BDP ENVIRONMENT DESIGN GUIDE

Newcastle CSIRO Energy Centre

Jason Veale

The CSIRO's Energy Centre at Newcastle has many innovative energy saving and renewable energy generation systems. The Centre explores new methods of using a mix of natural ventilation and low-energy air conditioning to provide comfortable environments, and multiple renewable energy systems are architecturally integrated into the buildings and around the site. A 5-star ABGR greenhouse performance has been met for three years, thanks to exceptional building management and energy aware staff.

1.0 Project Outline

1.1 Project details

Architects
Cox Richardson Architects and Planners

Builder
John Holland

Building Services, ESD and Civil Engineer
Flack and Kurtz/GHD

Structural Engineer
Ove Arup

Year of completion
2004

Project type
Research centre

Building area
10,000m² of offices, auditorium, research laboratories and support areas.

Location and climate
The site is located 3km north west of central Newcastle near the Hunter River. Newcastle is a subtropical climate with mild winters and warm summers with a regular cooling breeze near the coast.

Local wind data was used to research the effectiveness of wind turbines on the site and Windscape software developed by the CSIRO was used to precisely locate the turbines. Acoustic assessments were made to ensure minimal noise impact from the wind turbines.

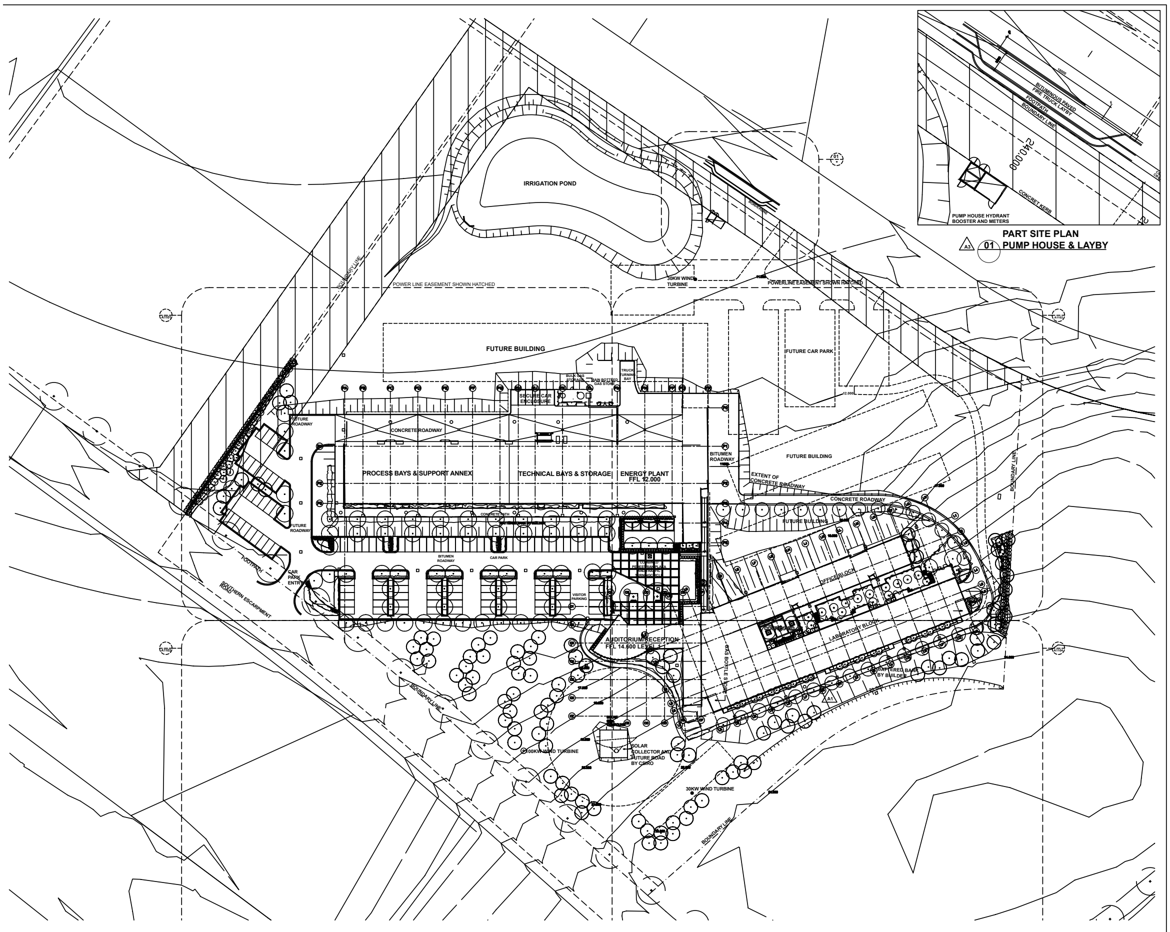


Figure 1. Site plan

2.0 Project Brief

The building is regularly open to visitors including the public, community groups, designers, scientists and government officials. The brief specified the use of predominantly 'off the shelf' technology to show that they could be easily applied to other buildings. Some prototype systems are also being tested for durability and effectiveness.

The building is used by the CSIRO to develop and test advanced renewable energy technology.

3.0 Siting

The site is in a relatively low density part of Newcastle near the Hunter River; there are other industrial/office buildings to the north, east and west 200-500m away and the edge of a suburb across a main road 200m away. The air quality and noise levels are generally suitable for using natural ventilation to cool the office spaces. This strategy would have application to many of the office/light industrial parks in suburban areas around Australia; although most of the buildings in these parks are fully air conditioned, they have no operable glazing and generally poor sun control on their facades.

The site is wide enough to allow the 3-4 storey buildings to be aligned with their long facades facing north and 10 degrees west of north.

Figure 2. Aerial photo of CSIRO Newcastle Energy Centre

4.0 Building Design

The offices, laboratories and process bays (hangar used to build large scale prototype equipment) are contained in three long east-west forms and the office and labs joined to a square volume containing reception, the library and circulation spaces. Shallow plans facilitate natural ventilation of the offices when the conditions are calculated by the building management system to be beneficial.

