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IT Field Trial 1:
Office – Air and Water system

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Field Trials: Office building with centralized chillers. HVAC consumption during non-occupation schedule

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[anonymous Field Trial]

Overview of building and system

The building considered is formed by a 5 floors building, 2005 construction, connected to a XIX century building. The building is the headquarter of a service company. The system is an air/water multi zone, with two main AHU serving the two zone of the building. Terminals unit are chilled beams and fan-coils.

Parameter	Installed electrical load / kW	Floor area served / m2 GIA	Installed capacity W/m2 GIA	Annual consumption kWh	Average annual power W/m2	Annual use kWh/m2	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output)	648.0	3'500.0	185.1				
Total Chillers	162.0	3'500.0	46.3	140'582.6	4.6	40.2	9.9
Total CW pumps	13.8	3'500.0	3.9				
Total fans	45.0	3'500.0	12.9	35'000.0	1.1	10.0	8.9
Total humidifiers		3'500.0					
Total boilers ELECTRICAL		3'500.0					
Total HW pumps	12.4	3'500.0	3.5	5'246.6	0.2	1.5	4.8
Total HVAC electrical	220.8	3'500.0	63.1	180'000.0	5.9	51.4	9.3
Total Building Elec kWh		3'500.0		887'822.0	29.0	253.7	
Total Boilers/Heat kWh	600.0	3'500.0	171.4				
Total Building Gas/Heat kWh		3'500.0					

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Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E2.6	Apply night time over ventilation	PI6, PI12, C5, C6, C7	Modify control strategy
E4.5	Replace electrical equipment with Energy Star or low consumption types	PI22	--
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.1	Generate instructions (“user guide”) targeted to the occupants	PI7, PI8, PI9, PI10, P4	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O2.3	Shut off auxiliaries when not required	PI7, PI8, PI9, PI10, P4	Modify control strategy
O3.1	Shut chiller plant off when not required	PI7, PI12, PI21, C8	Re-programming schedule
O3.5	Maintain proper starting frequency and running time of (reversible) chillers	PI7, PI12, PI21, C8	Modify control strategy
O3.20	Apply indirect free cooling using the existing cooling tower (free chilling)	PI7, PI12, PI21, C8	Modify cool water circuits
O4.3	Shut off coil circulators when not required	PI7, PI12, PI21, C8	Modify control strategy
P2.5	Improve central chiller / refrigeration control	PI7, PI12, PI21, C8	Installing external RH measurement

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Office
Geographical location	Italy, Aosta
Gross Area	3500
N° Floors	5

Zone Description

Main Activity	Office
Area Conditioned [m^2]	3500
Volume conditioned [m^3]	9000
Max. Number of occupants	75
Occupation schedule /Hours Operation	8:30-13:30 14:30-17:00
Lighting Power density [w/m^2]	15
Type Lighting/lighting control	Automatic lighting control
Lighting schedule /Hours Operation	8:00-19:00

Construction Details (only as a support of EES tools)

Due to the heterogeneous type of building the EES tool was not be applied

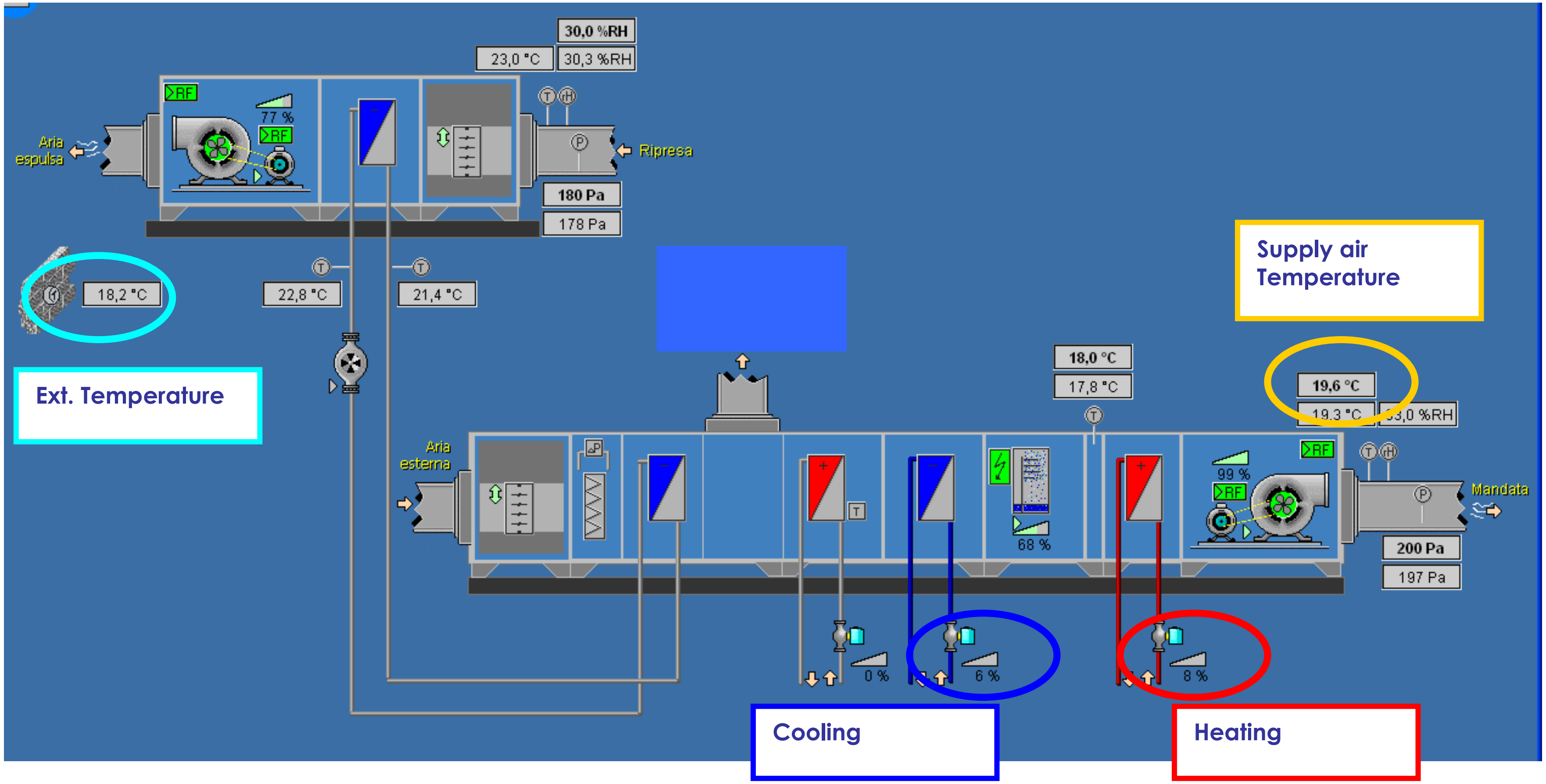
System Zone Description

System Type	Air/water system with chilled beams
Cooling Equipment Type of Fuel	Electricity
	BMS monitoring
Schedule and Operation Time [h/year]	6 days per week 8:00-18:00
Heating Equipment Type of Fuel	Gas
	Counters
Schedule and Operation Time [h/year]	6 days per week 8:00-18:00
Auxiliary HVAC Equipment	……………………………………kW
Terminal units	Chilled beams

Indoor Environment Parameters	**Measure/observe - Winter/Summer (average)**
Ventilation Rate [ach]	1 design
Indoor Relative Humidity [%]	50% design / 60% measured
Indoor air Temperature [°C] – Winter/Summer	20/26°C design 23°C average temperature measured during winter

Outdoor Environment Parameters	**Measure/observe - Winter/Summer (average)**
Outdoor air temperature [°C] Winter/Summer	-10° winter design temperature 20°C average temperature in July
Outdoor Relative Humidity [%] Winter/Summer	60/70

The inspection of the HVAC system, conduced in January 2008, revealed that chiller was in operation also during winter. The AHU's supply terminal units with 19°C 50% RH neutral air: it is unclear why is necessary cooling air when external conditions are below (in terms of Temperature and Relative Humidity) supply conditions. A simultaneous heating and cooling was detected.



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Quantifying the Energy losses due to simultaneous heating and cooling is possible by simulation or measurements. Simulation on a yearly basis could be really inaccurate, while measurements will be available only if building property will modify the control system.
Static energetic analysis indicates that, in the case showed before, for one hour, in stable conditions, 5.83 kWh of primary energy would be sufficient to heat the external air, while the overall consumption of primary energy in the actual case is 67,3 kWh to:

- cool the air from 18°C to 14°C (by electric chiller): 30.5 kWh
- heating the air from 14°C to 19°C (by gas boiler): 36.8 kWh

The estimation was calculated using Italian electric energy conversion factor and an average chiller COP of 3.5.
This simple estimation shows the huge potential of energy conservation in this system. Nevertheless, further quantification on annual basis has to be evaluated.

ECO P2.5, Improve central chiller/refrigeration control

An evaluation of this ECO was possible with medium term measurements, carried out from January to May 2009. Monitored data used for this purpose were:

- Consumption of HVAC system (AHU's not included)
- External Conditions (Temperature and Relative Humidity)

From hourly consumption data, the operation hours when External conditions was below 18°C and 50% Relative Humidity were selected:

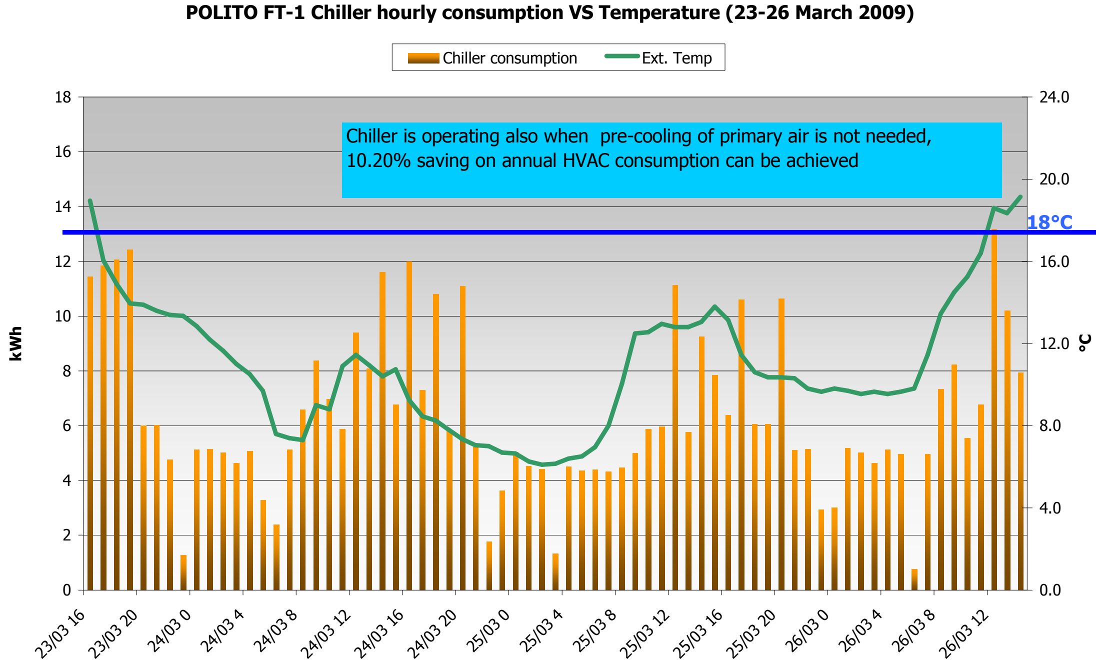
2009 HVAC Consumption (Chillers + pumps+ev. tower)			
I	01 Jan-27 Mar	22'989	kWh
II	27 Mar-11 May	12'349	kWh
III	11 May-15 June	14'236	kWh
IV	15 June-15 sept	70'090	kWh
Total		119'664	kWh

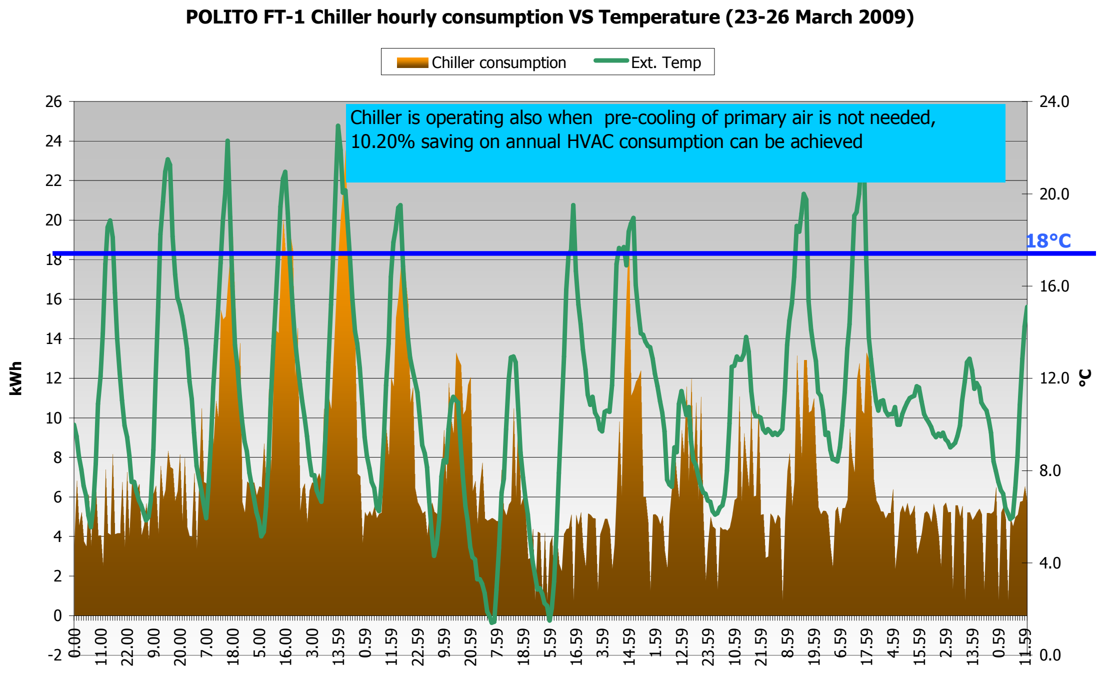
HVAC system consumption when T<18℃ & RH<50%					
I	**01 Jan-27 Mar**	9503.653	kWh	41.34%	on Jan-Mar consumption
II	27 Mar-11 May	2706.199	kWh	21.91%	on April-May consumption
Total		12209.85	kWh	10.20%	on annual consumption of HVAC
				34.55%	on Jan-May consumption of HVAC

These values permit to estimate savings, if a free cooling strategy based on enthalpy control was implemented. If the values of external temperature and RH was used to control the chiller equipment (shut off when T and RH are below supply conditions) the saving on January-May consumption of HVAC system would be:

- **34,55% on Jan-May HVAC consumption**
- **10.2% on annual consumption**

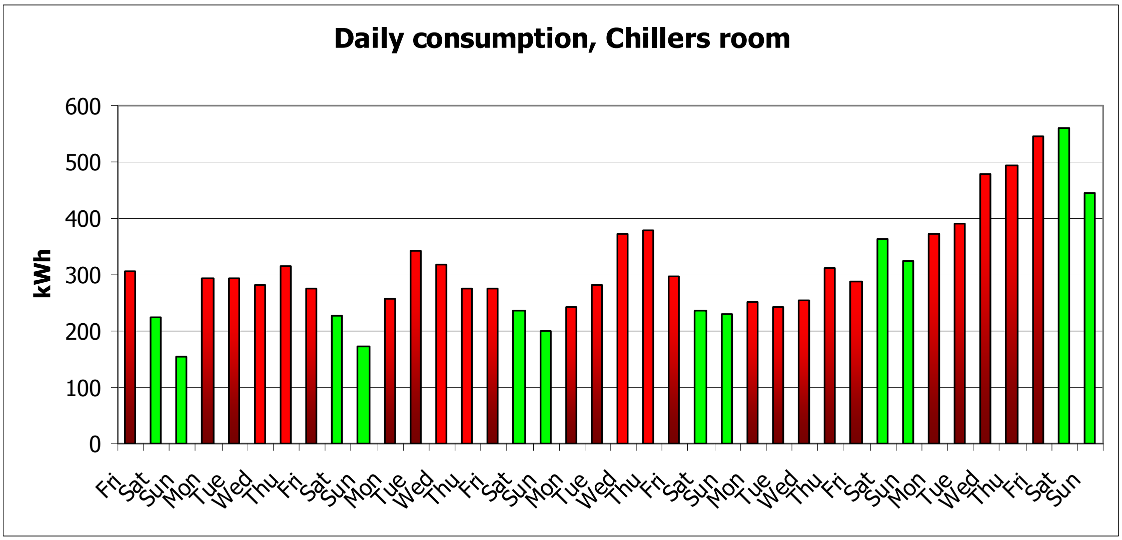
The annual value is underestimated, since the analysis does not consider the summer season (when it is reasonable to assume that external conditions below 18°C and 50% RH are less frequent).



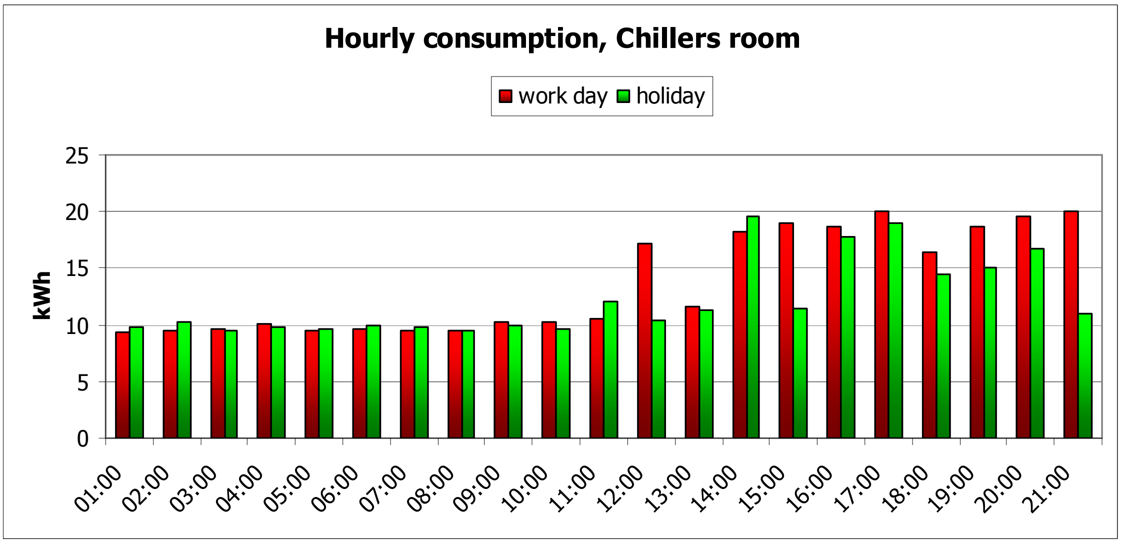


ECO O 3.1, Shut chiller plant off when not required

With medium term measurements (March-May 2008), it was possible to analyze the consumption of Chiller room.



In green non working days.



As seen in the graph, it is not possible to individuate any difference in system consumption between work days and holidays: relatively high energy conservation by simple schedule operation changing is therefore possible.

March-May consumption measurements			
Total		12'349	kWh
"7.00-18:00", Mon-Fri	39.9%	4'926.5	kWh
non-occupation	60.1%	7'422.5	kWh

From spot measurements, performed on 11 August 2008 (work day), the following result was obtained:

Summer day (11.08.2008) spot measurement		
Total		kWh
"7.00-18:00"	61.0%	kWh
non-occupation	39.0%	kWh

On a weekly basis, it seems reasonable **an energy saving about 40%** if the system was shut down when not needed. In this specific case the system is on because the setback temperature is not set properly.

HVACs' system components

The system in centralized. The main heating plant comprises a pair of Viessmann condensation boilers, rated at 300 thermal kW each (678 W electrical power each). The water from the boilers is circulated by 3 x 1,65 kW primary pumps, in a main collector, and six secondary pumps for different sections of the system (0,2 kW / 0,6 kW / 0,9 kW / 0,9 kW / 1,65 kW).

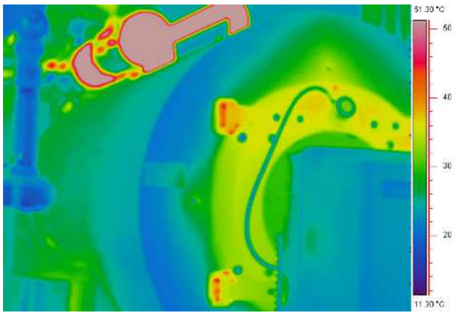
The cold water is provided by two McQuay electric chillers (screw) with heat recovery system on condenser, rated at 324 kW cooling capacity each, with a maximum electrical consumption of 92.5 kW each, and a nominal COP equal to 3.5. The refrigerant gas is R134A.

The system is an air/water multi-zone, with two main AHUs serving the two main zones of the building. Another AHU serves the archive. Terminal units are chilled beams and fan-coils.

- Heating systems (heat generators) and pumps
- Cooling systems (cold generators) and pumps
- Heat rejection and pumps
- AHU
- Pumps monitoring

Heat Generator and Pumps

Boiler Identification (X2)	
Manufacture/Model	Viessman / DMV
Year	2005
Equipment Type	Condensing boiler
Fuel Type	natural gas
Performance Data	
Nominal Heating Capacity [kW]	300
Installed Heating Capacity /m² GIA	171.4
Nominal Efficiency [%]	98
Water outlet temperature [°C]	60
Water inlet temperature [°C]	50
Electrical data	
Power supply [V/Ph/Hz]	230/1/50
Start-up amps [A]	NA



Auxiliary Equipment	
Pumps Electric Demand [kW]	4.95

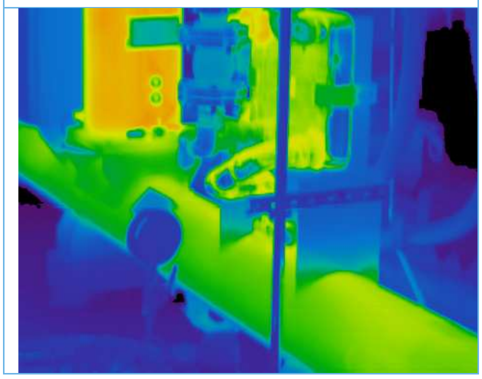
Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	No
Operation time estimated [h/year]	1800
Operating mode	automatic
Dirtiness of burner	**Satisfactory**
Thermal Insulation (Visual)	**Satisfactory**
Fuel leaks	no
Water leaks	no
Pressure status	**Satisfactory**
Sensors calibration records	no
Meter readings data	no

Field measurements	
Electricity consumption [kWh]	2500 kWh for the winter season

Cold Generator and Pumps

Chiller Identification (X2)	
Manufacture/Model	McQuay
Year	2005
System Type	Vapour compression
Compressor Type	Screw
Fuel Type	electric
Performance Data	
Nominal Cooling Capacity [kW]	324
Installed Cooling Capacity /m² GIA	92.5
Nominal Electric Power [kW]	81
COP	4
Refrigerant Gas	R134a
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	572



Auxiliary Equipment	
Fan Electrical Demand [kW]	
Pumps Electrical Demand primary cool water [kW]	4.5
Pumps El. Dem. heat rejection [kW]	6.6

Recuperator

Water leaking

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Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	no
Operating mode	automatic (always on, also in winter season)
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	4000
Vibration eliminators	**Satisfactory**
Worn couplings	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Satisfactory**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	water leakage from condenser/evaporative towers circuit
Sensors calibration records	no
Refrigerant leaks	no
Location of the equipment	inside

Field measurements	
Electricity consumption [kWh]	See previous ECO analysis
Electric voltage [V]	< 0.5 % variable in respect of nominal value
Electric current [A]	Max: 520 A

Heat Rejection System

Heat Rejection Identification	
Manufacture/Model	Baltimore VTL 072 K
Year	2005
Cooling method	evaporative towers
Performance Data	
Nominal Electric Power [kW]	7,5+2,2
Total Heat Rejection [kW]	360
Water flow rate [m³/h]	60
Water outlet temperature [°C]	29
Water inlet temperature [°C]	34
Electrical data	
Power supply [V/Ph/Hz]	380/3/50
Start-up amps [A]	21.5

Figure –Heat Rejection Plant

Auxiliary Equipment	
Fan Electrical Demand [kW]	11 kW
Pumps Electric Demand [kW]	3X 2.2

Water discharge due to broke automatic level trigger

Water connections

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	No
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	Serve only the chillers (4000
Equipment cleanliness	**Satisfactory**
Operation mode	automatic
Operating water level (sump)	**Unsatisfactory, water was continuously discharged**
Fan shaft bearings lubrication	**Satisfactory**
Drive system belt condition and tension	**Satisfactory**
Heat transfer section cleanliness	**Satisfactory**
Water systems leaks	No leaks, but the system is wasting a lot of water
Sensors calibration records	No
Correct rotation of the fan	Yes
Bleed rate [l/s]	

Control systems

The control system is based on Siemens DESIGO®. The system controls the schedule of different zones, and, depending on which occupation profile is currently active, it changes the set point for different zone.
Every zone has an ambient temperature probe and local control of temperature (± 3°C with respect to set-point).

AHUs provide neutral air for the chilled beams (18-22°C, depending on the season).

Energy consumption data

Metering information

The BEMS installed provides electric consumption of some HVAC sub-system:

- Evaporative towers
- Chillers and heat rejection water pumps
- Secondary water pumps (heat and cool water)

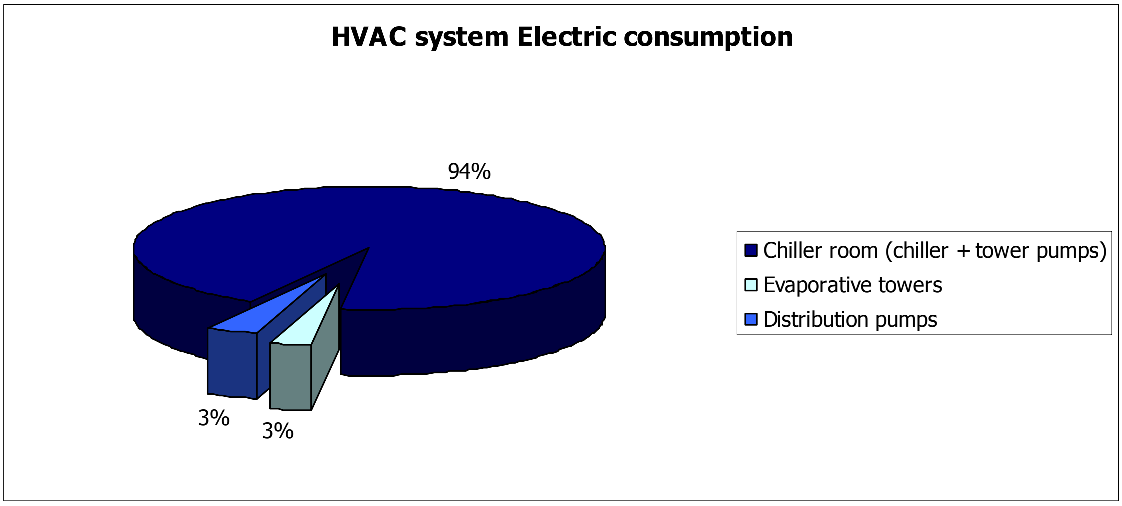
Monitoring observations

Despite the high potential performance of system components (variable flow pumps and fans, active chilled beams, active ventilated facade with solar irradiance control) the building presents a relatively high specific consumption:

- Chiller+cool pumps+evaporative towers : 38.16 kWh/m^2 year
- Chiller+cool pumps+evaporative towers : 20 kWh/m^2 summer season
-

Those values indicate that the cooling system has a huge consumption on the whole year. This seems not normal: Aosta is situated in climatic zone E (2800 heating degree days), normally in Winter and middle season cooling system has to be shut off.
Data on overall consumption were provided by BEMS:

Consumption 01-Jan-15 Sept	**kWh**	
HVAC system	133'572	% on HVAC
Chiller room (chiller + tower pumps)	125'186	93.72%
Evaporative towers	3'714	2.78%
Distribution pumps	4'672	3.50%



As seen in the graph the chiller is responsible for 94% of the HVAC system consumption (AHU's are not included).

Timing for inspection

Inspection Item	Short Description	Time (mins)
PI1	Location and number of AC zones	18
PI2	Documentation per zone	35
PI3	Images of zones/building	15
PI4	General zone data/zone	14
PI5	Construction details/zone	17
PI6	Building mass/air tightness per zone	15
PI7	Occupancy schedules per zone	8
PI8	Monthly schedule exceptions per zone	2
PI9	HVAC system description and operating setpoints per zone	45
PI10	Original design conditions per zone	15
PI11	Current design loads per zone	28
PI12	Power/energy information per zone	10
PI13	Source of heating supplying each zone	4
PI14	Heating storage and control for each zone	15
PI15	Refrigeration equipment for each zone	15
PI16	AHU for each zone	10
PI17	Cooling distribution fluid details per zone	8
PI18	Cooling terminal units details in each zone	15
PI19	Energy supply to the system	1
PI20	Energy supply to the building	1
PI21	Annual energy consumption of the system	10
PI22	Annual energy consumption of the building	10
	TOTAL TIME TAKEN (minutes)	**311**
	TOTAL (seconds/m^2)	**5.33**

Centralised system inspection data

Inspection	Short Description	Time (mins)

Item		
PC1	Details of installed refrigeration plant	20
PC2	Description of system control zones, with schematic drawings.	15
PC3	Description of method of control of temperature.	11
PC4	Description of method of control of periods of operation.	4
PC5	Floor plans, and schematics of air conditioning systems.	16
PC6	Reports from earlier AC inspections and EPC's	0
PC7	Records of maintenance operations on refrigeration systems	4
PC8	Records of maintenance operations on air delivery systems.	4
PC9	Records of maintenance operations on control systems and sensors	0
PC10	Records of sub-metered AC plant use or energy consumption.	4
PC11	Commissioning results where relevant	0
PC12	An estimate of the design cooling load for each system	45
PC13	Records of issues or complaints concerning indoor comfort conditions	0
PC14	Use of BMS	14
PC15	Monitoring to continually observe performance of AC systems	
C1	Locate relevant plant and compare details	35
C2	Locate supply the A/C system and install VA logger(s)	160
C3	Review current inspection and maintenance regime	5
C4	Compare system size with imposed cooling loads	5
C5	Estimate Specific Fan Power of relevant air movement systems	4
C6	Compare AC usage with expected hours or energy use	24
C7	Locate refrigeration plant and check operation	11
C8	Visual appearance of refrigeration plant and immediate area	4
C9	Check refrigeration plant is capable of providing cooling	3
C10	Check type, rating and operation of distribution fans and pumps	15
C11	Visually check condition/operation of outdoor heat rejection units	15
C12	Check for obstructions through heat rejection heat exchangers	10
C13	Check for signs of refrigerant leakage	9
C14	Check for the correct rotation of fans	0
C15	Visually check the condition and operation of indoor units	50
C16	Check air inlets and outlets for obstruction	20

C17	Check for obstructions to airflow through the heat exchangers	20
C18	Check condition of intake air filters.	10
C19	Check for signs of refrigerant leakage.	10
C20	Check for the correct rotation of fans	30
C21	Review air delivery and extract routes from spaces	15
C22	Review any occupant complaints	
C23	Assess air supply openings in relation to extract openings.	25
C24	Assess the controllability of a sample number of terminal units	20
C25	Check filter changing or cleaning frequency.	10
C26	Assess the current state of cleanliness or blockage of filters.	4
C27	Note the condition of filter differential pressure gauge.	3
C28	Assess the fit and sealing of filters and housings.	25
C29	Examine heat exchangers for damage or significant blockage	4
C30	Examine refrigeration heat exchangers for signs of leakage	4
C31	Note fan type and method of air speed control	2
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4
C33	Check location of inlets for proximity to sources of heat	2
C34	Assess zoning in relation to internal gain and solar radiation.	15
C35	Note current time on controllers against the actual time	10
C36	Note the set on and off periods	6
C37	Identify zone heating and cooling temperature control sensors	15
C38	Note zone set temperatures relative to the activities and occupancy	13
C39	Check control basis to avoid simultaneous heating and cooling	6
C40	Assess the refrigeration compressor(s) and capacity control	480
C41	Assess control of air flow rate through air supply and exhaust ducts	10
C42	Assess control of ancillary system components e.g. pumps and fans	10
C43	Assess how reheat is achieved, particularly in the morning	0
C44	Check actual control basis of system	8
	TOTAL TIME TAKEN (minutes)	**1'268**
	TOTAL (seconds/m^2)	**21.74**

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E2.6	Apply night time over ventilation	PI6, PI12, C5, C6, C7	Modify control strategy
E4.5	Replace electrical equipment with Energy Star or low consumption types	PI22	S.E.[1]
E4.6	Replace lighting equipment with low consumption types	PI22	S.E.
O1.1	Generate instructions ("user guide") targeted to the occupants	PI7, PI8, PI9, PI10, P4	S.E.
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	S.E.
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	S.E.
O2.3	Shut off auxiliaries when not required	PI7, PI8, PI9, PI10, P4	Modify control strategy
O3.1	Shut chiller plant off when not required	PI7, PI12, PI21, C8	Re-programming schedule
O3.5	Maintain proper starting frequency and running time of (reversible) chillers	PI7, PI12, PI21, C8	Modify control strategy
O3.20	Apply indirect free cooling using the existing cooling tower (free chilling)	PI7, PI12, PI21, C8	Modify cool water circuits
O4.3	Shut off coil circulators when not required	PI7, PI12, PI21, C8	Modify control strategy
P2.5	Improve central chiller / refrigeration control	PI7, PI12, PI21, C8	Installing external RH measurement

[1] Self explanatory

Overall conclusions

Considering the operation strategy of the plant, according to ECO O 3.1 it seems reasonable (and underestimated) **a percentage of 40% of savings** on cooling production consumption, if the system was shut down when not needed.

