Bega Valley Hospital

Closed Circuit Geothermal Energy System – DA Report

STEENSENVARMING

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1 Executive Summary

This report has been prepared by Steensen Varming to summarise the benefits of incorporating a ground source heat pump system into the proposed Hospital development at Bega Valley.

The purpose of this report is to form part of the development application (DA) submission that is being submitted to the Council.

Due the lack of a natural gas supply on the site, the design team have had to look at alternative fuel sources to deliver the thermal energy necessary to provide heating and hot water to the site. After analysing a number of fuel sources, Geothermal has been shown to provide the most benefits in terms of life cycle costs and carbon reduction.

While this system involves a significant capital investment, the savings from the system will be expected to pay for itself within 5 years. These savings have been based on a conservative estimation of fuel cost increase, and the payback could be as low as 3.5 years should fuel costs rise faster.

Detailed analysis has been undertaken by Steensen Varming to evaluate the environmental and economic benefits of the proposed system. This analysis has been documented in the mechanical services reports.

Key inferences from these investigations are presented in this DA report.

2 Introduction

2.1 System Selection

Following a report undertaken by C&M Consulting Engineers and additional discussions with the gas network area manager, it was understood during the concept design phase of this project that there is currently no natural gas infrastructure in Bega and there are no plans to bring gas to Bega within the next 15 to 20 years as a minimum.

Taking the above into account, a comprehensive energy supply options investigation has been undertaken by Steensen Varming with a focus on energy supply to provide the Hospitals base heating demand due to the absence of natural gas on site. Alternative heating energy storage options were investigated, being, bulk liquefied petroleum gas (LPG), biomass heating and geothermal as the preferred energy.

Based on a life cycle cost analysis of the three systems, the geothermal system performed best over the 20 year period with a payback period of 6 years. The reason for this lies in the reduced annual fuel costs and maintenance of this system.

The geothermal system is proposed to provide the base heating and cooling demand for the Hospital with LPG boilers and electric chillers providing supplementary heating and cooling supply during peak periods of the year.

2.2 System Overview

A Ground-Source Heat Pump (GSHP) taps into energy stored within the earth and transforms it into useful energy to heat and cool buildings. It provides low temperature heat by extracting it from the ground and provides cooling by reversing this process.

Harnessing this free energy makes the system very efficient. For every unit of electricity used to power the heat pump, approximately 3-4 units of heat are captured and distributed. In effect this means a Ground Source Heat Pump is 300-400% efficient in terms of its use of electricity.

2.3 System Benefits

Geothermal has the potential to supply a portion of the cooling and heating energy required for Bega Hospital. Although incurring a higher capital cost a ground source heat pump system has numerous benefits including:

- **Reduced maintenance** - contributes to the low lifecycle costs of the system. These costs are comparatively small in comparison to alternative solutions.
- **Higher redundancy** - resulting from multiple loops that positively contribute to the reliability of energy supply to the building. Also as the geothermal heat pumps use electricity as their primary energy source they have a reliable and secure source of energy.
- **Higher efficiency, lower total energy input** – as the system uses heat pumps for every unit of energy put in, multiple units of heating or cooling are achieved (referred to as the Co-efficient of Performance of the system or COP)
- **Reduced peak loads** – due to the thermal capacitance of the ground the COP of the system is relative stable during the day as opposed to a system using only cooling towers which has its COP affected by outdoor conditions.
- **Positive environmental impact** – closed loop systems have no effect on aquifers or groundwater contamination. Fluids used in ground loop systems will be designed to be non-toxic and bio-degradable. A Heat which is dissipated in summer cooling months, is absorbed in winter heating months and in affect recharges the grounds thermal capacity on an annual basis. A report undertaken by the US Environmental Protection Agency (EPA) entitled 'Space Conditioning: The Next Frontier' noted ground source heat pump systems as being the most energy-efficient, environmentally clean, and cost-effective space conditioning systems available (Report 430-R-93-004).

