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UCC's Western Gateway Building: a Case Study for the Integration of Low Temperature Heating and High Temperature Cooling Systems

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SDAR Award winner 2011

UCC's Western Gateway Building

A case study for the integration of low temperature heating and high temperature cooling systems

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Abstract

This paper deals with the installation of a 1 MW groundwater heat pump for cooling and heating, a server room heat recovery system and a novel VAV underfloor mechanical ventilation system, in a large third level university building in Cork, Ireland. After describing the building and the mechanical systems the paper presents energy usage and analysis of results for the first year in operation. Such an installation is of interest to engineers and facility managers in order to determine how all the systems complement each other, as well as the resultant energy saving potential compared to conventional systems. Large scale groundwater heat pumps with simultaneous heating and cooling capabilities can provide significant operational cost savings, as described in the paper.

Key Words:

VAV Underfloor Mechanical Ventilation, Demand Control Ventilation, Groundwater Heat Pump, Simultaneous Heating and Cooling, and Server Room Heat Recovery.

1. Introduction

In the Cork area a number of a small and medium scale groundwater heat pumps have been installed which use ground-water from the Lee Buried Ribbon Valley for space heating and cooling of buildings. Installations of the scale 1 MW have not previously been attempted.

The presence of a simultaneous heating and cooling load within a building significantly enhances the economic and environmental argument for the installation of heat pumps.

Water-cooled technology for server rooms is now becoming established for high heat gain racks (>15kW). This new development provides an opportunity for high temperature chilled water cooling and significant heat recovery potential using heat pump systems.

The use of underfloor mechanical ventilation systems has become popular in large university buildings where natural ventilation is not suitable.

This paper outlines an innovative approach to the successful integration of all three technologies in the one building. The objective of this installation was to reduce significantly the energy costs and carbon emissions associated with running large third level buildings.

1.1 Project background

University College Cork's (UCC) Western Gateway Building (WGB) is the largest building on the UCC Complex at 25,000m² (269,100ft²) providing research and teaching accommodation for a range of academic departments such as Computer Science, Biochemistry, Mathematics, Pharmacology, Physiology, ICT and Cancer Research.

Master-planning for the site located on the western edge of the campus (on the old greyhound track on Western Road) by Scott Tallon Walker Architects began in 1999. After a series of delays, contract work commenced on the project in September 2006.

The first three floors (16,000m²) of the five storey structure were completed in June 2009. Major flooding of the River Lee down stream of Inniscarra at the end of 2009 interrupted building operations until June 2010. Fit out of the shell and core top two floors commenced in early 2011.

2. Building description

The 5-storey reinforced concrete above ground building (plus basement for M&E plantrooms) is situated on the banks of the River Lee and is aligned on a southwest/northeast axis. The area south of the courtyards is a 4-storey cellular/open plan office block, which provides staff accommodation and research space. Areas with high internal heat gains including the main teaching areas, computer and research labs, cafeterias and toilet blocks are located to the north of the building surrounding the main atrium which runs the

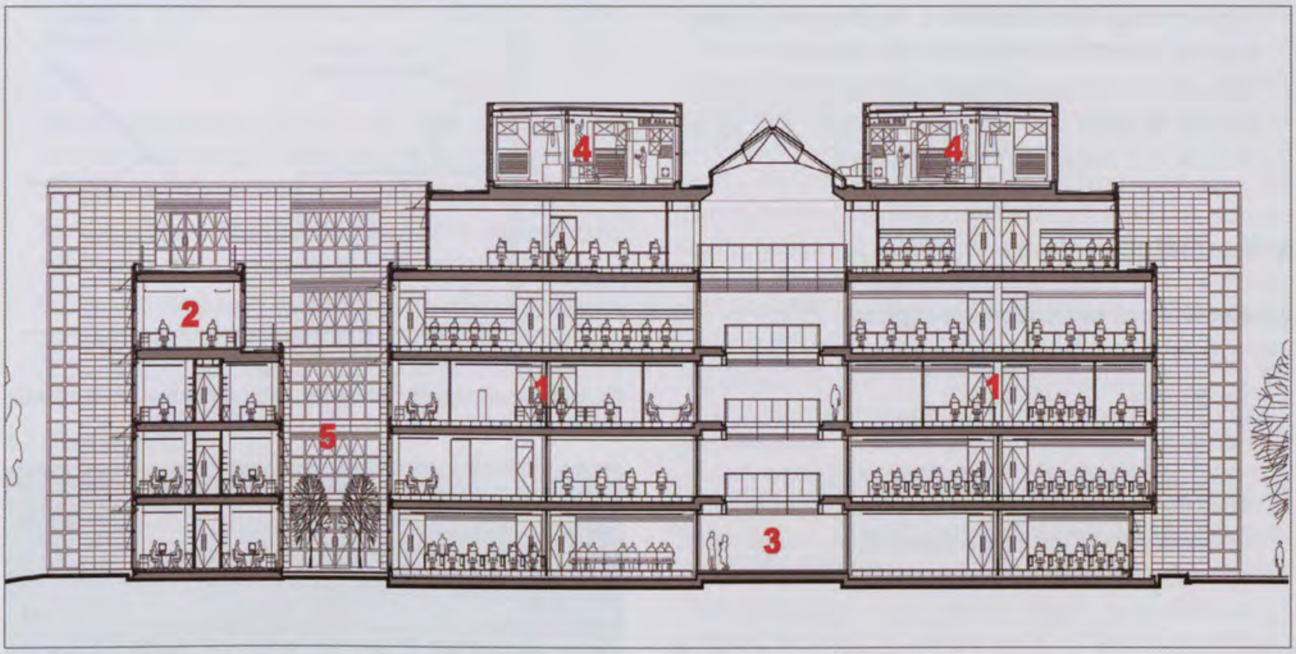

Fig. 1: Section through WGB from left to right – southern cellular and open plan offices, courtyard, classrooms and labs and main atrium

full length of the building. Full height glazing (overall U-value 1.84 W/m²k, shading coefficient 0.43, light transmission 67%) dominates the southern and northern facades accounting for 60% of the exposed wall surface area. The main atrium roof light has the same specification and accounts for 9.5% of the total roof area.

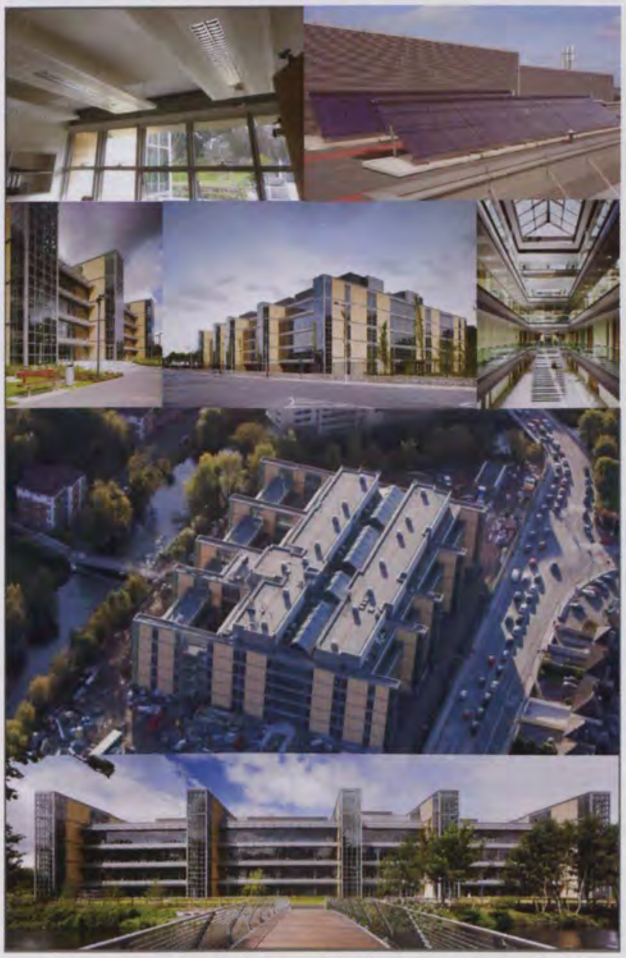

Fig. 2: Photo collage of building externals and atrium

Building element U values, which were specified pre-2006 Building Regulations are 0.25 W/m²k for roof and external walls with 0.16 W/m²k for the ground floor.