According to ECO P 2.5, if an external humidity sensor was installed and the values of external temperature and RH were used to control the chiller equipment (shut off when T and RH are below supply conditions) the saving on January-May consumption of HVAC system would be:

- **34,55% on Jan-May HVAC consumption**
- **10.2% on annual consumption**

The annual value is underestimated, since the analysis does not consider the summer season (when are less frequent external conditions below 18°C and 50% RH, but still happens).

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IT Field Trial 2: Theatre – All air system

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IT

August 2010

Supported by
Intelligent Energy Europe

Field Trial 2: Theatre served by underground source heat pump

Overview of building and system

The building considered is a XVIII century theatre. The building and the HVAC system were completely refurbished in 2009. The new system is based on a underground source water-to-water heat pump (open loop) serving an all air system for the main zones of the building and a radiant floor system for the entrance area.

Parameter	Installed electrical load / kW	Floor area served / m^2 GIA	Installed capacity W/m^2 GIA
Total Chillers nominal cooling capacity (cooling output) [e]	478.0	2'000.0	239.0 [a]
Total Chillers	144.0	2'000.0	72.0 [a]
Total CW pumps	36.0 [b]	2'000.0	18.0 [a]
Total fans	29.0	2'000.0	14.5 [a]
Total humidifiers		2'000.0	
Total boilers ELECTRICAL		2'000.0	
Total HW pumps	20.7	2'000.0	10.4 [a]
Total HVAC electrical	229.7	2'000.0	114.9 [a]
Total Building Elec kWh		2'000.0	
Total Boilers/Heat kWh	506.0	2'000.0	253.0 [a]
Total Building Gas/Heat kWh			

[a] The height of the ceiling in the main space is about 14 meters, this value explain the high electrical load per square meter of surface

[b] Include well water submersed pumps and fan coil pumps

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.6	Replace lighting equipment with low consumption types	PI22	Verify if possible, due to the nature of Scenic lighting
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O3.20	Apply indirect free cooling using underground water (free chilling)	PI7, PI12, PI21, C8	Modify cool water circuits

Due to the recent refurbishment, potential ECOs are few. Nevertheless some Operation and Management ECOs should be applied, along with circuit modification, to allow indirect free cooling. This ECO is potentially possible, but it implies significant modification: well water circuit and heat pump are located underground, while AHU are installed above the main zone, at almost 14 meter height.

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Sports and Entertainment
Geographical location	Turin
Net Area	2000 m^2
N° Floors	5 (the main stalls is on a single level, while the boxes are arranged on 3 tiers plus gallery)

Zone Description

Main Activity	Theatre
Area Conditioned [m^2]	2'000
Volume conditioned [m^3]	10'000 (estimated)
Max. Number of occupants	900
Occupation schedule /Hours Operation	19:30-23:00

System Zone Description

System Type	ground water heat pump
Cooling Equipment Type of Fuel	Electricity
	Meters
Schedule and Operation Time [h/year]	1000 (estimated)
Heating Equipment Type of Fuel	Electricity
Terminal units	All air

Indoor Environment Parameters	Measure/observe - Winter/Summer (average)
Indoor Relative Humidity [%]	50%
Indoor air Temperature [°C] – Winter/Summer	20-26°C

Outdoor Environment Parameters	Design	Measure/observe - Winter/Summer (average)
Outdoor air temperature [°C] Winter/Summer	-8 / 30.7	min -3 / max 36.4 avg: 6.1/ 25.3
Outdoor Relative Humidity [%] Winter/Summer	85% / 46%	77/ 61.6
Max. Solar Radiation [W/m²]		max 1119 (10.06.2008) avg : 63.6 / 203.1 (on 24h)

HVAC system components

The system considered based on a underground source water to water heat pump (open loop). Different systems serve different parts of the building, specifically: main stage, lobbies, stalls, boxes, and gallery are served by an all-air system, while a small portion of the building (entrance and bar) is served by radiant floor.

Heat Pump

General Identification	
Manufacture/Model	Climave neta / ERACS
Year	2008
Type	water to water
Performance Data	
EER – Cooling mode	2.9
COP – Heating mode	3.1
SEER	n.a.
Nominal Cooling Capacity [kW]	478
Nominal Heating Capacity [kW]	506
Refrigerant Gas	R134a
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Full load Ampere	263

Figure – Equipment pictures

Figure – Equipment pictures

Monitoring observations

Inspection	
Operating Mode	**automatic**
Maintenance status	**satisfactory**
Maintenance reports	**no**
Equipment cleanliness	**satisfactory**
Pressure status	**N.A.**
Water systems leaks	**no**
Sensors calibration records	**no**

Previous inspection reports	**no**
Operating time estimated [h/year]	**1000**
Tightness of wiring connections	**satisfactory**
Thermal insulation (Visual)	**satisfactory**

Figure – Pumps with inverter (cool/hot water)

Figure – underground water pumps

Field measurements	
Electricity consumption [kWh]	N.A.
Electric voltage [V]	400
Electric current [A]	N.A.

Timing for inspection

Inspection Item	Short Description	Time (mins)	Notes
PI1	Location and number of AC zones	18	
PI2	Documentation per zone	30	
PI3	Images of zones/building	15	
PI4	General zone data/zone	14	
PI5	Construction details/zone	30	
PI6	Building mass/air tightness per zone	10	
PI7	Occupancy schedules per zone	8	
PI8	Monthly schedule exceptions per zone	2	
PI9	HVAC system description and operating setpoints per zone	20	
PI10	Original design conditions per zone	15	
PI11	Current design loads per zone	23	
PI12	Power/energy information per zone	10	
PI13	Source of heating supplying each zone	2	
PI14	Heating storage and control for each zone	3	
PI15	Refrigeration equipment for each zone	3	
PI16	AHU for each zone	5	
PI17	Cooling distribution fluid details per zone	8	
PI18	Cooling terminal units details in each zone	4	
PI19	Energy supply to the system	1	
PI20	Energy supply to the building	1	
PI21	Annual energy consumption of the system		N.A.
PI22	Annual energy consumption of the building		N.A
	TOTAL TIME TAKEN (minutes)	**232**	
	TOTAL (seconds/m^2)	**6.96**	2000

Inspection Item	Short Description	Time (mins)	Notes
PC1	Details of installed refrigeration plant	15	
PC2	Description of system control zones, with schematic drawings.	10	
PC3	Description of method of control of temperature.	10	
PC4	Description of method of control of periods of operation.	2	
PC5	Floor plans, and schematics of air conditioning systems.	12	
PC6	Reports from earlier AC inspections and EPC's	0	not available
PC7	Records of maintenance operations on refrigeration systems	4	
PC8	Records of maintenance operations on air delivery systems.	4	
PC9	Records of maintenance operations on control systems and sensors	0	not available
PC10	Records of sub-metered AC plant use or energy consumption.		N.A.
PC11	Commissioning results where relevant	0	not available
PC12	An estimate of the design cooling load for each system	25	
PC13	Records of issues or complaints concerning indoor comfort conditions	0	not available
PC14	Use of BMS	10	
PC15	Monitoring to continually observe performance of AC systems		
C1	Locate relevant plant and compare details	25	
C2	Locate supply the A/C system and install VA logger(s)	45	include PC 15
C3	Review current inspection and maintenance regime	5	
C4	Compare system size with imposed cooling loads	5	
C5	Estimate Specific Fan Power of relevant air movement systems	4	on label data
C6	Compare AC usage with expected hours or energy use	20	compare bills
C7	Locate refrigeration plant and check operation	8	
C8	Visual appearance of refrigeration plant and immediate area	4	
C9	Check refrigeration plant is capable of providing cooling	3	termometers mounted on fluid distribution network
C10	Check type, rating and operation of distribution fans and pumps	10	
C11	Visually check condition/operation of outdoor heat rejection units		underground water consensed
C12	Check for obstructions through heat rejection heat		underground water

	exchangers		conensed
C13	Check for signs of refrigerant leakage	5	1 unit
C14	Check for the correct rotation of fans		not possible
C15	Visually check the condition and operation of indoor units		all air system
C16	Check air inlets and outlets for obstruction	20	in addiction to C15
C17	Check for obstructions to airflow through the heat exchangers	20	in addiction to C15
C18	Check condition of intake air filters.	10	in addiction to C15
C19	Check for signs of refrigerant leakage.	10	in addiction to C15
C20	Check for the correct rotation of fans	30	in addiction to C15
C21	Review air delivery and extract routes from spaces	15	in addiction to C15
C22	Review any occupant complaints		not available
C23	Assess air supply openings in relation to extract openings.	20	
C24	Assess the controllability of a sample number of terminal units		all air system
C25	Check filter changing or cleaning frequency.	10	
C26	Assess the current state of cleanliness or blockage of filters.	4	
C27	Note the condition of filter differential pressure gauge.	3	
C28	Assess the fit and sealing of filters and housings.	20	
C29	Examine heat exchangers for damage or significant blockage	4	
C30	Examine refrigeration heat exchangers for signs of leakage	4	
C31	Note fan type and method of air speed control	2	
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4	
C33	Check location of inlets for proximity to sources of heat	2	
C34	Assess zoning in relation to internal gain and solar radiation.	10	
C35	Note current time on controllers against the actual time		
C36	Note the set on and off periods	6	
C37	Identify zone heating and cooling temperature control sensors	15	
C38	Note zone set temperatures relative to the activities and occupancy	10	
C39	Check control basis to avoid simultaneous heating and cooling	6	
C40	Assess the refrigeration compressor(s) and capacity control	240	with climacheck
C41	Assess control of air flow rate through air supply and exhaust ducts	10	

C42	Assess control of ancillary system components e.g. pumps and fans	10	
C43	Assess how reheat is achieved, particularly in the morning		not available
C44	Check actual control basis of system	8	
	TOTAL TIME TAKEN (minutes)	**719**	
	TOTAL (seconds/m^2)	**21.57**	2000

Overall conclusions

The system analyzed represents state of the art of HVAC in historical buildings. Different thermal loads and air exchange per hour in different zones represented an interesting challenge for system designer. In addition, noise control of HVAC system was crucial in this project: air outlet and intake in the zones was in general over sized to insure low air flow speed.

HVAC systems of such complexity should be thoroughly commissioned and monitored for at least one entire year of operation, and then conducted by a highly qualified operator, in order to be able to deliver their expected design performance. In this case the overall system performance was not assessed, due to lack of measurements.

HARMONAC

IT Field Trial 3:
Surgery rooms – All Air system

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IT

August 2010

Supported by
Intelligent Energy Europe

Field Trials 3: Hospital, electrical consumption of an all air system for surgery rooms, winter season.

Overview of building and system

The system considered is "all-air" (100% outdoor air) serving three surgery rooms. Total conditioned surface is about 105 square meters. Cooling is provided by two identical chillers, each rated at 210 kW of refrigerant power. Ambient conditions for surgery rooms are imposed by national law: the air exchange rate must be at least 15 vol/hour and no recirculation is allowed; temperature in the room has to be limited between 20° and 24°C.

Some user feedbacks indicate that in surgeries characterized by high internal load (typically orthopedic surgery) the room temperature increase causing discomfort.

Parameter	Installed electrical load / kW	Floor area served / m^2 GIA	Installed capacity W/m^2 GIA	Annual consumption kWh	Average annual power W/m^2	Annual use kWh/m^2	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output) [e]	420.0	105.0	4'000.0				
Total Chillers	155.4	105.0	1'480.0	110'407.0	120.0	1'051.5	8.1
Total CW pumps	15.0	105.0	142.9				
Total fans	48.4	105.0	461.0				
Total humidifiers		105.0					
Total boilers ELECTRICAL		105.0					
Total HW pumps	10.0	105.0	95.2				
Total HVAC electrical		105.0					
Total Building Elec kWh		105.0					
Total Boilers/Heat kWh		105.0					
Total Building Gas/Heat kWh		105.0					

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--

O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--
O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--
O3.5	Maintain proper starting frequency and running time of (reversible) chillers	PI7, PI12, PI21, C8	Modify control strategy
P2.5	Improve central chiller / refrigeration control	PI7, PI12, PI21, C8	Modify control strategy

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Health and Care
Geographical location	Ivrea, (Turin Province)
Net Area	105 m^2
N° Floors	1

Zone Description

Main Activity	Surgery rooms
Area Conditioned [m^2]	105
Volume conditioned [m^3]	420
Max. Number of occupants	30
Occupation schedule /Hours Operation	variable
Lighting Power density [w/m^2]	20
Type Lighting/lighting control	manual
Lighting schedule /Hours Operation	variable
Other Equipment [kW]	10

Construction Details (only as a support of EES tools)

Not provided, the surgery rooms do not have external wall

System Zone Description

System Type	All air
Cooling Equipment Type of Fuel	Electricity
	Meters
Schedule and Operation Time [h/year]	8600 (the surgery rooms has to be operational during the whole year)
Heating Equipment Type of Fuel	Low sulphur Oil
Terminal units	All air

Indoor Environment Parameters	Measure/observe - Winter/Summer (average)
Ventilation Rate [ach]	15
Indoor Relative Humidity [%]	50%
Indoor air Temperature [°C] – Winter/Summer	18-22°C

Outdoor Environment Parameters	Measure/observe - Winter/Summer (average)
Outdoor air temperature [°C] Winter/Summer	min -3 / max 36.4 avg: 6.1/ 25.3
Outdoor Relative Humidity [%] Winter/Summer	77/ 61.6

HVAC system components

The system considered is an "all-air" (100% outdoor air) serving three surgery rooms. Cooling is provided by two identical chillers, rated at 210 kW of refrigerant power. Air is provided by a single AHU with duplicated motor (to ensure operation reliability).

The Case Study considers the cooling system.

Cold Generator and Pumps

Chiller Identification (X2)	
Manufacture/Model	CLIVET WRAT-2 2.100
Year	1995 (?)
System Type	Dry cooled
Compressor Type	Reciprocating
Fuel Type	electricity
Performance Data	
Nominal Cooling Capacity [kW]	210
Installed Cooling Capacity /m² GIA	4038
Nominal Electric Power [kW]	77.7
COP/EER (Eurovent)	2.7
Refrigerant Gas	R407c
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	N.A.

Figure – Equipment pictures

Figure – cool water inlet and outlet

Auxiliary Equipment	
Fan Electrical Demand [kW]	N.A.
Pumps Electric Demand [kW]	N.A.

Figure – damaged insulation

Vibrations eliminator

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	**No**
Operating mode	**Automatic**
Thermal Insulation (Visual)	Satisfactory, unless some damage on the cold water pipe's insulation
Operation time estimated [h/year]	4000 each group
Vibration eliminators	**Satisfactory**
Worn couplings	**No**
Equipment cleanliness	**Satisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Satisfactory**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	**No**
Sensors calibration records	**No**
Refrigerant leaks	**No**
Location of the equipment	**Exterior**

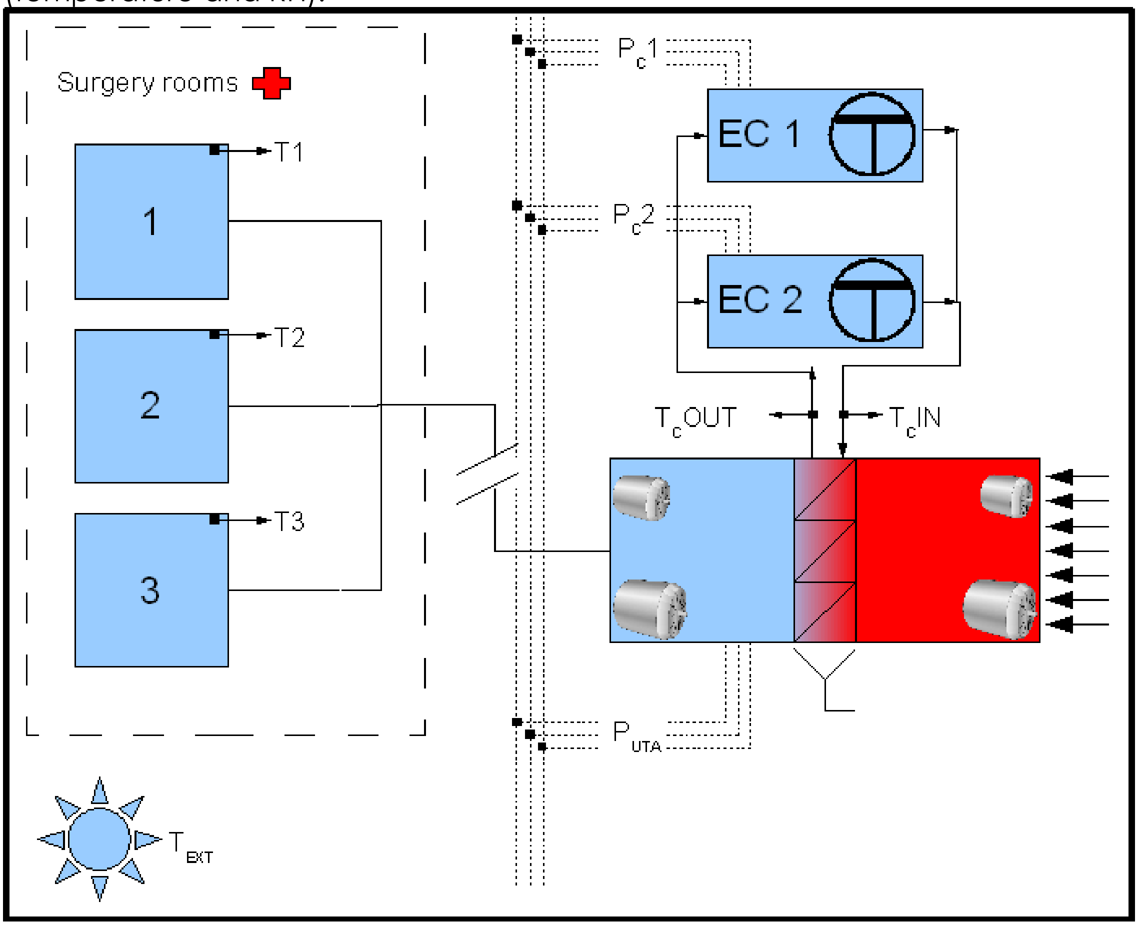
Field measurements	
Electricity power [kW]	69.2
Electric voltage [V]	400

Control systems

The system was not provided of BEMS, so the unit works in manual settings. The chillers were never stopped, even in the winter season.

Metering information

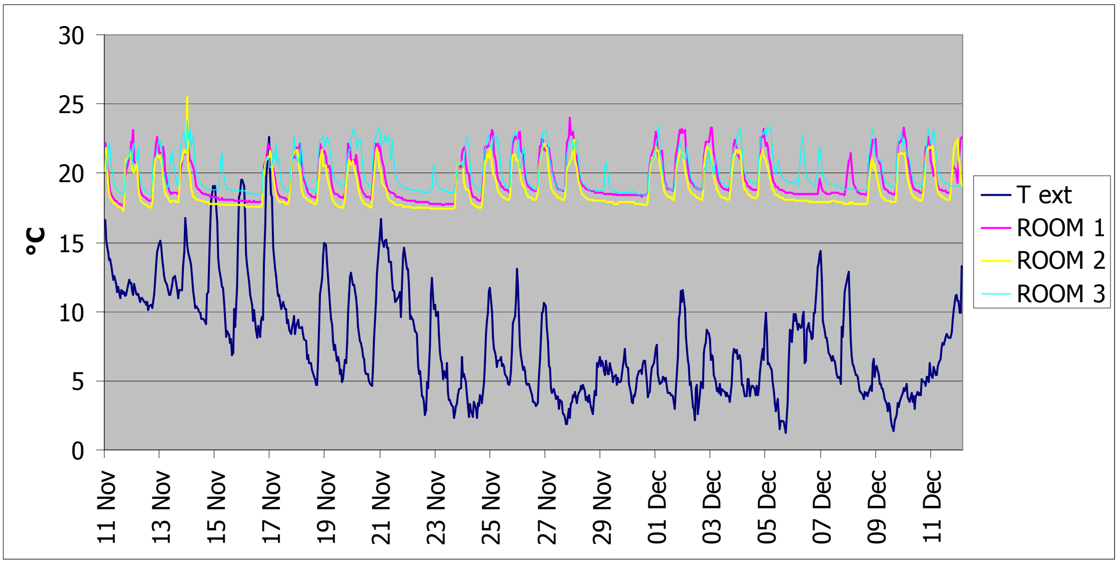
From December 2008 to February 2009 the system and the surgery rooms were monitored, to log chiller consumption and room ambient condition (temperature and RH).



EC:	electric chiller
Pc:	active power of electric chillers
Tc:	cooling water temperature
PUTA:	AHU's fans active power
T:	temperature and relative humidity

Monitoring observations

The graphs shown below demonstrate that users complaints was well addressed: despite the chillers works without interruption (at 25% load) the rooms temperature increase dramatically during surgeries. **The ideal temperature for surgery room during orthopedic surgeries should be 18°C, in some cases this temperature reach 25°C.**



ECO P2.5, Improve central chiller/refrigeration control

An evaluation of this ECO was possible with medium term measurements, carried out from December 2008 to February 2009. Monitored data used for this purpose were:

- Consumption of electric chillers
- Outdoor Conditions (Temperature and Relative Humidity)
- Room conditions (Temperature and Relative Humidity)

Due to high internal loads, surgery rooms often present a positive cooling load in winter too; for this reason we assumed that such loads could be offset with outdoor air (without mechanical cooling) when external conditions are below 14°C and 50% Relative Humidity. From hourly consumption data, the operation hours were selected that satisfy such condition.

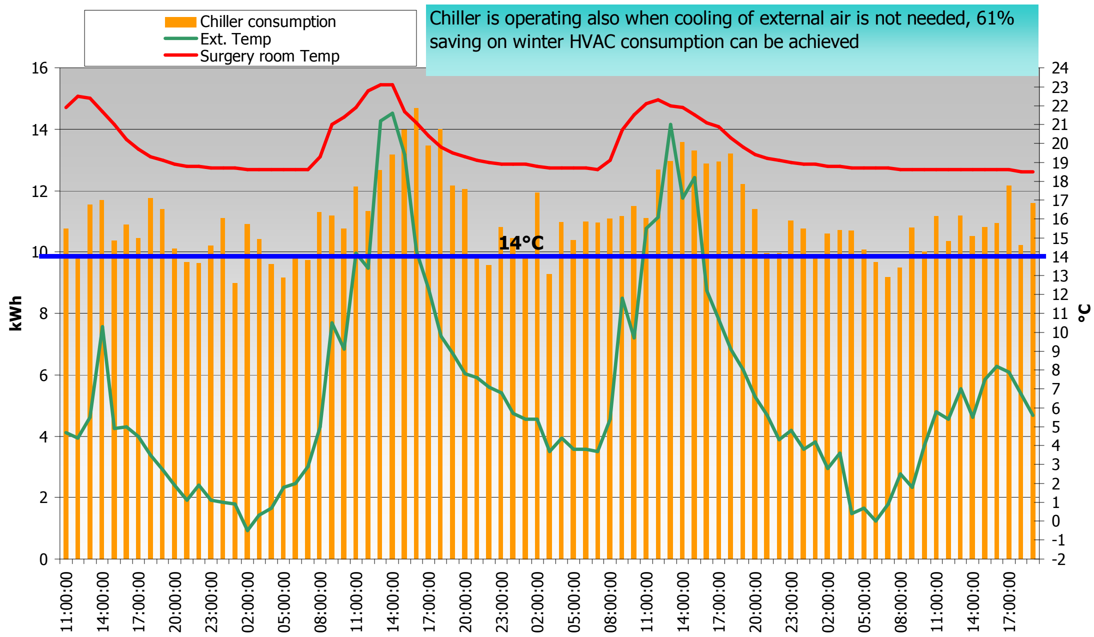
Chillers Consumption (22 Dec 2008- 18 Jan 2009)
7'979 kWh
Chiller room consumption when T<14°C & RH<50%
4'879 kWh

The above values permit to estimate the savings that could be achieved if the values of external temperature and RH were used to control the chiller equipment (shut off when T and RH are below supply conditions); the saving on Dec-Jan consumption of HVAC system would be:

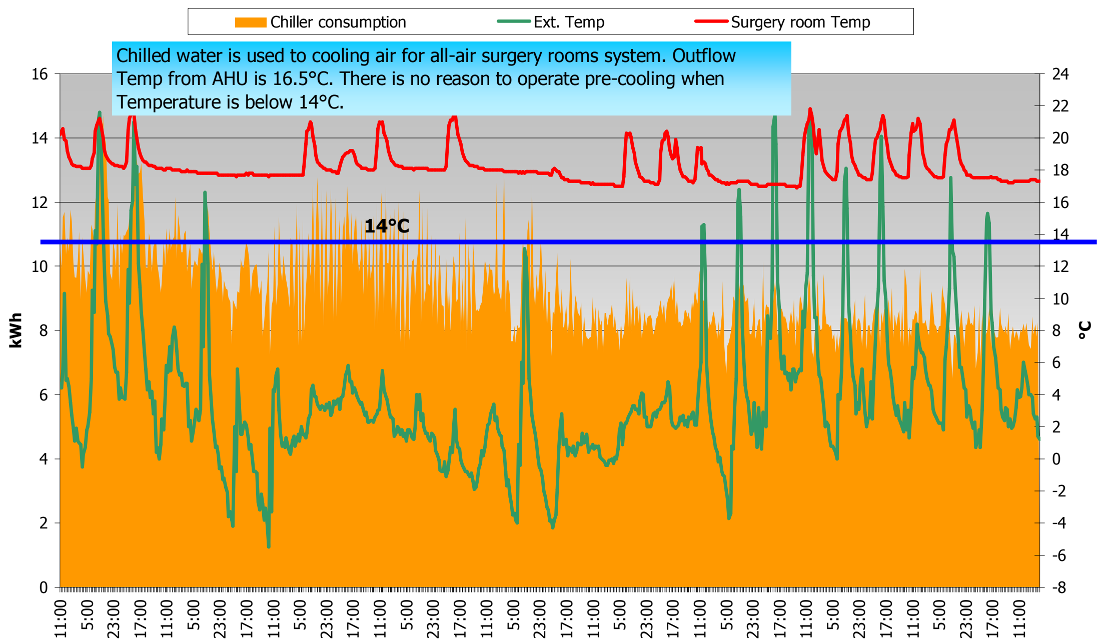
- **61.15% on Dec-Jan chiller consumption**

The annual value is not available, but, by former experience in relatively cool climatic conditions, it is reasonable to estimate a yearly saving of 8-15% on chillers consumption.

POLITO FT-SRI Chiller hourly consumption VS Temperature (22-25 Dec 2008)



POLITO FT-SRI Chiller hourly consumption VS Temperature (22 Dec 2008-18 Jan 2009)



Inspection Item	Short Description	Time (mins)
PI1	Location and number of AC zones	1
PI2	Documentation per zone	1
PI3	Images of zones/building	5
PI4	General zone data/zone	5
PI5	Construction details/zone	10
PI6	Building mass/air tightness per zone	5
PI7	Occupancy schedules per zone	
PI8	Monthly schedule exceptions per zone	2
PI9	HVAC system description and operating setpoints per zone	8
PI10	Original design conditions per zone	5
PI11	Current design loads per zone	5
PI12	Power/energy information per zone	4
PI13	Source of heating supplying each zone	1
PI14	Heating storage and control for each zone	2
PI15	Refrigeration equipment for each zone	3
PI16	AHU for each zone	5
PI17	Cooling distribution fluid details per zone	4
PI18	Cooling terminal units details in each zone	
PI19	Energy supply to the system	1
PI20	Energy supply to the building	1
PI21	Annual energy consumption of the system	
PI22	Annual energy consumption of the building	
	TOTAL TIME TAKEN (minutes)	**68**
	TOTAL (seconds/m^2)	**35.48**

Centralised system inspection data

Inspection Item	Short Description	Time (mins)
PC1	Details of installed refrigeration plant	15

PC2	Description of system control zones, with schematic drawings.	10
PC3	Description of method of control of temperature.	10
PC4	Description of method of control of periods of operation.	2
PC5	Floor plans, and schematics of air conditioning systems.	4
PC6	Reports from earlier AC inspections and EPC's	0
PC7	Records of maintenance operations on refrigeration systems	4
PC8	Records of maintenance operations on air delivery systems.	4
PC9	Records of maintenance operations on control systems and sensors	0
PC10	Records of sub-metered AC plant use or energy consumption.	
PC11	Commissioning results where relevant	0
PC12	An estimate of the design cooling load for each system	5
PC13	Records of issues or complaints concerning indoor comfort conditions	0
PC14	Use of BMS	10
PC15	Monitoring to continually observe performance of AC systems	
C1	Locate relevant plant and compare details	15
C2	Locate supply the A/C system and install VA logger(s)	90
C3	Review current inspection and maintenance regime	5
C4	Compare system size with imposed cooling loads	5
C5	Estimate Specific Fan Power of relevant air movement systems	4
C6	Compare AC usage with expected hours or energy use	20
C7	Locate refrigeration plant and check operation	8
C8	Visual appearance of refrigeration plant and immediate area	4
C9	Check refrigeration plant is capable of providing cooling	3
C10	Check type, rating and operation of distribution fans and pumps	5
C11	Visually check condition/operation of outdoor heat rejection units	3
C12	Check for obstructions through heat rejection heat exchangers	3
C13	Check for signs of refrigerant leakage	8
C14	Check for the correct rotation of fans	7
C15	Visually check the condition and operation of indoor units	
C16	Check air inlets and outlets for obstruction	10
C17	Check for obstructions to airflow through the heat exchangers	10
C18	Check condition of intake air filters.	10

C19	Check for signs of refrigerant leakage.	10
C20	Check for the correct rotation of fans	15
C21	Review air delivery and extract routes from spaces	15
C22	Review any occupant complaints	10
C23	Assess air supply openings in relation to extract openings.	
C24	Assess the controllability of a sample number of terminal units	
C25	Check filter changing or cleaning frequency.	10
C26	Assess the current state of cleanliness or blockage of filters.	4
C27	Note the condition of filter differential pressure gauge.	3
C28	Assess the fit and sealing of filters and housings.	20
C29	Examine heat exchangers for damage or significant blockage	4
C30	Examine refrigeration heat exchangers for signs of leakage	4
C31	Note fan type and method of air speed control	2
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4
C33	Check location of inlets for proximity to sources of heat	2
C34	Assess zoning in relation to internal gain and solar radiation.	0
C35	Note current time on controllers against the actual time	
C36	Note the set on and off periods	6
C37	Identify zone heating and cooling temperature control sensors	5
C38	Note zone set temperatures relative to the activities and occupancy	0
C39	Check control basis to avoid simultaneous heating and cooling	10
C40	Assess the refrigeration compressor(s) and capacity control	240
C41	Assess control of air flow rate through air supply and exhaust ducts	10
C42	Assess control of ancillary system components e.g. pumps and fans	10
C43	Assess how reheat is achieved, particularly in the morning	
C44	Check actual control basis of system	8
	TOTAL TIME TAKEN (minutes)	**666**
	TOTAL (seconds/m^2)	**347.48**

Overall conclusions

If improvement on the system control was adopted (chiller control based on outdoor temperature and RH) , the saving on HVAC consumption would be:

- **61.15% on Dec-Jan chiller consumption**

HARMONAC

IT Field Trial 4:
Laboratories and Office – Ground source heat pump

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August 2010

Supported by
Intelligent Energy Europe

Field Trial: EIDOS Laboratories and office with ground source heat pump

Overview of building and system

The building is situated in Chieri in Turin province (Italy) and consists of three storeys, for a total floor surface area of 6,500 m² and a volume of 21,600 m³. The basement includes a large parking area, services, and the heating and cooling central plant; the production and storage areas are at the ground floor, while most offices and laboratories are situated at the first floor. The top floor hosts the meeting rooms, cafeteria and nursery. The HVAC system is of air and water type, served by two ground source heat pumps (GSHPs). Two phase change storage (PCS) vessels are installed.

Parameter	Installed electrical load / kW	Floor area served / m² GIA	Installed capacity W/m² GIA	Annual consumption kWh	Average annual power W/m²	Annual use kWh/m²	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output)	600.0	6'500.0	92.3				
Total Chillers	114.0	6'500.0	17.5	103'011.3	1.8	15.8	10.3
Total fans		6'500.0		16'668.0	0.3	2.6	
Total Boilers/Heat kWh	436.0	6'500.0	67.1		error	error	error

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Office/Laboratories
Geographical location	Italy, Turin
Gross Area	6500
N° Floors	3

Zone Description

Main Activity	Office/Laboratories
Area Conditioned [m^2]	6500
Volume conditioned [m^3]	18200
Max. Number of occupants	100
Occupation schedule /Hours Operation	10h/day, 5days/week
Lighting Power density [W/m^2]	25
Type Lighting/lighting control	manual
Lighting schedule /Hours Operation	8:00-18:00 Mon-Fri
Other Equipment [kW]	n° 90 computers (100 W each in normal operation, 350 W as maximum input) = 1.3 W/m^2

System Zone Description

System Type	air and water
Required Cooling capacity	254 kW
Cooling Equipment Type of Fuel	Electricity
	BMS
Required Heating capacity	152 kW
Heating Equipment Type of Fuel	Electricity
	BMS
Cooling/Heating capacity [kW]	299/218 ; 57 kW each of electric input

Indoor Environment Parameters	Measure/observe - Winter/Summer (average)
Ventilation Rate [ach]	0.2
Indoor Relative Humidity [%]	50%/55%
Indoor air Temperature [°C] – Winter/Summer	20/25

Outdoor Environment Parameters	Measure/observe - Winter/Summer (average)
Outdoor air temperature [°C] Winter/Summer	-8/33
Outdoor Relative Humidity [%] Winter/Summer	not available

HVACs' system components

The building is entirely conditioned year-round with a centralized four-pipe air–water HVAC system. Hot and chilled water are produced by two reversible ground-source heat pumps (GSHP), with vertical borehole heat exchangers (HX). In the intermediate season, one HP may provide heating and the other cooling. The HPs have a heating output of 218 kW each and a cooling output of 299 kW each. The electric input is 57 kW for each HP.