Further benefits of the system are summarised below:

- Durability – Geothermal heat exchange systems last longer than conventional systems as they are protected from the weather. The unit is housed indoors and the loop underground. Cooling towers have an economic life of 10 to 25 years, air cooled packages units have an economical life of 10 to 15 years, while the ground heat exchanger has an expected life of 50 years.
- Low Maintenance – Geothermal heat exchangers require no regular chemical dosing or make up water.
- Energy Efficiency – Geothermal heat exchangers achieve greater efficiencies due to constant return water temperatures from the ground. With air cooled equipment, efficiency varies with changes in ambient air temperature. On hot days, air cooled systems are less efficient as more energy is required to achieve the same level of cooling.
- Flexibility – Ground source heat pumps can be applied to both residential and commercial buildings. They can be proposed for new buildings or even during retrofits of existing buildings.
- Carbon dioxide emissions – Use of fossil fuels are reduced due to the energy efficient operation.
- Energy costs – Significant savings in energy costs can be made, as compared to conventional air-conditioning systems.
- Aesthetics – No visual exposure, since the entire system is below ground.
- Lower ambient noise levels - Due to absence of cooling fans in either water cooling towers or adiabatic air coolers.

In summary, the design team have identified a geothermal heat pump system as being the optimal base heating and cooling solution in providing the new Bega Valley Hospital with significant benefits in energy savings, running costs and CO_2 reduction.

3 Suitability to Bega

In terms of environmental conditions, the graph below illustrates the average outside air temperature in Bega over the past 20 years and the internal comfort band, indicating required internal comfort conditions, within the hospital spaces. This indicates that Bega Hospital will have a heating demand for a large proportion of the year caused by the outside air conditions. This is a significant fact as it tells us that a geothermal system will have both a base heating and cooling load throughout the year. These are the optimum conditions for a geothermal storage system and is essential to ensure a geothermal system can operate most effectively.

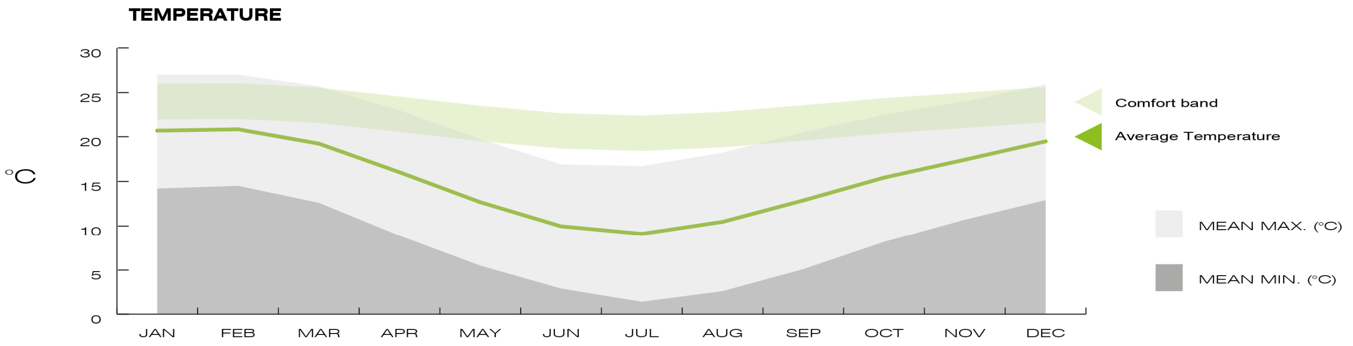

***Fig 1:** Outside air Temperature Graph for Bega*

The expected load profile for the building below, illustrates the effect geothermal can have on the annual heating and cooling profile for Bega Hospital.

