Geothermal HVAC –
Shifting Performance Risk from Buyer to Seller

A view of Apollo Cancer Hospital, Hyderabad

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In this third and concluding article on Geothermal HVAC, we shall introduce Water-Source Heat Pump HVAC solutions and Energy Performance Guarantees through a case study of the Novalis Cancer Treatment Building of Apollo Hospitals in Hyderabad. The first two articles appeared in the Oct.-Dec. 2010 and Jan.-Mar. 2011 issues respectively.

What happens when either the hydro-geological conditions are unsuitable or the project timetable is too compressed to support Geothermal HVAC? The solution lies in a Water-Source Heat Pump (WSHP) HVAC. The WSHP HVAC solution utilizes the same heat pumps as a Geothermal HVAC solution. The only difference is the use of a standard cooling tower instead of a Ground Heat Exchange.

The Project

Apollo Hospitals required an HVAC solution for their remodeled building at Hyderabad. As the building was a retrofit project, we mutually decided to implement a WSHP HVAC solution to meet the pressing deadlines. Apollo Hospitals were initially skeptical of a WSHP HVAC solution providing energy consumption savings compared to a conventional water-cooled chiller application. We offered a Water Source HVAC solution backed by an Energy Performance Guarantee to reduce any perceived operational or financial risk of implementing a new technology. The basic premise of the Energy Performance Guarantee is that the HVAC design team will receive service fees only if the HVAC solution is more efficient than the benchmark solution. The Energy Performance Guarantee shifts the performance risk of the HVAC solution from the buyer to the seller.

Design Objectives

We designed the Water Source HVAC solution to meet the following requirements:

1. Space temperature of 23°C (21°C for the rooms on fourth floor).
2. Relative humidity less than 60-65%.
3. Outside air per ASHRAE Standards on ground to third floors; 100% outside air on fourth floor.
4. Fresh air requirements of ground to third floors via RE units of terrace.
5. Energy Performance Guarantee - higher energy efficiency than conventional water-cooled chiller

About the Authors

Grant Morrison has over 20 years experience in a broad range of operations and finance roles in the logistics, construction and finance industries across Australia, Asia and Europe. With a degree in Business from UTS, Australia, he has previously worked with Barclays Bank in the UK and ING, Australia.

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HVAC solution benchmarked at 1.14 kW/TR as provided by an independent HVAC Consultant.

The Methodology

We built a model to simulate and replicate the conventional HVAC for the proposed development, considering the following factors:

- Heat Loads – equipment, lighting, people
- Building characteristics and operations
- ISHRAE weather bin data for Hyderabad

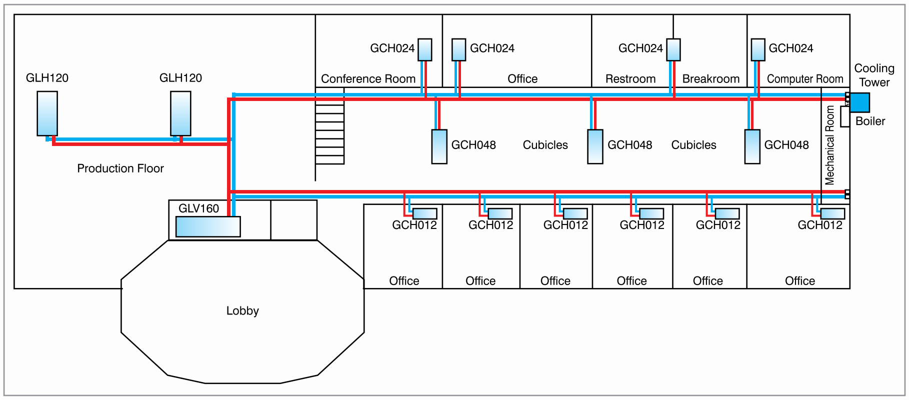

Diagram 1: Cooling tower linked to Heat Pumps at Novalis Cancer Treatment building

This building simulation created

- The energy consumption baseline for comparative purposes and financial viability
- The building model to assess Water Source Heat Pump (WSHP) performance
- The building simulations have been proven to match actual performance

We created design option for WSHP HVAC by

- Assessing and sizing the Genesis models of WSHP from ClimateMaster for ground to third floors and Tranquility RE outside units from ClimateMaster for the fourth floor.
- Following ClimateMaster's recommendation to deliberately undersize the solution for the conditioned space. According to ClimateMaster, under-sizing the unit results in better handling of dehumidification and longer life cycle of the equipment.