Based on preliminary field tests, 32 single pipe, 100 m deep borehole HX were installed. All HVAC equipment was sized for low-temperature heating and high-temperature cooling to maximize the HP efficiency.

In order to reduce the installed heating and cooling power – and consequently to limit the system initial cost, including the cost of the borehole field – it was decided to equip the system with two (hot and cold) phase-changing storage (PCS) vessels, connected in parallel to the HPs. The phase transition temperature is 46°C and 13°C, respectively for the hot and cold storage; the corresponding thermal capacity of the two vessels is 900 kWh (heating) and 990 kWh (cooling).

A main collector feeds hot/cold water, with variable speed pumps, two three distinct circuits:

- Air Handling Units (equipped with air-to-air heat recuperators on exhaust air) for mechanical ventilation of all zones;
- Four-pipe fan coils in the production and storage areas;
- Four-pipe active chilled beams active chilled beams in the offices, laboratories, and meeting rooms.

The HVAC system has an electrical consumption metering system, which provides disaggregate consumption of AHU and HPs. Nevertheless, data logged were not adequate to allow an hourly energy analysis; daily consumption for some months and annual consumption data are provided.

Heat Pump

General Identification	
Manufacture/Model	E-transfer ETF114DE
Year	2004
Type	water to water
Equipment	electricity
Performance Data	
EER – Cooling mode	5.25
COP – Heating mode	3.8
SEER	N.A.
Nominal Cooling Capacity [kW]	299
Nominal Heating Capacity [kW]	218
Refrigerant Gas	
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	N.A.


Figure – Equipment pictures


Figure – Equipment pictures

Monitoring observations

Inspection	
Operating Mode	**automatic**
Maintenance status	**Satisfactory**
Maintenance reports	**No**
Storage water level	**N.A.**
Equipment cleanliness	**Satisfactory**
Pressure status	**Satisfactory**
Water systems leaks	**Satisfactory**
Sensors calibration records	**No**
Previous inspection reports	**No**
Operating time estimated [h/year]	**2600**

Air filter cleanness	**N.a. (water condensed)**
Tightness of wiring connections	**Satisfactory**
Thermal insulation (Visual)	**Satisfactory**

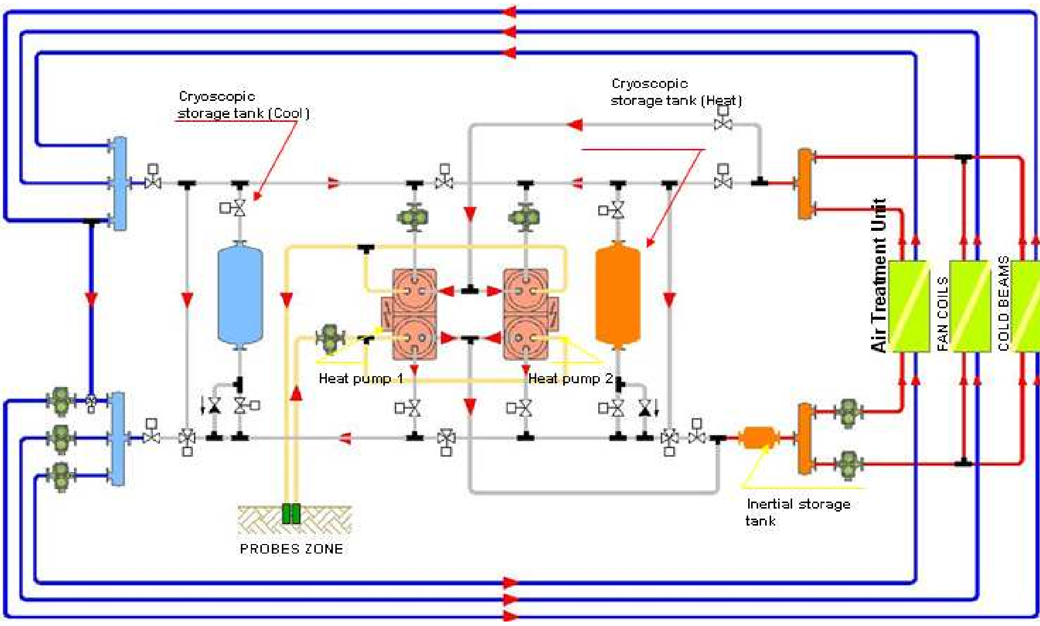
During the second inspection it was perceived that one of the HPs had been replaced with a similar model, obviously new. Substitution occurred because one HP had a fatal fault during operation. One possible explanation for this is the fact that the HPs are highly oversized with respect to building thermal demand. The excessive power provided by the HP implies frequent start and stop cycles, since no continuous modulation of the output is possible. In addition the thermal vessels were not used, thereby increasing the frequency of start and stop cycles.

Control systems

Control system is installed in HPs room, with internet connection and remote control. Potentially the control system should provide 11 operation strategies, depending on season, external temperature and internal conditions.

Control panel is installed on main electric board.

The schemes below show the system control strategy in different seasonal and internal load conditions. The figure below shows the functional layout of the system. The two HPs are clearly visible in the middle of the scheme as well as the schematic representation of the geothermal probes.

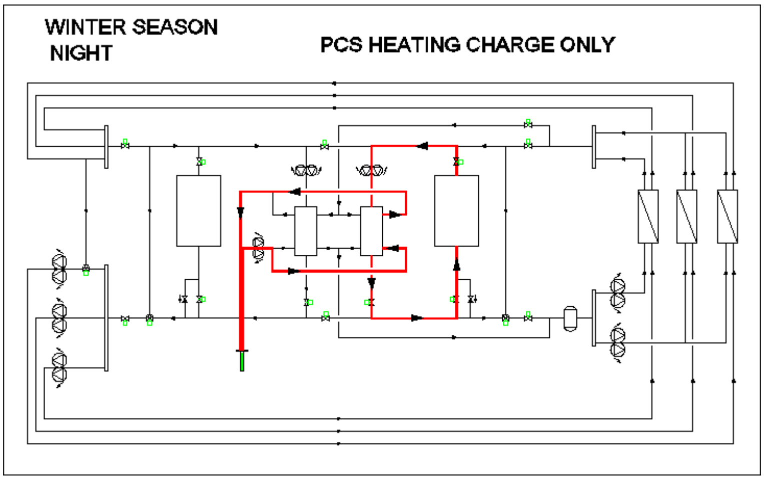


Functional Layout of the system

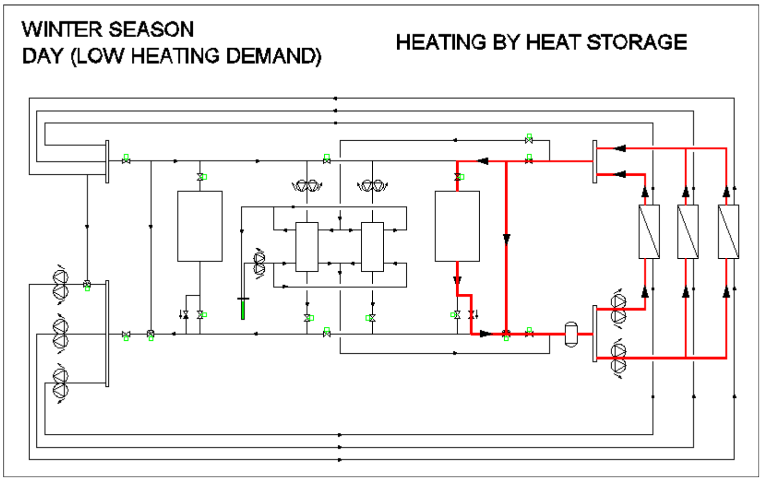
On the left of the HPs the blue vessel indicates the cold PCS while on the right the orange one indicates the hot PCS. At the extreme right, the air handling unit, the fan coils and the chilled beams circuits are represented.
An exhaustive set of conditions is here illustrated, considering all possible situations for winter, summer and middle season. Red connections indicate the elements that are operative for the specified control strategy.

Winter season

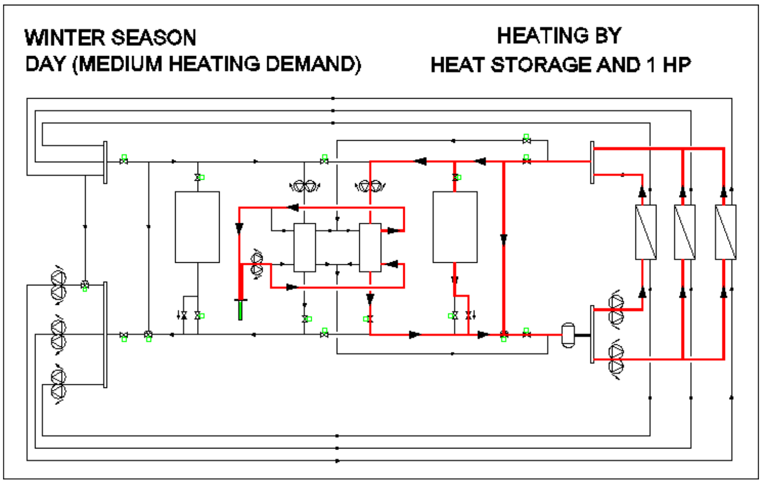
Figure below shows how, during the night, the heat extracted from the ground is processed in the HP and then stored in the hot vessel.



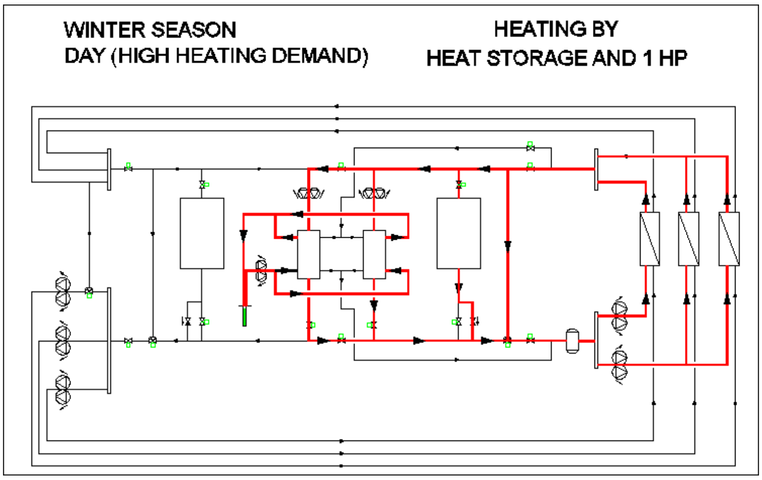
During winter temperate days, the energy stored in the hot PCS is sufficient to match the heating demand without the intervention of the HP, as seen in figure below.



When Winter outdoor temperatures are lower, the heat storage is no longer sufficient to guarantee a proper comfort, so the output of one HP is needed.

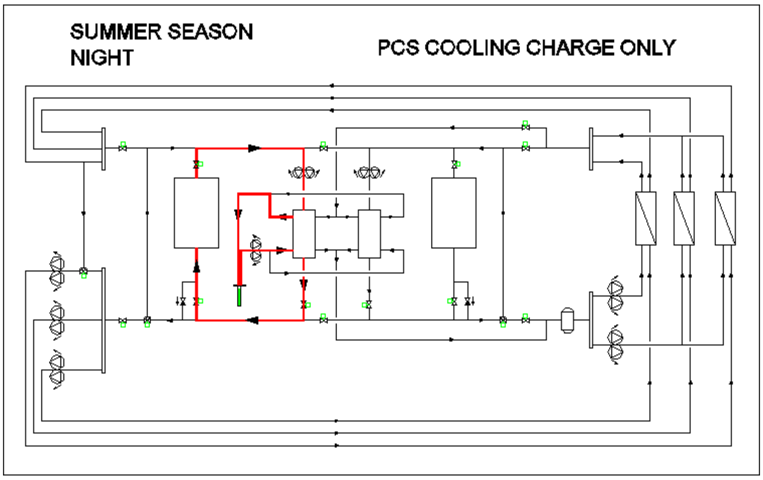


For the most severe climatic conditions, in order to provide the maximum thermal output, the system can simultaneously extract heat from the hot storage and the both HPs.

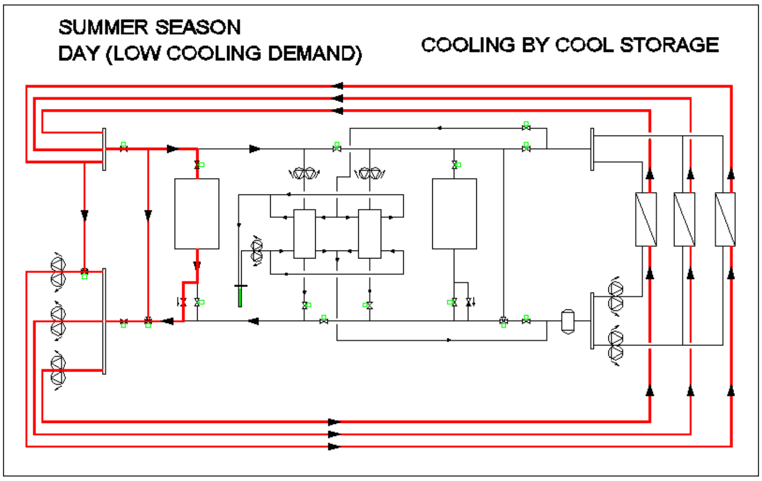


Summer season

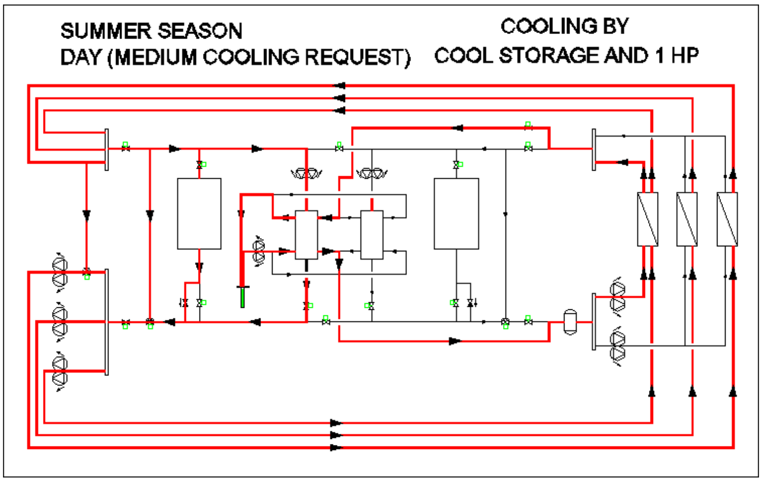
For summer season, similar considerations as in the winter case apply, remembering that the storage to be charged is the cold one.

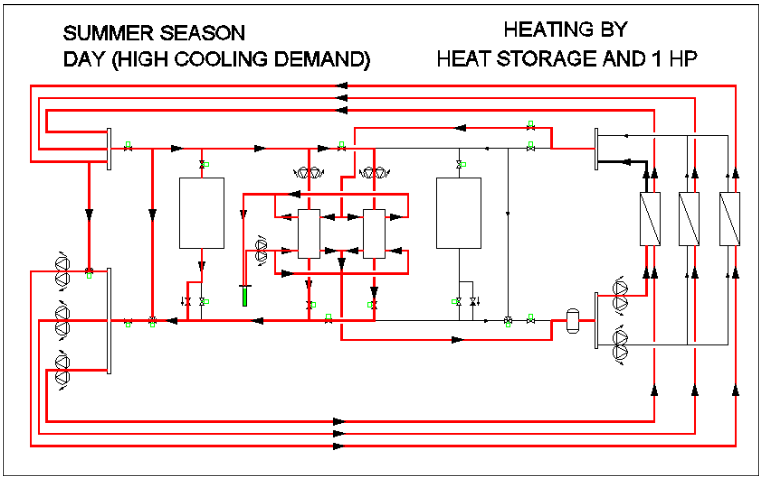


During moderate summer days, the energy stored in the cold PCS is sufficient to mach the cooling demand without the intervention of the HP.



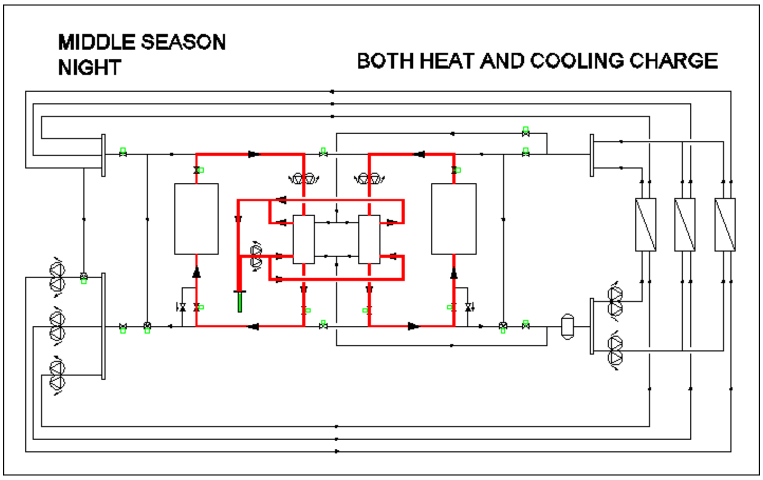
When summer temperatures are hotter, the cold PCS is no more sufficient to guarantee a proper comfort, so the help of one HP is needed, while during hottest days also the second HP operates.



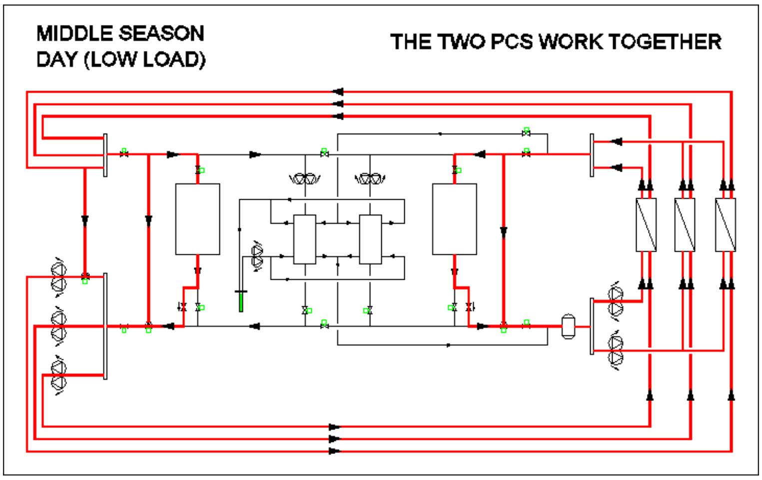


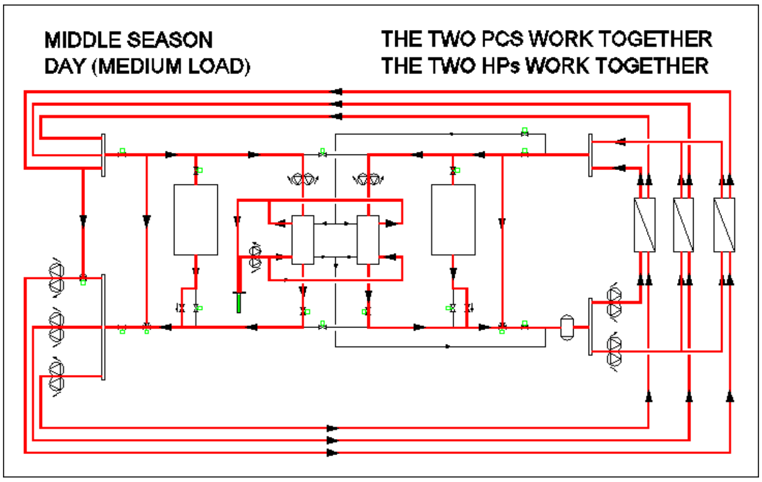
Middle season

During middle season three situations are considered. In the charging mode during the night, both the PCS are filled by the two HPs.



In low load operation, both the PCS operate, supplying heating and cooling to the building. With medium load conditions, the PCS work in parallel with the HPs.





The schemes describing the system control strategy were provided by the HVAC system designer. The inspection showed that not all the foreseen strategies had been put into operation during the previous year. In particular the storage vessels had never been used. This fact was partially due to an electric supply contract that did not apply different costs for peak and off-peak hours. In addition some technical problems occurred on one HP, which had been substituted before the second inspection.

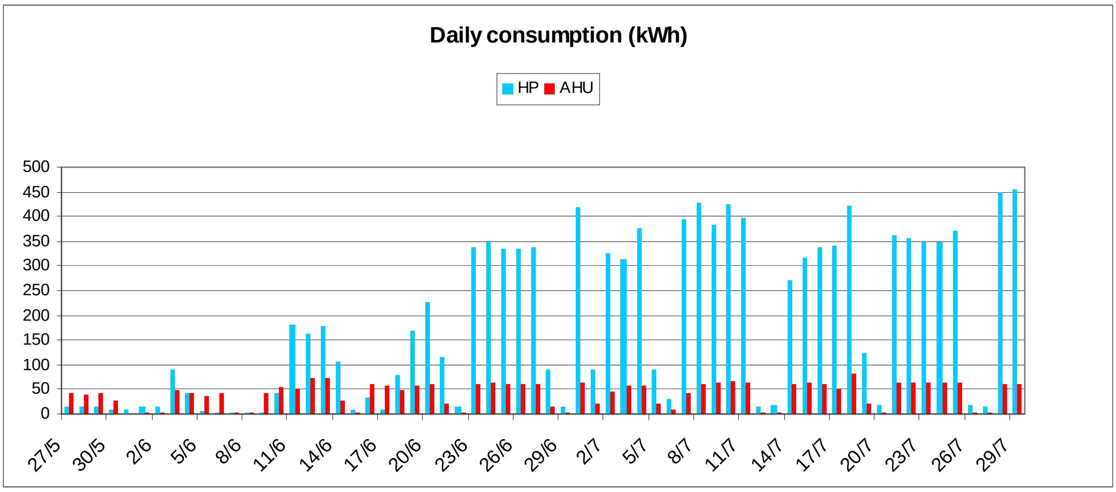
Energy consumption data

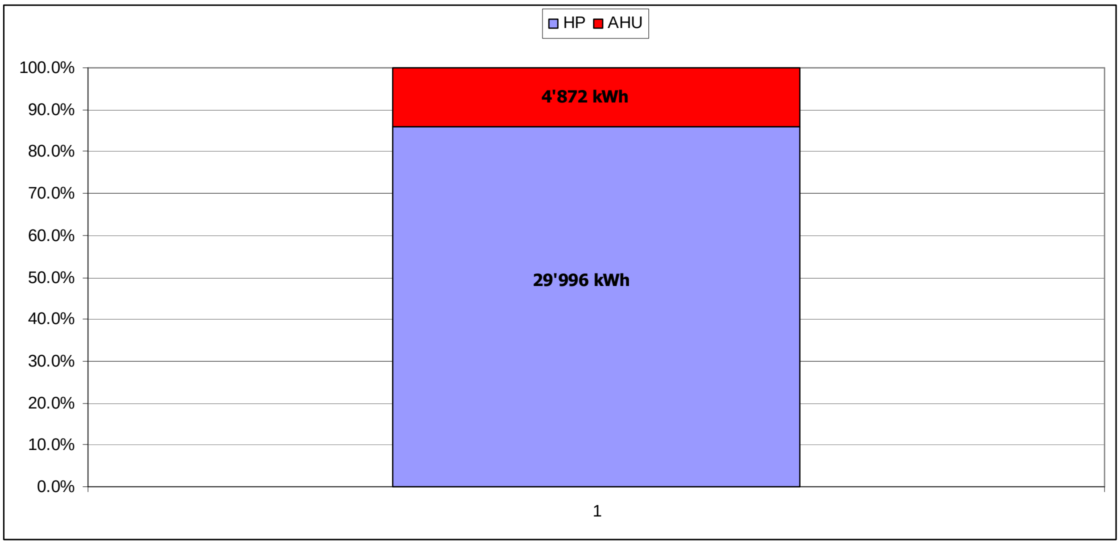
Metering information

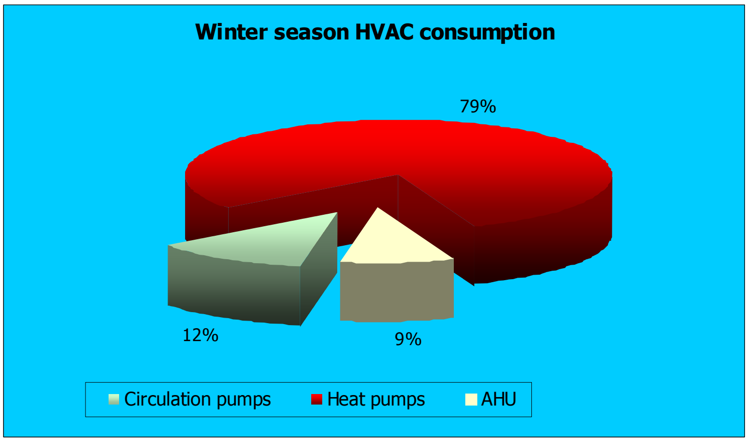
The HVAC system has an electrical consumption metering system, which provides disaggregate consumption of AHU and HPs. Nevertheless data logged were characterized by high percentage of void logging periods. Based on the available data it has been possible to analyze a few complete period: results are presented below.

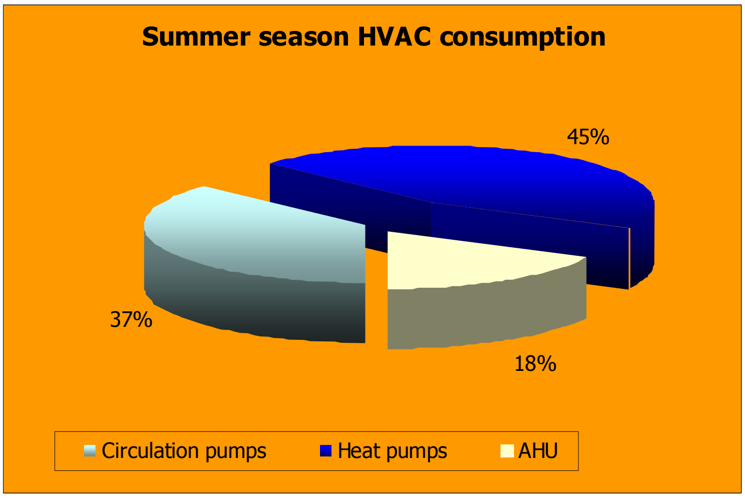
Monitoring observations

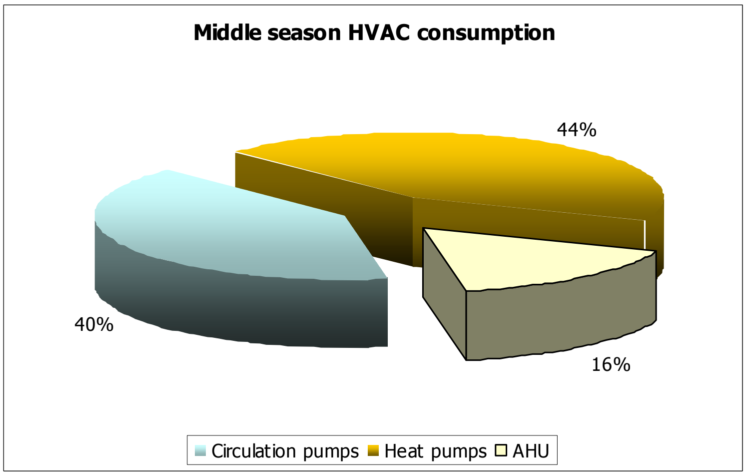
The data available are referred to 2008/season.

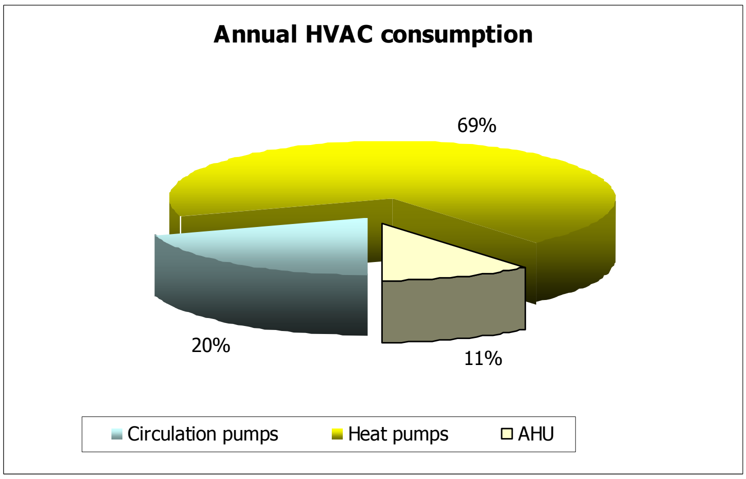


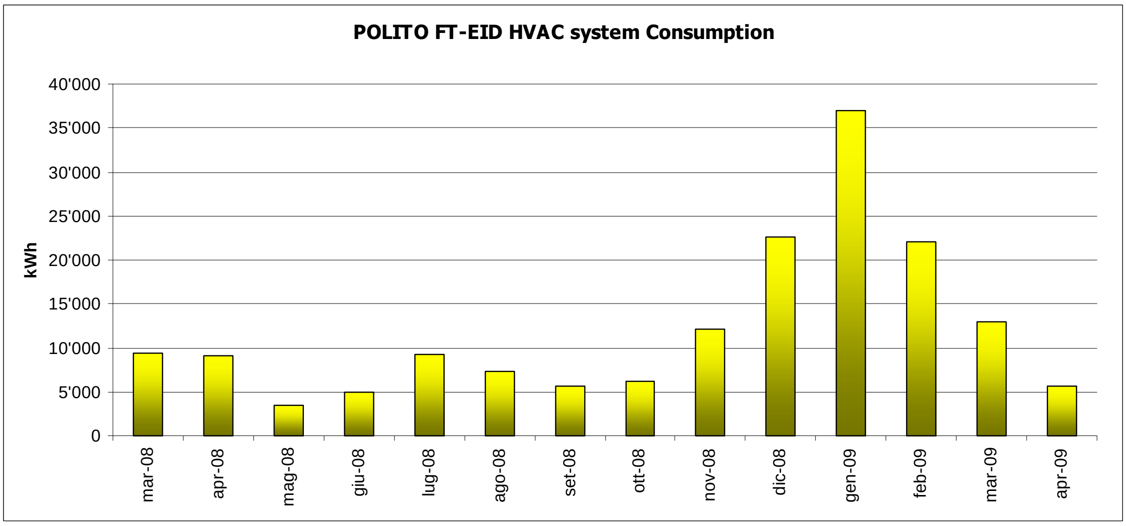



Winter season HVAC consumption
79%
12%
9%
Circulation pumps
Heat pumps
AHU


Summer season HVAC consumption
45%
37%
18%
Circulation pumps
Heat pumps
AHU


Middle season HVAC consumption
44%
40%
16%
Circulation pumps
Heat pumps
AHU


Annual HVAC consumption
69%
20%
11%
Circulation pumps
Heat pumps
AHU


POLITO FT-EID HVAC system Consumption
kWh
40'000
35'000
30'000
25'000
20'000
15'000
10'000
5'000
0
mar-08
apr-08
mag-08
giu-08
lug-08
ago-08
set-08
ott-08
nov-08
dic-08
gen-09
feb-09
mar-09
apr-09

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.5	Replace electrical equipment with Energy Star or low consumption types	PI22	--
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.1	Generate instructions ("user guide") targeted to the occupants	PI7, PI8, PI9, PI10, P4	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--
O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--

Timing for inspection

Pre-inspection data (mainly building)

Inspection Item	Short Description	Time (mins)	Savings	Notes
PI1	Location and number of AC zones	14		
PI2	Documentation per zone	20		
PI3	Images of zones/building	15		
PI4	General zone data/zone	11		
PI5	Construction details/zone	20		
PI6	Building mass/air tightness per zone	5		
PI7	Occupancy schedules per zone	8		
PI8	Monthly schedule exceptions per zone	2		
PI9	HVAC system description and operating setpoints per zone	60		HEAT PUMP + HOT/COOL STORAGE. 11 CONTROL STRATEGIES
PI10	Original design conditions per zone	15		
PI11	Current design loads per zone	15		
PI12	Power/energy information per zone	10		
PI13	Source of heating supplying each zone	4		
PI14	Heating storage and control for each zone	10		
PI15	Refrigeration equipment for each zone	5		
PI16	AHU for each zone	6		
PI17	Cooling distribution fluid details per zone	12		
PI18	Cooling terminal units details in each zone	10		
PI19	Energy supply to the system	1		
PI20	Energy supply to the building	1		
PI21	Annual energy consumption of the system	10		
PI22	Annual energy consumption of the building	10		
	TOTAL TIME TAKEN (minutes)	**264**		
	TOTAL (seconds/m^2)	**2.44**	Area (m^2)	6500

Centralised system inspection data

Inspection Item	Short Description	Time (mins)	Savings	Notes
PC1	Details of installed refrigeration plant	22		
PC2	Description of system control zones, with schematic drawings.	12		
PC3	Description of method of control of temperature.	15		
PC4	Description of method of control of periods of operation.	4		
PC5	Floor plans, and schematics of air conditioning systems.	15		
PC6	Reports from earlier AC inspections and EPC's	0		not available
PC7	Records of maintenance operations on refrigeration systems	4		
PC8	Records of maintenance operations on air delivery systems.	4		
PC9	Records of maintenance operations on control systems and sensors	0		not available
PC10	Records of sub-metered AC plant use or energy consumption.	4		Advanced BMS
PC11	Commissioning results where relevant	0		not available
PC12	An estimate of the design cooling load for each system	35		
PC13	Records of issues or complaints concerning indoor comfort conditions	0		not available
PC14	Use of BMS	20		
PC15	Monitoring to continually observe performance of AC systems			
C1	Locate relevant plant and compare details	40		
C2	Locate supply the A/C system and install VA logger(s)	60		include PC 15
C3	Review current inspection and maintenance regime	5		
C4	Compare system size with imposed cooling loads	5		
C5	Estimate Specific Fan Power of relevant air movement systems	4		on label data
C6	Compare AC usage with expected hours or energy use	15		compared data of BMS with expected occupancy
C7	Locate refrigeration plant and check operation	10		
C8	Visual appearance of refrigeration plant and immediate area	4		
C9	Check refrigeration plant is capable of providing cooling	3		termometers mounted on fluid distribution network

C10	Check type, rating and operation of distribution fans and pumps	15		
C11	Visually check condition/operation of outdoor heat rejection units			underground water condensed
C12	Check for obstructions through heat rejection heat exchangers			underground water condensed
C13	Check for signs of refrigerant leakage	9		2 units
C14	Check for the correct rotation of fans	0		underground water condensed
C15	Visually check the condition and operation of indoor units	40		10 min per floor
C16	Check air inlets and outlets for obstruction	20		in addiction to C15
C17	Check for obstructions to airflow through the heat exchangers	20		in addiction to C15
C18	Check condition of intake air filters.	10		in addiction to C15
C19	Check for signs of refrigerant leakage.	10		in addiction to C15
C20	Check for the correct rotation of fans	20		in addiction to C15
C21	Review air delivery and extract routes from spaces	15		in addiction to C15
C22	Review any occupant complaints			not available
C23	Assess air supply openings in relation to extract openings.	25		
C24	Assess the controllability of a sample number of terminal units	17		
C25	Check filter changing or cleaning frequency.	10		
C26	Assess the current state of cleanliness or blockage of filters.	4		
C27	Note the condition of filter differential pressure gauge.	3		
C28	Assess the fit and sealing of filters and housings.	22		
C29	Examine heat exchangers for damage or significant blockage	4		
C30	Examine refrigeration heat exchangers for signs of leakage	4		
C31	Note fan type and method of air speed control	2		
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4		
C33	Check location of inlets for proximity to sources of heat	2		
C34	Assess zoning in relation to internal gain and solar radiation.	30		
C35	Note current time on controllers against the actual time	10		
C36	Note the set on and off periods	6		
C37	Identify zone heating and cooling temperature control sensors	15		

C38	Note zone set temperatures relative to the activities and occupancy	13		
C39	Check control basis to avoid simultaneous heating and cooling	6		
C40	Assess the refrigeration compressor(s) and capacity control	480		240 min per unit
C41	Assess control of air flow rate through air supply and exhaust ducts	10		
C42	Assess control of ancillary system components e.g. pumps and fans	10		
C43	Assess how reheat is achieved, particularly in the morning	0		not available
C44	Check actual control basis of system	8		
	TOTAL TIME TAKEN (minutes)	**1'125**		
	TOTAL (seconds/m^2)	**10.38**	Area (m^2)	6500

Overall conclusions

This field trial presented an interesting example of low energy building. The specific energy consumption for heating and cooling, during the whole year, is in fact the lowest among Italian case studies and field trials. The building envelope good properties are unquestionable, while HVAC system operation and design should be object of some criticism.