3. Passive design features

The building is designed with a number of passive design features including:

- Building orientation is southeast facing to capture morning sunshine for solar heating and to provide shading against evening sun.
- High heat gain areas are placed to the north of the building to avoid solar gains.
- There are no occupied spaces with eastern and western facades, eliminating low angle sun issues and consequent glare.
- The atrium and courtyards are used to bring light into the core of the building.
- Air tight construction with an actual test of 4.4 m³/hr per m² @ 50pa.
- Use of thermal mass in the form of exposed concrete soffits for over 90% of the ceiling area.
- Natural ventilation is utilised in areas (33% of existing floor plan) with low heat gain as per UCC policy. Night cooling occurs via automated vents.
- The naturally lit 100-metre long atrium concourse accommodates day-lighting, acts as a common return air path, and solar collector for heat recovery.
- Horizontal Brise Soleil is used on the southern facade to mitigate peak summer solar gains.
- 43m² of evacuated tube solar water heating panels in conjunction with gas fired condensing instantaneous stand-alone water heater for DHW.

- Localised manual light switching and PIR sensor for occupancy detection (lights off 30 minutes after last occupant).
- Photocells to allow daylight harvesting by continuous lux level dimming to preset levels (350 lux for offices, 500 lux for computer class rooms, 150 lux for the atrium).

4. Ventilaion systems

4.1 Mechanical ventilation description

The mechanical ventilation systems have the following energy efficient properties:

- Underfloor mechanical ventilation is used for areas with high internal heat gains in which spaces (classrooms, computer labs, lecture theatres, wet labs and research areas) are supplied by pressurised plenum and swirl diffusers (300mm raised access floor) with a minimum supply air temperature of 16°C (Fig 3).

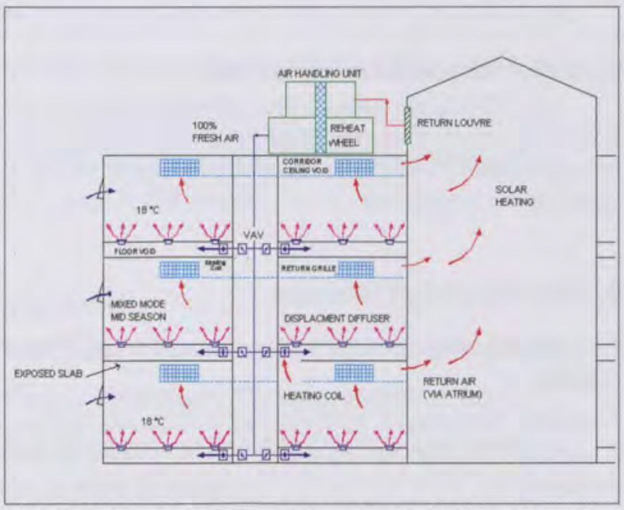

Fig. 3: Underfloor mechanical ventilation schematic for three-storey design, (Keohane 2005)

- Displacement ventilation in which auditoria spaces are supplied by pressurised plenum with a minimum supply air temperature of 18°C.
- 100% fresh air supply with pressure independent VAV system that operates on the dual maximum setpoint principle (see Fig. 4), demand based static pressure reset, and supply air temperature reset.
- Widened dead bands between cooling and heating setpoints of 2°C.
- Demand Control Ventilation (DCV) based on CO_2 sensing (1,000-ppm setpoint).
- Occupancy detection allowing VAV air supply shutoff for all rooms. If the room is within +/- 3°C of the base setpoint the VAV box closes fully. Should the room go outside these parameters the VAV box and reheat will re-activate to bring the room to within +/- 2°C of the base setpoint.
- Each air handling unit (AHU) has an Enthalpy wheel for sensible and latent heat recovery (70% efficient). There is no active humidity control in the building.

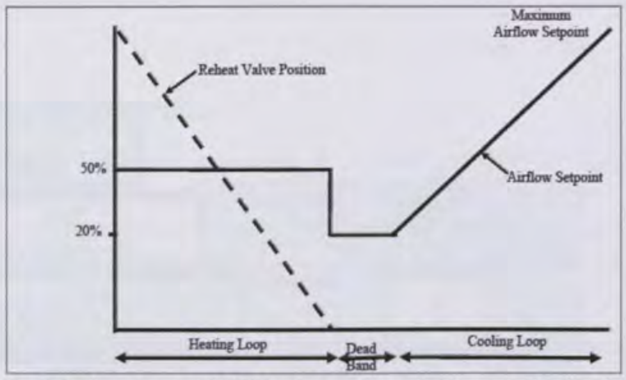

Fig. 4: Dual maximum with VAV heating – valve and airflow together (Pacific and Gas 2007)

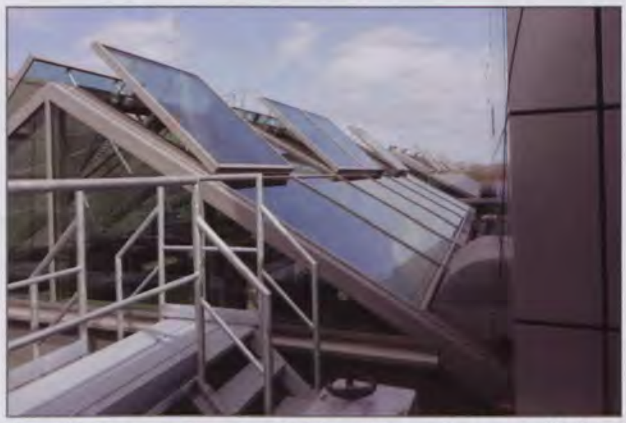

Fig. 5: If heat recovery is not required the AHU return fans are disabled, and air is exhausted through atrium rooflights

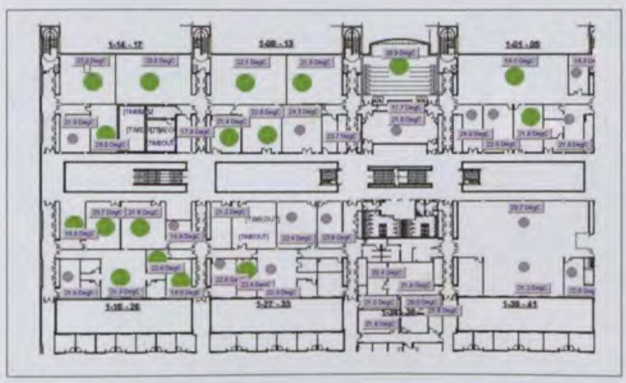

Fig. 6: Occupancy detection in green areas, no occupancy in grey areas where VAV air supply is disabled

- The majority of the spaces (14 of 18 AHUs) utilises the main atrium as a common return air path. Exhaust air is exfiltrated from the rooms at high level to the atrium or corridors, which are linked to the atrium. AHU return air is collected from the top of the atrium.
- When heat recovery is not required (Tex>17°C) the AHU return fans are disabled, and air from the spaces is exhausted through the atrium rooflight windows.
- At night the atrium rooflight and gable end windows provide night cooling to vent heat from the building.
- Typical AHUs contain direct drive centrifugal plenum fans with VSDs, an enthalpy wheel and no heating coil. The enthalpy wheel provides frost protection and reheats provide all required

heating for spaces. Cooling coils are provided for summer comfort cooling (sized for operation with 13°C chilled water (CHW).