The auditorium is a separate wedge/sector shape off the entry. The building maximises north facing glass to regularly occupied areas which means simple, fixed external horizontal shading devices can provide effective sun control throughout the year. The shade and roof overhang provides articulation of the three long buildings.

4.1 Construction

Like many office buildings of this scale, the concrete floor and structural frame provides a substantial amount of thermal mass to absorb heat during the day. Lightweight walls and ceilings are well insulated.

The floor slab has greater direct contact with both the conditioned air pushed through the plenum and the air in the habitable areas than conventional office buildings (which often have false ceilings and carpet lining the concrete), increasing its ability to modulate temperatures. The temperature in the plenum space is regularly checked and rarely varies from 19°C all year.

Shading is provided to north, west and east external windows by a combination of roof overhangs, fibre cement light shelves and fixed metal screens. The designers avoided operable external louvres due to the higher maintenance requirements. Photovoltaic panels are also used to shade windows in the process bay building.

External louvres and an internal automatic horizontal blind reduce solar gain to the glass roof of the library. The natural ventilation system is used in this space however the conducted gains through the large area of glass and small direct solar gains cause this space to overheat on warm to hot days.

The process bays are insulated lightweight 'shed' construction with shaded windows and good ventilation.

The internal laboratory layout has been designed for maximum flexibility. It can be completely reconfigured both spatially and for equipment without the use of construction materials.

Figure 3. Elevation detail showing shading devices on offices and laboratories

5.0 Energy Efficiency

5.1 Office air conditioning

The air conditioning system for the offices uses a mix of new and existing energy efficiency strategies.

The system operates in a mixed mode where a building management system uses either unconditioned fresh air from outside if it is sufficiently cool, or activates an air conditioned mode.

Natural Ventilation mode – if the system determines that outside air is beneficial, air is brought in from the shaded courtyard through the air handling units (AHUs) on the south facade. It is pushed through the plenum (without artificial conditioning) and into the offices. The air is drawn out through the now open office windows, automatic louvres in the offices, and up through the stair wells. The stair wells act as a solar chimney whereby the hot air at the top increases ventilation and pulls air through the system.

The automated monitoring system aims to maintain a higher temperature in the solar chimney (using automatic louvres) than the offices to ensure air is drawn upwards out of the solar chimney. At times the algorithm that evaluates the different temperatures has not worked correctly and warm air has been drawn down into the offices. The system has been updated as a result of this ongoing experience.