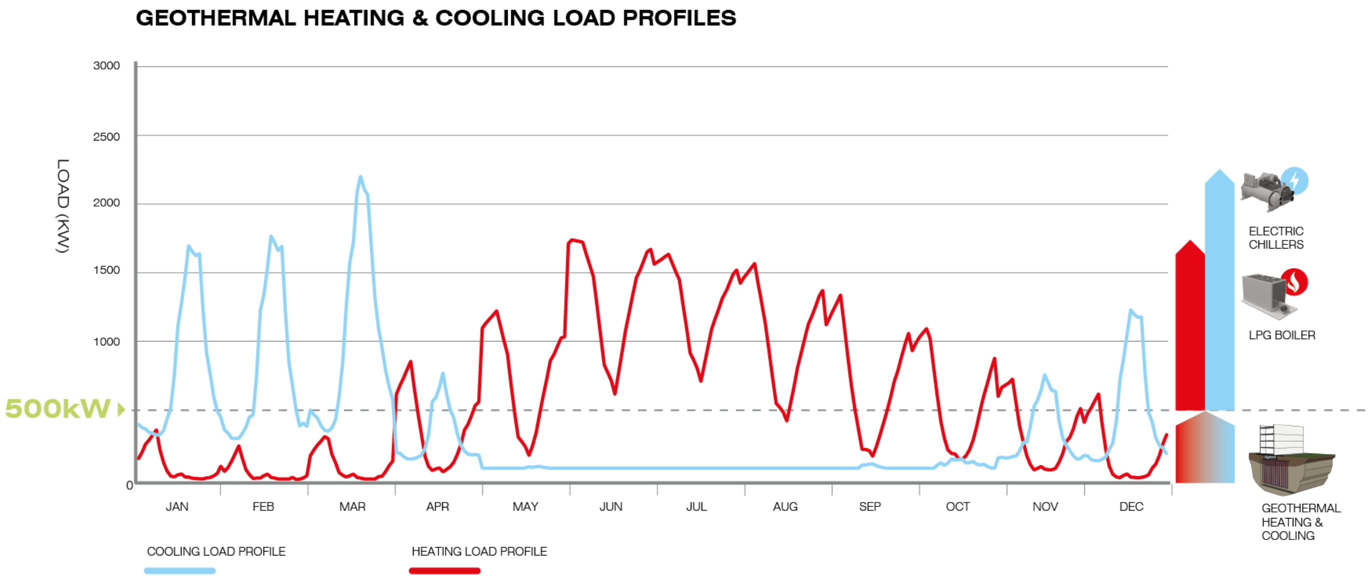

***Fig 2:** Geothermal Heating and Cooling Load Profiles*

4 System Description

A ground-source heat pump (GSHP) system has three major components:

- an earth connection,
- a heat pump and
- an interior heating or cooling distribution system.

4.1 Earth Connection

The earth connection is where heat is transferred between the soil and the GSHP system. GSHP systems can be divided into two main types:

- Open loop and
- Closed loop.

A closed loop system has been selected for use in Bega Hospital. Closed loop systems are made up of a network of sealed pipes buried underground. A mixture of water treated with corrosion inhibitor is constantly circulated around these pipes, exchanging heat (during the winter period) and coolth (during the summer period) with the earth. This particular installation will use vertical pipes, however, closed loop systems can also be arranged horizontally in shallow trenches. The latter takes up vast amounts of space and as the ground temperature is less stable close to the surface they are generally less efficient than a vertical system.