- Postgraduate research areas have VAV fume hoods with PIR automated sash control. Undergraduate teaching areas have constant volume fume hoods.
- Mixed airflow strobic extract fans are used for fume dilution, and to create the required exhaust stack heights of 14m.
- Kitchen and restaurant, toilets (constant volume) and postgraduate research areas employ traditional VAV overhead mixed air distribution.

4.2 Data analysis

Table 1 indicates the recorded BMS data for the ventilation electrical energy. Typically two AHUs plus miscellaneous extract fans are wired through a single motor control centre (MCC) panel (with energy pulse meter). Ten such MCC panels are connected to separately energy-metered north and south plantroom power supply panels (five each).

The total commissioned ventilation power is in excess of 160 kW (10 W/m²). Fig. 7 indicates the average annual weekly power draw-down is approximately 50 kW (3.13 W/m²). The innovative VAV strategy, occupancy linked shutdown, and return fan disable strategies are responsible for the load factor of 31%.

The Energy Performance Indicator (EPI) value achieved for 2010 was 13.6 kWh/m² for the mechanically ventilated area. An ECON 19 type 3 building with similar operating hours (2,750) would expect to use 22 kWh/m².

In Fig. 7 there is a decline in average day loads (20 kW) during the summer as the return fans are disabled to allow rooflight exhaust. However, average weekly loads do not decrease. Due to lower undergraduate occupancy in the summer it would be expected that a reduction in fan power should be visible, and this pattern is partially indicated by a reduction in mid-May and an increase at the start of October. However, a spike occurs during the summer months. This can be explained by a large number of unoccupied computer labs (peak heat gain 35 W/m²) where PCs were running (PCs were scheduled to start and shutdown automatically between 6.00 – 22.00 hrs), and as a result required cooling as temperatures rose outside the upper unoccupied limits. This was corrected by the end of October by programming PCs to shutdown after 15 minutes of non-use.

The classroom/lecturing/computer room areas have the lowest EPI values (5.9 – 14.4 kWh/m²) where different occupancy and usage rates explain variations.

The highest value of 43.9 kWh/m² (41% of total) relates to the combined areas of the toilet core (all six floors), the kitchen-restaurant and the incubation suites. The reasons for this are:

- Constant volume toilet AHU running extended hours.
- Kitchen variable speed extract fan (25 ACH) is manually set locally to 100%, therefore supply VAV box is 100% open continuously.
- Kitchen extract fan (3 kW) running 24/7 to vent heat from refrigerators at night (40% of MCC energy).
- Servery area (VAV box @100% continuously) is overheating due to a large number of refrigerated cabinets. The cabinet condensers are currently being moved externally.

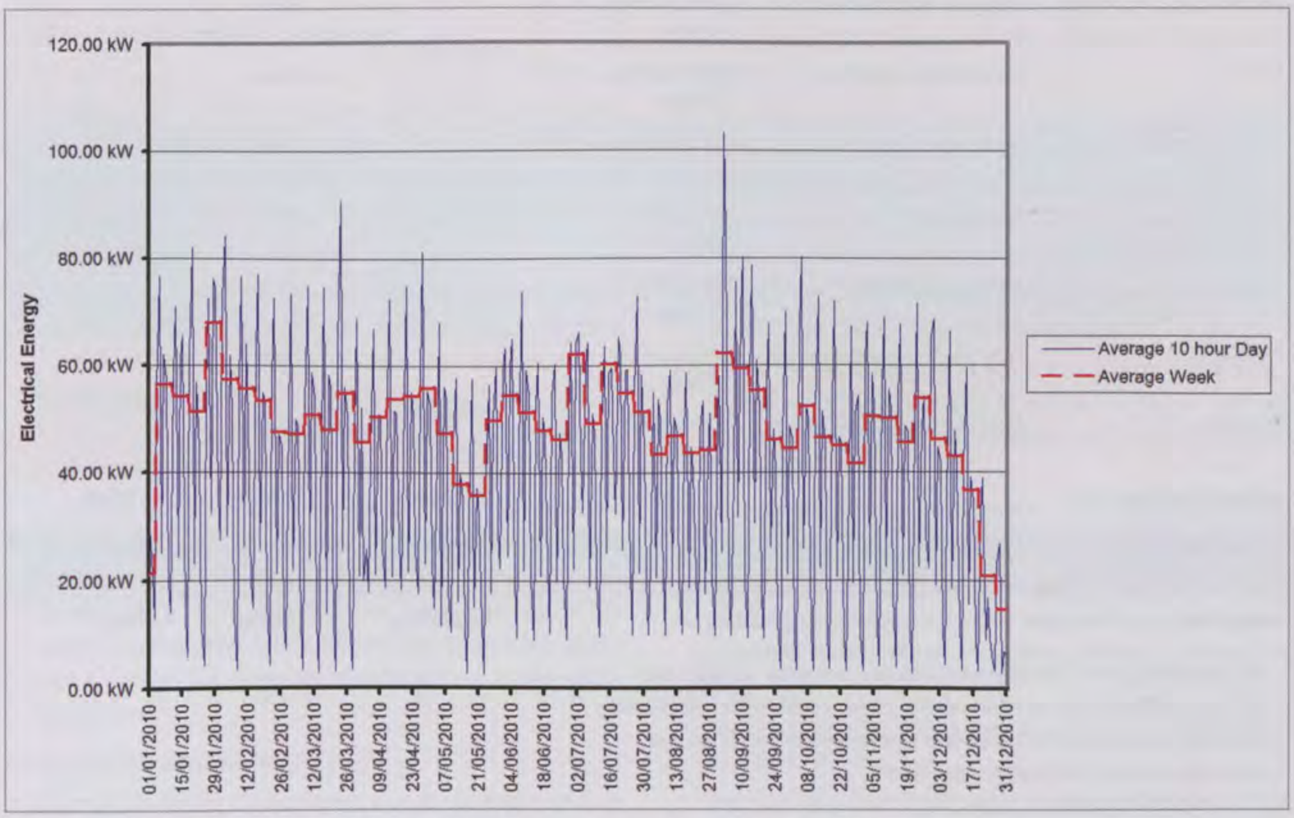

Fig. 7: Ventilation (AHU & Extract Fans, Heat Recovery Motors) Electrical Power Requirement Jan – Dec 2010