If the field trial had been solely based on provided documents and information, without a deep analysis on effective installed power, the system would have been evaluated as a fully satisfactory state of the art example. When design calculations were analyzed, an oversizing of the HPs was revealed.

Furthermore, the on site Inspection added extremely relevant information about system real operation: one HP had already been replaced after few years of service, and the storage vessels had never been used.

In conclusion, the potential of geothermal HP system coupled with a low-temperature heating / high-temperature cooling HVAC system, and the presence of a high thermal performance envelope are clearly state of the art solutions for energy conservation. Nevertheless, HVAC systems of such complexity should be thoroughly commissioned and monitored for at least one entire year of operation, and the conducted by a highly qualified operator, in order to be able to deliver their expected design performance. Even if in this case the overall system performance turned out to be good, the failure of one HP and the fact that the storage vessels were not in use reveal that the high energy saving potential of this system has not been fully exploited, which implies higher operational costs for building owner.

HARMONAC

IT Field Trial 6:
Retirement Home – All Air system

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DENER, Politecnico di Torino
IT

August 2010

Supported by

Intelligent Energy Europe

Field Trials 6: Retirement home with water condensed electric chillers, performance assessment of chiller

Overview of building and system

ITIS is a public structure hosting non self-sufficient elderly people. The structure is also used for cultural activities jointly with the Municipality of Trieste and for teaching and practicing by the School of Medicine of the local university.

The main building, dating from the early XIX Century, has been completely refurbished. The annex service building (kitchen, boiler room, etc) was built around 1970. The heated volume is 112500 m^3 and the conditioned area is 8000 m^2. The A/C system monitored in this building is an all air system.

HVAC system

The central thermal plant includes two gas-fired boilers (with oil backup) for space heating and two gas-fired boilers for SHW production; the total power rating is 6823 kW.

The cooling plant includes three electrical chillers with cooling tower heat rejection, rated at 1468 kW cooling capacity.

The water/air HVAC system includes 10 AHUs (primary air only); water terminals are two-pipe radiators for heating; in summer season the system works as an all air system.

The yearly electricity consumption is on the order of 1.6 GWh

Parameter	Installed electrical load / kW	Floor area served / m^2 GIA	Installed capacity W/m^2 GIA	Annual consumption kWh	Average annual power W/m^2	Annual use kWh/m^2	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output)	1'468.0	8'000.0	183.5				
Total Chillers	410.0	8'000.0	51.3	244'200.0	3.5	30.5	6.8
Total CW pumps	56.0	8'000.0	7.0	31'500.0	0.4	3.9	6.4
Total fans	15.0	8'000.0	1.9				
Total humidifiers							
Total boilers		25'065.0			-	-	
Total HW pumps	35.4	25'065.0	1.4	63'720.0	0.3	2.5	20.5
Total HVAC electrical							
Total Building Elec kWh		25'065.0		1'614'786.0	7.4	64.4	
Total Boilers/Heat kWh	5'232.0	25'065.0	208.7	2'902'100.0	13.2	115.8	6.3
Total Building Gas/Heat kWh		25'065.0		2'902'100.0	13.2	115.8	

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--

O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--
O3.7	Maintain proper evaporating and condensing temperatures	C1, C2 C8	Clean condenser circuit, Verify correct operation of expansion valve
O3.12	Maintain proper heat source/sink flow rates	C1, C2 C8	Clean condenser circuit
O3.17	Clean condenser tubes periodically	C1, C2 C8	Clean condenser circuit

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Health and care
Geographical location	Trieste (Italy)
Gross net Area	25065 (net)
N° Floors	3

Zone Description

Main Activity	Retirement Home
Area Conditioned [m^2]	8000
Volume conditioned [m^3]	28000
Max. Number of occupants	80
Occupation schedule /Hours Operation	24h, 7 days per week
Lighting Power density [w/m^2]	17
Type Lighting/lighting control	fluorescent, manual controlled
Lighting schedule /Hours Operation	15h per day

Construction Details (only as a support of EES tools)

Envelope – Heat Transfer Coefficient [W/m².K]	
External wall (predominant)	1
Floor (predominant)	1.2
Intermediated floor (predominant)	1.2
Roof (predominant)	1.3

Windows	
U- value (predominant) [W/m².K]	3
Window type	wood/aluminium
Window gas	air
Solar Factor	0.8
Solar Protection Devices	
Window Overhangs	**no**
Shading Device	**curtains**

System Zone Description

System Type	Air and water
Cooling Equipment Type of Fuel	Electricity
	meters
Schedule and Operation Time [h/year]	3000
Required Heating capacity	1600 kW 2796 MWh/year (2007/2008 winter season)
Heating Equipment Type of Fuel	Gas
	Counters
Schedule and Operation Time [h/year]	The whole year (in summer for DHW)
Terminal units	Fan coil/AHUs
Cooling/Heating capacity [MW]	1.5/6.8

Indoor Environment Parameters	**Measure/observe - Winter/Summer (average)**
Ventilation Rate [ach]	0.5
Indoor Relative Humidity [%]	50
Indoor air Temperature [°C] – Winter/Summer	21/25

Outdoor Environment Parameters	**Measure/observe - Winter/Summer (average)**
Outdoor air temperature [°C] Winter/Summer	/
Outdoor Relative Humidity [%] Winter/Summer	/

HVACs' system components

The central thermal plant includes two gas-fired boilers (with oil backup) for space heating and two gas-fired boilers for SHW production; the total power rating is 6823 kW.

The cooling plant includes three electrical chillers with cooling tower heat rejection, rated at 1468 kW cooling capacity.

The water/air HVAC system includes 10 AHUs (primary air only); water terminals are two-pipe radiators for heating; in summer season the system works as an all air system.

The yearly electricity consumption is on the order of 1.6 GWh.

Cold Generator


Chiller Identification	
Manufacture/Model	Mc Quay WHR 160.2
Year	1998
System Type	2 circuits
Compressor Type	Reciprocating
Fuel Type	electricity
Performance Data	
Nominal Cooling Capacity [kW]	548.6
Installed Cooling Capacity /m² GIA	
Nominal Electric Power [kW]	137.4
COP/EER (Eurovent)	4
SEER	
Refrigerant Gas	R 22
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	

Auxiliary Equipment	
Fan Electrical Demand [kW]	25 (heat rej. system)
Pumps Electric Demand [kW]	17
Other	/

Monitoring observations

Inspection	
Maintenance status	**Unsatisfactory**
Previous inspection/maintenance Reports	**No**
Operation time estimated [h]	**1500 each**
Operating mode	**automatic**
Thermal Insulation (Visual)	**Satisfactory**
Vibration eliminators	**Satisfactory**
Worn couplings	**Satisfactory**
Equipment cleanliness	**Unsatisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Unsatisfactory**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	**No**
Sensors calibration records	**No**
Refrigerant leaks	**No**
Location of the equipment	**Indoor**
Oil leaks	**Yes**
Field measurements	
Electricity consumption [kWh]	50 MWh from 1 to 30 September 2008

Heat Rejection system

Heat Rejection Identification	
Manufacture/Model	Sital Clima TRS 140
Year	1998
Cooling method	evaporative
Type	
Performance Data	
Nominal Cooling Capacity [kW]	
Installed Cooling Capacity /m² GIA	
Nominal Electric Power [kW]	15
Total Heat Rejection [kW]	
Water flow rate [m³/h]	
Water Pressure Drop [kPa]	
Electrical data	
Power supply [V/Ph/Hz]	
Start-up amps [A]	

Auxiliary Equipment	
Fan Electrical Demand [kW]	15
Pumps Electric Demand [kW]	4
Other	

Monitoring observations

Inspection	
Maintenance status	Satisfactory
Previous inspection/maintenance Reports	No
Operation time estimated [h]	
Operating mode	
Thermal Insulation (Visual)	Satisfactory
Equipment cleanliness	Satisfactory
Operating water level (sump)	Satisfactory
Fan shaft bearings lubrification	N.A.
Drive system belt condition and tension	N.A.
Heat transfer section cleanliness	Satisfactory
Refrigerant leaks	No
Water systems leaks	Yes (minor)
Sensors calibration records	No
Correct rotation of the fan	Yes
Bleed rate [l/s]	

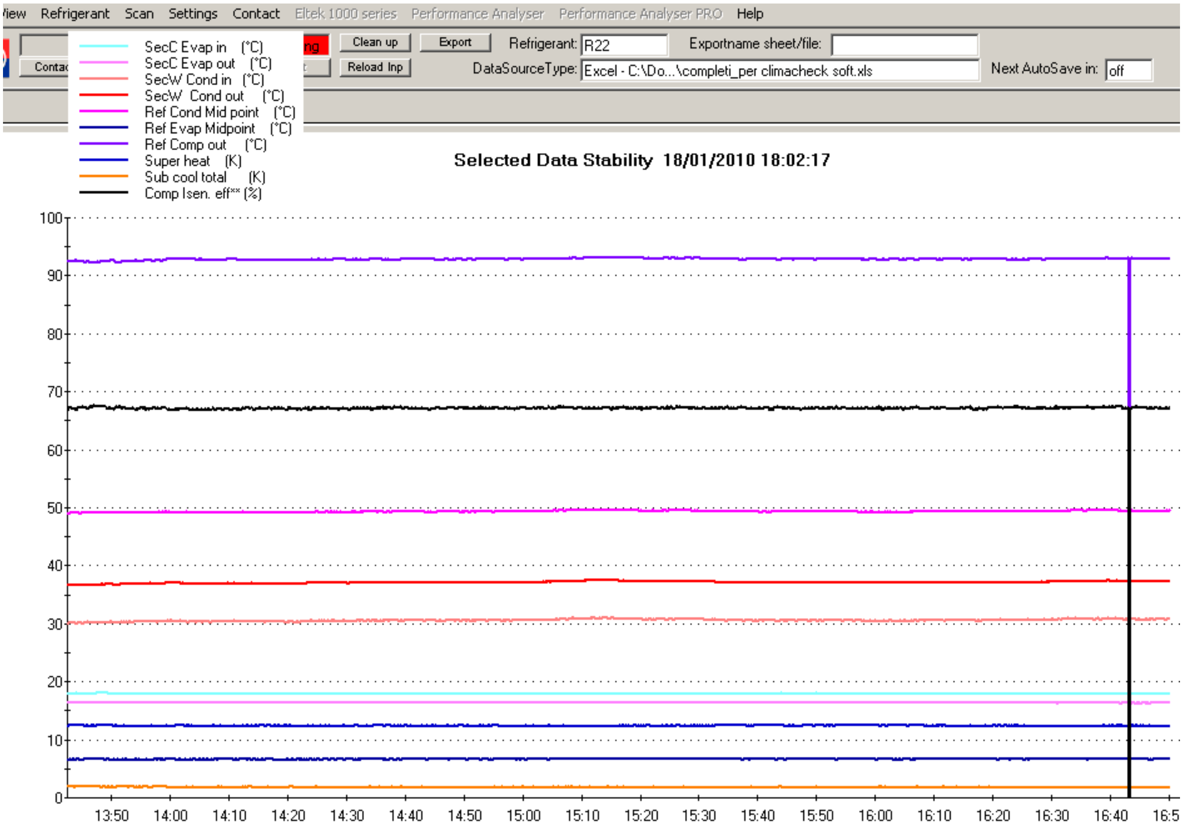
Climacheck® assessment of chiller

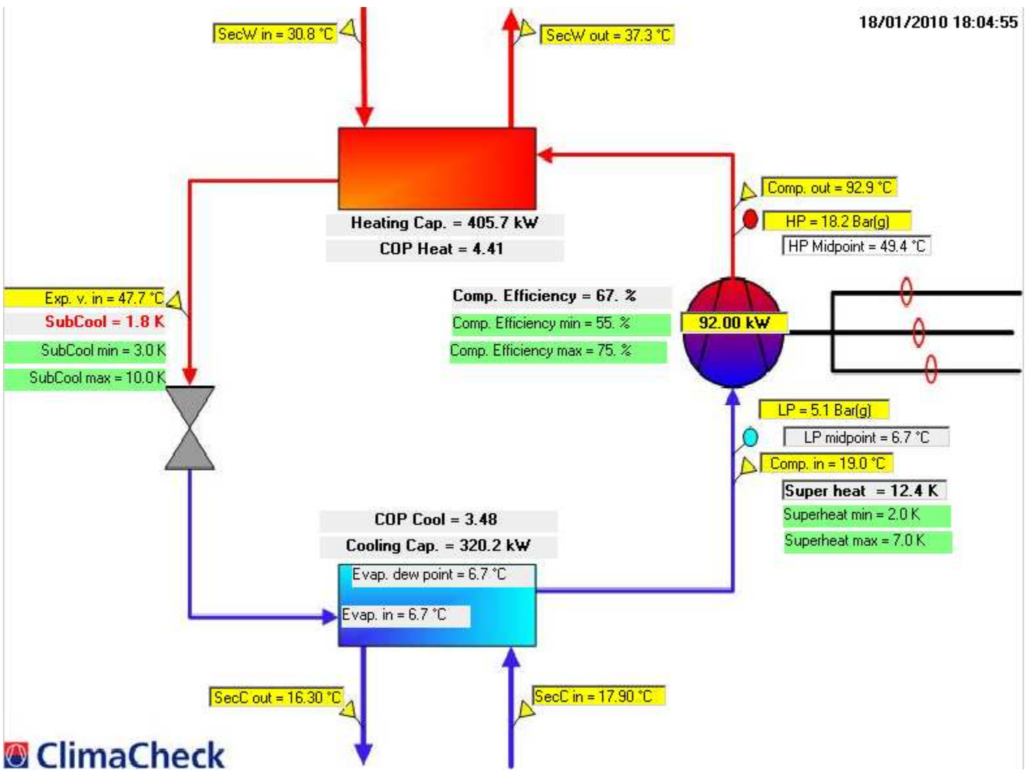
Previous to the assessment with Climacheck® instrument, the HVAC system was inspected following the HarmonAC guidelines and inspection methodology.

The unit assessed is a McQuay WHR 160.2, water condensed chiller. The unit is composed by two circuits of refrigerant gas, served by two compressor, two condenser and a single evaporator. The compressors are of the reciprocating type with multiple cylinders and suction and discharge valves.

The inspection results, for the considered chiller, showed a poor maintenance state, with only one of two compressor working. Some signs of oil leakages on the working compressor could indicate that it was not maintained in proper manner, and we assessed the unit with Climacheck® instrument searching for likely compressor malfunctioning. The assessment data turned over our hypothesis, showing that the compressor was in good shape, while the heat exchangers were fouled and some operative parameters of the unit should be improved.

As seen in the graph below the unit worked in almost constant conditions for the whole time of the test.





The analysis shows that:

1. The ΔT in the evaporator between evaporation dew point and cool water outlet is very high, more than 10 K. A good system would have 3-5 K. The high value of the ΔT is probably caused by the high value of the superheat (12.4 °C). Decreasing the value of superheating appears to be a good solution to increase temperature of evaporation. Experimental data indicate that for every degree of evaporation temperature increase, the capacity / COP would increase almost 3-5%.
2. The ΔT between outlet gas temperature and condensing water outlet in the condenser is very high, more than 10 K. A good value for a new condenser would be 2 K, and an adequate value for an old condenser 6 K. It appears that the condenser is undersized or fouled. Experimental data indicate that for every degree over the mentioned ΔT, the system wastes 1-3% energy.
3. The compressor is working properly and is in good state, with a 67% isentropic efficiency.
4. The sub-cooling could be raised to 4-6 K (actually is about 1.8 K), and the evaporator would have better thermal exchange efficiency with this value.

Conclusion: COP would have been much better with higher evaporator temperature and lower condenser temperature.

Timing table for second inspection, with assessment of chiller operation

Inspection Item	Short Description	Time (mins)	Savings	Notes
PI1	Location and number of AC zones	0		A
PI2	Documentation per zone	0		A
PI3	Images of zones/building	0		A
PI4	General zone data/zone	0		A
PI5	Construction details/zone	0		A
PI6	Building mass/air tightness per zone	0		A
PI7	Occupancy schedules per zone	0		A
PI8	Monthly schedule exceptions per zone	0		A
PI9	HVAC system description and operating setpoints per zone	0		A
PI10	Original design conditions per zone	0		A
PI11	Current design loads per zone	0		A
PI12	Power/energy information per zone	0		A
PI13	Source of heating supplying each zone	0		A
PI14	Heating storage and control for each zone	0		A
PI15	Refrigeration equipment for each zone	0		A
PI16	AHU for each zone	0		A
PI17	Cooling distribution fluid details per zone	0		A
PI18	Cooling terminal units details in each zone	0		A
PI19	Energy supply to the system	0		A
PI20	Energy supply to the building	0		A
PI21	Annual energy consumption of the system	0		A
PI22	Annual energy consumption of the building	0		A
	TOTAL TIME TAKEN (minutes)	**0**		
	TOTAL (seconds/m^2)	**0.00**	Area (m^2)	8000

A = already done during the first inspection

Centralised system inspection data

Inspection Item	Short Description	Time (mins)	Savings	Notes
PC1	Details of installed refrigeration plant	8		
PC2	Description of system control zones, with schematic drawings.	3		
PC3	Description of method of control of temperature.	2		

PC4	Description of method of control of periods of operation.	2		
PC5	Floor plans, and schematics of air conditioning systems.	0		already available from pre-inspection
PC6	Reports from earlier AC inspections and EPC’s	0		not available
PC7	Records of maintenance operations on refrigeration systems	2		4 min for each chiller
PC8	Records of maintenance operations on air delivery systems.	5		3 min for each AHU
PC9	Records of maintenance operations on control systems and sensors	0		not available
PC10	Records of sub-metered AC plant use or energy consumption.	0		not available
PC11	Commissioning results where relevant	0		not available
PC12	An estimate of the design cooling load for each system	30		affected from tha availability and order of the pre-inspection data
PC13	Records of issues or complaints concerning indoor comfort conditions	0		not available
PC14	Use of BMS	3		
PC15	Monitoring to continually observe performance of AC systems	0		not yet executed
C1	Locate relevant plant and compare details	10		
C2	Locate supply the A/C system and install VA logger(s)	120		
C3	Review current inspection and maintenance regime	3		
C4	Compare system size with imposed cooling loads	5		
C5	Estimate Specific Fan Power of relevant air movement systems	5		
C6	Compare AC usage with expected hours or energy use	5		
C7	Locate refrigeration plant and check operation	5		
C8	Visual appearance of refrigeration plant and immediate area	3		
C9	Check refrigeration plant is capable of providing cooling	5		
C10	Check type, rating and operation of distribution fans and pumps	0		already made in C1

C11	Visually check condition/operation of outdoor heat rejection units	15		
C12	Check for obstructions through heat rejection heat exchangers	0		not possible
C13	Check for signs of refrigerant leakage	6		
C14	Check for the correct rotation of fans	0		impossible
C15	Visually check the condition and operation of indoor units	0		all air
C16	Check air inlets and outlets for obstruction	0		
C17	Check for obstructions to airflow through the heat exchangers	0		
C18	Check condition of intake air filters.	16		2 min for each AHU
C19	Check for signs of refrigerant leakage.	8		1 min for each AHU
C20	Check for the correct rotation of fans	32		4 min for each AHU
C21	Review air delivery and extract routes from spaces	40		
C22	Review any occupant complaints	0		
C23	Assess air supply openings in relation to extract openings.	30		extimate for ALL openings in ALL zones
C24	Assess the controllability of a sample number of terminal units	15		
C25	Check filter changing or cleaning frequency.	5		
C26	Assess the current state of cleanliness or blockage of filters.	16		2 min for each AHU
C27	Note the condition of filter differential pressure gauge.	8		1 min for each UTA
C28	Assess the fit and sealing of filters and housings.	16		2 min for each AHU
C29	Examine heat exchangers for damage or significant blockage	16		2 min for each AHU
C30	Examine refrigeration heat exchangers for signs of leakage	16		2 min for each AHU
C31	Note fan type and method of air speed control	8		1 min for each AHU
C32	Check for obstructions to inlet grilles, screens and pre-filters.	8		1 min for each AHU
C33	Check location of inlets for proximity to sources of heat	8		1 min for each AHU
C34	Assess zoning in relation to internal gain and solar radiation.	60		
C35	Note current time on controllers against the actual time	5		on BMS

C36	Note the set on and off periods	2		on BMS
C37	Identify zone heating and cooling temperature control sensors	5		in addiction to travel time, already take in count in other part of the inspection
C38	Note zone set temperatures relative to the activities and occupancy	25		as before
C39	Check control basis to avoid simultaneous heating and cooling	1		
C40	Assess the refrigeration compressor(s) and capacity control	240		CLIMACHECK ANALYSIS
C41	Assess control of air flow rate through air supply and exhaust ducts	120		with measurement of air flow at the first and the last of each air channel
C42	Assess control of ancillary system components e.g. pumps and fans	3		
C43	Assess how reheat is achieved, particularly in the morning	0		not available
C44	Check actual control basis of system	10		
	TOTAL TIME TAKEN (minutes)	**950**		
	TOTAL (seconds/m^2)	**7.13**	Area (m^2)	8000

Overall conclusions

In this case the chiller presented, with a visual inspection, a bad state of maintenance, while the instrumental assessment showed that the compressor status is satisfactory. Nevertheless, a better regulation of the chiller, coupled with an adequate cleaning of the condensers, should provide better performance, estimated in 10% raise of the COP.

Conclusion: COP would have been much better with higher evaporator temperature and lower condenser temperature, condensers cleaning is needed.

HARMONAC

IT Field Trial 7:
Office –Water system

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August 2010

Supported by

Intelligent Energy Europe

Italy Field Trial 7: Porcia City house: performance analysis of chiller condensed by underground water

Overview of building and system

The system considered is an all water system with fan coils as terminal units. Heating is provided by one gas fired boiler rated at 680 kW of thermal gross power. Cool water is provided by an electric chiller (reciprocating type compressors, 2 circuits, r407c) condensed by underground water (provided by a well). No nominal refrigerant power was provided, a 250 kW cooling capacity was measured with chiller operation analysis. There is no mechanical ventilation. The distribution system was built in 1970 (contemporary with the building) while the chiller was substituted in 2002.

Parameter	Installed electrical load / kW	Floor area served / m^2 GIA	Installed capacity W/m^2 GIA	Annual consumption kWh	Average annual power W/m^2	Annual use kWh/m^2	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output) [e]	250.0	3'426.0	73.0				
Total Chillers	80.0	3'426.0	23.4	39'042.0	1.3	11.4	5.6
Total CW pumps		3'426.0					
Total fans		3'426.0					
Total humidifiers		3'426.0					
Total boilers ELECTRICAL		3'426.0					
Total HW pumps		3'426.0					
Total HVAC electrical		3'426.0					
Total Building Elec kWh		3'426.0					
Total Boilers/Heat kWh	680.0	3'426.0	198.5				
Total Building Gas/Heat kWh		3'426.0					

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.1	Generate instructions ("user guide") targeted to the occupants	PI7, PI8, PI9, PI10, P4	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--

O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--
O3.7	Maintain proper evaporating and condensing temperatures	C1, C2 C8	Clean condenser circuit, Verify correct operation of expansion valve
O3.12	Maintain proper heat source/sink flow rates	C1, C2 C8	Clean condenser circuit
O3.15	Maintain full charge of refrigerant	C1, C2 C8	Control charge and refill
O3.17	Clean condenser tubes periodically	C1, C2 C8	Clean condenser circuit
O3.20	Apply indirect free cooling using underground water (free chilling)	PI7, PI12, PI21, C8	Modify cool water circuits

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Public assembly spaces
Geographical location	Porcia, PD, ITALY
Gross Area (m^2)	3426
N° Floors	4

Zone Description

Main Activity	City hall
Area Conditioned [m^2]	3426
Volume conditioned [m^3]	10991
Max. Number of occupants	100
Occupation schedule /Hours Operation	Monday to Friday (8:00-16:00) Saturday (8:00-13:00)
Lighting Power density [W/m^2]	About 20
Type Lighting/lighting control	Mainly fluorescent tube/manual switch
Lighting schedule /Hours Operation	N.A.
Other Equipment [kW]	About 15 W/m^2 of computers, printers, etc…

System Zone Description

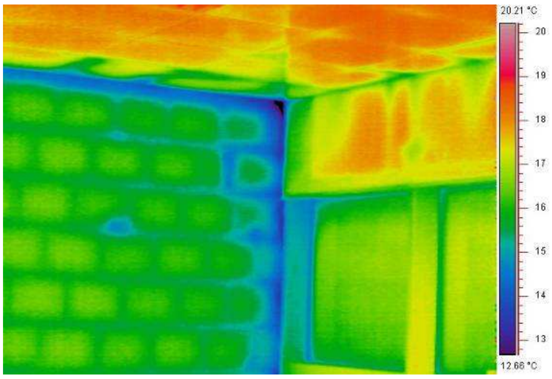
System Type	**All Water**
Required Cooling capacity	**165 kW** (refrigerant power, energy signature calculation method) **39042** kWh/year
Cooling Equipment Type of Fuel	**Electricity**
	Meters
Schedule and Operation Time [h/year]	About 1000 h/year
Required Heating capacity	**243 kW** (gross power, energy signature calculation method) **30227 kWh/year** gross energy (counted)
Heating Equipment Type of Fuel	**Gas**
	Counters
Schedule and Operation Time [h/year]	About 2500 h/year
Terminal units	**Fan coil**
Cooling/Heating capacity [kW]	**250 / 680**

Indoor Environment Parameters	**Measure - Winter/Summer (average)**
Ventilation Rate [ach]	N.A.
Indoor Relative Humidity [%]	40%/60%
Indoor air Temperature [°C] – Winter/Summer	21.4/25.6 (2009/2010 season)

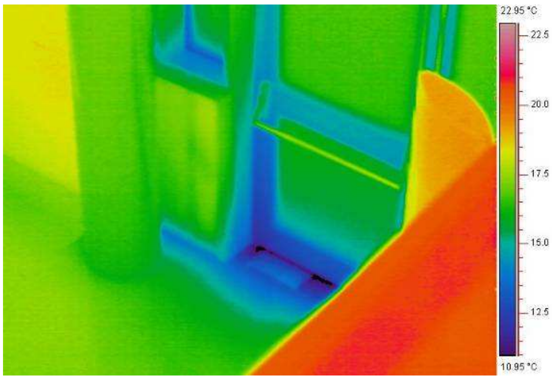
Outdoor Environment Parameters	**Measure - Winter/Summer (average)**
Outdoor air temperature [°C] Winter/Summer	8.9/24.1 (2009/2010 season)
Outdoor Relative Humidity [%] Winter/Summer	81/75.5 (2009/2010 season)

Thermographic assessment of the building

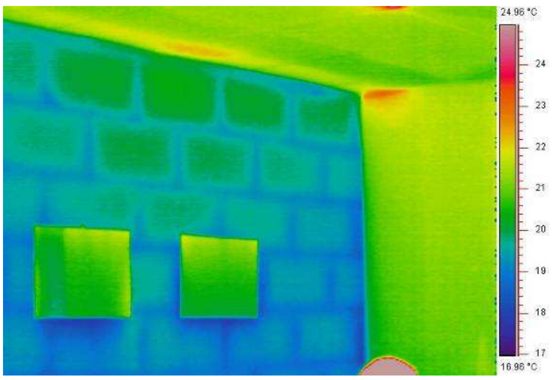
Some thermographic images of the building were taken to emphasize some problems of windows sealing and thermal resistance of the opaque surfaces.



As seen the thermal bridge on the corner of the building affects notably the temperature on the inside surface of the building.



This door has an unsatisfactory sealing especially on the lower part.



The image shows that the concrete blocks have heterogeneous thermal properties; this fact has to be take into account when simulating or certificating the building.

HVACs' system components

HVAC system of City Hall is centralized, all water type. There is no mechanical ventilation. Fan coils are installed in all the zones. as terminal units. Heating is provided by one gas fired boiler rated at 680 kW of installed power. Cool water is provided by an electric chiller (reciprocating type compressors, two circuits, r407c) condensed by underground water (provided by a well). No nominal refrigerant power was provided; a 250 kW cooling capacity was measured with chiller operation analysis.

Five distribution pumps serve the circuit:

- 2 X 0.63 kW for the primary circuit
- 1 X 1.3 kW serve the secondary circuit of the original city hall
- 1 X 0.86 kW serve the secondary circuit of bibliotheca
- 1 X 0.43 kW serve the secondary circuit of the city hall expansion

The distribution system was built in 1970 (contemporary with the building) while the chiller was substituted in 2002.

The Case Study considers each of the components of the system individually in the following order:

- Cooling systems
- All water system

Cold Generator and Pumps

Chiller Identification	
Manufacture/Model	Bluebox Omega
Year	2001
System Type	Vapour compression
Compressor Type	Reciprocating
Fuel Type	Electricity
Performance Data	
Nominal Cooling Capacity [kW]	N.A.
Measured cooling power [kW]	250
Installed Cooling Capacity /m² GIA	73
Measured Electric Power [kW]	80
COP	2.9
Refrigerant Gas	R407c
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	N.A.

