2/year

The areas of the various components of the Landcare building, calculated from data provided by the architects, Chow:Hill, are shown in Table 3.

Table 3: Floor areas of Landcare building

Type of space	*Area*
Offices	2308 m^2
Labs	1231 m^2
Archives	655 m^2
Total for whole	4194 m^2

The values from Tables 2 and 3 allow the construction of a set of benchmark targets for the Landcare building, as shown in Table 4.

Table 4: Benchmark energy consumption for the Landcare building (area x benchmark demand)

Type of space	*Annual Consumption*
Offices	577,000 kWh/year
Labs	369,300 kWh/year
Archives	131,000 kWh/year
TOTAL	1,077,300 kWh/year

These benchmark values can be compared with the measured energy consumption of the building for 2005, as shown in Table 5.

Table 5: Energy consumption of the Landcare building for 2005

Annual consumption electricity	706,500 kWh
Annual consumption gas	70,263 kWh
Total annual energy consumption	776,763 kWh (185 kWh/m^2)

The measured performance of the Landcare Research building can be shown to represent a 28% reduction in energy demand compared with the consumption that could be expected of a typical building containing the same areas and range of uses. This can be only a very coarse comparison, as the degree of variability of benchmark values for laboratories in particular is likely to be high.

7.2 Water

The water consumption performance of the Tamaki building is remarkably low. With little or no mains water used in the toilets, urinals and glasshouses the overall mains water consumption of the building is considerably reduced. The water consumption for the building and the greenhouses in the year ending March 2006 was 741 cubic meters. This is 0.16 m^3/m^2/year. An appropriate benchmark might be with a commercial office building, as water consumption data for laboratories are not available for New Zealand. The recently produced National Australian Built Environment Rating System (NABERS) scores the environmental performance of commercial office buildings in a range of areas, including water consumption, and can serve as a benchmark of performance. The NABERS value for an average commercial building is 1.2 m^3/m^2/year The top score (five stars) in NABERS is awarded for water consumption of 0.2 m^3/m^2/year. (NABERS, 2006). When divided by staff FTEs within the building the water consumption is 10 m^3 per person per year. To provide a further comparison, for a residential house in the Auckland Region the average consumption is 63 m^3 per person (Bannister et al., 2004) consequently the water consumption of the whole Landcare Research building is the equivalent of four three-person Auckland houses.

Table 6: Mains water consumption comparison

NABERS commercial average	1.2 m^3/m^2/year
NABERS 'five star' score	0.2 m^3/m^2/year
Landcare Research building	0.16 m^3/m^2/year

The Landcare Research building is showing a reduction of mains water demand of 87% compared with an average commercial building. This is in spite of the presence of laboratories and greenhouses, both high consumers of water.

8. CONCLUSION

The Landcare Research building has provided a successful demonstration of what can be achieved to reduce some of the environmental impacts of a complex building. In spite of the need to accommodate demanding research spaces, the building is still showing significant savings in the demands it makes on energy and water resources. It should also be noted that these savings have been achieved without any increase in the cost of the building. The Landcare Research building was constructed to the budget allowed for a conventional building. Its success is largely a reflection of the commitment by all parties involved to the demonstration of improved sustainability in all aspects of the building's design.

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