When the system is about to enter air conditioned mode an automated reminder over the PA system asks staff to shut the windows. This system replaces an email reminder which struck problems with overflowing email inboxes where these emails were not always seen.

The fresh air mode is used for approximately 25% of occupied hours. When there is a strong northerly wind it tends to create negative pressure in the wrong locations and slows or stops the fresh air cycle.

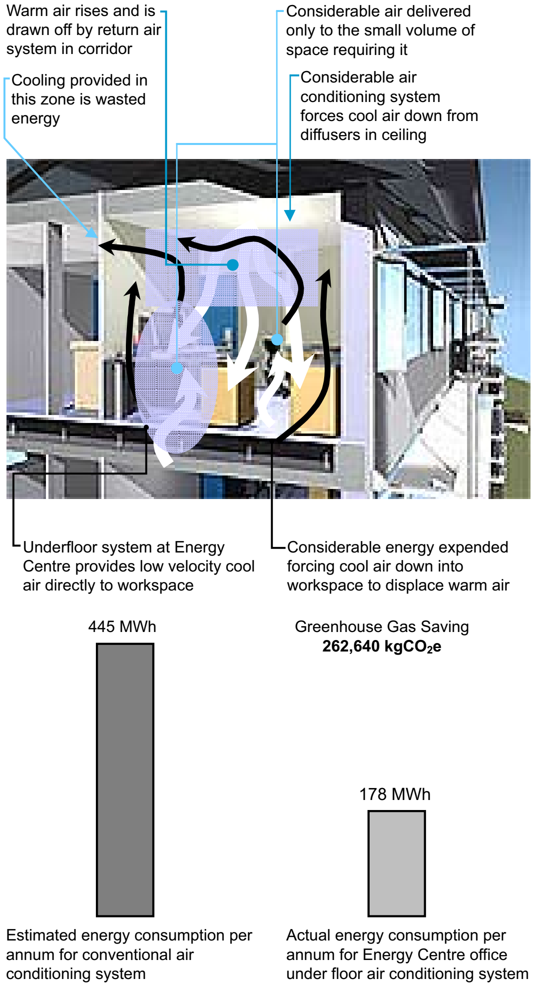


Figure 4. Ventilation pathway of underfloor air conditioning system

Air conditioning mode – air is delivered by air handling units (AHUs) into a pressurised plenum space below the offices. From the plenum, air is delivered into each office via outlets which are built into movable 600x600mm aerated concrete floor tiles with a metal finish. The tiles are placed near occupants to provide optimum comfort and can be moved to suit different office layout configurations. Although a small proportion of the air in the plenum does leak into the office spaces other than through the outlets due to pressure, this contributes to general cooling and does not compromise the overall advantage of the system.

Delivering air from under the floor means the air is cool from floor level to roughly head height and warms as it rises above head height. Cooled air is delivered only where it is needed and temperatures are permitted to rise where cool air is not needed. This simple strategy saves energy compared to conventional air conditioning systems which deliver cool air from ceiling level and must be configured to maintain comfortable temperatures in the entire volume of air.

Air is returned to the AHUs over the top of the corridor walls (not full height) and down the corridor.

A similar system is used in the library and circulation spine/atrium except that air is pre-cooled by service tunnels in the basement rather than a plenum space.

In air conditioning mode the time dedicated throughout the year to heating and cooling has been roughly equal.

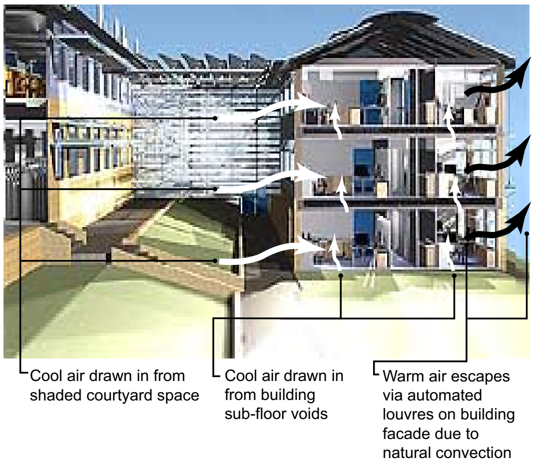


Figure 5. Ventilation pathway in natural ventilation mode

5.2 Laboratory air conditioning

The Building Code of Australia sets stricter temperature control standards for laboratory spaces due to the greater potential for heavy asphyxiating gases, so a mixed mode system or plenum delivery system was not appropriate. An efficient variable air volume (VAV) system is used to provide the tightly controlled conditions for comfort and laboratory activities.