North of Atrium MCC Panels[3]	Space Description	AHU Commissioned[1]	Jan – Dec 2010	Area	Annual EPI
			52,995 kWh	5,044 m²	10.5 kWh/m²
AHU 0101	Comp Labs, Lecturing, Offices	SFP 1.9 kW/m³/s, 6.6 l/s/m²	8,180 kWh	632 m²	6.4 kWh/m²
AHU 0102	Recording Studio, Lecturing, Comp Labs, Offices	SFP 1.9 kW/m³s, 6.0 l/s/m²		639 m²	
AHU 0201 6.6 l/s/m²	Comp Labs, Lecturing, Offices	SFP 1.5 kW/m³/s,	14,410 kWh	632 m²	11.3 kWh/m²
AHU 0202	Comp Labs, Lecturing, Offices	SFP 1.5 kW/m³/s, 5.1 l/s/m²		651 m²	
AHU 0801	Main 300 seat Auditorium	SFP 2.0 kW/m³/s, 11.9 l/s/m²	13,629 kWh	328 m²	14.4 kWh/m²
AHU 0802	Auditorium, Lecturing, Offices, Server Room	SFP 2.0 kW/m³/s, 6.5 l/s/m²		619 m²	
AHU 0501	Lecturing, Undergraduate Wet Labs	SFP 2.2 kW/m³/s, 7.5 l/s/m²	8,482 kWh	630 m²	6.9 kWh/m²
AHU 0502	Lecturing, Undergraduate Wet Labs, Research Lab	SFP 2.0 kW/m³/s, 7.6 l/s/m²		591 m²	
Fume hood Extract	5 Under Graduate Fume Hoods	2 X 7.5kW Extract Fans	8,295 kWh	573 m²	14.5 kWh/m²
South of Atrium MCC Panels[3]			**96,380 kWh**	**5,905 m²**	**16.3 kWh/m²**
AHU 0301	Comp Labs, Research Office	SFP 1.6 kW/m³/s, 5.9 l/s/m²	7,471 kWh[2]	658 m²	6.0 kWh/m²
AHU 0302	Comp Labs, Research Office	SFP 1.7 kW/m³/s, 6.5 l/s/m²		597 m²	
AHU 0303	Cancer Research and 4 Fume hoods, 2 Extract Fans[4]	SFP N/A kW/m³/s, N/A l/s/m²	4,000 kWh[2]	383 m²	10.4 kWh/m²
AHU 0401	Comp Labs, Research Office	SFP 1.7 kW/m³/s, 5.4 l/s/m²	7,471 kWh[2]	660 m²	5.9 kWh/m²
AHU 0402	Comp Labs, Research Office	SFP 1.6 kW/m³/s, 6.3 l/s/m²		600 m²	
AHU 0701	Toilet Core all 6 floors	SFP 2.6 kW/m³/s, 8.2 l/s/m²	61,602 kWh	473 m²	43.9 kWh/m²
AHU 0901	Incubation Suites	SFP 1.8 kW/m³/s, 6.0 l/s/m²		591 m²	
AHU 1101	Kitchen and Restaurant	SFP 5.4 kW/m³/s, 10.9 l/s/m²		339 m²	
AHU 0601	Comp Labs, Undergraduate Wet Labs	SFP 1.4 kW/m³/s, 6.0 l/s/m²	15,837 kWh	795 m²	12.4 kWh/m²
AHU 0602	Comp Labs, Undergraduate Wet Labs,	SFP 1.9 kW/m³/s, 7.6 l/s/m²		485 m²	
Mechanical Ventilation Total			**149,376 kWh**	**10,949 m²**	**13.6 kWh/m²**
Natural Ventilation	Open Plan Offices, Cellular Offices, Stairwells, Atrium		**0,000 kWh**	**5,051 m²**	**0 kWh/m²**
Building Total			**149,376 kWh**	**16,000m²**	**9.4 kWh/m²**

1 AHU Commissioned Figures for 100% Design flow, flow rate per m² is an average of all spaces served

2 BMS Meter not functioning, figures are estimates based on size and the overall North or South MCC reading

3 The area totals for MCC North and South include 648m² of corridor space split evenly for each panel.

4 AHU and Fume hood Extract Sized for additional floor (766 m²)

Table I: BMS ventilation energy data

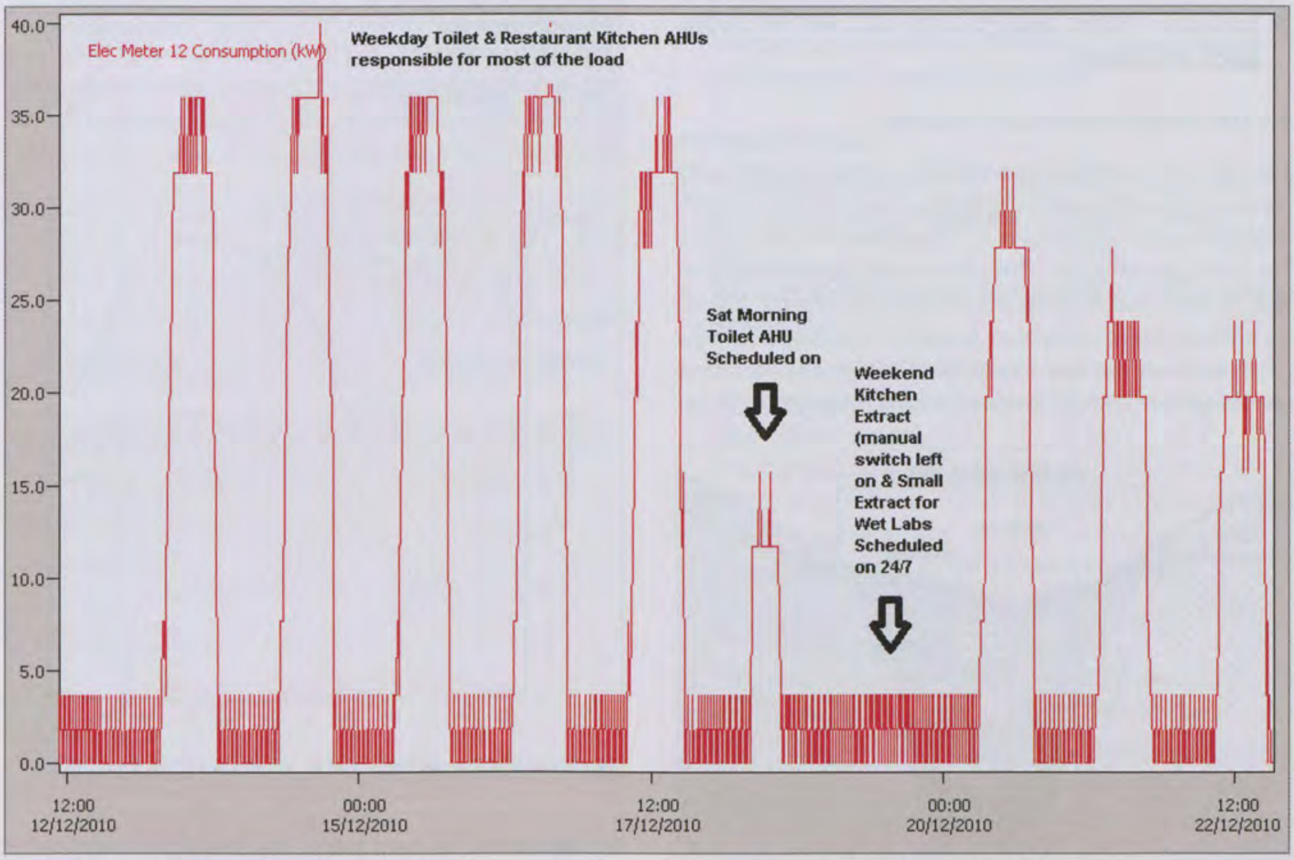

Fig. 8: BMS snapshot – South MCC combined ventilation (AHUs and extract fans, heat recovery motors) electrical power, Dec 2010

- High SPFs for the toilets and kitchen-restaurant AHU.
- Higher airflows for kitchen-restaurant AHU as a result of higher CHW temperatures designed for the underfloor AHUs.