We benchmarked Chiller vs. WSHP HVAC

We created a Lifecycle Cost Analysis model including

- Design and Installation costs
- Energy consumption comparisons
- Total Life Cycle Cost Analysis – initial and on-going costs; project pay-back period

The Solution

1. Water Source Heat Pumps (WSHP)

Genesis Series (GR) units for ground to third floors

A unitary, modular device containing the condenser and blower to produce cool or warm air depending upon requirements. Individual thermostats are connected to each Water Source Heat Pump for control and operation, thus enabling individual units to be on/off depending upon space occupancy.

Tranquility Rooftop Series (TRE) units for the fourth floor - the TRE product line offers the option of introducing a fixed amount of outside air year-round or a modulating Economizer to provide free cooling when outdoor conditions are favorable. According to ISHRAE Temperature Bin Data for Hyderabad, there are 976 hours within the year where the outside air temperature is equal to or lower than space temperature requirements of the fourth floor.

An option for the rooftop units is to be mated to an ERV unit. The energy recovery wheel inside the ERV unit transfers energy from the warmer to the cooler air stream by counter-flowing supply and exhaust air streams through the slowly rotating wheel (less than 60 revolutions per minute). The large energy transfer surface arranged to provide laminar air flow through the wheel causes the constant flow of recovered energy to represent up to 80% of the difference in total energy contained within the two air streams.

As an example, when outdoor air is at 95°F (35°C) DB, 75°F (24°C) WB and 40% RH and indoor air is at 75°F (24°C) DB and 50% RH, the ventilation air is conditioned by the ERV system to enter the building not at 95°F (35°C) DB and 75°F (24°C) WB but of the order of 79°F (26°C) DB and 51% RH. This example of reduced load on an air conditioning system at summer temperature extremes illustrates the basis for downsizing of cooling equipment.

At design conditions of 95°F (35°C) DB and 75°F (24°C) WB, cooling equipment capacity can be reduced by 3.1 tons per 1,000 CFM (2.31 Watts per 100 l/s) at the time of design or when replacing existing equipment.

2. A standard cooling tower infrastructure linked to Heat Pumps for heat dissipation and rejection. See *Diagram 1*.

3. Outside Air Requirement

- 100% outside air is provided to the fourth floor via Tranquility Rooftop units.
- 8000 cfm of outside air is served to first to third floors.
- Outside air for the ground floor is delivered through natural ventilation.
- Ventilation exceeds *AHSRAE Standard 170 – Ventilation for Healthcare Facility*.

4. Variable Air Volume (VAV)

We provided VAV system in five spaces on the fourth floor at the request of Apollo Hospitals.

5. Filters

- HEPA filters were installed in a plenum connected to each Tranquility Rooftop Unit.
- Each Heat Pump unit has individual filters.

6. Part load

Part load is zero as each unit can be turned off when space is unoccupied.

Results & Outcomes

Each of the aims and objects of the Novalis Cancer Treatment Building HVAC project for Apollo Hospitals have been met.

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Energy Efficiency

The Water Source Heat Pump solution is 43.6% more efficient than the benchmark solution and greatly exceeds *ASHRAE Standard 90.1* energy efficiency. As such, our HVAC exceeded the terms of the Energy Performance Guarantee. A 43.6% reduction in energy consumption results in financial and environmental benefits. See *Table 1*.

Table 1: Actual vs Benchmark

	Actual	HVAC Consultant Benchmark
Solution Size (TR)	201.25	258
Solution Efficiency (kW/TR)	0.837	1.14
Hours of Operation*	4,980	4,980
Total Energy Consumption (kW)	8,51,891	14,64,718
Energy Saved	43.6%	-

** Weighted average hours of operation; Floors G-3 @ 12 hours; Floor 4 @ 24 hours*

Our Building Simulation and Energy Model predicted the solution to achieve 0.79 kW/TR efficiency: about 7% difference between actual and predicted efficiency.