Good thermal design places a lower initial load on the space than a conventional building.

Energy efficiencies are also gained from exchanging cool exhaust air with incoming air to lower its temperature.

5.3 Lighting

The offices, library and circulation spaces are designed to maximise the use of natural light. Atria and stair wells are naturally lit directly and corridors are either directly lit or 'borrow' light from adjacent offices through translucent panels above door height.

The offices have light shelves of fibre-cement sheet held outside the facade. The shelves provide shade to the lower windows while bouncing light up onto the ceiling through the upper window. This system, occasionally used in other offices and residential buildings, has the advantage of providing daylight deeper into the office without direct solar access which can create glare and overheating problems for workers.

An automatic light sensor controls the high efficiency T5 fluorescent lights.

Figure 6. Natural daylighting strategy using light shelves

6.0 Low Greenhouse and Renewable Energy Generation

An energy management system (EMS) monitors and controls the energy imported from the grid and exported energy generated on site. The EMS also includes data logging of all energy uses on the site (HVAC, lights, etc. down to the individual floor level). This is used to report on energy use and to test the energy impact of new equipment.

6.1 Co-Generation system

Two co-generation gas turbines are used to generate heat and power for the Centre. These turbines are slightly larger than a big residential scale refrigerator. When used only for power, they are less efficient than a conventional power station. When used for Combined Heat and Power (CHP) however, they are up to 85% efficient – which is far higher than using electricity from the grid to provide heating.

6.2 Photovoltaic Energy

Testing and demonstrating the benefits of photovoltaic cells is an important function for the Centre. A number of arrays are used to generate electricity, test under real circumstances and show how PV can be attractively integrated into the building's fabric.

Cells provide electricity and shade to windows on the northern facade of the processing bays.

A small prototype 6kW glass encapsulated (the PV is contained within the glass and can then be used as a conventional glass element in a wall or window) titanium dye prototype array is integrated into the west facing glass wall of the atrium space. These are less efficient for conversion of direct sun; however they can convert diffuse light which expands their application. Any colour can be used which makes it more attractive for aesthetic integration into the building design; however colour has an impact on the efficiency of the cells. While used strikingly to light an atrium space, this system has had problems with variable heat expansion which has caused some delamination and detracts a little from the visual effect.

The library roof has glass encapsulated polycrystalline.

Other photovoltaics – the auditorium has polycrystalline cells on the roof.

The total output of all PV systems is approximately 130 MWh a year. There is a small battery storage on site however most of the energy generated goes into the grid to offset against electricity drawn from the grid by the Centre.

Figure 7. Glass encapsulated photovoltaics in library roof

6.3 Solar Concentrators

The Centre is home to a ground-breaking technology which concentrates the sun's energy rather than converting it to electricity. A bank of mirrors (this can be simple bathroom glass) are laid out in an area the size of a basketball court and carefully angled up to a target around 17m above the ground. The heat at the target is approximately 1400°C.

Natural Gas and water are passed through a reactor at the target to be reformed into a hydrogen rich synthetic gas which has 26% more energy than the original natural gas.

Other solar thermal technologies are being tested which use parabolic troughs to super-heat organic oil at the focal point which then drives a solar turbine.

6.4 Wind Power

The site was assessed as being appropriate for wind power generation with an estimated 10% return on investment – lower than commercial wind farms, but sufficient for testing and demonstration. There are three 20kW wind turbines currently with one 100kW turbine planned for the future. Collectively they are estimated to produce 676MWh a year.

The turbines have 18-19% reduced output as a result of turbulence from obstructions such as buildings however a study was conducted to locate them for minimum turbulence. They are estimated to have a 15 year payback at market electricity rates. CSIRO claims the turbines have low maintenance costs. Even with moderate-high wind, the turbines cannot be heard above normal noise levels inside the building and the noise is barely noticeable outside moving around the Centre.