4.3 Conclusions and lessons learned

While the overall fan power energy improves upon ECON by 38%, there are still a number of notable lessons. The commissioning of the AHUs aimed to achieve the design SFPs of 2.0 kW/m^3/s or lower, however this was only achieved by 14 of the units (overall average 1.9 kW/m^3/s). A number of units achieved 1.5 kW/m^3/s.

The reasons for higher than expected SFPs include:

- Issues with leaking floor plenums. Only representative sample areas were tested, all floor plenums should be tested on projects using pressurised plenums. Complex detailing is required to insure integrity.
- High-pressure drop associated with acoustic transfer devices allowing air to return to the atrium.
- End of line VAV boxes on the ground floor with large flow rates required significantly higher than expected static pressure to maintain control. Duct static pressure reset to 350 Pa was required for a 100% demand, even though the rest of the system was operating at low volumes. Where possible situate rooms with large airflow requirements as near to the supply fan as possible.

Other notable lessons learned include:

- Close VAV boxes for spaces experiencing the prolonged periods of inactivity.
- The absence of a heating coil in the AHUs has resulted in supply air temperatures lower than 16°C in extreme weather (-7°C) with the consequence of draught complaints.
- Higher chilled water temperatures may not reduce energy consumption for traditional VAV overhead mixed air distribution systems as fan energy is increased.
- A significant commissioning effort was required to get the system operating as per the design intent.

The use of 100% fresh air VAV underfloor mechanical ventilation in conjunction with DCV for areas with high occupant density heat gains in this project has demonstrated the following benefits:

- Significantly lower ventilation energy consumption compared to traditional VAV mixed air distribution systems.
- Allows the use of heat recovery, which will significantly reduce thermal energy use compared to natural ventilation solutions, while achieving high indoor air quality (IAQ) with 100% fresh air supply.
- Occupancy detection combined with temperature setback and room airflow disable in large buildings with variable occupancy is a very effective measure.
- Disabling AHU return fans when heat recovery is not required is recommended, where alternative passive exhaust routes exist.
- Thermal wheels for frost protection instead of traditional frost coils are effective.
- Free-cooling is available for large portions of the year, and the system can be integrated with groundwater cooling sources.

5. Ground water heat pump and server room heat recovery

5.1 Lee Buried Valley ribbon aquifer

The Cork harbour area is characterised by a series of buried valley ribbon aquifer systems, which represents a major source of groundwater in the area. (O'Connor et al 1998, Milenic and Allen 2001). The heat island effect of urban areas raises the temperature of shallow groundwater in the aquifer by a few degrees, making it a ready usable low temperature heat sink. Groundwater from the Lee Buried Valley has more recently been employed as a source of geothermal energy for space heating/cooling buildings in Cork city.

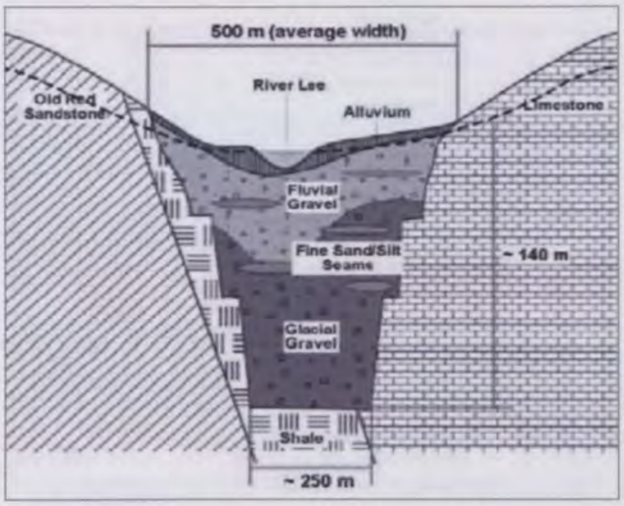

Fig. 9: Lee Buried Valley cross-section (Allen & Milenic, 2003)

Feasibility studies (Sikora 2002) and local trial borehole results (Connor 1998) indicated that the site had the potential to provide groundwater at stable temperatures of 12 to 13°C with flow rates in excess of 40 l/s. Originally for the 3-storey building it was proposed to utilise the groundwater directly for cooling purposes only.

Trial boreholes completed onsite in September 2006 indicated that flowrates of 45 l/s were achievable. Unexpectedly the groundwater temperatures recorded were in excess of 19°C. This recorded temperature was unprecedented for the Lee Buried Valley, highlighting an extreme heat island affect onsite. The ground-water temperature swings annually (8°C - 19°C) following air temperature with a lag of three months. Consequently the original concept was superseded and a 1 MW groundwater heat pump was proposed.

5.2 Server rooms

A key factor in the decision to provide mechanical refrigeration was the proposed expansion of the server room requirements from the original design. In the future when all five floors are operational a load of 300 kW can be expected.

The server room design consists of a mixture of integrated in-row water cooling for high-density heat racks (>15kW) and CRAC units for low-density heat racks (<5kW). Both systems are designed to use elevated chilled water (CHW) temperatures (<16°C), by allowing higher than normally accepted air temperatures (22°C) to enter the server equipment (ASHRAE 2008). CRAC units contain both CHW coils and DX coils which operate only in the event of CHW failure or elevated CHW temperatures as a result of elevated groundwater temperatures. In addition there are five comms rooms for communications networks served by variable speed fan coil units (FCU). These rooms are maintained at 24°C.

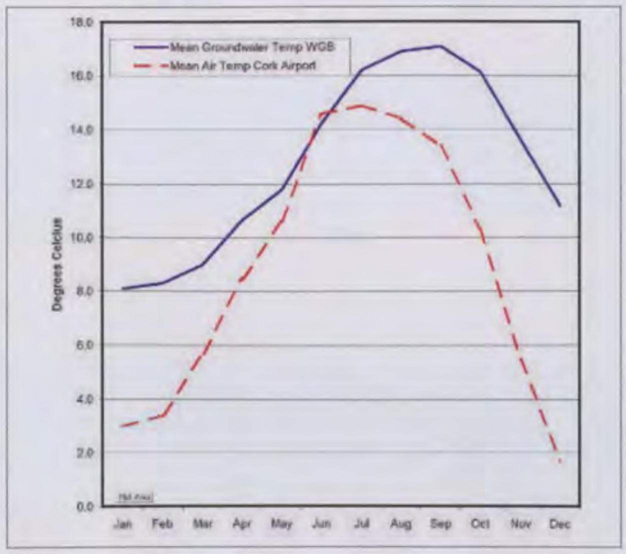

Fig. 10: Mean WGB groundwater and air temperature (Jan – Dec 2010)

5.3 Groundwater heat pump description

The system was designed from first principles and has unique hydronic configuration coupled to a complex control strategy.

The 1 MW heat pump system consists of two York YCWL 425 HE water-cooled chillers (500 kW each). Each chiller is equipped with four scroll compressors (R410a), which allows the entire system to turn down to 12.5% of peak load. These non-reversible units are equipped with a heat pump function that allows control of the condenser water leaving temperature or the evaporator leaving water temperature in cooling mode. This innovative system solution allows heat recovery from the servers through the heat pump for space heating, use of ground water as heat source or heat rejection outlet, or can allow efficient free cooling through the groundwater system. Both the CHW systems and low pressure warm water (LPWW) systems are variable speed with two port control valves.

A weather-compensated (60 - 40°C) low pressure hot water (LPHW) radiator system heats naturally ventilated areas. Heating is provided by 2 X 1.1 MW gas fired condensing boilers, which also provides back up for the Heat Pump heating system.