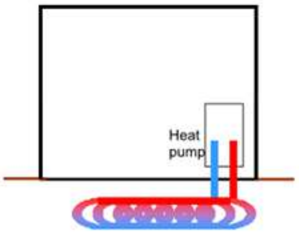

***Fig 3:** Closed Loop Borehole – Horizontal Array*

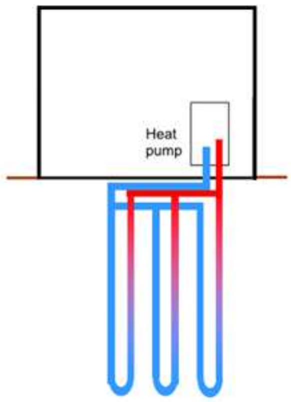

***Fig 4:** Closed Loop Borehole – Vertical Array*

The vertical boreholes (approx. 120m deep) are drilled by rigs normally used for drilling wells. They contain either one or two loops of pipe with a U-bend at the bottom. After the pipe is inserted, the hole is backfilled and grouted. The grout prevents surface water from draining into the borehole. Following backfilling and grouting, the vertical pipes are connected to horizontal underground supply and return header pipes. The header pipes carry the heat transfer fluid to and from the heat pump.

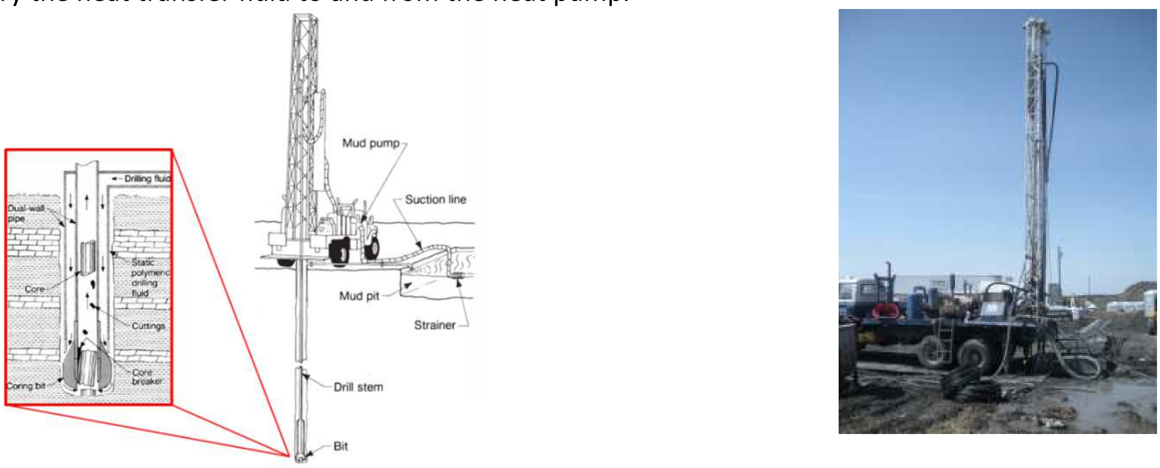

***Fig 5:** Drilling Rig & Borehole*

4.2 Water cooled chiller (heat pump)

The heat pump transfers heat between this sealed network of buried pipes and the buildings heating/cooling distribution system. It operates in a similar way to a refrigerator, using compression and expansion of refrigerant to drive heat flow between the ground loops and the inside of the building.

In heating mode, low grade heat is extracted from the ground and transferred to the heat pump via a heat exchange device inside the heat pump known as the evaporator. The other side of the heat exchanger contains cold liquid refrigerant. The refrigerant is colder than the temperature of the water from the earth loop, so heat flows into the refrigerant. This heat causes the liquid refrigerant to evaporate. The low pressure, low temperature refrigerant gas then passes into an electrically-driven compressor which raises the refrigerant’s pressure and, as a result, its temperature. The high temperature, high pressure, gas from the compressor is fed into a second heat exchanger, called the condenser. Water flows over the condenser, picking up heat before being circulated round the building. As the refrigerant loses heat, its temperature drops and condenses. The liquid refrigerant then passes through an expansion valve. The valve reduces the pressure of the refrigerant, and as a result, its temperature drops. This low temperature liquid then flows to the evaporator, and the cycle starts again.

When in cooling mode the heat pump uses an internal valve to reverse the order of operation, providing cold water for the HVAC systems.