Figure – Equipment pictures

Figure – Cold generator Plant

Auxiliary Equipment	
Pumps Electric Demand [kW]	3.5

Figure – Well water feeding condenser

Figure – Electric panel with meter installed

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	no
Operating mode	automatic
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	1300
Vibration eliminators	**Satisfactory**
Worn couplings	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Unsatisfactory (circuit 2, low temp on evaporator)**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	No
Sensors calibration records	No
Refrigerant leaks	No
Location of the equipment	Inside

Field measurements	
Electricity load[kW]	43 kW(comp1) 35 kW(comp2)
Electric voltage [V]	399

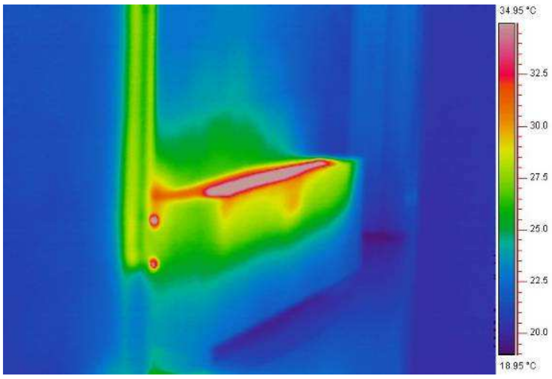
All Water System

General Identification	
Manufacture/Model	Danfoss
Year	1970
Type	2 tube fan coil
Performance Data	
Nominal Cooling Capacity [kW]	
Nominal Heating Capacity [kW]	N.A.
Fan power [W]	45
Electrical data	
Power supply [V/Ph/Hz]	220/1/50
Start-up amps [A]	N.A.

Figure – Equipment pictures

Monitoring observations

Inspection	
Heat transfer section cleanliness	**Satisfactory**
Thermal Insulation (Visual)	**Unsatisfactory**
Air-Filter cleanliness	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Operation mode	**Automatic**
Operation time estimated (h/year)	**2000**
Water leaks	**No**
Sensors calibration records	**No**
Maintenance status	**Unsatisfactory**
Previous inspections reports	**No**
Maintenance reports	**No**



In the thermal image it is clearly seen that pipe insulation is not adequate.

Control systems

The control system provides zone temperature control, through old but still functioning Danfoss thermostats.

Energy consumption data

Metering information

During this inspection we concentrated on chiller performance.
The unit assessed is a water condensed chiller, using underground water as the cooling medium. The unit consists of two refrigerant circuits, each including compressor and evaporator, connected to a single condenser. The compressors are of the reciprocating type, with multiple cylinders and suction and discharge valves, and can operate at two load levels, thus allowing four degrees of partialisation. Previous to the performance assessment, the HVAC system was inspected following the HARMONAC guidelines and inspection methodology. The inspection results, for the considered chiller, showed a good state of maintenance. No sign of oil leakages was detected. Prior to the test the unit was considered perfect. The assessment data (Figure 1), however, showed that some operating parameters were critical, and that the unit performance was not always satisfactory.

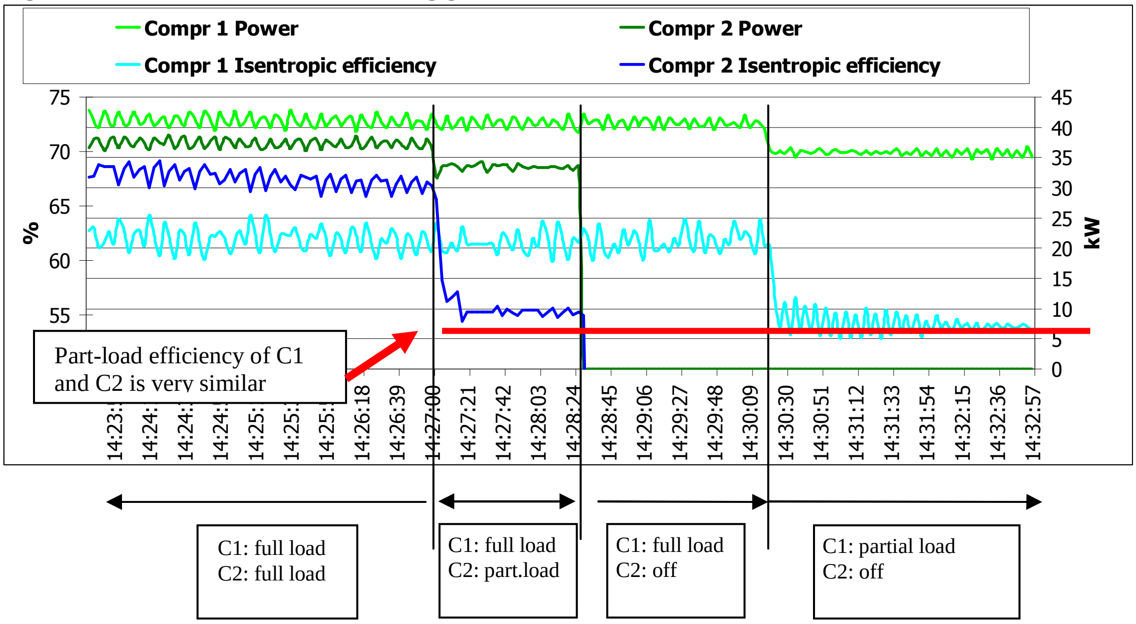
Figure 1a shows the electric power input and the isentropic efficiency of the two compressors under different load conditions. Figure 1b shows, for the same operating conditions, the chilled water temperatures at the evaporator's inlet and outlet, and the refrigerant fluid temperature in the two evaporators. Finally, Figure 1c indicates the two circuits COP and compression ratio. The experimental data reveal that:

At full load, the power input to compressor n. 1 (C1) is very close to its nominal value (39.45 kW), while the corresponding value for compressor n. 2 (C2) is about 10% lower; in terms of isentropic efficiency, C2 is about 5% more efficient than C1. At partial load, the performance difference between C1 and C2 is very small, both in terms of isentropic efficiency and input power (see Fig. 13a). Probably, the lower C2 performance at full load is caused by problems in the cylinders that are disconnected at part load.

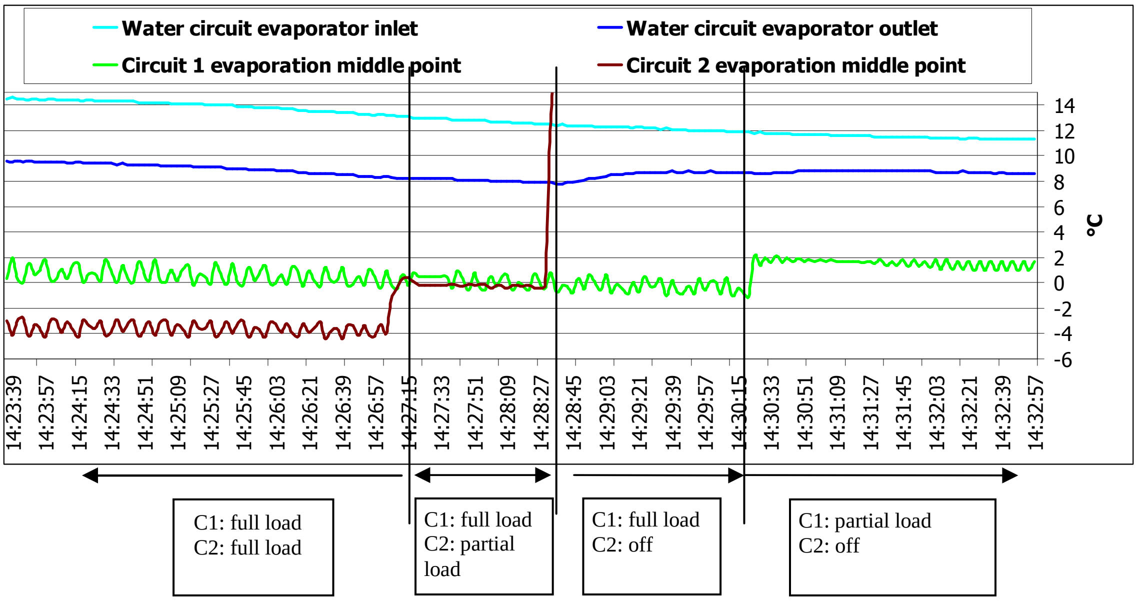
Circuit 2 is likely to have a low refrigerant charge, which explains the lower evaporation temperature (around – 4°C, with risk of freezing at the water side, see Fig. 13b), and unstable COP values, caused by continuous flash evaporation (Fig. 13c); the same graph also indicates that C2 has a higher pressure ratio than C1. A correct charge would increase the evaporation temperature with an increase in COP on the order of 3-5%/K.

Other monitoring results (not shown in the graphs) also reveal an excessive superheat at the evaporator's outlet, which may be corrected by adjusting or replacing the expansion valve.

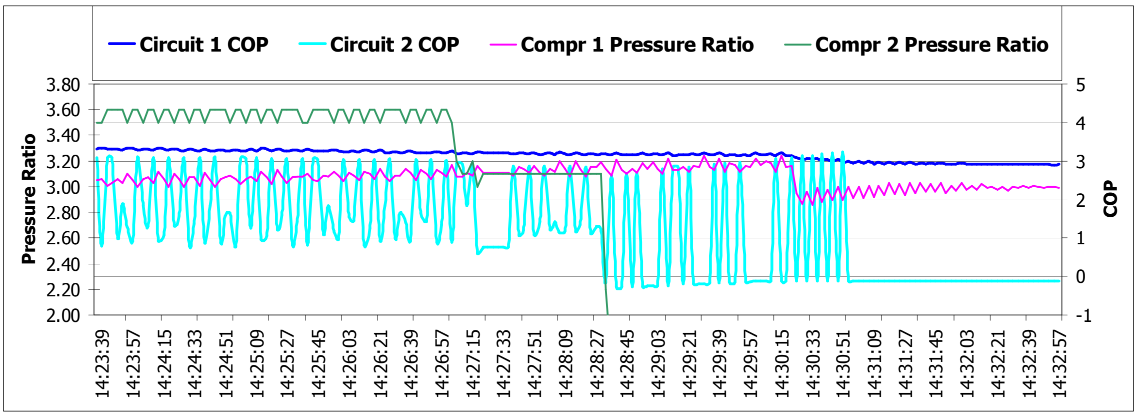
Figure 1. Chiller parameters logged



(a)



(b)



(c)

Timing for inspection

Inspection Item	Short Description	Time (mins)
PI1	Location and number of AC zones	15
PI2	Documentation per zone	40
PI3	Images of zones/building	15
PI4	General zone data/zone	14
PI5	Construction details/zone	22
PI6	Building mass/air tightness per zone	10
PI7	Occupancy schedules per zone	10
PI8	Monthly schedule exceptions per zone	5
PI9	HVAC system description and operating setpoints per zone	15
PI10	Original design conditions per zone	
PI11	Current design loads per zone	
PI12	Power/energy information per zone	10
PI13	Source of heating supplying each zone	4
PI14	Heating storage and control for each zone	15
PI15	Refrigeration equipment for each zone	10
PI16	AHU for each zone	
PI17	Cooling distribution fluid details per zone	10
PI18	Cooling terminal units details in each zone	20
PI19	Energy supply to the system	1
PI20	Energy supply to the building	1
PI21	Annual energy consumption of the system	
PI22	Annual energy consumption of the building	10
	TOTAL TIME TAKEN (minutes)	**227**
	TOTAL (seconds/m^2)	**4.01**

Centralised system inspection data

Inspection Item	Short Description	Time (mins)
PC1	Details of installed refrigeration plant	15
PC2	Description of system control zones, with schematic drawings.	17
PC3	Description of method of control of temperature.	10
PC4	Description of method of control of periods of operation.	4
PC5	Floor plans, and schematics of air conditioning systems.	20
PC6	Reports from earlier AC inspections and EPC's	
PC7	Records of maintenance operations on refrigeration systems	4
PC8	Records of maintenance operations on air delivery systems.	4
PC9	Records of maintenance operations on control systems and sensors	
PC10	Records of sub-metered AC plant use or energy consumption.	
PC11	Commissioning results where relevant	
PC12	An estimate of the design cooling load for each system	45
PC13	Records of issues or complaints concerning indoor comfort conditions	
PC14	Use of BMS	15
PC15	Monitoring to continually observe performance of AC systems	
C1	Locate relevant plant and compare details	45
C2	Locate supply the A/C system and install VA logger(s)	120
C3	Review current inspection and maintenance regime	5
C4	Compare system size with imposed cooling loads	5
C5	Estimate Specific Fan Power of relevant air movement systems	
C6	Compare AC usage with expected hours or energy use	24
C7	Locate refrigeration plant and check operation	10
C8	Visual appearance of refrigeration plant and immediate area	4
C9	Check refrigeration plant is capable of providing cooling	3
C10	Check type, rating and operation of distribution fans and pumps	20
C11	Visually check condition/operation of outdoor heat rejection units	
C12	Check for obstructions through heat rejection heat exchangers	
C13	Check for signs of refrigerant leakage	5
C14	Check for the correct rotation of fans	

C15	Visually check the condition and operation of indoor units	40
C16	Check air inlets and outlets for obstruction	
C17	Check for obstructions to airflow through the heat exchangers	
C18	Check condition of intake air filters.	
C19	Check for signs of refrigerant leakage.	
C20	Check for the correct rotation of fans	
C21	Review air delivery and extract routes from spaces	
C22	Review any occupant complaints	
C23	Assess air supply openings in relation to extract openings.	
C24	Assess the controllability of a sample number of terminal units	10
C25	Check filter changing or cleaning frequency.	
C26	Assess the current state of cleanliness or blockage of filters.	
C27	Note the condition of filter differential pressure gauge.	
C28	Assess the fit and sealing of filters and housings.	
C29	Examine heat exchangers for damage or significant blockage	
C30	Examine refrigeration heat exchangers for signs of leakage	
C31	Note fan type and method of air speed control	
C32	Check for obstructions to inlet grilles, screens and pre-filters.	
C33	Check location of inlets for proximity to sources of heat	
C34	Assess zoning in relation to internal gain and solar radiation.	15
C35	Note current time on controllers against the actual time	10
C36	Note the set on and off periods	6
C37	Identify zone heating and cooling temperature control sensors	12
C38	Note zone set temperatures relative to the activities and occupancy	13
C39	Check control basis to avoid simultaneous heating and cooling	6
C40	Assess the refrigeration compressor(s) and capacity control	240
C41	Assess control of air flow rate through air supply and exhaust ducts	
C42	Assess control of ancillary system components e.g. pumps and fans	15
C43	Assess how reheat is achieved, particularly in the morning	0
C44	Check actual control basis of system	10
	TOTAL TIME TAKEN (minutes)	**752**
	TOTAL (seconds/m^2)	**13.27**

Overall conclusions

As seen a visual inspection of electric chillers should not be sufficient to check potential inefficiency of the system. **In the analyzed unit the charge was low and one compressor shows problem in efficiency, maybe due to worn segments.**

HARMONAC

IT Field Trial 8:
Retirement home – Air and Water system

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IT

August 2010

Supported by

Intelligent Energy Europe

Italy Field Trial 8: Porcia Retirement home, Air and water system with electric chiller

Overview of building and system

The system considered is an air and water system with fan coils as terminal units and mechanical ventilation provided by one Air Handling Unit (constant air volume type). Heating is provided by one gas fired boiler rated at 290 kW of thermal net power. Cool water is provided by an electric chiller (scroll type compressors, 1 circuit with 3 compressors in parallel, air condensed) rated at 120 kW of cooling power.

Parameter	Installed electrical load / kW	Floor area served / m^2 GIA	Installed capacity W/m^2 GIA	Annual consumption kWh	Average annual power W/m^2	Annual use kWh/m^2	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output)	120.0	1'600.0	75.0				-
Total Chillers		1'600.0					
Total CW pumps		1'600.0					
Total fans		1'600.0					
Total humidifiers							
Total boilers		1'600.0					
Total HW pumps	3.5	1'600.0	2.2				
Total HVAC electrical		1'600.0					
Total Building Elec kWh		1'600.0		76'800.0	5.5	48.0	
Total Boilers/Heat kWh	290.0	1'600.0	181.3	200'574.0	14.3	125.4	7.9
Total Building Gas/Heat kWh		1'600.0					

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--
O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--

O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--
O3.7	Maintain proper evaporating and condensing temperatures	C1, C2 C8	Clean condenser circuit, Verify correct operation of expansion valve
O3.12	Maintain proper heat source/sink flow rates	C1, C2 C8	Clean condenser circuit
O3.15	Maintain full charge of refrigerant	C1, C2 C8	Control charge and refill
O3.16	Clean finned tube evaporator / condenser air side and straighten damaged fins	C1, C2 C8	Control , clean and straighten damaged fins
O3.17	Clean condenser tubes periodically	C1, C2 C8	Clean condenser circuit

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Health and care
Geographical location	Porcia, PD, ITALY
Gross Area (m^2)	1600
N° Floors	1

Zone Description

Main Activity	Health and care
Area Conditioned [m^2]	1600
Volume conditioned [m^3]	6210
Max. Number of occupants	70
Occupation schedule /Hours Operation	24 hours, 7 days per week
Lighting Power density [W/m^2]	15
Type Lighting/lighting control	Mainly fluorescent tube/manual switch
Lighting schedule /Hours Operation	N.A.
Other Equipment [kW]	almost nothing

System Zone Description

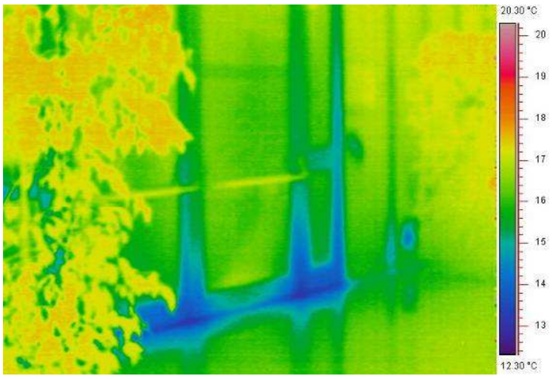
System Type	**Air and Water**
Cooling Equipment Type of Fuel	**Electricity**
	Meters
Schedule and Operation Time [h/year]	About 3000 h/year
Required Heating capacity	**131 kW** (gross power, energy signature calculation method) **216450 kWh/year** gross energy (counted)
Heating Equipment Type of Fuel	**Gas**
	Counters
Schedule and Operation Time [h/year]	About 4000 h/year
Terminal units	**Fan coil**
Cooling/Heating capacity [kW]	**120 / 290**

Indoor Environment Parameters	**Measure - Winter/Summer (average)**
Ventilation Rate [ach]	N.A.
Indoor Relative Humidity [%]	40%/60%
Indoor air Temperature [°C] – Winter/Summer	21.4/25.6 (2009/2010 season)

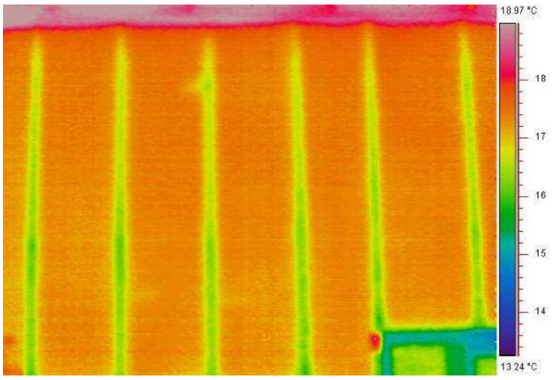
Outdoor Environment Parameters	**Measure - Winter/Summer (average)**
Outdoor air temperature [°C] Winter/Summer	8.9/24.1 (2009/2010 season)
Outdoor Relative Humidity [%] Winter/Summer	81/75.5 (2009/2010 season)

Thermo graphic assessment of the building

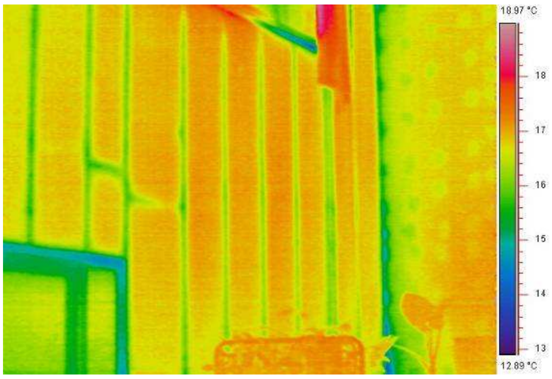
Some thermo graphic images of the building were taken to emphasize problems of poor window sealing and low thermal resistance of the opaque surfaces.



This door has an unsatisfactory sealing especially on the lower part.



The images show that the cast concrete construction has heterogeneous thermal properties. The joints are characterized by a lower heat resistance. This fact has to be taken into account when simulating or certificating the building.



As seen, the thermal bridge on the lower corner of the building affects the temperature of the inside surface of the building.

HVACs' system components

HVAC system of Retirement home is centralized, air and water type. Mechanical ventilation is provided by one single AHU (CAV). Fan coils are installed in all the zones. Heating is provided by one gas fired boiler rated at 290 kW of thermal net power. Cool water is provided by one electric chiller (scroll type compressors, 1 circuit with 3 compressors in parallel, air condensed).

The Field trial considers each of the components of the system individually in the following order:

- Cooling systems

Cold Generator and Pumps

Chiller Identification	
Manufacture/Model	VENCO
Year	2000
System Type	Vapour compression
Compressor Type	Scroll
Fuel Type	Electricity
Performance Data	
Nominal Cooling Capacity [kW]	N.A.
Rated cooling power [kW]	120
Installed Cooling Capacity /m² GIA	75
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	N.A.

Figure – Equipment pictures

Figure – Cold generator Plant

Auxiliary Equipment	
Pumps Electric Demand [kW]	3.5

Figure – Vibration eliminator

Figure – Pressure gauges

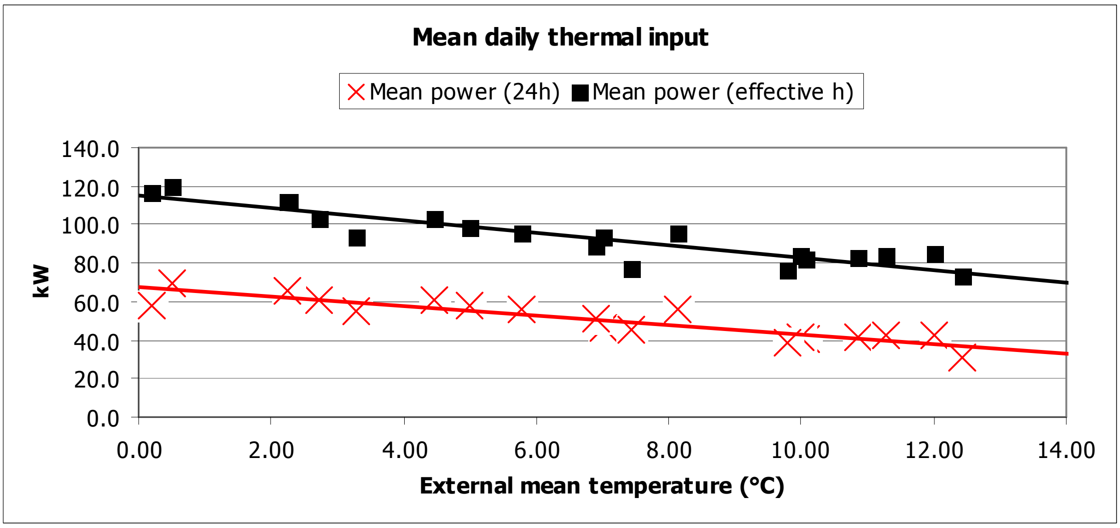
Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	no
Operating mode	automatic
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	3000
Vibration eliminators	**Satisfactory**
Worn couplings	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Satisfactory**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	No
Sensors calibration records	No
Refrigerant leaks	No
Location of the equipment	Outdoor

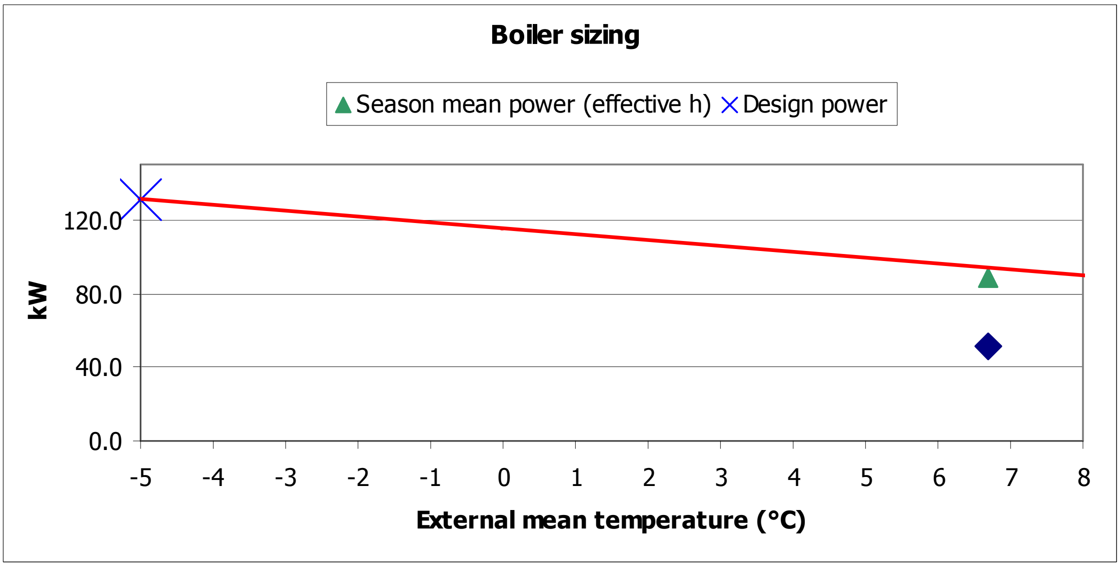
Field measurements	
Electricity load[kW]	N.A.
Electric voltage [V]	N.A.

Gas consumption analysis

Gas consumption weekly data were analyzed to find a correlation with external temperature. The quite accurate fitting curve implies that control strategy is well addressed, at least for heating season.



From these data ideal design power should be calculated. The design power for heating was calculated at 130 kW (corresponding to the outdoor design temperature of -5°C), almost one third of the actual power installed.



Timing for inspection

Pre-inspection data (mainly building)

Inspection Item	Short Description	Time (mins)	Notes
PI1	Location and number of AC zones	15	
PI2	Documentation per zone	20	
PI3	Images of zones/building	15	
PI4	General zone data/zone	14	
PI5	Construction details/zone	17	
PI6	Building mass/air tightness per zone	10	
PI7	Occupancy schedules per zone	8	
PI8	Monthly schedule exceptions per zone	2	
PI9	HVAC system description and operating setpoints per zone	20	
PI10	Original design conditions per zone		N.A.
PI11	Current design loads per zone		N.A.
PI12	Power/energy information per zone	10	
PI13	Source of heating supplying each zone	4	
PI14	Heating storage and control for each zone	12	
PI15	Refrigeration equipment for each zone	5	
PI16	AHU for each zone	8	
PI17	Cooling distribution fluid details per zone	8	
PI18	Cooling terminal units details in each zone	8	
PI19	Energy supply to the system	1	
PI20	Energy supply to the building	1	
PI21	Annual energy consumption of the system	5	
PI22	Annual energy consumption of the building	5	
	TOTAL TIME TAKEN (minutes)	**188**	
	TOTAL (seconds/m^2)	**7.05**	1600

Inspection Item	Short Description	Time (mins)	Notes
PC1	Details of installed refrigeration plant	10	
PC2	Description of system control zones, with schematic drawings.	15	
PC3	Description of method of control of temperature.	10	
PC4	Description of method of control of periods of operation.	4	
PC5	Floor plans, and schematics of air conditioning systems.	10	
PC6	Reports from earlier AC inspections and EPC's		not available
PC7	Records of maintenance operations on refrigeration systems	4	
PC8	Records of maintenance operations on air delivery systems.	4	
PC9	Records of maintenance operations on control systems and sensors		not available
PC10	Records of sub-metered AC plant use or energy consumption.		not available
PC11	Commissioning results where relevant		not available
PC12	An estimate of the design cooling load for each system	45	
PC13	Records of issues or complaints concerning indoor comfort conditions		not available
PC14	Use of BMS	14	
PC15	Monitoring to continually observe performance of AC systems		
C1	Locate relevant plant and compare details	15	
C2	Locate supply the A/C system and install VA logger(s)	120	include PC 15
C3	Review current inspection and maintenance regime	5	
C4	Compare system size with imposed cooling loads	5	
C5	Estimate Specific Fan Power of relevant air movement systems	4	on label data
C6	Compare AC usage with expected hours or energy use	20	compare bills with expected occupancy
C7	Locate refrigeration plant and check operation	5	
C8	Visual appearance of refrigeration plant and immediate area	4	
C9	Check refrigeration plant is capable of providing cooling	3	termometers mounted on fluid distribution network
C10	Check type, rating and operation of distribution fans and pumps	10	
C11	Visually check condition/operation of outdoor heat rejection units	2	Air exchanger
C12	Check for obstructions through heat rejection heat exchangers	2	

C13	Check for signs of refrigerant leakage	4	1 unit
C14	Check for the correct rotation of fans		not possible
C15	Visually check the condition and operation of indoor units	20	10 min per floor
C16	Check air inlets and outlets for obstruction	5	in addiction to C15
C17	Check for obstructions to airflow through the heat exchangers	5	in addiction to C15
C18	Check condition of intake air filters.	10	in addiction to C15
C19	Check for signs of refrigerant leakage.	10	in addiction to C15
C20	Check for the correct rotation of fans	10	in addiction to C15
C21	Review air delivery and extract routes from spaces	15	in addiction to C15
C22	Review any occupant complaints		not available
C23	Assess air supply openings in relation to extract openings.	15	
C24	Assess the controllability of a sample number of terminal units	10	
C25	Check filter changing or cleaning frequency.	10	
C26	Assess the current state of cleanliness or blockage of filters.	4	
C27	Note the condition of filter differential pressure gauge.	3	
C28	Assess the fit and sealing of filters and housings.	15	
C29	Examine heat exchangers for damage or significant blockage	4	
C30	Examine refrigeration heat exchangers for signs of leakage	4	
C31	Note fan type and method of air speed control	2	
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4	
C33	Check location of inlets for proximity to sources of heat	2	
C34	Assess zoning in relation to internal gain and solar radiation.	15	
C35	Note current time on controllers against the actual time	10	
C36	Note the set on and off periods	6	
C37	Identify zone heating and cooling temperature control sensors	15	
C38	Note zone set temperatures relative to the activities and occupancy	13	
C39	Check control basis to avoid simultaneous heating and cooling	6	
C40	Assess the refrigeration compressor(s) and capacity control	240	240 min per unit
C41	Assess control of air flow rate through air supply and exhaust ducts	10	
C42	Assess control of ancillary system components e.g. pumps and fans	10	

C43	Assess how reheat is achieved, particularly in the morning	0	not available
C44	Check actual control basis of system	8	
	TOTAL TIME TAKEN (minutes)	**796**	
	TOTAL (seconds/m^2)	**29.85**	1600

Overall conclusions

This FT represents a typical system for retirement home, which must operate 24 hours per day with a high level reliability level: this implies simple systems, often over sized. In this case the over sizing of gas fired boiler is huge, while cooling power seems more adequate to building properties.

HARMONAC

IT Field Trial 9:
Classroom – Desiccant cooling system

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IT

August 2010

Supported by

Intelligent Energy Europe

Field Trial 9: Classroom served by Desiccant cooling system

Overview of building and system

The building considered is an ex industry building converted in classrooms in 2004. A specific part of this building, used as University classrooms, was object of the HEGEL (EU Sixth Framework Programme) project. The system considered is an all air CAV system. A Combined Heat and Power system was installed to provide heating and electricity. The system is composed by one gas fired Internal combustion engine. Heating provided, in summer season, feeds an absorption chiller. In addition, the AHU is coupled with a liquid desiccant system that utilizes a water solution of Li-Cl. The field trial is focused mainly on the desiccant system.

Parameter	Installed electrical load / kW	Floor area served / m^2 GIA	Installed capacity W/m^2 GIA
Desiccant Chillers nominal cooling capacity (latent cooling output)	160.0	2'100.0	76.2
Total Chillers [a]	1.0	2'100.0	0.5
Total CW pumps	3	2'100.0	1.4
Total fans	7.0	2'100.0	3.3
[a] the electric input is limited to the solution pumps. Heating input needed is not considered			

Input table provided for this field trial is limited, because, due the experimental type of installation, other specific values are not representative: CHP system was installed to test the energy and economic balance of IC engine and was not specifically sized for the building considered. This system is coupled with the main hot water loop that serves all the Politecnico campus.

On the other hand no ECO could be assessed due to the innovative and experimental nature of the installation.