Groundwater is delivered from two 10inch diameter wells 25m deep with submersible pumps (22kW motors) equipped with variable speed drives (VSD). Groundwater is discharged into the river Lee through a specially designed diffuser to avoid thermal plumes. Groundwater is also harvested for use in a dedicated greywater system for toilet and urinal flushing.

Heating mode

- The ground source water serves as heat source on the evaporator side of the heat pump.

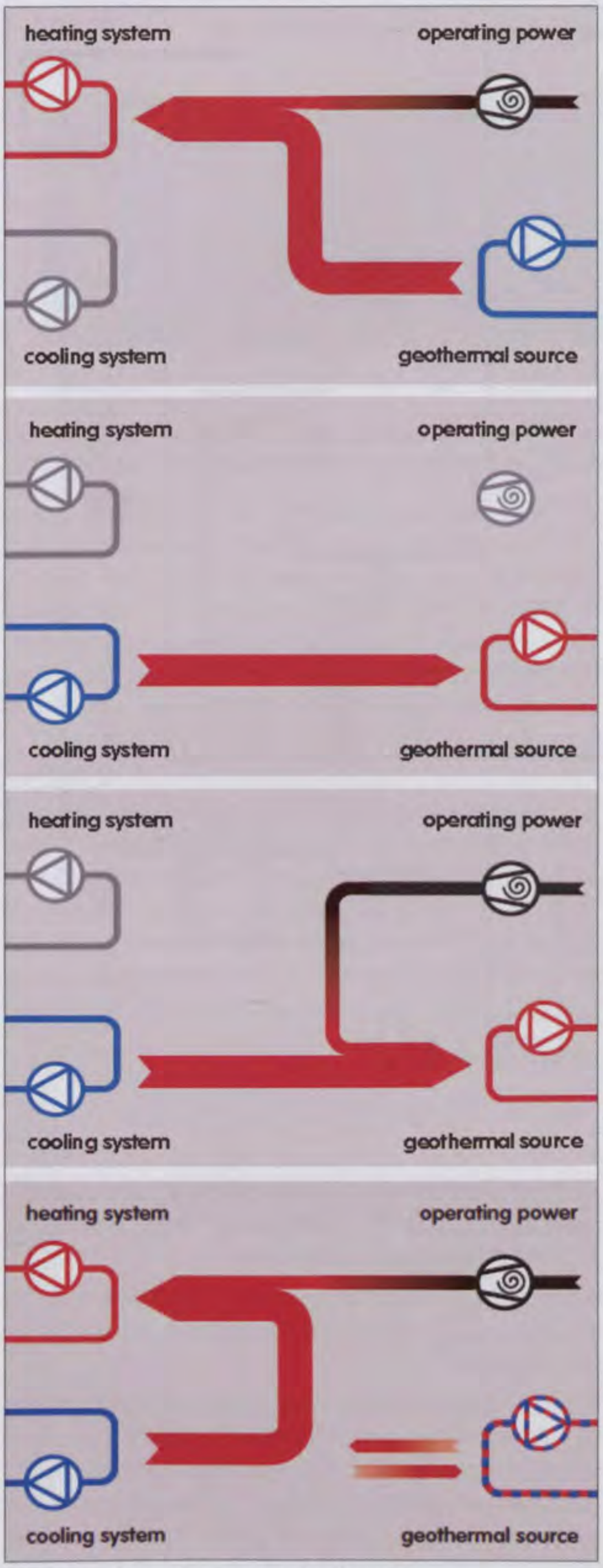

Fig. 11: Ground source heat pump modes of operation

- The heat pump raises the medium temperature groundwater (8 –19°C) heat source to a temperature level usable for the building (40 – 30°C LPWW).
- The LPWW system consists of AHU heating coils, reheat batteries, and FCU heating coils.
- The theoretical COP of the heat pump ranges between 5.1 – 7.7 in heating mode depending on LPWW supply temperatures (weather compensated) and CHW return temperatures, which are groundwater temperature dependent.

Free cooling mode

- Free cooling directly from the ground water without recourse to mechanical refrigeration is possible for large portions of the year.
- This is beneficial for server room cooling with COPs ranging between 10 - 20.
- The ground water provides chilled water in the range of 9 – 18°C depending on the time of year. During normal scheduled hours (NSH – typically 8.30 – 21.30 Mon - Fri) the CHW temperature is restricted to a maximum of 13°C for cooling of AHU coils and fan coils. Outside of NSH the CHW temperature is allowed to rise to 18°C to derive the maximum benefit of ground water cooling for the 24/7-server room load.

Cooling mode

- The ground source water serves as a cooling source by providing heat rejection on the condenser side of the heat pump.
- If no heating is required heat pump condenser inlet water temperatures are controlled in a range of 18 -22°C, depending on groundwater temperatures.
- The heat pump provides chilled water at 12°C when groundwater temperatures are too high during or outside NSH.
- The theoretical heat pump COP exceeds 7.5 in cooling mode for these conditions.

Simultaneous heating and cooling

- Can occur in heating or cooling mode.
- For dominant cooling loads the condenser water heat rejection is used by LPWW system (at required setpoint), and any excess heat is rejected to the ground water.
- For dominant heating loads, heat rejected to the CHW system by the server room and other sources provides the low temperature heat sink for the heat pump to produce upgraded heat for the LPWW system. If this is insufficient then the groundwater system will provide the required elevated CHW temperatures.
- COPs in excess of 10 are theoretically possible.

5.4 Data analysis

Due to the flood reinstatement works there are only six months (Jul – Dec 2010) operational energy data available. These figures have been extrapolated to provide estimated annual figures for 2010.

In Table 2 the MCC B9 (pumps) figures represent all primary and secondary pumps for the building, including groundwater pumps. The heat pump EPI of 7.14 kWh/m^2 is for the entire building area but distributed across only the conditioned areas served would increase to 10.4 kWh/m^2. This is the combined energy requirement for heating and cooling for areas of 10,979m^2, which illustrates the