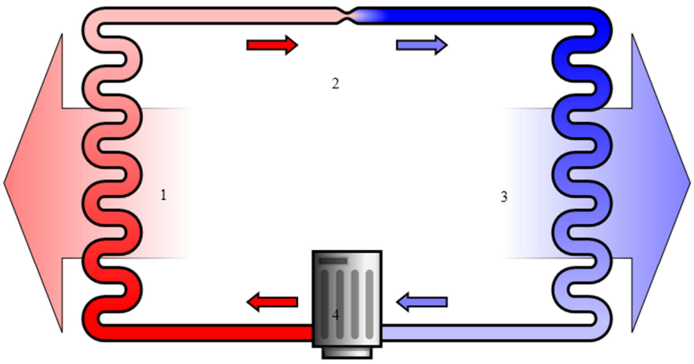

Fig 6: *A simple stylized diagram of a heat pump's* vapor-compression refrigeration *cycle:*
1) condenser, 2) expansion valve, 3) evaporator, 4) compressor

4.3 Distribution System

The distribution system delivers heating or cooling from the heat pump to the building. In a typical air distribution system, hot and cold water from the GSHP is fed to coils within local and central air handling plant which is then used to heat or cool the air before it is supplied to the building.

The milder water temperatures produced by the heat pump mean that it is also well suited for use in warm/cool ceiling and floors to provide a passive means of tempering internal environments.

Typical Operation Process

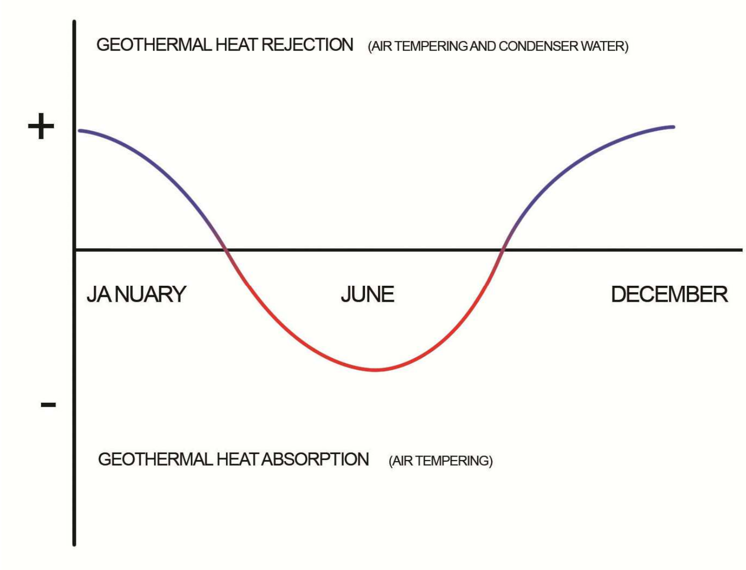

Fig 7: *Energy balance of a geothermal system*

Geothermal bores are used to reject thermal energy from condenser water to the ground, and also to temper the incoming air. Geothermal cooling water is pumped directly through the air tempering coil to provide either heating or cooling without requiring operation of the chillers refrigeration compressor which requires large electrical energy input. In summer intake air can be slightly cooled, reducing required air conditioning load, whilst in winter the heating load may be reduced through extracting heat from the ground.

In both cases either electricity or gas can be offset by reducing runtime and peak loads for mechanical chillers runtime and/or LPG boilers. The principal of operation relies on the fact that the ground is a large thermal sink which can be used to moderate the building temperatures.

In the summer months a large amount of thermal energy is transferred to the ground. During winter months a larger amount of thermal energy is extracted from the ground. Ideally the year round net heat transfer from the ground would be zero as summer heat loads are offset by winter demands, resulting in an energy balance as illustrated in the figure 7.

High density poly ethylene (HDPE) pipework reticulates flow and return water down each hole. The holes are filled with Bentonite slurry that acts as a bonding agent binding the pipework to the mass of the earth to ensure effective heat exchange is achieved. Horizontal pipe work joins each bore hole and connects the field to the building. Ground loops circuits are setup in an innovative way to minimise pipework and hence pumping energy, compared to the 3 pipe traditional approach. This setup called *Reverse Return* is illustrated in the following diagram.