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Educational
Geographical location	Turin
Net Area	2’100
N° Floors	1

Zone Description

Main Activity	Classroom
Area Conditioned [m^2]	2’100
Volume conditioned [m^3]	9’000
Max. Number of occupants	500
Occupation schedule /Hours Operation	8:00-18:30

System Zone Description

System Type	Desiccant Li-Cl water solution
Cooling Equipment Type of Fuel	Electricity, Hot water
Schedule and Operation Time [h/year]	980 (estimated)
Heating Equipment Type of Fuel	gas fired
Terminal units	all air system

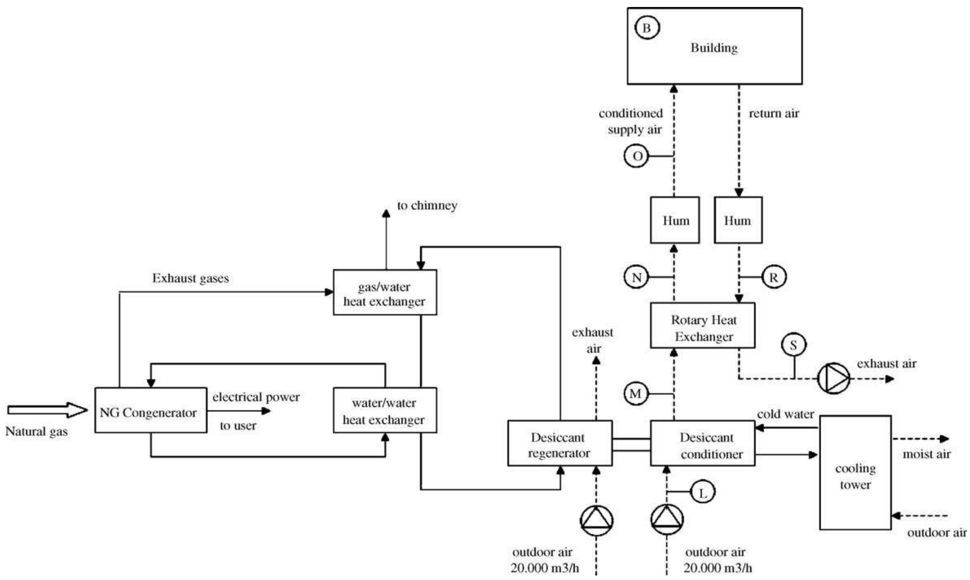
Indoor Environment Parameters	Measure/observe - Winter/Summer (average)
Ventilation Rate [ach]	2.2
Indoor Relative Humidity [%]	50%
Indoor air Temperature [°C] – Winter/Summer	20-26°C

Outdoor Environment Parameters	Design	Measure/observe - Winter/Summer (average)
Outdoor air temperature [°C] Winter/Summer	-8 / 30.7	min -3 / max 36.4 avg: 6.1/ 25.3
Outdoor Relative Humidity [%] Winter/Summer	85% / 46%	77/ 61.6
Max. Solar Radiation [W/m²]		max 1119 (10.06.2008) avg : 63.6 / 203.1 (on 24h)

HVAC system components

The HVAC system analyzed comprises a CHP system coupled to cooling absorption system and desiccant system.
The layout of the system is shown below, and consists of:

- one natural gas (NG) reciprocating internal combustion cogenerator (capacity of 126 kWel, 220 kWth);
- a liquid desiccant system operating on fresh air, with a nominal capacity of 20,000 m^3/h and with approximately 160 kW of latent cooling power (a unit is shown in Fig. 3);
- a cooling tower to dissipate heat from the desiccant conditioner;
- two heat exchangers, which recover heat from the cooling water and from the flue gases of the engine;
- a secondary hot water circuit that allows the desiccant unit regenerators to be fed with the heat recovered from the engine;
- a rotary heat exchanger between the supply and return airstreams.



Chp system

General Identification	
Manufacture/Model	CRF
Year	2006
Type	gas ICE
Performance Data	
Electrical power (kW)	126
Thermal power (kW)	220
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Full load Ampere	N.A.

Figure – Equipment pictures

Desiccant system

Heat Rejection Identification	
Manufacture/Model	Ducool DH
Year	2006
Cooling method	absorption, Li-Cl water solution
Performance Data	
Nominal latent Cooling Capacity [kW]	160
air flow rate [m³/h]	20'000 (4X5'000)

Figure – Equipment pictures

Figure – Solution heat exchanger

Figure – Li-Cl Solution pumps

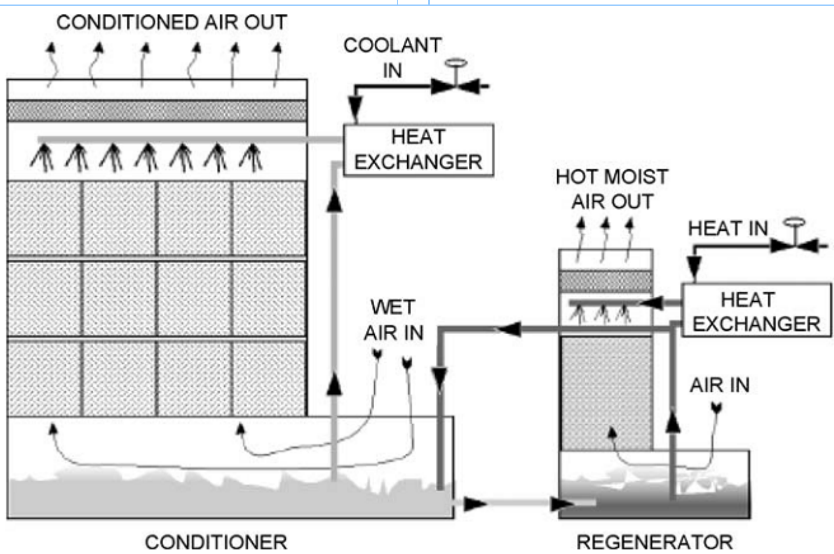


Figure – Functional scheme of a liquid desiccant cooling system

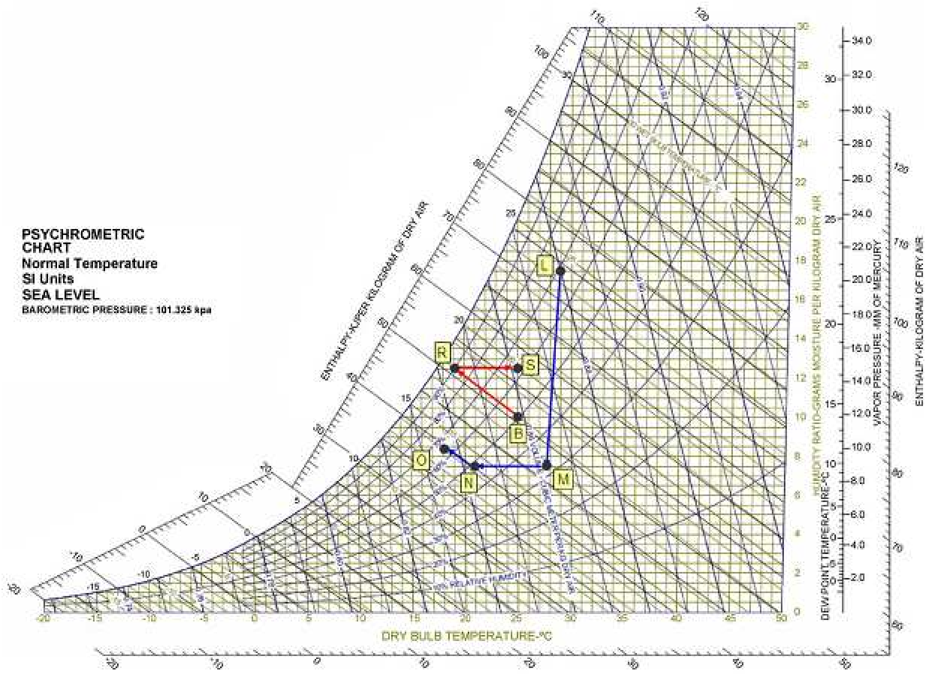
Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	**No**
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Operation mode	**Automatic**
Li-Cl Solution leaks	**No**
Water systems leaks	**No**
Sensors calibration records	**No**

The system manager reported that some problems on solution pipes sealing occurred. Extraordinary maintenance was needed to provide better pipe connections and sealing. These problems are probably caused by the construction of the desiccant units. Due to a low market penetration, these products are made with a relatively low production control. The photo below shows some pipes connection and sealing: clearly hand made with heterogeneous quality.

Energy balance

The further analysis was made by the HVAC system responsible. It shows the specific thermodynamic conditions of ventilation system. For the assessment of performance during the summer season, the outside air reference conditions were assumed equal to the ASHRAE monthly design values in Turin (T_{db} = 28.8 8C,T_{wb} = 24.2 8C, RH = 68%). The nominal temperature and relative humidity values that are expected to be reached in different points of the plant layout are listed in the table below (reference can be made to the figure for the position of the different points). All the transformations operated on outdoor air (point L), in order to reach the supply air condition to the building (point O), are shown in the psychrometric chart. The temperature and humidity of the air inside the building (point B) and the conditions of the return airstream after the humidification (point R) and at the exhaust (point S) are also pointed out.



	POINT ON THE GRAPH	T [°C]	RH (%)
Outdoor air	L	28.8	68
Supply air after the conditioner	M	27.6	32
Supply air after the rotary heat exchanger	N	21.0	48
Supply air after the humidifier (to the building)	O	18.0	66
Set point inside the building	B	25.0	50
Return air after the humidifier	R	19.0	90
Return air after the rotary heat exchanger	S	25.0	60

Timing for inspection

Inspection Item	Short Description	Time (mins)	Notes
PI1	Location and number of AC zones	3	
PI2	Documentation per zone	10	
PI3	Images of zones/building	15	
PI4	General zone data/zone	15	
PI5	Construction details/zone	8	
PI6	Building mass/air tightness per zone	10	
PI7	Occupancy schedules per zone	2	
PI8	Monthly schedule exceptions per zone	1	
PI9	HVAC system description and operating setpoints per zone	20	
PI10	Original design conditions per zone	10	
PI11	Current design loads per zone	25	
PI12	Power/energy information per zone	5	
PI13	Source of heating supplying each zone	5	
PI14	Heating storage and control for each zone	1	
PI15	Refrigeration equipment for each zone	10	
PI16	AHU for each zone	4	
PI17	Cooling distribution fluid details per zone	6	
PI18	Cooling terminal units details in each zone	1	
PI19	Energy supply to the system	5	
PI20	Energy supply to the building	1	
PI21	Annual energy consumption of the system	0	N.A.
PI22	Annual energy consumption of the building	0	N.A.
	TOTAL TIME TAKEN (minutes)	**157**	
	TOTAL (seconds/m²)	**4.49**	2100

Centralised system inspection data

Inspection Item	Short Description	Time (mins)	Notes
PC1	Details of installed refrigeration plant	20	
PC2	Description of system control zones, with schematic drawings.	15	
PC3	Description of method of control of temperature.	10	
PC4	Description of method of control of periods of operation.	2	
PC5	Floor plans, and schematics of air conditioning systems.	4	
PC6	Reports from earlier AC inspections and EPC’s	3	
PC7	Records of maintenance operations on refrigeration systems	5	
PC8	Records of maintenance operations on air delivery systems.	2	
PC9	Records of maintenance operations on control systems and sensors	0	N.A.
PC10	Records of sub-metered AC plant use or energy consumption.	8	
PC11	Commissioning results where relevant	5	
PC12	An estimate of the design cooling load for each system	15	
PC13	Records of issues or complaints concerning indoor comfort conditions		N.A.
PC14	Use of BMS	4	
PC15	Monitoring to continually observe performance of AC systems	15	
C1	Locate relevant plant and compare details	15	
C2	Locate supply the A/C system and install VA logger(s)	30	
C3	Review current inspection and maintenance regime	10	
C4	Compare system size with imposed cooling loads	30	
C5	Estimate Specific Fan Power of relevant air movement systems	5	
C6	Compare AC usage with expected hours or energy use	30	
C7	Locate refrigeration plant and check operation	15	
C8	Visual appearance of refrigeration plant and immediate area	5	
C9	Check refrigeration plant is capable of providing cooling	5	
C10	Check type, rating and operation of distribution fans and pumps	5	
C11	Visually check condition/operation of outdoor heat rejection units	5	
C12	Check for obstructions through heat rejection heat exchangers	5	
C13	Check for signs of refrigerant leakage	10	

C14	Check for the correct rotation of fans	15	
C15	Visually check the condition and operation of indoor units	15	
C16	Check air inlets and outlets for obstruction	10	
C17	Check for obstructions to airflow through the heat exchangers	6	
C18	Check condition of intake air filters.	4	
C19	Check for signs of refrigerant leakage.	7	
C20	Check for the correct rotation of fans	15	
C21	Review air delivery and extract routes from spaces	15	
C22	Review any occupant complaints	15	
C23	Assess air supply openings in relation to extract openings.	10	
C24	Assess the controllability of a sample number of terminal units	5	
C25	Check filter changing or cleaning frequency.	5	
C26	Assess the current state of cleanliness or blockage of filters.	6	
C27	Note the condition of filter differential pressure gauge.	1	
C28	Assess the fit and sealing of filters and housings.	9	
C29	Examine heat exchangers for damage or significant blockage	9	
C30	Examine refrigeration heat exchangers for signs of leakage	4	
C31	Note fan type and method of air speed control	4	
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4	
C33	Check location of inlets for proximity to sources of heat	3	
C34	Assess zoning in relation to internal gain and solar radiation.	10	
C35	Note current time on controllers against the actual time	2	
C36	Note the set on and off periods	2	
C37	Identify zone heating and cooling temperature control sensors	5	
C38	Note zone set temperatures relative to the activities and occupancy	15	
C39	Check control basis to avoid simultaneous heating and cooling	10	
C40	Assess the refrigeration compressor(s) and capacity control		N.A.
C41	Assess control of air flow rate through air supply and exhaust ducts	15	
C42	Assess control of ancillary system components e.g. pumps and fans	10	
C43	Assess how reheat is achieved, particularly in the morning	5	

C44	Check actual control basis of system	15	
	TOTAL TIME TAKEN (minutes)	**529**	
	TOTAL (seconds/m^2)	**15.11**	2100

Overall conclusions

Field trial analyzed presents an innovative system on Italian market. Desiccant systems are commonly used in very hot countries, but demonstrate its validity also for temperate climatic conditions.

HARMONAC

IT Field Trial 10:
Office – VRF HP system

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IT

August 2010

Supported by
Intelligent Energy Europe

Field Trial 10: Office served by Variable Refrigerant flow Heat pump

Overview of building and system

The building considered is a XIX century building, which hosts the headquarters of the Regional Environmental Council. The HVAC system was completely refurbished in 2006: the original all water system (with radiators) was substituted with air to air VRF heat pump system.

The modular VRF system employs 11 roof-mounted air-cooled external units. An inverter drives one of the two scroll compressors present in each module, in order to continuously vary the cooling output according to the actual demand. Rated power values are:

- heating: 333 kW;
- cooling: 298 kW;
- electrical: 84 kW

The building is equipped with a two-pipe system, in which the refrigerant fluid is distributed by a single main loop to the internal units that operate either in heating or cooling regime, according to a seasonal changeover scheme.

The central Building Monitoring System (BMS) allows monitoring of the internal / external units using the building Ethernet network from a remote PC. Features include: remote internal unit set-point control, alarm handling, energy consumption recording, fire prevention system monitoring, monitoring of window opening / closing, lighting system and PC on / off switching (internal heat load monitoring).

Parameter	Installed electrical load / kW	Floor area served / m² GIA	Installed capacity W/m² GIA
Total Chillers nominal cooling capacity (cooling output)	298.0	5'000.0	59.6
Total VRF el. Input	84.0	5'000.0	16.8
Total Building Elec kWh		5'000.0	
Total Boilers/Heat kWh	333.0	5'000.0	66.6
Total Building Gas/Heat kWh		5'000.0	

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--
O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--
O2.2	Shut off A/C equipments when not needed	PI7, PI12, PI21, C8	Modify control strategy
O2.6	Implement pre-occupancy cycle	PI7, PI12, PI21, C8	Modify control strategy
O3.16	Clean finned tube evaporator / condenser air side and straighten damaged fins	C1, C2 C8	Control , clean and straighten damaged fins

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Service / Office
Geographical location	Turin
Net Area	5000 m^2
N° Floors	6

Zone Description

Main Activity	Office
Area Conditioned [m^2]	5’000
Volume conditioned [m^3]	24’000
Max. Number of occupants	200
Occupation schedule /Hours Operation	08:30-17:00

System Zone Description

System Type	VRF HP
Cooling Equipment Type of Fuel	Electricity
	Meters
Schedule and Operation Time [h/year]	1800 (estimated)
Heating Equipment Type of Fuel	Electricity
Terminal units	air to air internal units

Indoor Environment Parameters	Measure/observe - Winter/Summer (average)
Ventilation Rate [ach]	N.A.
Indoor Relative Humidity [%]	50%
Indoor air Temperature [°C] – Winter/Summer	20-26°C

Outdoor Environment Parameters	Design	Measure/observe - Winter/Summer (average)
Outdoor air temperature [°C] Winter/Summer	-8 / 30.7	min -3 / max 36.4 avg: 6.1/ 25.3
Outdoor Relative Humidity [%] Winter/Summer	85% / 46%	77/ 61.6
Max. Solar Radiation [W/m²]		max 1119 (10.06.2008) avg : 63.6 / 203.1 (on 24h)

HVAC system components

The system considered is a Variable Refrigerant Flow air-to-air heat pump. Eleven external units are coupled to 105 internal units. Refrigerant gas utilized is R410a. In the main hall of the building, on the first storey, a Heat Recovery Ventilation system is installed.
The modular VRF system employs 11 roof-mounted air-cooled external units. An inverter drives one of the two scroll compressors present in each module, in order to continuously vary the cooling output according to the actual demand.
Rated power values are:

- heating: 333 kW;
- cooling: 298 kW;
- electrical: 84 kW

The building is equipped with a two-pipe system, in which the refrigerant fluid is distributed by a single main loop to the internal units that operate either in heating or cooling regime, according to a seasonal changeover scheme.
The central Building Monitoring System (BMS) allows monitoring of the internal / external units using the building Ethernet network from a remote PC. Features include: remote internal unit set-point control, alarm handling, energy consumption recording, fire prevention system monitoring, monitoring of window opening / closing, lighting system and PC on / off switching (internal heat load monitoring).

Heat Pump

General Identification	
Manufacture/Model	Daikin/VRV-II RXYQ10M9
Year	2006
Type	air to air
Performance Data	
EER – Cooling mode	3.5
COP – Heating mode	4.1
SEER	n.a.
Nominal Cooling Capacity [kW]	28
Nominal Heating Capacity [kW]	31.5
Refrigerant Gas	R410a
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Full load Ampere	N.A.

Figure – Equipment pictures

Figure – Equipment pictures

Monitoring observations

Inspection	
Operating Mode	**automatic**
Maintenance status	**satisfactory**
Maintenance reports	**no**
Equipment cleanliness	**satisfactory**
Pressure status	**N.A.**
Water systems leaks	**no**
Sensors calibration records	**no**
Previous inspection reports	**no**
Operating time estimated [h/year]	**1800**
Tightness of wiring connections	**satisfactory**
Thermal insulation (Visual)	**satisfactory**

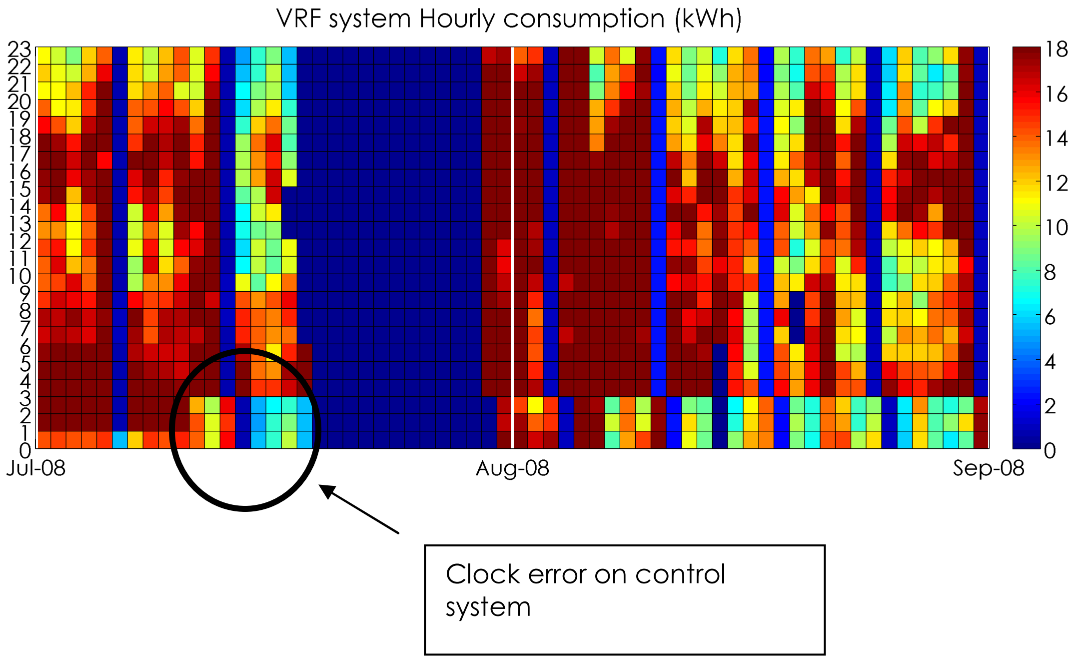
Control systems

The central Building Monitoring System (BMS) allows monitoring of the internal / external units using the building Ethernet network from a remote PC. Features include: remote internal unit set-point control, alarm handling, energy consumption recording, fire prevention system monitoring, monitoring of window opening / closing, lighting system and PC on / off switching (internal heat load monitoring). Energy performance data acquired by the BMS have been recorded and stored since 2007.

The metering currently available are:

- Main electrical incomer
- Global consumption of the VRF system

During Inspection data stored revealed a poor reliability, with a lot of null data. Logging appears to be shut off after installation. For this reason just the data regarding 3 months are analyzed.
The graph shown below demonstrates the poor reliability of data: almost two weeks of July were in fact not logged. Nevertheless some issues could be revealed. Generally the system is on 24 h per day, 5 days per week. After the second week of July the control strategy "lost" three hours: instead of turning off on 0:00 AM on Sunday, the system turned off on 03:00 on Sunday. This problem was probably due to some clock problem on the system control. This problem remained unresolved for the whole Summer.



Timing for inspection

Inspection Item	Short Description	Time (mins)	Notes
PI1	Location and number of AC zones	5	
PI2	Documentation per zone	10	
PI3	Images of zones/building	15	
PI4	General zone data/zone	15	
PI5	Construction details/zone	8	
PI6	Building mass/air tightness per zone	10	
PI7	Occupancy schedules per zone	5	
PI8	Monthly schedule exceptions per zone	1	
PI9	HVAC system description and operating setpoints per zone	13	
PI10	Original design conditions per zone	10	
PI11	Current design loads per zone	45	
PI12	Power/energy information per zone	5	
PI13	Source of heating supplying each zone	2	
PI14	Heating storage and control for each zone	1	
PI15	Refrigeration equipment for each zone	4	
PI16	AHU for each zone	4	
PI17	Cooling distribution fluid details per zone	6	
PI18	Cooling terminal units details in each zone	2	
PI19	Energy supply to the system	2	
PI20	Energy supply to the building	1	
PI21	Annual energy consumption of the system	0	N.A.
PI22	Annual energy consumption of the building	5	N.A
	TOTAL TIME TAKEN (minutes)	**169**	
	TOTAL (seconds/m^2)	**2.03**	5000

Packaged system inspection data

Inspection Item	Short Description	Time (mins)	Notes
PP1	List of installed refrigeration plant	8	
PP2	Method of control of temperature.	3	
PP3	Method of control of periods of operation	5	
PP4	Reports from earlier AC inspections and EPC's	5	
PP5	Records of maintenance operations	14	
PP6	Records of maintenance (control systems and sensors)	0	n.a.
PP7	Records of sub-metered air conditioning plant (use or energy)	25	
PP8	Design cooling load for each system	5	
PP9	Description of the occupation of the cooled spaces	25	
P1	Review available documentation from pre-inspection	30	
P2	Locate the plant and compare details with pre-inspection data	30	
P3	Locate supply to the A/C system and install VA logger(s)	70	
P4	Review current inspection and maintenance regime	12	
P5	Compare size with imposed cooling loads	18	
P6	Compare records of use or sub-metered energy with expectations	45	
P7	Locate outdoor plant	5	
P8	Check for signs of refrigerant leakage.	60	VRV refrigerant network
P9	Check plant is capable of providing cooling	3	
P10	Check external heat exchangers	10	
P11	Check location of outdoor unit	2	
P12	Assess zoning in relation to internal gain and orientation	12	
P13	Check indicated weekday and time on controllers against actual	105	1 minute per each internal unit, there are 105 internal unit
P14	Note the set on and off periods	5	global
P15	Identify zone heating and cooling temperature control sensors.	1	in the internal unit
P16	Note set temperatures in relation to the activities and occupancy	1	assessing with P13
P17	Provision of controls or guidance on use while windows open	15	
P18	Type, age and method of capacity control of the equipment	2	

P19	Write report	60	
	TOTAL TIME TAKEN (minutes)	**576**	
	TOTAL (seconds/m^2)	**6.91**	5000

Overall conclusions

The system analyzed represents a possible state of the art of HVAC in historical buildings, where traditional gas fired systems could be a problem in terms of fire prevention and safety. In addition, refrigerant pipes are smaller than water pipes and can be installed with less modification on the building walls.
In this kind of architectural panorama, the HP VRF solution is quite interesting, thanks to its minimum impact on internal walls and the modularity of its installation, which permits having the external units distributed in several small zones, instead of two large centralized cooling and heating stations.
The performance of the system assessed is quite good, in comparison to other Italian field trials. Nevertheless, the inspection conducted and the data analysis revealed that schedule control was not optimized: the system ran 24 hours a day, 6 days per week and the internal clock of control system was probably not set properly.

HARMONAC

IT Field Trial 11:
Office – Air and Water system

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IT

August 2010

Supported by

Intelligent Energy Europe

Field Trial

Italy Field Trial 11: PORCIA City house chiller consumption on different schedules

Overview of building and system

The system considered is an all water system with fan coils as terminal units. Heating is provided by one gas fired boiler rated at 680 kW of thermal gross power. Cool water is provided by an electric chiller (reciprocating type compressors, 2 circuits, r407c) condensed by underground water (provided by a well). No nominal refrigerant power was provided, a 250 kW cooling capacity was measured with chiller operation analysis. There is no mechanical ventilation. The distribution system was built in 1970 (contemporary with the building) while the chiller was substituted in 2002.

Parameter	Installed electrical load / kW	Floor area served / m² GIA	Installed capacity W/m² GIA	Annual consumption kWh	Average annual power W/m²	Annual use kWh/m²	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output) [e]	250.0	3'426.0	73.0				
Total Chillers	80.0	3'426.0	23.4	39'042.0	1.3	11.4	5.6
Total CW pumps		3'426.0					
Total fans		3'426.0					
Total humidifiers		3'426.0					
Total boilers ELECTRICAL		3'426.0					
Total HW pumps		3'426.0					
Total HVAC electrical		3'426.0					
Total Building Elec kWh		3'426.0					
Total Boilers/Heat kWh	680.0	3'426.0	198.5				
Total Building Gas/Heat kWh		3'426.0					

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.1	Generate instructions ("user guide") targeted to the occupants	PI7, PI8, PI9, PI10, P4	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--

O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--
O3.7	Maintain proper evaporating and condensing temperatures	C1, C2 C8	Clean condenser circuit, Verify correct operation of expansion valve
O3.12	Maintain proper heat source/sink flow rates	C1, C2 C8	Clean condenser circuit
O3.15	Maintain full charge of refrigerant	C1, C2 C8	Control charge and refill
O3.17	Clean condenser tubes periodically	C1, C2 C8	Clean condenser circuit
O3.20	Apply indirect free cooling using underground water (free chilling)	PI7, PI12, PI21, C8	Modify cool water circuits

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Public assembly spaces
Geographical location	Porcia, PD, ITALY
Gross Area (m^2)	3426
N° Floors	4

Zone Description

Main Activity	City hall
Area Conditioned [m^2]	3426
Volume conditioned [m^3]	10991
Max. Number of occupants	250
Occupation schedule /Hours Operation	Monday to Friday (8:00-16:00) Saturday (8:00-13:00)
Lighting Power density [W/m^2]	About 20
Type Lighting/lighting control	Mainly fluorescent tube/manual switch
Lighting schedule /Hours Operation	N.A.
Other Equipment [kW]	About 15 W/m^2 of computers, printers, etc…

System Zone Description

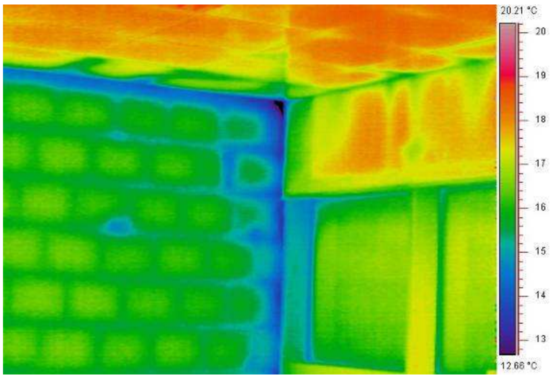
System Type	**All Water**
Required Cooling capacity	**165 kW** (refrigerant power, energy signature calculation method) **39042** kWh/year
Cooling Equipment Type of Fuel	**Electricity** **Meters**
Schedule and Operation Time [h/year]	About 1000 h/year
Required Heating capacity	**243 kW** (gross power, energy signature calculation method) **30227 kWh/year** gross energy (counted)
Heating Equipment Type of Fuel	**Gas** **Counters**
Schedule and Operation Time [h/year]	About 2500 h/year
Terminal units	**Fan coil**
Cooling/Heating capacity [kW]	**250 / 680**

Indoor Environment Parameters	**Measure - Winter/Summer (average)**
Ventilation Rate [ach]	N.A.
Indoor Relative Humidity [%]	40%/60%
Indoor air Temperature [°C] – Winter/Summer	21.4/25.6 (2009/2010 season)

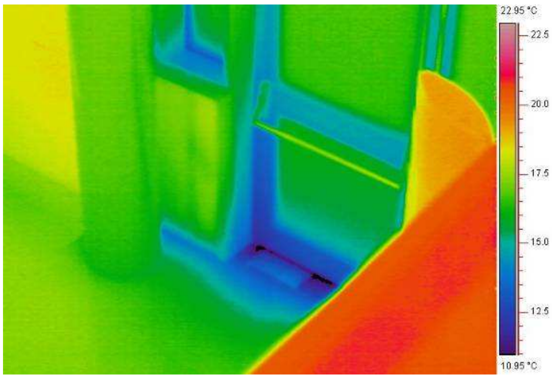
Outdoor Environment Parameters	**Measure - Winter/Summer (average)**
Outdoor air temperature [°C] Winter/Summer	8.9/24.1 (2009/2010 season)
Outdoor Relative Humidity [%] Winter/Summer	81/75.5 (2009/2010 season)

Thermo graphic assessment of the building

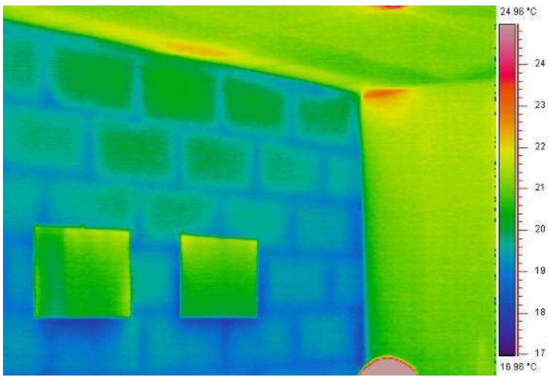
Some thermo graphic images of the building was made to emphasize some problem of windows sealing and thermal resistance of the opaque surfaces.



As seen the thermal bridge on the corner of the building affects notably the temperature on the inside surface of the building.



This door has an unsatisfactory sealing especially on the lower part.



The image shows that the concrete blocks shows heterogeneity in thermal properties, this fact has to be take into account when simulating or certificating the building.

HVACs' system components

HVAC system of City hall is centralized, all water type. There is no mechanical ventilation. Fan coil are installed in all the zones. Heating is provided by one gas fired boiler rated at 680 kW of thermal gross power. Cool water is provided by an electric chiller (reciprocating type compressors, 2 circuits, r407c) condensed by underground water (provided by a well). No nominal refrigerant power was provided, a 250 kW cooling capacity was measured with chiller operation analysis.

Five distribution pumps serve the circuit:

- 2 X 0.63 kW for the primary circuit
- 1 X 1.3 kW serve the secondary circuit of the original city hall
- 1 X 0.86 kW serve the secondary circuit of bibliotheca
- 1 X 0.43 kW serve the secondary circuit of the city hall expansion

The distribution system was built in 1970 (contemporary with the building) while the chiller was substituted in 2002.

The Field trial considers each of the components of the system individually in the following order:

- Cooling systems
- All water system

Field Trial

Cold Generator and Pumps

Chiller Identification	
Manufacture/Model	Bluebox Omega
Year	2001
System Type	Vapour compression
Compressor Type	Reciprocating
Fuel Type	Electricity
Performance Data	
Nominal Cooling Capacity [kW]	N.A.
Measured cooling power [kW]	250
Installed Cooling Capacity /m² GIA	73
Measured Electric Power [kW]	80
COP	2.9
Refrigerant Gas	R407c
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	N.A.