Figure 8. On-site wind turbine

7.0 Building Management/Post Occupancy Evaluation

With so many strategies and high aspirations of energy savings, this building could have fallen short in its operation.

The strategy to ensure the energy saving targets has been to treat it like any other corporate goal:

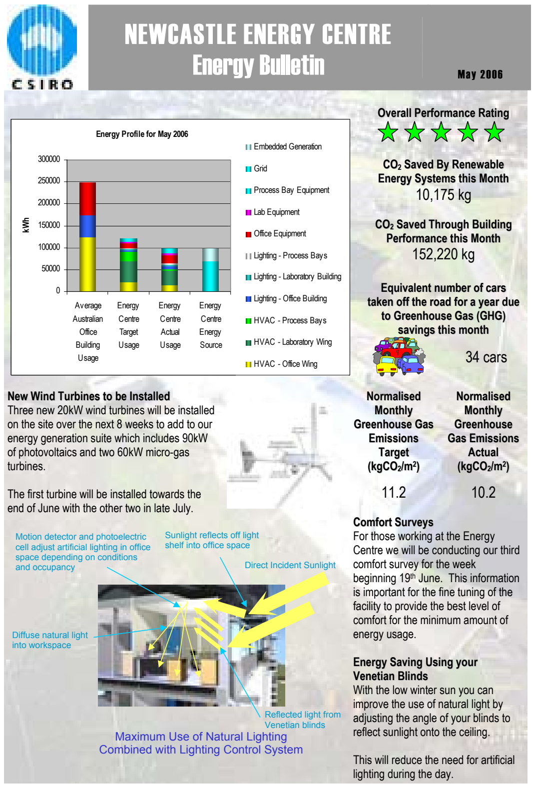
- there is a clear plan
- funding is maintained to the Manager position and the plan
- the strategies are simple and well communicated
- the staff are regularly involved and consulted
- there is regular feedback and refining of the plan.

CSIRO staff and management are not typical of Australian office workers; however the concept of addressing energy savings in a businesslike manner may help to demystify the subject and integrate it with other aspects of office policy.

7.1 Energy Manager and Energy Bulletin

Beyond a simple post occupancy evaluation, the building has an Energy Systems Manager on site to ensure the strategies run as planned and to assist staff with the limited participation required to ensure the energy saving targets are met. This commitment has been a key element of the recorded savings during the building's operation.

The Manager produces monthly energy bulletins for the staff to report on energy use (both absolute and compared to the average office building), provides tips, news and a brief description of various energy efficiency and generation features of the building. Data of energy use for the month from the EMS is summarised in the Bulletin. The bulletins have been a great success in educating staff and keeping them up to date with the energy savings strategy.



CSIRO

NEWCASTLE ENERGY CENTRE
Energy Bulletin
May 2006

Overall Performance Rating

CO_2 Saved By Renewable Energy Systems this Month
10,175 kg

CO_2 Saved Through Building Performance this Month
152,220 kg

Equivalent number of cars taken off the road for a year due to Greenhouse Gas (GHG) savings this month
34 cars

New Wind Turbines to be Installed
Three new 20kW wind turbines will be installed on the site over the next 8 weeks to add to our energy generation suite which includes 90kW of photovoltaics and two 60kW micro-gas turbines.

The first turbine will be installed towards the end of June with the other two in late July.

Normalised Monthly Greenhouse Gas Emissions Target ($kgCO_2/m^2$)	Normalised Monthly Greenhouse Gas Emissions Actual ($kgCO_2/m^2$)
11.2	10.2

Comfort Surveys
For those working at the Energy Centre we will be conducting our third comfort survey for the week beginning 19th June. This information is important for the fine tuning of the facility to provide the best level of comfort for the minimum amount of energy usage.

Energy Saving Using your Venetian Blinds
With the low winter sun you can improve the use of natural light by adjusting the angle of your blinds to reflect sunlight onto the ceiling.

This will reduce the need for artificial lighting during the day.

Figure 9. Sample of a monthly energy bulletin

7.2 Comfort Surveys

Comfort surveys are conducted at regular intervals to ensure comfort is being maintained, that there are no glare problems and to fine tune the management system to further reduce savings. There is a yearly presentation to staff on the annual performance.