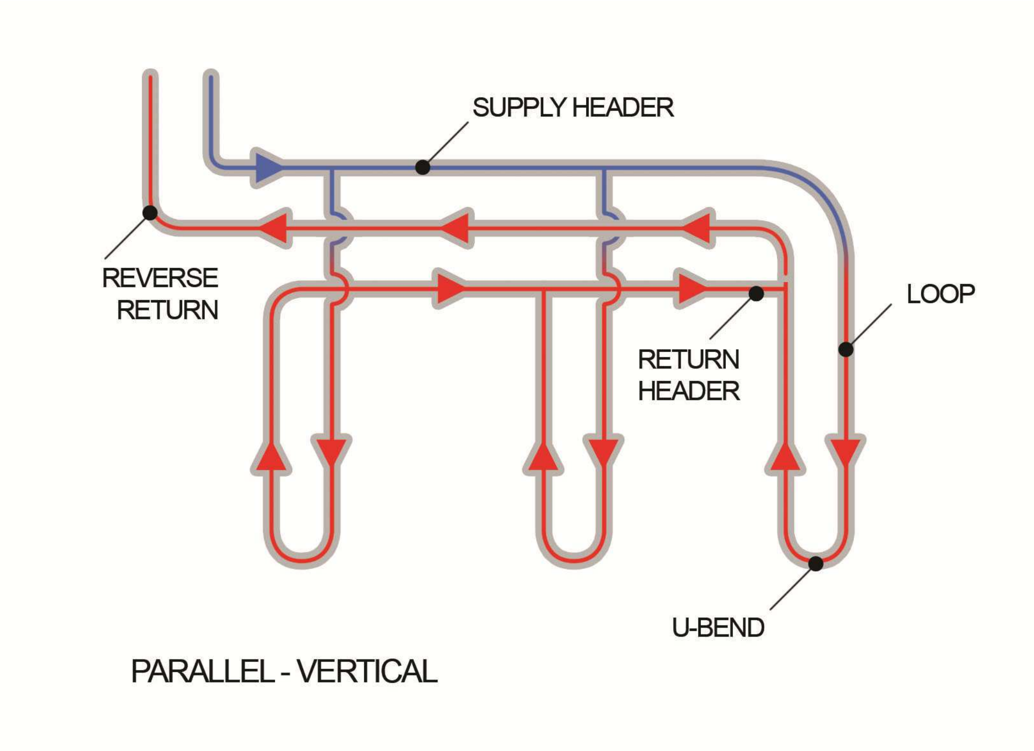

Fig 8: *Reverse return pipework configuration*

Ideally the reticulation pipework diameter would be large so that static pressure drops can be reduced which translates to dramatic decreases in pumping power required. Reduced pumping power will greatly reduce payback period due to the reduced electrical energy operating costs for the pump motors. Optimising pipework for minimal pumping energy is integral to this designs improved energy efficiency as compared to a conventional cooling tower/ air cooler approach.

To maximise energy efficiency and cost savings the system should be balanced on commissioning to provide the optimum between reduced pumping power (reducing flow rate) to minimise motor power consumption and increasing pumping flow rate so that average ground loop temperatures are reduced. This increases the Coefficient of Performance (COP) of the chiller resulting in less electrical power required by its compressor.

Fig 9: *Pipework reticulation*

Once installed, the loop is flushed, pressure tested and charged before the horizontal pipework connection to the valve plantroom is buried at a depth of approximately 600mm. Trace wires are laid for future detection of pipework.

Fig 10: *view of a completed geothermal field.*

5 System Configuration and Components

The proposed system utilises a 500kW heat pump / water cooled chiller to provide base heating and cooling. This will be topped up by high efficiency electric chillers and cooling towers to provide the chilled water for space cooling peak loads, and LPG gas boilers to provide heating hot water for space heating peak loads.