Figure – Equipment pictures


Figure – Cold generator Plant

Auxiliary Equipment	
Pumps Electric Demand [kW]	3.5


Figure – Well water feeding condenser


Figure – Electric panel with meter installed

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	no
Operating mode	automatic
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	1300
Vibration eliminators	**Satisfactory**
Worn couplings	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Unsatisfactory (circuit 2, low temp on evaporator)**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	No
Sensors calibration records	No
Refrigerant leaks	No
Location of the equipment	Inside

Field measurements	
Electricity load[kW]	43 kW(comp1) 35 kW(comp2)
Electric voltage [V]	399

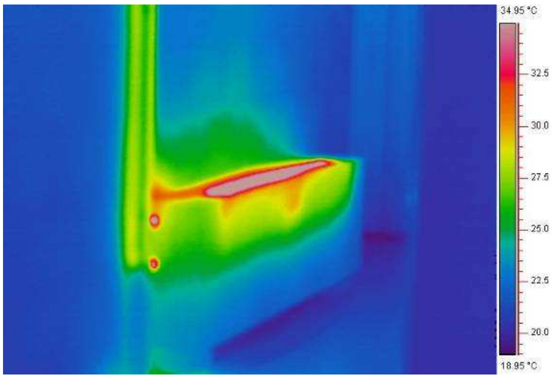
All Water System

General Identification	
Manufacture/Model	Danfoss
Year	1970
Type	2 tube fan coil
Performance Data	
Nominal Cooling Capacity [kW]	
Nominal Heating Capacity [kW]	N.A.
Fan power [W]	45
Electrical data	
Power supply [V/Ph/Hz]	220/1/50
Start-up amps [A]	N.A.

Figure – Equipment pictures

Monitoring observations

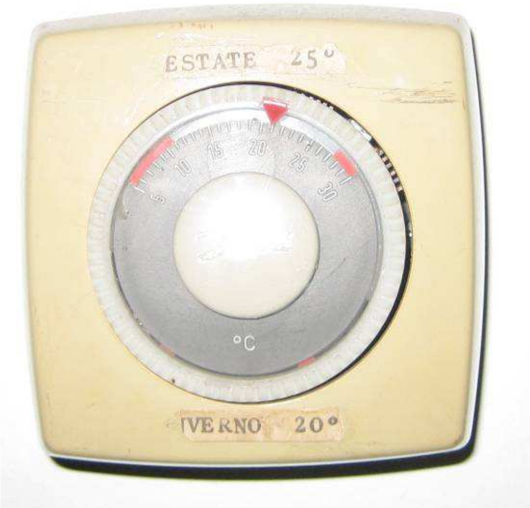
Inspection	
Heat transfer section cleanliness	**Satisfactory**
Thermal Insulation (Visual)	**Unsatisfactory**
Air-Filter cleanliness	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Operation mode	**Automatic**
Operation time estimated (h/year)	**2000**
Water leaks	**No**
Sensors calibration records	**No**
Maintenance status	**Unsatisfactory**
Previous inspections reports	**No**
Maintenance reports	**No**



In the thermal image is clearly seen that tube insulation is not adequate.

Control systems

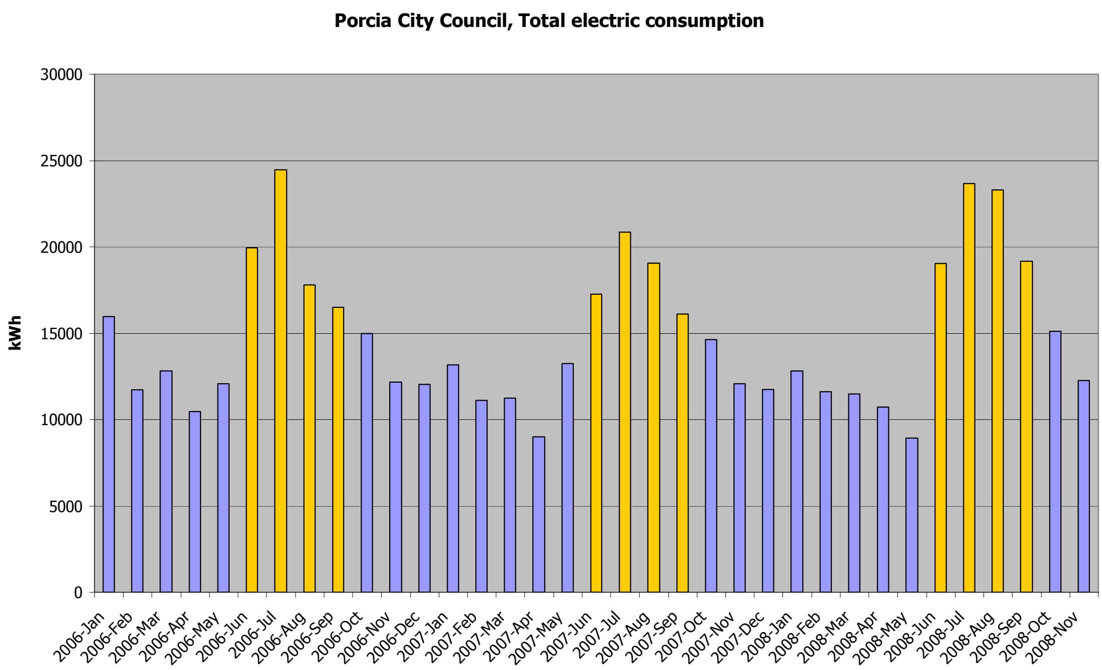
The control system provide zone temperature control, trough old but still functioning danfoss set point regulator.



Energy consumption data

Metering information

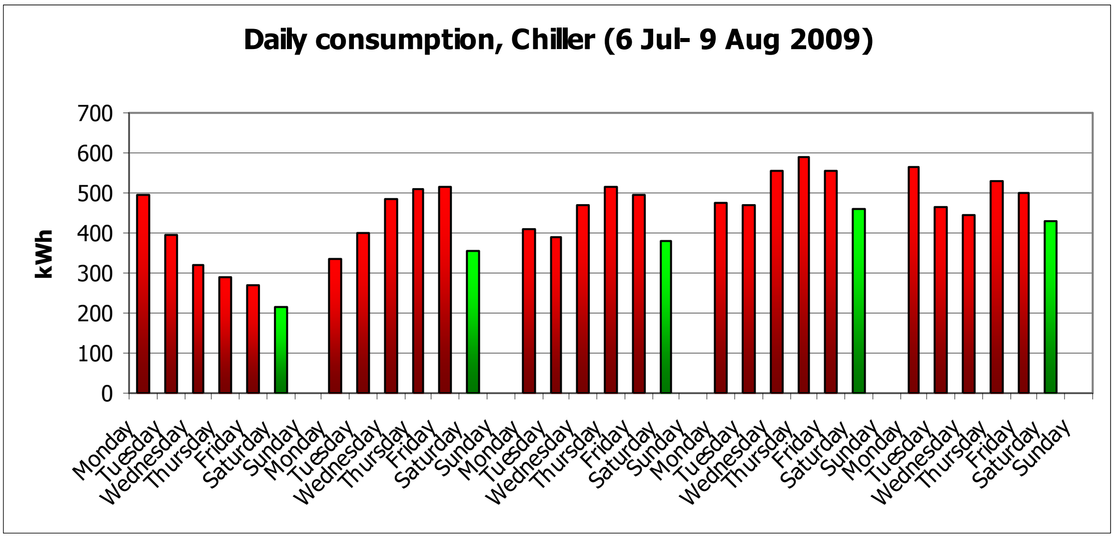
An electric meter was installed on the chiller, to measure the hourly consumption. In consideration of the low thermal capacity of the building it was decided to change HVAC system operational schedule.
The energy consumption at different hourly operation was measured to provide Energy Conservation Opportunities data.



The graph shows monthly electric consumption of the whole building, the orange bars represent summer season: the consumption for cooling is clearly seen: in some case it represents almost 50% of the total building consumption.

ECO O 3.1, Shut chiller plant off when not required

With medium term measurements (Jul-Sept 2009), it was possible to analyze the consumption of electric chiller. The graph below shows the consumption during 5 weeks, as an example of data collected.



Green colour for Saturday. The chiller, when not operating is shut off, without stand-by consumption: on Sunday the chiller consumption is equal to zero.

Three mode of operation was used for assessing ECO as stated in table below:

	HVAC schedule		
	A	B	C

on/off	7.00/18.00	6.00/20.00	7.00/17.00
hours ON	11	14	10

During different parts of 2009 summer season chiller operated with different schedule:

- A from 1 to 27 July
- B from 28 July to 23 August
- C from 24 August to 17 September

The daily consumption data were collected depending on average daily temperature, to provide an estimation based on similar climatic conditions. Days were grouped by mean external temperature and schedule type (A,B,C). Mean daily consumption was calculated for these groups. Daily mean consumption difference (D_{diff}) was calculated. This value was divided by the difference, in hours, for different schedule (H_{diff}). This operation provides a rough estimate about the consumption of one hour of "unnecessary" operation (when the building has no occupancy and the system is on).

				B-A		B-C		A-C	
Mean ext. Temp °C	Mean cons A	Mean cons B	Mean cons C	D_{diff}	D_{diff}/H_{diff}	D_{diff}	D_{diff}/H_{diff}	D_{diff}	D_{diff}/H_{diff}
25	388.3	548	368	**29.2%**	9.7%	**32.8%**	8.2%	**5.2%**	5.2%
26	411.6	518.5	414.5	**20.6%**	6.9%	**20.1%**	5.0%	**-0.7%**	**-0.7%**
27	487	473.8	446	**-2.8%**	-0.9%	**5.9%**	1.5%	**8.4%**	**8.4%**
28	506	525	469	**3.6%**	1.2%	**10.7%**	2.7%	**7.3%**	**7.3%**
29	513	611.3		**16.1%**	5.4%				
30	508	606.5		**16.2%**	5.4%				

On this basis we can estimate that in each hour of no-occupancy operation the chiller consumes from 5 to 7% of daily consumption and that a reduction of operational schedule will save:

- **20% of chiller mean daily consumption was saved lowering the daily operating hours from 14 to 11.**

To provide more reliability on estimation another analysis was performed. In this case we focused on time period from 28 July to 23 August, when the system worked with B schedule. The consumption in the no-occupancy hours was simply eliminated from the hourly data:

Day	kWh 6-20	kWh 7-17	Difference
28 July 2009	472	351	25.6%
29 July 2009	557	446	19.9%
30 July 2009	589	467	20.7%
31 July 2009	557	437	21.5%
01 August 2009	461	361	21.7%
02 August 2009	0	0	
03 August 2009	563	434	22.9%
04 August 2009	465	360	22.6%

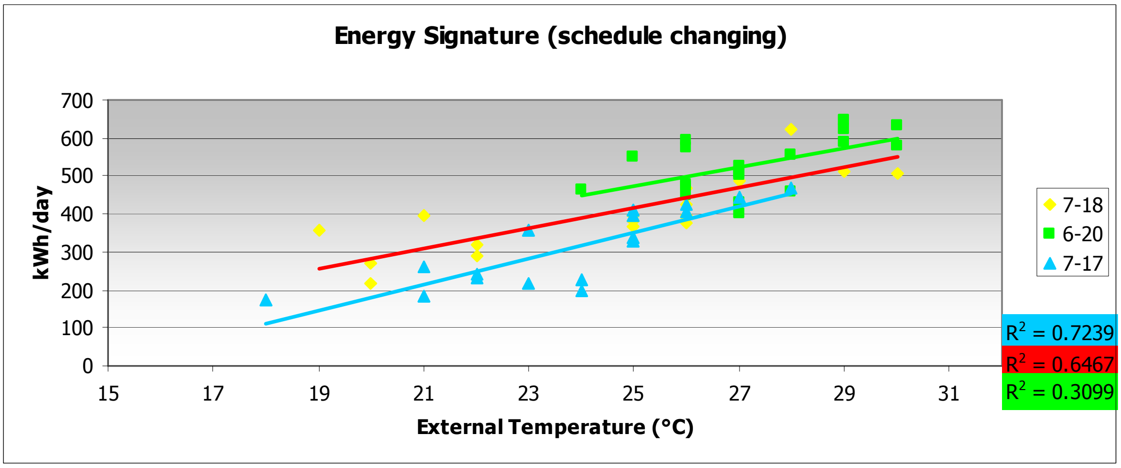
05 August 2009	447	342	23.5%
06 August 2009	528	420	20.5%
07 August 2009	501	391	22.0%
08 August 2009	430	337	21.6%
09 August 2009	0	0	
10 August 2009	542	414	23.6%
11 August 2009	596	470	21.1%
12 August 2009	548	421	23.2%
13 August 2009	576	452	21.5%
14 August 2009	478	362	24.3%
15 August 2009	403	314	22.1%
16 August 2009	0	0	
17 August 2009	588	449	23.6%
18 August 2009	621	485	21.9%
19 August 2009	579	442	23.7%
20 August 2009	634	496	21.8%
21 August 2009	647	505	21.9%
22 August 2009	507	405	20.1%
23 August 2009	0	0	

The overall difference is:

- **-22.2% of chiller consumption during the period, lowering the daily operating hours from 14 to 10.**

The last value confirms the previous estimation.

Energy signature was determined for different schedule times. As seen in the graph below, longer daily operation provided a less accurate linear regression (lower correlation coefficient).



Timing for inspection

Inspection Item	Short Description	Time (mins)
PI1	Location and number of AC zones	15
PI2	Documentation per zone	40
PI3	Images of zones/building	15
PI4	General zone data/zone	14
PI5	Construction details/zone	22
PI6	Building mass/air tightness per zone	10
PI7	Occupancy schedules per zone	10
PI8	Monthly schedule exceptions per zone	5
PI9	HVAC system description and operating setpoints per zone	15
PI10	Original design conditions per zone	
PI11	Current design loads per zone	
PI12	Power/energy information per zone	10
PI13	Source of heating supplying each zone	4
PI14	Heating storage and control for each zone	15
PI15	Refrigeration equipment for each zone	10
PI16	AHU for each zone	
PI17	Cooling distribution fluid details per zone	10
PI18	Cooling terminal units details in each zone	20
PI19	Energy supply to the system	1
PI20	Energy supply to the building	1
PI21	Annual energy consumption of the system	
PI22	Annual energy consumption of the building	10
	TOTAL TIME TAKEN (minutes)	**227**
	TOTAL (seconds/m^2)	**4.01**

Centralised system inspection data

Inspection Item	Short Description	Time (mins)

PC1	Details of installed refrigeration plant	13
PC2	Description of system control zones, with schematic drawings.	12
PC3	Description of method of control of temperature.	5
PC4	Description of method of control of periods of operation.	4
PC5	Floor plans, and schematics of air conditioning systems.	15
PC6	Reports from earlier AC inspections and EPC’s	
PC7	Records of maintenance operations on refrigeration systems	4
PC8	Records of maintenance operations on air delivery systems.	4
PC9	Records of maintenance operations on control systems and sensors	
PC10	Records of sub-metered AC plant use or energy consumption.	
PC11	Commissioning results where relevant	
PC12	An estimate of the design cooling load for each system	25
PC13	Records of issues or complaints concerning indoor comfort conditions	
PC14	Use of BMS	15
PC15	Monitoring to continually observe performance of AC systems	
C1	Locate relevant plant and compare details	20
C2	Locate supply the A/C system and install VA logger(s)	90
C3	Review current inspection and maintenance regime	5
C4	Compare system size with imposed cooling loads	5
C5	Estimate Specific Fan Power of relevant air movement systems	
C6	Compare AC usage with expected hours or energy use	18
C7	Locate refrigeration plant and check operation	6
C8	Visual appearance of refrigeration plant and immediate area	4
C9	Check refrigeration plant is capable of providing cooling	3
C10	Check type, rating and operation of distribution fans and pumps	15
C11	Visually check condition/operation of outdoor heat rejection units	
C12	Check for obstructions through heat rejection heat exchangers	
C13	Check for signs of refrigerant leakage	5
C14	Check for the correct rotation of fans	
C15	Visually check the condition and operation of indoor units	35
C16	Check air inlets and outlets for obstruction	
C17	Check for obstructions to airflow through the heat exchangers	

C18	Check condition of intake air filters.	
C19	Check for signs of refrigerant leakage.	
C20	Check for the correct rotation of fans	
C21	Review air delivery and extract routes from spaces	
C22	Review any occupant complaints	
C23	Assess air supply openings in relation to extract openings.	
C24	Assess the controllability of a sample number of terminal units	10
C25	Check filter changing or cleaning frequency.	
C26	Assess the current state of cleanliness or blockage of filters.	
C27	Note the condition of filter differential pressure gauge.	
C28	Assess the fit and sealing of filters and housings.	
C29	Examine heat exchangers for damage or significant blockage	
C30	Examine refrigeration heat exchangers for signs of leakage	
C31	Note fan type and method of air speed control	
C32	Check for obstructions to inlet grilles, screens and pre-filters.	
C33	Check location of inlets for proximity to sources of heat	
C34	Assess zoning in relation to internal gain and solar radiation.	15
C35	Note current time on controllers against the actual time	10
C36	Note the set on and off periods	6
C37	Identify zone heating and cooling temperature control sensors	12
C38	Note zone set temperatures relative to the activities and occupancy	13
C39	Check control basis to avoid simultaneous heating and cooling	6
C40	Assess the refrigeration compressor(s) and capacity control	240
C41	Assess control of air flow rate through air supply and exhaust ducts	
C42	Assess control of ancillary system components e.g. pumps and fans	15
C43	Assess how reheat is achieved, particularly in the morning	0
C44	Check actual control basis of system	10
	TOTAL TIME TAKEN (minutes)	**640**
	TOTAL (seconds/m^2)	**11.29**

Overall conclusions

As seen the HVAC consumption is largely affected by different schedule. Optimized timing is the easiest and the cheapest way to improve energy efficiency of HVAC system. **In the analyzed case, 22% on electric energy consumed by chiller should be saved.**

IT Field Trial 12:
Surgery rooms – All Air system

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IT

August 2010

Supported by

Field Trial 12: Hospital, electrical consumption of an all air system for surgery rooms, summer season.

Overview of building and system

The system considered is "all-air" (100% outdoor air) serving three surgery rooms. Total conditioned surface is about 105 square meters. Cooling is provided by two identical chillers, each rated at 210 kW of refrigerant power. Ambient conditions for surgery rooms are imposed by national law: the air exchange rate must be at least 15 vol/hour and no recirculation is allowed; temperature in the room has to be limited between 20° and 24°C.

Some user feedbacks indicate that in surgeries characterized by high internal load (typically orthopedic surgery) the room temperature increase causes discomfort. This field trial describes the second inspection on the same system analyzed in FT n°3.

Parameter	Installed electrical load / kW	Floor area served / m^2 GIA	Installed capacity W/m^2 GIA	Annual consumption kWh	Average annual power W/m^2	Annual use kWh/m^2	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output) [e]	420.0	105.0	4'000.0				
Total Chillers	155.4	105.0	1'480.0	110'407.0	120.0	1'051.5	8.1
Total CW pumps	15.0	105.0	142.9				
Total fans	48.4	105.0	461.0				
Total humidifiers		105.0					
Total boilers ELECTRICAL		105.0					
Total HW pumps	10.0	105.0	95.2				
Total HVAC electrical		105.0					
Total Building Elec kWh		105.0					
Total Boilers/Heat kWh		105.0					
Total Building Gas/Heat kWh		105.0					

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--

O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--
O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--
O3.5	Maintain proper starting frequency and running time of (reversible) chillers	PI7, PI12, PI21, C8	Modify control strategy
P2.5	Improve central chiller / refrigeration control	PI7, PI12, PI21, C8	Modify control strategy

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Health and Care
Geographical location	Ivrea, (Turin Province)
Net Area	105 m²
N° Floors	1

Zone Description

Main Activity	Surgery rooms
Area Conditioned [m²]	105
Volume conditioned [m³]	420
Max. Number of occupants	30
Occupation schedule /Hours Operation	variable
Lighting Power density [w/m²]	20
Type Lighting/lighting control	manual
Lighting schedule /Hours Operation	variable
Other Equipment [kW]	10

Construction Details (only as a support of EES tools)

Not provided, the surgery rooms do not have external wall

System Zone Description

System Type	All air
Cooling Equipment Type of Fuel	Electricity
	Meters
Schedule and Operation Time [h/year]	8600 (the surgery rooms has to be operational during the whole year)
Heating Equipment Type of Fuel	Low sulphur Oil
Terminal units	All air

Indoor Environment Parameters	Measure/observe - Winter/Summer (average)
Ventilation Rate [ach]	15
Indoor Relative Humidity [%]	50%
Indoor air Temperature [°C] – Winter/Summer	18-22°C

Outdoor Environment Parameters	Measure/observe - Winter/Summer (average)
Outdoor air temperature [°C] Winter/Summer	min -3 / max 36.4 avg: 6.1/ 25.3
Outdoor Relative Humidity [%] Winter/Summer	77/ 61.6

HVAC system components

The system considered is an "all-air" (100% outdoor air) serving three surgery rooms. Cooling is provided by two identical chillers, rated at 210 kW of refrigerant power. Air is provided by a single AHU with duplicated motor (to ensure operation reliability).

The Case Study considers the cooling system.

Cold Generator and Pumps

Chiller Identification (X2)	
Manufacture/Model	CLIVET WRAT-2 2.100
Year	1995 (?)
System Type	Dry cooled
Compressor Type	Reciprocating
Fuel Type	electricity
Performance Data	
Nominal Cooling Capacity [kW]	210
Installed Cooling Capacity /m² GIA	4038
Nominal Electric Power [kW]	77.7
COP/EER (Eurovent)	2.7
Refrigerant Gas	R407c
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	N.A.

Figure – Equipment pictures


Figure – cool water inlet and outlet

Auxiliary Equipment	
Fan Electrical Demand [kW]	N.A.
Pumps Electric Demand [kW]	N.A.


Figure – damaged insulation


Vibrations eliminator

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	**No**
Operating mode	**Automatic**
Thermal Insulation (Visual)	Satisfactory, unless some damage on the cold water pipe's insulation
Operation time estimated [h/year]	4000 each group
Vibration eliminators	**Satisfactory**
Worn couplings	**No**
Equipment cleanliness	**Satisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Satisfactory**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	**No**
Sensors calibration records	**No**
Refrigerant leaks	**No**
Location of the equipment	**Exterior**

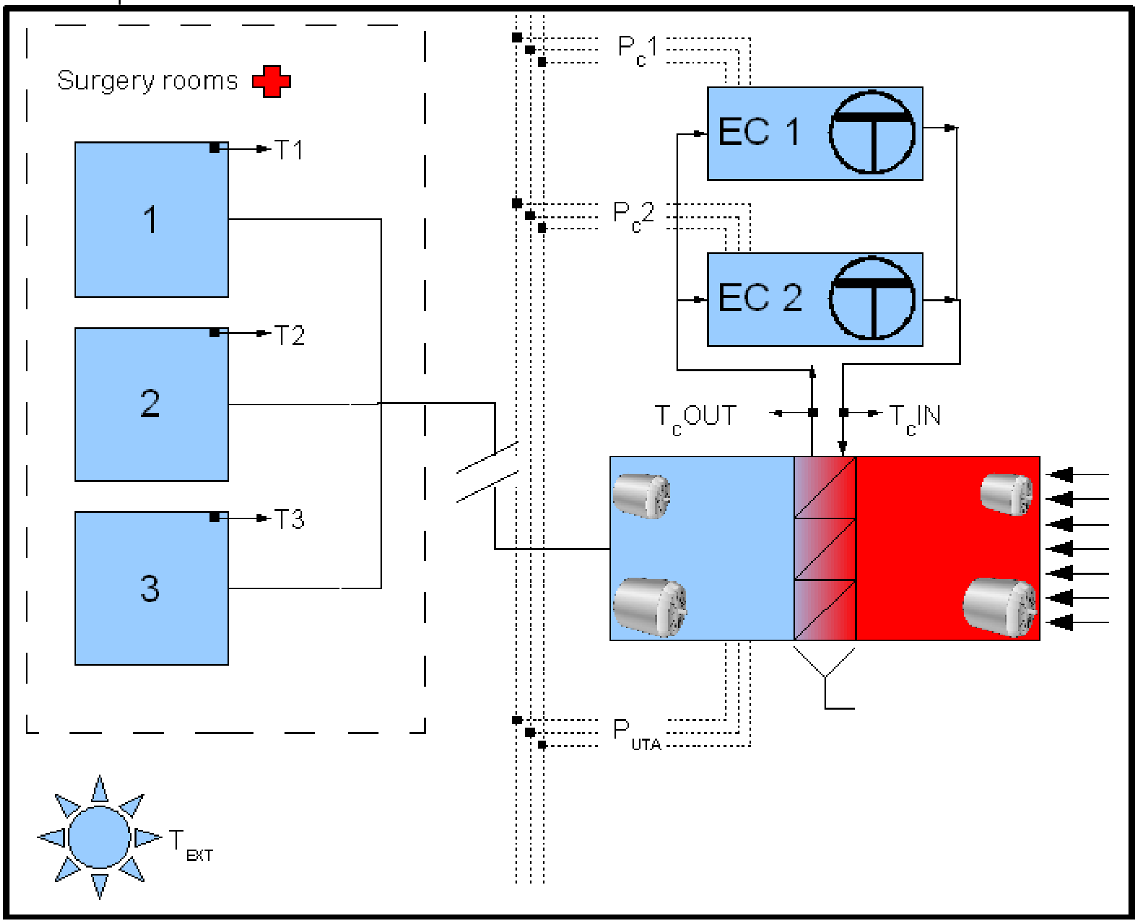
Field measurements	
Electricity power [kW]	69.2
Electric voltage [V]	400

Control systems

The system was not provided of BEMS, so the unit works in manual settings. The chillers were never stopped, even in the winter season.

Metering information

From July 2009 to October 2009 the system was monitored, to log chiller consumption.

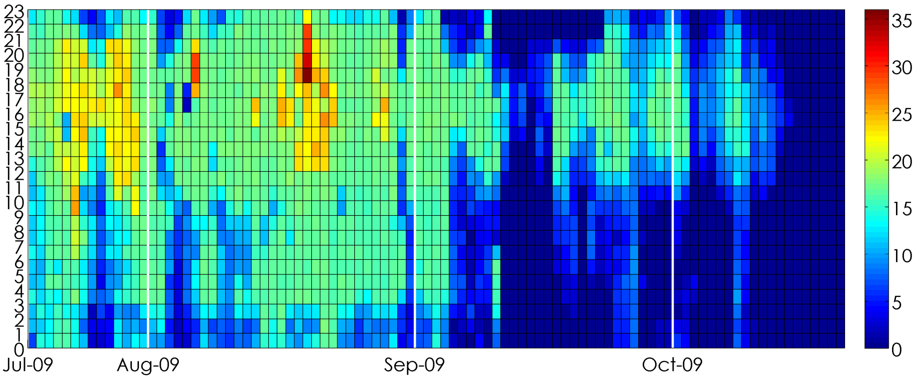


EC: electric chiller
Pc: active power of electric chillers
Tc: cooling water temperature
PUTA: AHU's fans active power
T: temperature and relative humidity

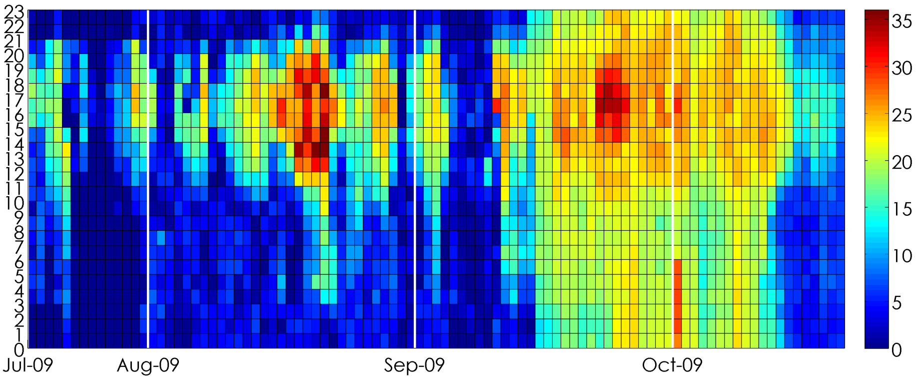
Monitoring observations

The graphs shown below indicate that control strategy impose different regimes for the two chillers. On Summer Chiller n°1 was used to provide base load, while chiller n°2 provided the peak load. In Autumn the strategy changed: chiller n°2 provided the base load, while chiller n°1 provided peak load. On the overall consumption of the two chillers, it is interesting to verify that peak consumption appears in August and during the second part of September. These data seem to confirm the hypothesis of a poor control strategy in the AHU, with potential simultaneous heating and cooling.

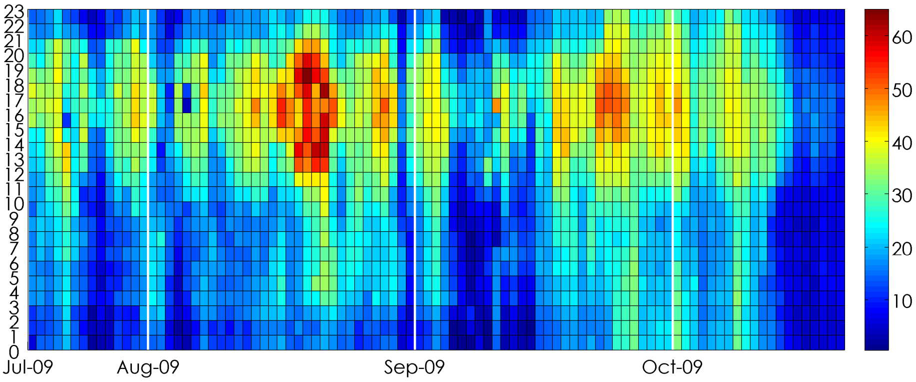
Chiller n°1 hourly Consumption (kWh)



Chiller n°2 hourly Consumption (kWh)



Chillers global hourly Consumption (kWh)



Timing (relative to second inspection)

Pre-inspection data (mainly building)

Inspection Item	Short Description	Time (mins)	Savings	Notes
PI1	Location and number of AC zones	0		
PI2	Documentation per zone	1		
PI3	Images of zones/building	0		
PI4	General zone data/zone	0		
PI5	Construction details/zone	0		
PI6	Building mass/air tightness per zone	0		
PI7	Occupancy schedules per zone			NOT OBTAINED
PI8	Monthly schedule exceptions per zone	2		
PI9	HVAC system description and operating setpoints per zone	1		
PI10	Original design conditions per zone	2		
PI11	Current design loads per zone	0		
PI12	Power/energy information per zone	0		
PI13	Source of heating supplying each zone	0		
PI14	Heating storage and control for each zone	0		
PI15	Refrigeration equipment for each zone	0		
PI16	AHU for each zone	0		
PI17	Cooling distribution fluid details per zone	0		
PI18	Cooling terminal units details in each zone			ALL AIR SYSTEM
PI19	Energy supply to the system	0		
PI20	Energy supply to the building	0		
PI21	Annual energy consumption of the system			N.A.
PI22	Annual energy consumption of the building			N.A.
	TOTAL TIME TAKEN (minutes)	**6**		
	TOTAL (seconds/m^2)	**3.13**	Area (m^2)	115

Centralised system inspection data

Inspection Item	Short Description	Time (mins)	Savings	Notes
PC1	Details of installed refrigeration plant	0		
PC2	Description of system control zones, with	0		

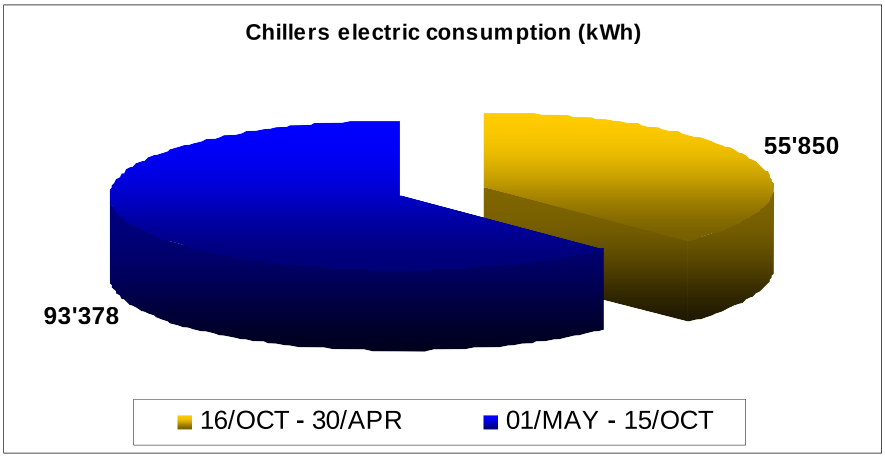
	schematic drawings.			
PC3	Description of method of control of temperature.	10		
PC4	Description of method of control of periods of operation.	0		
PC5	Floor plans, and schematics of air conditioning systems.	0		
PC6	Reports from earlier AC inspections and EPC's	0		not available
PC7	Records of maintenance operations on refrigeration systems	4		
PC8	Records of maintenance operations on air delivery systems.	4		
PC9	Records of maintenance operations on control systems and sensors	0		not available
PC10	Records of sub-metered AC plant use or energy consumption.			N.A.
PC11	Commissioning results where relevant	0		not available
PC12	An estimate of the design cooling load for each system	0		
PC13	Records of issues or complaints concerning indoor comfort conditions	0		not available
PC14	Use of BMS	5		
PC15	Monitoring to continually observe performance of AC systems			
C1	Locate relevant plant and compare details	5		
C2	Locate supply the A/C system and install VA logger(s)	90		include PC 15
C3	Review current inspection and maintenance regime	5		
C4	Compare system size with imposed cooling loads	5		
C5	Estimate Specific Fan Power of relevant air movement systems	4		on label data
C6	Compare AC usage with expected hours or energy use	15		
C7	Locate refrigeration plant and check operation	7		
C8	Visual appearance of refrigeration plant and immediate area	4		
C9	Check refrigeration plant is capable of providing cooling	3		termometers mounted on fluid distribution network
C10	Check type, rating and operation of distribution fans and pumps	5		
C11	Visually check condition/operation of outdoor heat rejection units	3		AIR WATER CONDENSED
C12	Check for obstructions through heat rejection heat exchangers	3		AIR WATER CONDENSED
C13	Check for signs of refrigerant leakage	8		2 UNITS

C14	Check for the correct rotation of fans	7		
C15	Visually check the condition and operation of indoor units			all air system
C16	Check air inlets and outlets for obstruction	10		in addiction to C15
C17	Check for obstructions to airflow through the heat exchangers	10		in addiction to C15
C18	Check condition of intake air filters.	10		in addiction to C15
C19	Check for signs of refrigerant leakage.	10		in addiction to C15
C20	Check for the correct rotation of fans	15		in addiction to C15
C21	Review air delivery and extract routes from spaces	15		in addiction to C15
C22	Review any occupant complaints	10		TOO HOT IN ORTHOPED IC SURGERYS
C23	Assess air supply openings in relation to extract openings.			N.A. TO ENTER INTO CONDITION ED SPACES
C24	Assess the controllability of a sample number of terminal units			all air system
C25	Check filter changing or cleaning frequency.	10		
C26	Assess the current state of cleanliness or blockage of filters.	4		
C27	Note the condition of filter differential pressure gauge.	3		
C28	Assess the fit and sealing of filters and housings.	20		
C29	Examine heat exchangers for damage or significant blockage	4		
C30	Examine refrigeration heat exchangers for signs of leakage	4		
C31	Note fan type and method of air speed control	2		
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4		
C33	Check location of inlets for proximity to sources of heat	2		
C34	Assess zoning in relation to internal gain and solar radiation.	0		
C35	Note current time on controllers against the actual time			
C36	Note the set on and off periods	6		
C37	Identify zone heating and cooling temperature control sensors	5		
C38	Note zone set temperatures relative to the activities and occupancy	0		
C39	Check control basis to avoid simultaneous heating and cooling	10		

C40	Assess the refrigeration compressor(s) and capacity control	200		with climacheck
C41	Assess control of air flow rate through air supply and exhaust ducts	10		
C42	Assess control of ancillary system components e.g. pumps and fans	10		
C43	Assess how reheat is achieved, particularly in the morning			not available
C44	Check actual control basis of system	8		
	TOTAL TIME TAKEN (minutes)	**569**		
	TOTAL (seconds/m²)	**296.87**	Area (m²)	115

Overall conclusions

The second inspection on the system revealed that problems with system controls were not solved. Measured consumption showed that chillers consumes high amounts of electric energy also during middle season. The graph shown below represents the annual consumption of chillers: respectively 37.4% during Winter season and 62.6% during Summer.