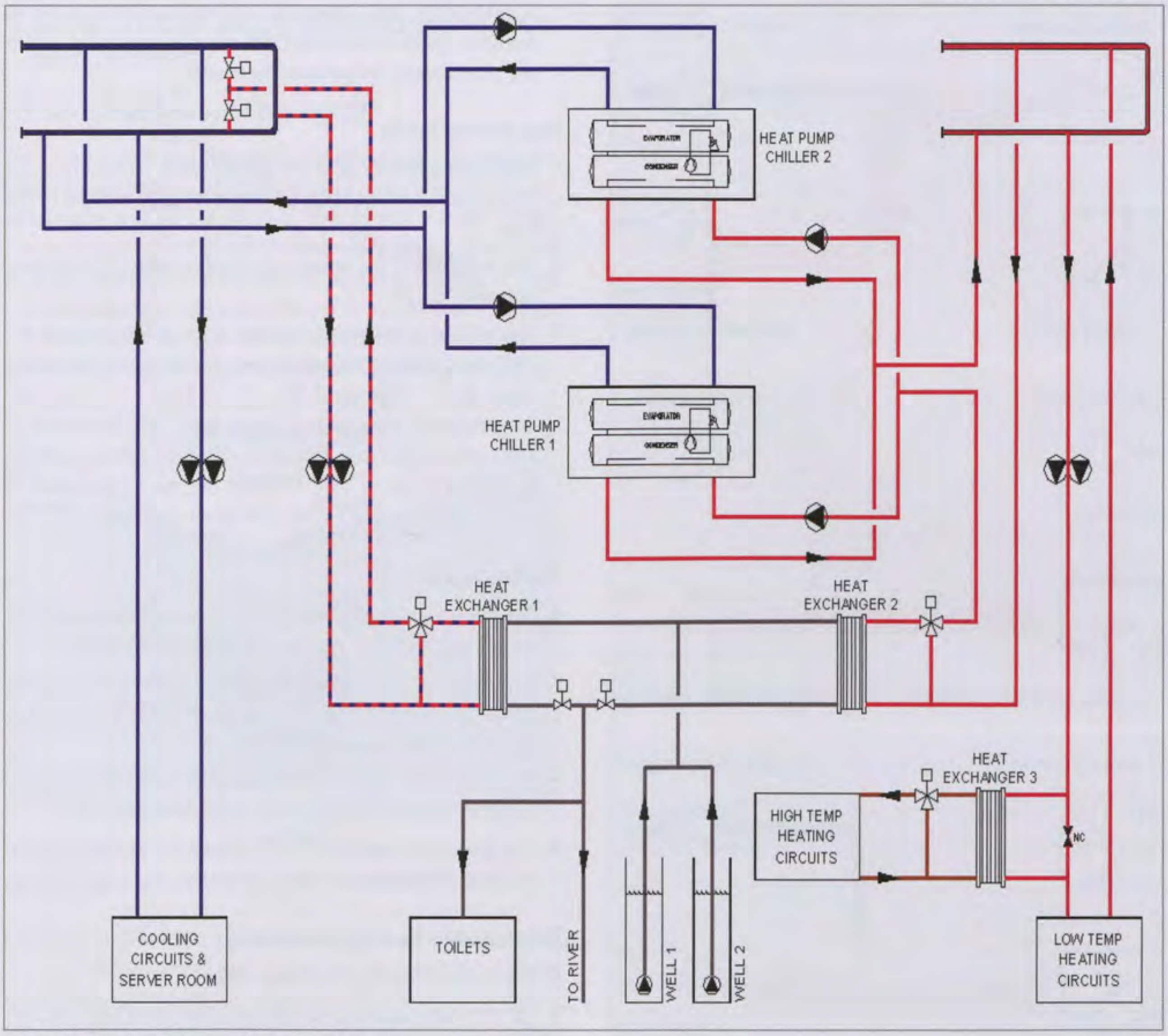

Fig. 12: Simplified ground source heat pump schematic

effectiveness of the simultaneous heating and cooling heat pump. To put the above figure in perspective, if the server room load of 60 kW were to be cooled by an air-cooled chiller with a seasonal COP of 3, the expected EPI would be 16.3 kWh/m² (area conditioned by heat pump).

	July – December Electrical Energy	Projected Annual Electrical Energy	Projected Annual EPI
MCC B9 (Pumps)	70,106 kWh	140,211 kWh	8.76 kWh/m²
Heat Pump 1	26,554 kWh	53,109 kWh	3.32 kWh/m²
Heat Pump 2	30,572 kWh	61,145 kWh	3.82 kWh/m²
Total Heat Pump	57,127 kWh	114,254 kWh	7.14 kWh/m²

Table 2: WGB heat pump heating and cooling electrical energy

	July – December Electrical Energy	Projected Annual Electrical Energy	Projected Annual EPI
Building Total	1,098,940 kWh	2,197,880 kWh	137.4 kWh/m²
Server Room	262,800 kWh	525,600 kWh	33.9 kWh/m²
Natural Gas	203,105 kWh	406,211 kWh	25.4 kWh/m²

Table 3: WGB building annual energy

Total mechanical electrical loads (including fans, pumps and heat pump) represents an EPI of 29.5 kWh/m² which accounts for 21.5% of the buildings total for the year.

In Table 3 the natural gas total includes LPHW boiler energy, lab gas usage and domestic hot water production by the stand alone gas fired heater.

A standard university building would be expected to achieve EPIs of 96.1 kWh/m² (electric) and 301.9 kWh/m² (fossil fuels) (CIBSE 2008) for similar operating hours. This represents a 59% reduction in energy use and a 30% reduction in CO_2 emissions (fig. 13). The building also compares favourably against Naturally Ventilated Office benchmarks indicated in ECON 19. Compared to the UCC average building stock for 09/10, the building represents a 47% improvement in energy usage and a 33% reduction in CO_2 emissions.

The server room constant electrical load is currently 60kW which represents 25% of the building total for the year. The server room is currently well under capacity compared to the original design, however, there are plans for significant further expansion in the next phase.

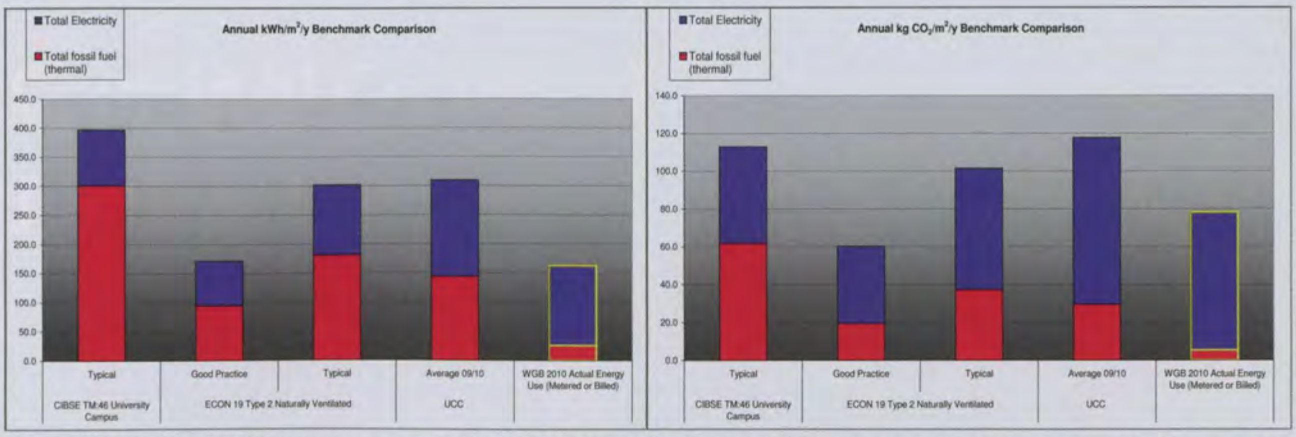

Fig. 13. CIBSE TM: 46 and ECON 19 Benchmarks adjusted for 2010 Cork Degree Heating Days (2,565) and actual building occupancy hours (5,235) according to CIBSE TM: 46 UCC 09/10 average figure (Ahern & O'Connor 2011) thermally adjusted only from 2,375 degree heating days to Cork 2010 Degree Heating Days (2,565)

In free cooling mode the submersible well VSD is currently operating at a minimum speed of 31 Hz (5.3 kW) which represents a cooling load of 300 kW (pump increases speed to maintain supply/exhaust temperature differentials). For free cooling of the server room at night the COP is currently above 10. As the cooling load increases in the future with the additional fit out, or during the summer months (largest recorded cooling currently is 330 kW), the COP of the free cooling mode will increase significantly.

Due to technical errors the energy meters recording cooling and heating demands for the building have not been recording data until December. As a result it is not possible to comment on the seasonal efficiency of the heat pump. A number of figures (14, 15, and 16) have been prepared to indicate the behaviour of the heat pump operation. During the summer an issue with the controls was preventing free cooling of the server room at night, meaning the heat pump was in cooling mode 24/7. This was rectified in September.

5.5 Conclusions and lessons learned

The analysis of the results indicates that the system is operating extremely efficiently with an annual combined EPI for cooling and heating of 10.4 kWh/m². This EPI is likely to improve as the building fit out is completed over the next two years.