The comfort surveys have revealed that staff are generally more comfortable when the building is in natural ventilation mode than full air conditioned mode. The reason is still to be confirmed, however the Manager suspects it is primarily a psychological effect of fresh air rather than an ability of the system to maintain a finer band of temperatures.

The staff has now become 'energy aware' and are passing their knowledge on to new staff in an informal way. Senior staff have provided important leadership by taking part in activities, programs and discussions to ensure energy saving targets are met.

7.3 Energy and Greenhouse Savings

The original target for the site was to achieve the equivalent of an Australian Building Greenhouse Rating

(ABGR) 5-star score for energy consumption. While ABGR does allow for renewable energy generation, this has not been included in the evaluation. The Centre has met the 5-star target for 3 years with 134kg CO_2/sqm/yr (ABGR does not include laboratories yet so some extrapolation has been necessary to enable comparison). This translates to less greenhouse gases than a conventional building of a similar type.

The data collected by the Centre allows a comparison of different parts of the system.

Building System	Greenhouse Gas savings compared to conventional system
Combined natural ventilation and underfloor A/C system	74% less than laboratory which is equivalent to conventional office A/C system
Laboratory VAV A/C system	Not known – the Australian Greenhouse Office is currently benchmarking the energy use of laboratories
Daylighting and efficient lighting system	90% less based on standard office light fittings and patterns of use

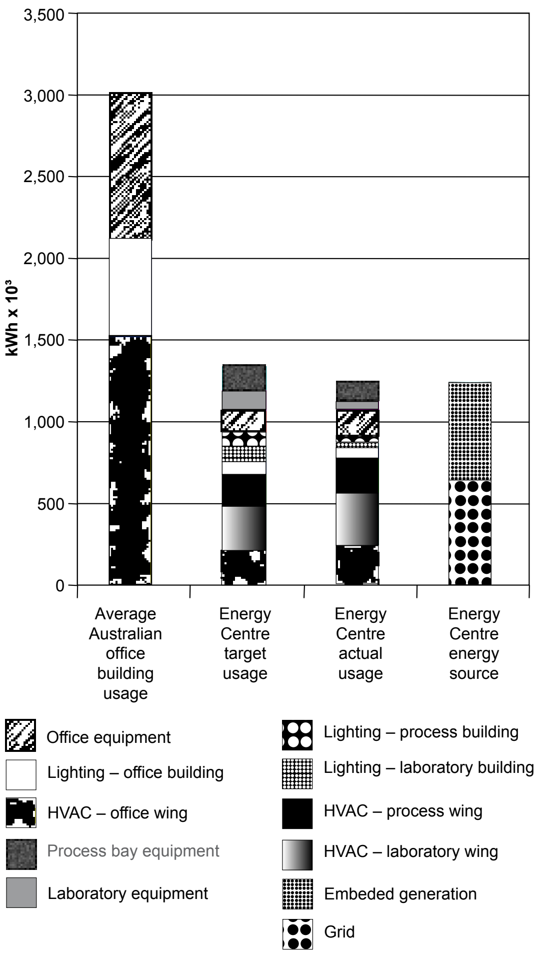


Figure 10. Building energy data – Annual Energy Profile for 2005

8.0 Conclusion

This building can tick just about every energy efficiency or renewable energy generation box. It is not only serious about building design and technologies to save energy, there is an effective and innovative strategy in place to ensure building occupants are involved in achieving the energy savings goals.

The energy efficiency and renewable energy technologies are not just bolted on like a science experiment; Cox Richardson have taken care to integrate the buildings with the landscape and locate the wind turbines and prototype technologies sensitively. Photovoltaics are proudly displayed, yet integrated with the facades. Shaded courtyards provide lunchtime outdoor spaces and pre-cool air for the natural ventilation system.

The strategies used for the offices are particularly relevant for wider application to offices in business parks, regional towns and suburban centres.

References

Photographic references

Information provided by James McGregor, Energy Systems Manager, CSIRO Division of Energy Technology.

Biography

Jason Veale, BArch UNSW, is a Director of SHACK Design architecture and environmental consulting firm. He has worked as a researcher at the UNSW Centre for Sustainable Built Environment (CSBE incorporating SOLARCH). Jason also works for the NSW Department of Planning as the coordinator of the BASIX Thermal Comfort Index.