The heat pump operates as the primary source of hot water and chilled water for the heating and cooling systems. This arrangement enables the simultaneous heating and cooling loads in the building to balance each other out up to a maximum capacity of 500kW. Any excess hot water or chilled water will be rejected to the geothermal array.

The use of high efficiency chillers as opposed to reversible heat pumps enables very good efficiencies particularly at part loads (COPs between 8-12). The use of the heat pump to provide heating will also reduce the reliance on the LPG. It utilises a centralised plantroom, which provides for ease of maintenance and it enables flexibility in the selection of the airside systems.

Additionally this type of system may be suitable for use with a chilled water storage system enabling chillers to run at night to make use of the lower night time electrical rates and ambient temperatures should such a system be installed in the future.

6 Installation and Maintenance

Ground source systems have low maintenance, low running costs, low noise and can be installed inside the building and out of sight, making them a very attractive option to both designers and clients. There are no hazardous gas emissions, flammable oil, fuel tanks, LPG or gas pipes so no need for regular safety checks. Routine maintenance is kept to a minimum as (with the exception of the heat pump and circulation pumps which have similar maintenance regimes as a traditional heating and cooling system) there are no moving parts and the controls are largely automated.

The earth loops are made from high density polyethylene piping that is fusion welded in much the same way as a natural gas pipe line so any problem with leakage is rare. However, since all earth connections in a GSHP system are usually very difficult to access after installation, the materials and workmanship used in construction must be of the highest quality.

Problems can also arise through the non-conventional diversity of trades involved in installing a GSHP system. Therefore, it is essential that a suitably experienced main contractor is appointed to co-ordinate all trades from the drillers to the heat pump manufacturers. An in depth commissioning programme will be developed to help provide the Client and design team with confidence that all parts of the diverse space conditioning system are properly integrated, from the earth coupling system to the in-building distribution systems.

7 Case Studies

7.1 National Projects

Lithgow Hospital
At Lithgow Hospital the pipes were buried in 96 holes drilled down 110metres below the car park. This was done to allow for future access and to limit interference with the construction program. The drill holes were 4” in diameter and were drilled 4.5 metres apart in an area 45m x 36m.

The closed loops provide enough capacity for 67 air conditioning units and 11 water to water units. The water to water units produce chilled and heated water to the operating theatre air handling units, heating water for kitchen space heating, water heating for the hydrotherapy pool and process cooling for the central sterilising unit.

Surry Hills Community Centre
The geothermal bore system operates in a closed circuit with water distributed through a network of plastic pipes. Heat is rejected and absorbed from the ground via a U-shaped pipe that is sunk into 100m deep holes that are 0.2m in diameter. Each bore will transfer 6-8kW of heat to/from the ground. Once installed, the pipe has been pressure-tested to ensure there are no leaks and then a filling material was poured into the hole to protect the pipe from shear loads and improve heat transfer. The bores are guaranteed for 25 years.
The only energy consumed by this system is the fan and pump energy. Ongoing maintenance is extremely simple as only the pumps need to be serviced and replaced. Leaks are extremely rare but relatively difficult to fix. If this occurs the bore can be isolated and replaced or more likely left in-situ and a replacement bore fitted elsewhere.

Western Sydney Records Centre (WSRC), located in Kingswood, NSW
There are a total of 70 vertical field loops

The depth of each loop is approximately 90m.

The WSRC was a staged development. Geothermal system was installed only for Stage-6.

Here is a comparison between the energy consumption of the different strategies within the development.

Stage 3 and 5, have an area of 11,000 m² = 118 kWh/m²

Stage 6 has an area of 15,000 m² = 42.6kWh/m²

Macquarie University Administration Building
"There are a total of 56 vertical field loops

› The depth of each loop is 90m

› The closed-loop system is connected to two variable speed pumps

› High pressure polyethelene piping is used for the bores

› Loops are caulked with bentonite for support and thermal conductive advantage."