Reasons for higher efficiency and lower capacity

a. Lower External Static Pressure (ESP)

The Water Source Heat Pumps are placed within the conditioned space. This is known as a distributed or decentralized HVAC solution. Therefore, the chilled air has less distance to travel to cool the conditioned space. Our low-side design, ducting and diffusers, has an ESP of 0.05" of wg. This is approximately 30-50% lower than a centralized water-cooled chiller and AHU plant.

b. Higher Air Coil Face Area

The air coil face area within the blower/AHU of each Water Source Heat Pump is relatively high compared to the air coil face area of AHUs/FCUs on a per TR basis.

The higher the air coil face area, the greater the Contact Factor. This increases efficiency through greater cooling of the return air and lower coil static pressure.

The Water Source Heat Pumps have at least 30% higher coil face area than leading brands of AHU/FCU.

c. Part Load = Zero

Each individual Water Source Heat Pump can be completely shut-down when a particular space is unoccupied whilst other units remain operational. This is the equivalent of zero part-load.

d. Precise Capacity Sizing

We sized the HVAC capacity using advanced Building Simulation and Energy Modeling software for precision sizing (see para earlier in this article - '*The Methodology*'). The Heat Pumps come in a range of sizes to suit small and larger conditioned spaces to allow for a closer match between equipment size and requirements.

If our HVAC solution was found to have been under-sized, space temperatures would have been higher than desired, air flow would have been inadequate and the energy consumption per TR would have increased as the equipment would work harder to make up for under-sizing. None of these shortcomings have been encountered in the project.

In comparison, many HVAC solutions are over-sized by about 47% according to the Consortium for Energy Efficiency (CEE).

Over-sizing increases equipment wear through short circuits and decreases dehumidification capacity.

According to Oak Ridge National Laboratory of the US Department of Energy, over-sizing increases the designers' profits because of fee structures based on the capital costs of the project. Other reasons for over-sizing the capacity can be lack of flexibility in cooling equipment sizes, deliberately manipulating kW/TR to be perceived as efficient and conservative safety factors.

Financial Pay-back

Our HVAC solution delivers substantial financial benefits to Apollo Hospitals compared to the benchmark solution of the independent HVAC consultant. Our HVAC solution results in an immediate project pay-back and will deliver **cost savings of**

Table 2: Analysis of Business Case

	Solution Delivered at Novalis	Independent Benchmark
(All figures in Rupees unless mentioned otherwise)		
Total Solution Cost	15,745,790	15,093,000
Alterations & Additions		
Fourth Floor Low Side	852,292	852,292
GI Disbursements		
VAV		-
Fresh Air Supply via 4F		-
Additional spaces or reconfigured space	1,169,499	1,169,499
Sub-total	2,021,791	2,021,791
Altered Total Costs	**17,767,581**	**17,114,791**
Difference	3.81%	
Tax Benefits		
Tax Benefit of Accelerated Depreciation	2,642,177	
Tax Benefit of Standard Depreciation		565,988
Total Adjusted Cost of HVAC Solution	**15,125,404**	**16,548,804**
Difference	-8.60%	
Cost Comparison	-1,423,400	
Operational Costs		
Energy Consumption		
Hours (weighted average between 12-24 hours)	4,980 hours	4,980 hours
TR	198.25 TR	258 TR
kW/TR	0.837 kW/TR	1.14 kW/TR
Total Consumption	**826,358 kWh**	**1,464,718 kWh**
Electricity Rate per kWh	5	5
Total Energy Costs	**4,214,423**	**7,323,588**
Savings	43.6%	
Total Costs After Year 1	19,339,827	23,872,392
Savings	19%	
Project Payback	Immediate	

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19% in the first year full of operation. These savings are possible through:

1. 43.6% energy saving (highlighted above)
2. 80% accelerated depreciation – heat pumps are classed as energy saving devices as per the Indian Income Tax Act
3. Comparable equipment and installation costs

Table 2 is a break-down of the Business Case comparing the solution delivered with the Independent HVAC Consultant Benchmark.

The Business Case is based on:

1. Solution cost and performance information supplied by Apollo Hospitals.
2. Actual performance of our HVAC solution.
3. Alterations and additions to the project would have the same cost implications for both the solutions.