Currently the system is significantly oversized as the heating and cooling loads (server room) predicted for the three storey building have not materialised. However, the additional two floors will have

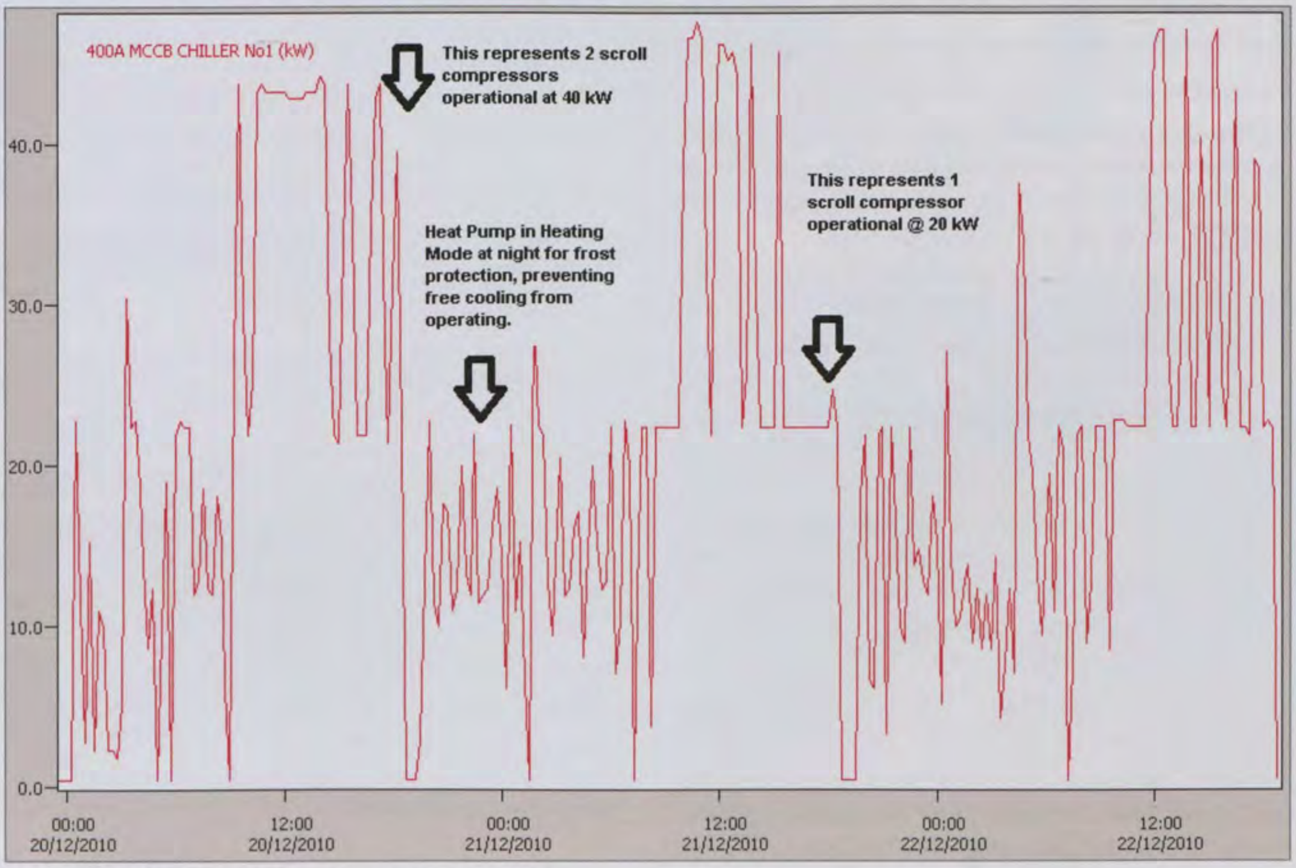

Fig. 14: WGB BMS snapshot – heat pump electrical power Dec 2010

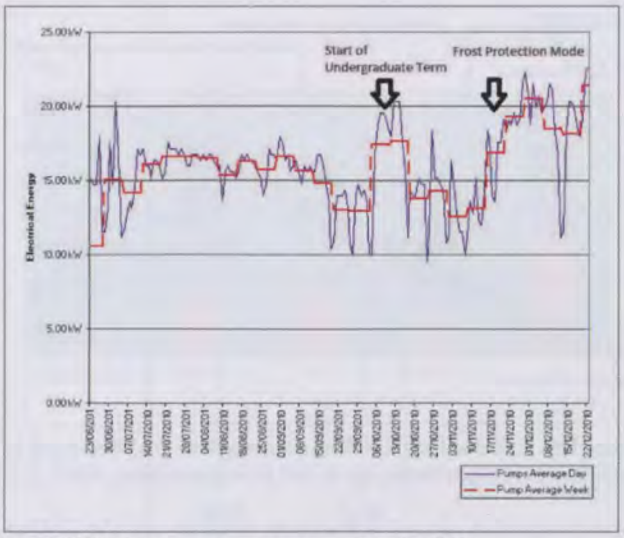

Fig. 15: WGB total pumping average energy Jul – Dec 2010

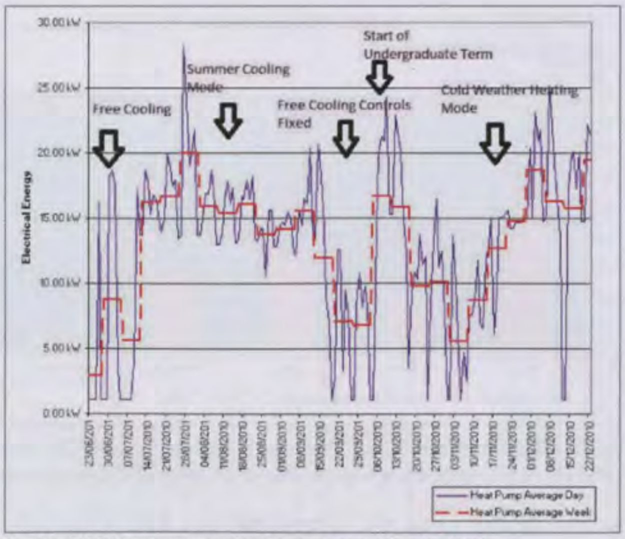

Fig. 16: WGB heat pump total average energy Jul – Dec 2010

significant heating and cooling requirements. The modular design of the system has ensured efficient operation at low part load.

Other notable lessons learned include:

- Complete trial boreholes well in advance of construction to avoid surprises.
- There is limited knowledge in the industry on how to construct and commission these systems. A detailed sequence of operations describing the complex control strategy is a prerequisite.
- Complex systems need seasonal commissioning in the first year of operation to ensure operation to the design intent.
- Avoid three-port valves on the CHW system as delta T degradation will significantly reduce heat recovery potential.

The project has demonstrated the following benefits:

- There is significantly lower energy consumption compared to traditional heating and cooling solutions. Fossil fuel heating is significantly reduced which, as the national electricity grid decarbonises, will reduce carbon emissions further.
- Successful recovery of waste heat from the server rooms (60 kW constant load with future expansion to 300 kW).
- Groundwater installations with highly variable water temperatures can be accommodated with the right control strategy and provide significant free cooling when coupled to high temperature CHW systems.
- Traditional CHW and LPHW systems can be designed to operate effectively with higher chilled water temperatures and significantly lower LPHW temperatures if carefully integrated into mechanical air systems.
- Energy usage and CO_2 emissions compares favourably with fully naturally ventilated buildings.

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