Sydney Water Police
Geothermal cooling system has been installed at the headquarters of the Sydney Water Police in Sydney Harbour.
The system is a hydrothermal system. (using the volume of water in Cameron’s Cove acts as the thermal mass). In a traditional geothermal loop, the coils are buried under the ground. In this project, the coils are submerged under the seawater as a hydrothermal loop.
With a total plant capacity of 150kW, an operating cost saving of around 40% was achieved, in comparison with an equivalent variable refrigerant flow (VRF) system.
With all equipment either submerged in the harbour, or located indoors to avoid the harmful effects of the sea air, the maintenance savings were in the order of 50% of that of a VRF system.

Geothermal Heat Pumps Australia

New South Wales
- Lithgow Hospital, Lithgow
- NPWS Tourist and Information Centre, Jindabyne
- Macquarie University, North Ryde
- Detention Centre, Dubbo
- Cowra Shire Council Offices, Cowra
- Wagga Wagga Civic Centre, Wagga Wagga
- Surry Hills Community Facility, Surry Hills
- Woolloomoolloo Wharves, Woolloomoolloo
- CSIRO, ATNF, Marsfield

Australian Capital Territory
- ACTEW Corporation, Canberra
- Geoscience Australia, Canberra
- Duntroon Headquarters, Canberra
- Airport Caltex, Pialligo
- ANU Research Laboratory, Canberra
- Solomon Islands High Commission, Canberra
- Belconnen Marketplace, Canberra (spec)

Tasmania
- Grand Chancellor Concert Hall, Hobart
- Queen Victoria Museum and Art Gallery, Launceston
- Southern Cross Homes/Aged Care, Moonah
- Antarctic Centre, Hobart
- Westpac Call Centre, Launceston
- Hobart Aquatic Centre, Hobart

Victoria
- Victoria University of Technology, Werribee
- Paynesville Pool, Paynesville
- Station Pier, Port Melbourne
- Wangaratta High School, Wangaratta
- Monash University, Melbourne
- Bandiana ALTC, Bandiana
- East Melbourne Library
- Mt Hotham Ski Lodge
- Corryong Council Offices, near Thredbo
- Acacia College, School, Mernda

South Australia
- Royal Adelaide Hospital, North Terrace
- Bureau of Meteorology, Kent Town
- Garden East, 320 Apartments, Adelaide
- Coober Pedy Police Station, Coober Pedy
- Mt Barker TAFE, Mt Barker

Queensland
- University of Southern Queensland swimming pool, Toowoomba
- Logan Institute of TAFE, Logan
- RAAF Amberley, Air Force Base

Northern Territory
- Bureau of Meteorology, Darwin

West Australia
- Challenge Stadium, Pool
- CSIRO, ASKAP, Boolardy

7.2 International Projects

Project	Location	Capacity	Boreholes	Year
Great River Medical Centre (Geothermal Lake)	West Burlington, IA, USA	400 tons	~126km of piping	2000
Kings Mill Hospital (Largest open loop in the world)	Nottinghamshire, UK	5.4 MW	60 @ 100m	2010
De Monfort University	Leicester, UK	360kW		
United States Marine Corps reserve centre	USA	900kW	180	2010
Ball State University	USA	--	--	2009
Mt. Comfort Elementary School	Greenfield, IN, USA	200 tons	220 Wells @ 200' with 1" loop	2008
Mt Vernon High School	Fortville, IN, USA	525 tons	450 Wells @ 300' with 1.25" loop	2009
Blue Earth County Justice Centre	Mankato, MN, USA	462 tons	500 Wells @ 200' with 1" loop	2008
Fairbault County Justice Centre	Blue Earth, MN, USA	70 tons	178 Wheels @ 100' with 0.75" loop	2009

8 Appendix A – Proposed Geothermal Layout

The following drawings indicate the proposed layout of the geothermal system for the Bega Hospital.