Thermal Comfort & Ventilation

Our HVAC solution at Novalis has been designed and implemented to conform to *ASHRAE Standard 170 – Ventilation of Healthcare Facilities* and the specific temperature requirements of Apollo Hospitals (21°C for fourth floor rooms, 23°C for all other spaces).

Our HVAC solution provides 100% outside air (OA) to the fourth floor, 8,000 CFM of OA to floors one to three, and natural ventilation to the ground floor.

ASHRAE Standard 170 states the following Air Change per Hour (ACH) for selected spaces of Healthcare Facilities. See *Table 3*.

Table 3: ASHRAE Std. 170 - Ventilation

Function of space	Minimum Total ACH
Treatment Room	6
Therapy Room	6
Laboratory	6
Examination Room	6
Inpatient Rooms	12
Corridors	2

Table 4 gives the actual data collected from Novalis Building and confirms compliance with ASHRAE Standard 170:

Thermal Comfort Survey & Results

We provided the building occupants with an anonymous web-based and paper-based survey. The survey addressed areas of thermal comfort including temperature, airspeed, humidity, clothing, and activity. The survey results were analyzed to identify any areas of concern and implement a corrective action plan for any issues.

The key findings of the Thermal Comfort Survey are

- 89% of the respondents have positive sentiments regarding air quality.
- 87.5% of the respondents have positive sentiments regarding the air-conditioning system.

Table 4: Actual data from the site

Floor	Sqf	CFM	CFM/sqf	Total ACH
Ground	6,370	11,902	1.87	11.80
First	6,482	13,127	2.03	12.79
1F Rooms	2,008	5,008	2.49	15.75
Second	6,767	11,857	1.75	11.07
2F Rooms	3,130	6,418	2.05	12.95
Third	6,112	12,748	2.09	13.17
3F Rooms	3,042	7,513	2.47	15.60
Fourth	5,988	19,445	3.25	20.51

Noise Levels

We measured the Sound Pressure Level within the space of Novalis Building during normal working hours with the HVAC solution operating. On an average, each space recorded a Sound Pressure Level of 52 dB which is about 15% less than the level of conversational speech at 1 meter (60 dB).

Conclusions

We have delivered an HVAC Solution which:

1. Meets the aims & objectives of the project.
2. Delivers 43.6% energy savings and is within 7% of the predicted savings.
3. Returns an immediate project pay-back.
4. Adheres to the energy performance guarantee.

Recommendations

1. Accelerated Depreciation

Since the acceptance of our offer by Apollo Hospitals, we have discovered that Heat Pumps attract financial incentives from the Government of India. Apollo Hospitals would be able to claim 80% accelerated depreciation on Heat Pumps for Year 1 as per the Income Tax Act.

We recommend to Apollo Hospitals to claim the allowable accelerated depreciation and the subsequent tax benefit to significantly increase the financial competitiveness of Heat Pumps. Other HVAC equipment only allow for the standard 25% straight line depreciation.

2. Increased Efficiency

ClimateMaster has introduced the Tranquility Compact (TC) range of Heat Pumps to replace the Genesis (GR) range. Tranquility Compact has 10% higher efficiency than Genesis at the same cost.

We would recommend Apollo Hospitals to consider the Tranquility Compact range of Heat Pumps for future HVAC projects.

3. Thermal Comfort Survey

We recommend Apollo Hospitals to conduct our Annual Thermal Comfort Survey with the people occupying the Novalis Building as part of our Annual Maintenance Contract. This will enable us to implement a plan of corrective action as needed.

References

1. We have used the following figures for the water-cooled chiller HVAC solution as the benchmark:
   - Energy Efficiency = 1.14kW/TR
   - Solution size = 258TR
   - Solution cost = Rs. 58,500/TR before alterations for the project were made

   These figures have been provided to Apollo Hospitals and subsequently to us by an Independent HVAC Consultant.
2. Coil Face Area: *http://www.mcquay.com/mcquaybiz/literature/lit_aa_iah/Catalogs/CAT550-5.pdf*
3. Sizing of HVAC Solutions: *http://www.ornl.gov/sci/eere/cef/CEFCh4.pdf*
4. ClimateMaster Product Range and Data: *www.climatemaster.com*