HARMONAC

IT Field Trial 13:
Elementary school – VRF HP system

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IT

August 2010

Supported by

Intelligent Energy Europe

Italy Field Trial 13: Porcia Elementary school with VRF system

Overview of building and system

The system considered is a VRF heat pump system serving some classrooms. No mechanical ventilation is provided. Heating system is based on gas fired boilers serving radiators and radiant beams.

Parameter	Installed electrical load / kW	Floor area served / m² GIA	Installed capacity W/m² GIA	Annual consumption kWh	Average annual power W/m²	Annual use kWh/m²	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output)	56.0	990.0	56.6				-
Total VRF el. Input	16.0	990.0	16.2				
Total CW pumps	n.a.	n.a.	n.a.				
Total fans	n.a.	n.a.	n.a.				
Total humidifiers	n.a.	n.a.	n.a.				
Total boilers							
Total HW pumps							
Total HVAC electrical							
Total Building Elec kWh		4'440.0		75'958.0		17.1	
Total Boilers/Heat kWh	840.0	4'440.0	189.2	710'405.0	18.3	160.0	9.7
Total Building Gas/Heat kWh		4'440.0					

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O1.5	Introduce benchmarks, metering and tracking as a clause in each O&M contract, with indication of values in graphs and tables	PI1, PI2	--
O1.6	Update documentation on system / building and O&M procedures to maintain continuity and reduce troubleshooting costs	PI1, PI2	--
O1.7	Check if O&M staff are equipped with state – of – the – art diagnostic tools	PI1, PI2	--

O3.7	Maintain proper evaporating and condensing temperatures	C1, C2 C8	Clean condenser circuit, Verify correct operation of expansion valve
O3.12	Maintain proper heat source/sink flow rates	C1, C2 C8	Clean condenser circuit
O3.15	Maintain full charge of refrigerant	C1, C2 C8	Control charge and refill
O3.16	Clean finned tube evaporator / condenser air side and straighten damaged fins	C1, C2 C8	Control , clean and straighten damaged fins
O3.17	Clean condenser tubes periodically	C1, C2 C8	Clean condenser circuit

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Educational
Geographical location	Porcia, PD, ITALY
Gross Area (m^2)	4'440
N° Floors	2

Zone Description

Main Activity	Classroom
Area Conditioned [m^2]	990
Volume conditioned [m^3]	3'350
Max. Number of occupants	115
Occupation schedule /Hours Operation	8:00-13:00, 6 days per week
Lighting Power density [W/m^2]	14
Type Lighting/lighting control	fluorescent tubes/manual switch
Lighting schedule /Hours Operation	8:00-13:00, 6 days per week
Other Equipment [kW]	n.a.

System Zone Description

System Type	**VRF HP**
Cooling Equipment Type of Fuel	**Electricity**
Schedule and Operation Time [h/year]	8:00-13:00, 6 days per week from 01 May to 15 June About 200 h/year (extimate)
Required Heating capacity	**640 kW** (net thermal power, energy signature calculation method) **710'405 kWh/year** gross energy
Heating Equipment Type of Fuel	**Gas** **Counters**
Schedule and Operation Time [h/year]	8:00-13:00, 6 days per week from 15 October to 15 April About 1300 h/year
Terminal units	**Radiators and radiant beams**
Cooling/Heating capacity [kW]	**56 / 840**

Indoor Environment Parameters	**Measure - Winter/Summer (average)**
Ventilation Rate [ach]	N.A.
Indoor Relative Humidity [%]	40%/60%
Indoor air Temperature [°C] – Winter/Summer	21.4/25.6 (2009/2010 season)

Outdoor Environment Parameters	**Measure - Winter/Summer (average)**
Outdoor air temperature [°C] Winter/Summer	8.9/24.1 (2009/2010 season)
Outdoor Relative Humidity [%] Winter/Summer	81/75.5 (2009/2010 season)

HVACs' system components

HVAC system of elementary school is composed by a centralized heating system and a VRF HP system for cooling of some classrooms. Heating is provided by two gas fired boiler rated at 420 kW each of net thermal power (465 gross). Cooling energy is provided by two multi split VRF HP systems.

The Field trial considers the VRF HP system.

Heat Pump (X2)

General Identification	
Manufacture/Model	Daikin/VRV-I
Year	2004
Type	air to air
Performance Data	
EER – Cooling mode	3.5
COP – Heating mode	4.1
SEER	n.a.
Nominal Cooling Capacity [kW]	25
Nominal Heating Capacity [kW]	28
Refrigerant Gas	R407c
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Full load Ampere	N.A.

Figure – Equipment pictures

Figure – Equipment pictures

Figure – Internal unit

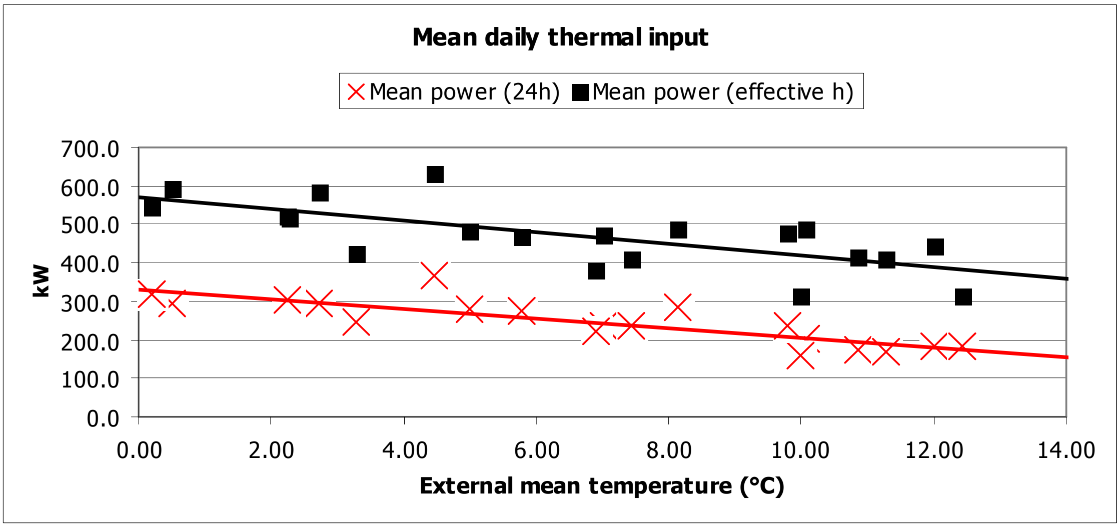
Figure – Control panel

Monitoring observations

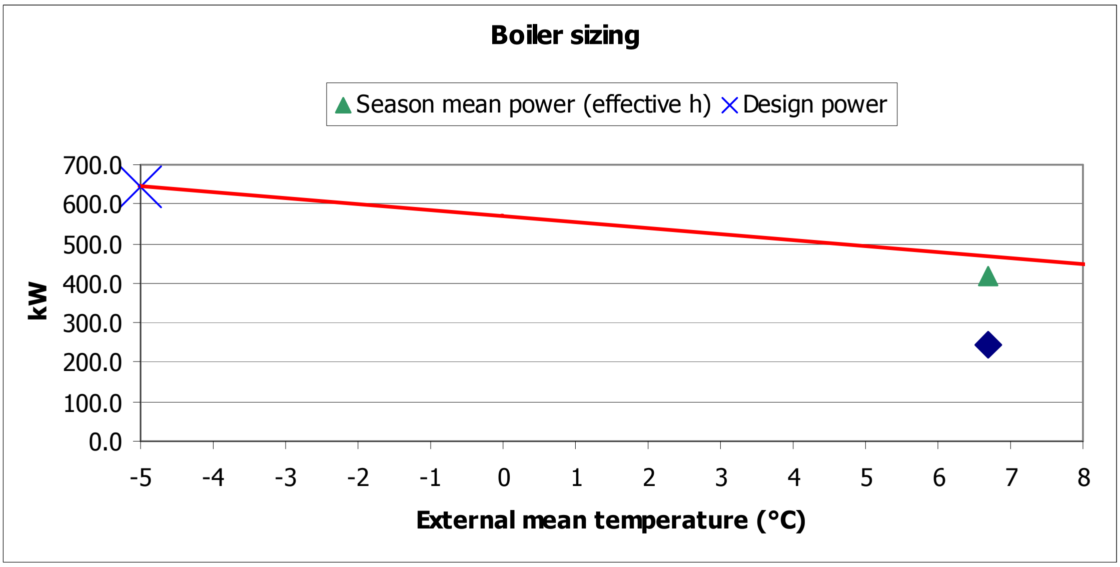
Inspection	
Operating Mode	**automatic**
Maintenance status	**satisfactory**
Maintenance reports	**no**
Equipment cleanliness	**satisfactory**
Pressure status	**N.A.**
Water systems leaks	**no**
Sensors calibration records	**no**
Previous inspection reports	**no**
Operating time estimated [h/year]	**200**
Tightness of wiring connections	**satisfactory**
Thermal insulation (Visual)	**satisfactory**

Gas consumption analysis

Gas consumption weekly data were analyzed to find a correlation with external temperature. The quite accurate fitting curve implies that control strategy is well addressed, at least for heating season.



From these data ideal design power should be calculated. The design power for heating was calculated at 130 kW (corresponding to the outdoor design temperature of -5°C), almost one third of the actual power installed.



Timing for inspection

Inspection Item	Short Description	Time (mins)	Notes
PI1	Location and number of AC zones	10	
PI2	Documentation per zone	10	
PI3	Images of zones/building	15	
PI4	General zone data/zone	12	
PI5	Construction details/zone	12	
PI6	Building mass/air tightness per zone	10	
PI7	Occupancy schedules per zone	8	
PI8	Monthly schedule exceptions per zone	2	
PI9	HVAC system description and operating setpoints per zone	10	
PI10	Original design conditions per zone		N.A.
PI11	Current design loads per zone		N.A.
PI12	Power/energy information per zone	10	
PI13	Source of heating supplying each zone	4	
PI14	Heating storage and control for each zone	10	
PI15	Refrigeration equipment for each zone	5	
PI16	AHU for each zone	8	
PI17	Cooling distribution fluid details per zone	8	
PI18	Cooling terminal units details in each zone	8	
PI19	Energy supply to the system	1	
PI20	Energy supply to the building	1	
PI21	Annual energy consumption of the system	10	
PI22	Annual energy consumption of the building		
	TOTAL TIME TAKEN (minutes)	**154**	
	TOTAL (seconds/m^2)	**9.33**	990

Inspection Item	Short Description	Time (mins)	Notes
PP1	List of installed refrigeration plant	4	
PP2	Method of control of temperature.	3	
PP3	Method of control of periods of operation	5	
PP4	Reports from earlier AC inspections and EPC's		N.A.
PP5	Records of maintenance operations	3	
PP6	Records of maintenance (control systems and sensors)		N.A.
PP7	Records of sub-metered air conditioning plant (use or energy)		N.A.
PP8	Design cooling load for each system	15	
PP9	Description of the occupation of the cooled spaces	2	
P1	Review available documentation from pre-inspection	10	
P2	Locate the plant and compare details with pre-inspection data	5	
P3	Locate supply to the A/C system and install VA logger(s)	40	
P4	Review current inspection and maintenance regime	10	
P5	Compare size with imposed cooling loads	10	
P6	Compare records of use or sub-metered energy with expectations	15	
P7	Locate outdoor plant	4	
P8	Check for signs of refrigerant leakage.	8	2 units
P9	Check plant is capable of providing cooling	5	
P10	Check external heat exchangers	5	
P11	Check location of outdoor unit	2	
P12	Assess zoning in relation to internal gain and orientation	10	
P13	Check indicated weekday and time on controllers against actual	5	2 units
P14	Note the set on and off periods	4	
P15	Identify zone heating and cooling temperature control sensors.	2	
P16	Note set temperatures in relation to the activities and occupancy	2	
P17	Provision of controls or guidance on use while windows open	2	
P18	Type, age and method of capacity control of the equipment	5	
P19	Write report	30	

	TOTAL TIME TAKEN (minutes)	**206**	
	TOTAL (seconds/m^2)	**12.48**	990

Overall conclusions

In Italy few school are conditioned during summer; in this case just some classroom are conditioned with small VRF system. This type of system is characterized by embedded components that highly reduce the possibility of equipment assessment. Nevertheless, rapid checking of control panel can easily give information on system set point and schedule.

HARMONAC

IT Field Trial 14:
Office – Air and Water system

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IT

August 2010

Supported by

Intelligent Energy Europe

Field Trial: Office building with centralized chillers. HVAC consumption during non-occupation schedule

No external photo permission available
[anonymous Field Trial]

Overview of building and system

The building considered is formed by a 5 floors building, 2005 construction, connected to a XIX century building. The building is the headquarter of a service company. The system is an air/water multi zone, with two main AHUs serving the two zones of the building. Terminals unit are chilled beams and fan-coils.

Parameter	Installed electrical load / kW	Floor area served / m2 GIA	Installed capacity W/m2 GIA	Annual consumption kWh	Average annual power W/m2	Annual use kWh/m2	Average annual power (% FLE)
Total Chillers nominal cooling capacity (cooling output)	648.0	3'500.0	185.1				
Total Chillers	162.0	3'500.0	46.3	140'582.6	4.6	40.2	9.9
Total CW pumps	13.8	3'500.0	3.9				
Total fans	45.0	3'500.0	12.9	35'000.0	1.1	10.0	8.9
Total humidifiers		3'500.0					
Total boilers ELECTRICAL		3'500.0					
Total HW pumps	12.4	3'500.0	3.5	5'246.6	0.2	1.5	4.8
Total HVAC electrical	220.8	3'500.0	63.1	180'000.0	5.9	51.4	9.3
Total Building Elec kWh		3'500.0		887'822.0	29.0	253.7	
Total Boilers/Heat kWh	600.0	3'500.0	171.4				
Total Building Gas/Heat kWh		3'500.0					

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E2.6	Apply night time over ventilation	PI6, PI12, C5, C6, C7	Modify control strategy
E4.5	Replace electrical equipment with Energy Star or low consumption types	PI22	--
E4.6	Replace lighting equipment with low consumption types	PI22	--
O1.1	Generate instructions ("user guide") targeted to the occupants	PI7, PI8, PI9, PI10, P4	--
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	--
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	--
O2.3	Shut off auxiliaries when not required	PI7, PI8, PI9, PI10, P4	Modify control strategy
O3.1	Shut chiller plant off when not required	PI7, PI12, PI21, C8	Re-programming schedule
O3.5	Maintain proper starting frequency and running time of (reversible) chillers	PI7, PI12, PI21, C8	Modify control strategy
O3.20	Apply indirect free cooling using the existing cooling tower (free chilling)	PI7, PI12, PI21, C8	Modify cool water circuits
O4.3	Shut off coil circulators when not required	PI7, PI12, PI21, C8	Modify control strategy
P2.5	Improve central chiller / refrigeration control	PI7, PI12, PI21, C8	Installing external RH measurement

Overview of building/zone and system

The following table summarises the main aspects of the zones within the building:

Building Description

Building Sector	Office
Geographical location	Italy, Aosta
Gross Area	3500
N° Floors	5

Zone Description

Main Activity	Office
Area Conditioned [m^2]	3500
Volume conditioned [m^3]	9000
Max. Number of occupants	75
Occupation schedule /Hours Operation	8:30-13:30 14:30-17:00
Lighting Power density [w/m^2]	15
Type Lighting/lighting control	Automatic lighting control
Lighting schedule /Hours Operation	8:00-19:00

Construction Details (only as a support of EES tools)

Due to the heterogeneous type of building the EES tool was not be applied

System Zone Description

System Type	Air/water system with chilled beams
Cooling Equipment Type of Fuel	Electricity
	BMS monitoring
Schedule and Operation Time [h/year]	6 days per week 8:00-18:00
Heating Equipment Type of Fuel	Gas
	Counters
Schedule and Operation Time [h/year]	6 days per week 8:00-18:00
Auxiliary HVAC Equipment	……………………………………kW
Terminal units	Chilled beams

Indoor Environment Parameters	**Measure/observe - Winter/Summer (average)**
Ventilation Rate [ach]	1 design
Indoor Relative Humidity [%]	50% design / 60% measured
Indoor air Temperature [°C] – Winter/Summer	20/26°C design 23°C average temperature measured during winter

Outdoor Environment Parameters	**Measure/observe - Winter/Summer (average)**
Outdoor air temperature [°C] Winter/Summer	-10° winter design temperature 20°C average temperature in July
Outdoor Relative Humidity [%] Winter/Summer	60/70

This field trial describe the second inspection on the same system of FT n°1

HVACs' system components

The system in centralized. The main heating plant comprises a pair of Viessmann condensation boilers, rated at 300 thermal kW each (678 W electrical power each). The water from the boilers is circulated by 3 x 1,65 kW primary pumps, in a main collector, and six secondary pumps for different sections of the system (0,2 kW / 0,6 kW / 0,9 kW / 0,9 kW / 1,65 kW).

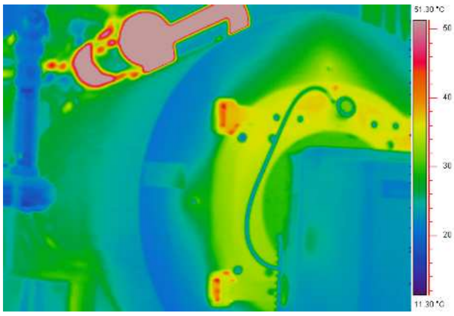
The cold water is provided by two McQuay electric chillers (screw compressors) with heat recovery system on condenser, rated at 324 kW cooling capacity each, with a maximum electrical consumption of 92.5 kW each, and a nominal COP equal to 3.5. The refrigerant gas is R134A.

The system is an air/water multi-zone, with two main AHUs serving the two main zones of the building. Another AHU serves the archive. Terminal units are chilled beams and fan-coils.

- Heating systems (heat generators) and pumps
- Cooling systems (cold generators) and pumps
- Heat rejection and pumps
- AHU
- Pumps monitoring

Heat Generator and Pumps

Boiler Identification (X2)	
Manufacture/Model	Viessman / DMV
Year	2005
Equipment Type	Condensing boiler
Fuel Type	natural gas
Performance Data	
Nominal Heating Capacity [kW]	300
Installed Heating Capacity /m² GIA	171.4
Nominal Efficiency [%]	98
Water outlet temperature [°C]	60
Water inlet temperature [°C]	50
Electrical data	
Power supply [V/Ph/Hz]	230/1/50
Start-up amps [A]	NA



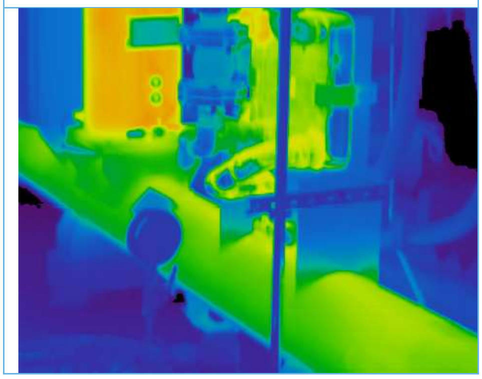
Auxiliary Equipment	
Pumps Electric Demand [kW]	4.95

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	No
Operation time estimated [h/year]	1800
Operating mode	automatic
Dirtiness of burner	**Satisfactory**
Thermal Insulation (Visual)	**Satisfactory**
Fuel leaks	no
Water leaks	no
Pressure status	**Satisfactory**
Sensors calibration records	no
Meter readings data	no

Cold Generator and Pumps

Chiller Identification (X2)	
Manufacture/Model	McQuay
Year	2005
System Type	Vapour compression
Compressor Type	Screw
Fuel Type	electric
Performance Data	
Nominal Cooling Capacity [kW]	324
Installed Cooling Capacity /m² GIA	92.5
Nominal Electric Power [kW]	81
COP	4
Refrigerant Gas	R134a
Electrical data	
Power supply [V/Ph/Hz]	400/3/50
Start-up amps [A]	572



Auxiliary Equipment	
Fan Electrical Demand [kW]	
Pumps Electrical Demand primary cool water [kW]	4.5
Pumps El. Dem. heat rejection [kW]	6.6

Recuperator

Water leaking

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	no
Operating mode	automatic (always on, also in winter season)
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	4000
Vibration eliminators	**Satisfactory**
Worn couplings	**Satisfactory**
Equipment cleanliness	**Satisfactory**
Compressor oil level	**Satisfactory**
Compressor oil pressure	**Satisfactory**
Refrigerant temperature	**Satisfactory**
Refrigerant pressure	**Satisfactory**
Chilled water systems leaks	water leakage from condenser/evaporative towers circuit
Sensors calibration records	no
Refrigerant leaks	no
Location of the equipment	inside

Field measurements	
Electricity consumption [kWh]	66'000 kWh during Summer season
Electric voltage [V]	< 0.5 % variable in respect of nominal value
Electric current [A]	Max: 520 A

Heat Rejection System

Heat Rejection Identification	
Manufacture/Model	Baltimore VTL 072 K
Year	2005
Cooling method	evaporative towers
Performance Data	
Nominal Electric Power [kW]	7,5+2,2
Total Heat Rejection [kW]	360
Water flow rate [m³/h]	60
Water outlet temperature [°C]	29
Water inlet temperature [°C]	34
Electrical data	
Power supply [V/Ph/Hz]	380/3/50
Start-up amps [A]	21.5

Figure –Heat Rejection Plant

Auxiliary Equipment	
Fan Electrical Demand [kW]	11 kW
Pumps Electric Demand [kW]	3X 2.2

Water discharge due to broke automatic level trigger

Water connections

Monitoring observations

Inspection	
Maintenance status	**Satisfactory**
Previous inspection/maintenance Reports	No
Thermal Insulation (Visual)	**Satisfactory**
Operation time estimated [h/year]	Serve only the chillers (4000
Equipment cleanliness	**Satisfactory**
Operation mode	automatic
Operating water level (sump)	**Unsatisfactory, water was continuously discharged**
Fan shaft bearings lubrication	**Satisfactory**
Drive system belt condition and tension	**Satisfactory**
Heat transfer section cleanliness	**Satisfactory**
Water systems leaks	No leaks, but the system is wasting a lot of water
Sensors calibration records	No
Correct rotation of the fan	Yes
Bleed rate [l/s]	

Control systems

The control system is based on Siemens DESIGO®. The system controls the schedule of different zones, and, depending on which occupation profile is currently active, it changes the set point for different zones.
Every zone has an ambient temperature sensor and local control of temperature (± 3°C with respect to set-point).

AHUs provide neutral air for the chilled beams (18-22°C, depending on the season).

Energy consumption data

Metering information

The BEMS installed provides electric consumption of some HVAC sub-system:

- Evaporative towers
- Chillers and heat rejection water pumps
- Secondary water pumps (heat and cool water)

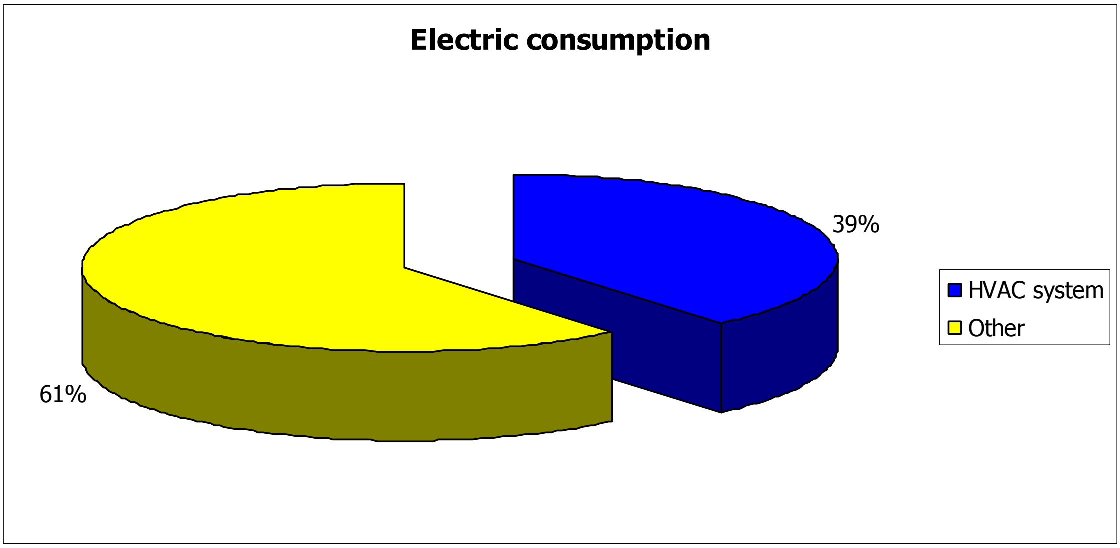
Monitoring observations

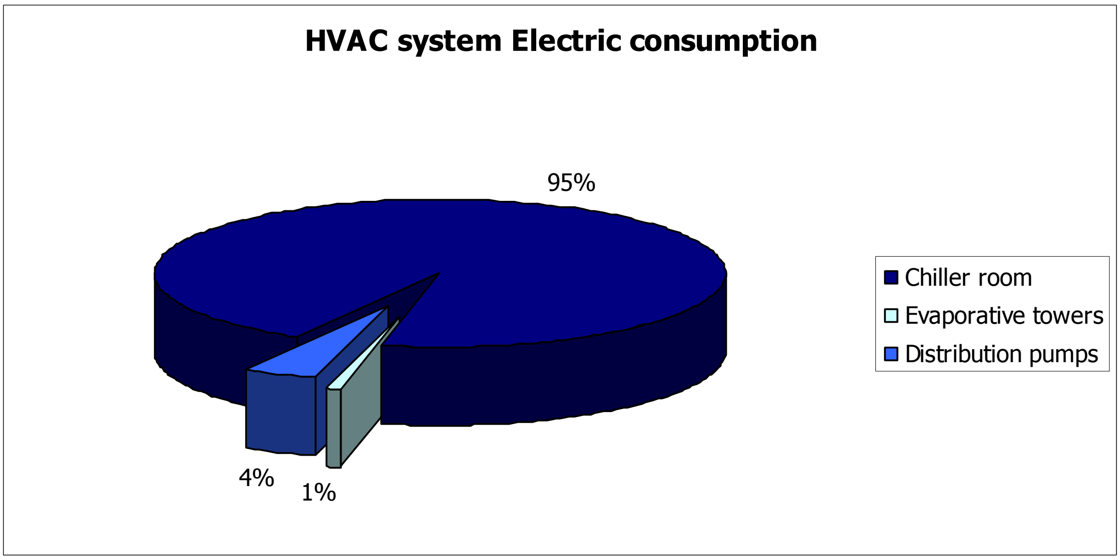
Despite the high potential performance of system components (variable flow pumps and fans, active chilled beams, active ventilated facade with solar irradiance control) the building presents a relatively high specific consumption:

- Chiller+cool pumps+evaporative towers : 38.16 kWh/m^2 year
- Chiller+cool pumps+evaporative towers : 20 kWh/m^2 summer season

Those values indicate that the cooling system has a huge consumption on the whole year. This seems not normal: Aosta is situated in climatic zone E (2800 heating degree days), normally in Winter and middle season cooling system has to be shut off.
Data on overall consumption were provided by BEMS:

Consumption 15 Jun-15 Sept (2009)		kWh	
Overall Building		179'769	
HVAC system		70'090	% on HVAC
Chiller room	(chiller + tower pumps)	66'634	95.07%
Evaporative towers		458	0.65%
Distribution pumps		2'998	4.28%





As seen in the graph the chiller is responsible for 95% of the HVAC system consumption (AHU's are not included).

Timing for inspection (second inspection)

Inspection Item	Short Description	Time (mins)	Savings	Notes
PI1	Location and number of AC zones	0		
PI2	Documentation per zone	0		
PI3	Images of zones/building	0		
PI4	General zone data/zone	0		
PI5	Construction details/zone	0		
PI6	Building mass/air tightness per zone	0		
PI7	Occupancy schedules per zone	0		
PI8	Monthly schedule exceptions per zone	0		
PI9	HVAC system description and operating setpoints per zone	15		
PI10	Original design conditions per zone	0		
PI11	Current design loads per zone	0		
PI12	Power/energy information per zone	0		
PI13	Source of heating supplying each zone	0		
PI14	Heating storage and control for each zone	0		
PI15	Refrigeration equipment for each zone	0		
PI16	AHU for each zone	0		
PI17	Cooling distribution fluid details per zone	0		
PI18	Cooling terminal units details in each zone	0		
PI19	Energy supply to the system	0		
PI20	Energy supply to the building	0		
PI21	Annual energy consumption of the system	10		The Building is provided with a complete monitoring system, that allow to obtain data about electrical consumption
PI22	Annual energy consumption of the building	10		The Building is provided with a complete monitoring system, that

				allow to obtain data about electrical consumption
	TOTAL TIME TAKEN (minutes)	**35**		
	TOTAL (seconds/m^2)	**0.60**	Area (m^2)	3500

Inspection Item	Short Description	Time (mins)	Savings	Notes
PC1	Details of installed refrigeration plant	0		
PC2	Description of system control zones, with schematic drawings.	0		
PC3	Description of method of control of temperature.	3		
PC4	Description of method of control of periods of operation.	3		
PC5	Floor plans, and schematics of air conditioning systems.	0		
PC6	Reports from earlier AC inspections and EPC’s	0		not available
PC7	Records of maintenance operations on refrigeration systems	4		
PC8	Records of maintenance operations on air delivery systems.	4		
PC9	Records of maintenance operations on control systems and sensors	0		not available
PC10	Records of sub-metered AC plant use or energy consumption.	4		Advanced BMS
PC11	Commissioning results where relevant	0		not available
PC12	An estimate of the design cooling load for each system	0		
PC13	Records of issues or complaints concerning indoor comfort conditions	0		not available
PC14	Use of BMS	10		
PC15	Monitoring to continually observe performance of AC systems			
C1	Locate relevant plant and compare details	25		
C2	Locate supply the A/C system and install VA logger(s)	135		include PC 15
C3	Review current inspection and maintenance regime	5		
C4	Compare system size with imposed cooling loads	0		
C5	Estimate Specific Fan Power of relevant air movement systems	0		on label data
C6	Compare AC usage with expected hours or energy use	15		compare mesures of BMS with expected occupancy

C7	Locate refrigeration plant and check operation	8		
C8	Visual appearance of refrigeration plant and immediate area	4		
C9	Check refrigeration plant is capable of providing cooling	3		termometers mounted on fluid distribution network
C10	Check type, rating and operation of distribution fans and pumps	10		
C11	Visually check condition/operation of outdoor heat rejection units	15		
C12	Check for obstructions through heat rejection heat exchangers	10		
C13	Check for signs of refrigerant leakage	9		2 units
C14	Check for the correct rotation of fans	0		not possible
C15	Visually check the condition and operation of indoor units	50		10 min per floor
C16	Check air inlets and outlets for obstruction	20		in addiction to C15
C17	Check for obstructions to airflow through the heat exchangers	20		in addiction to C15
C18	Check condition of intake air filters.	10		in addiction to C15
C19	Check for signs of refrigerant leakage.	10		in addiction to C15
C20	Check for the correct rotation of fans	30		in addiction to C15
C21	Review air delivery and extract routes from spaces	15		in addiction to C15
C22	Review any occupant complaints			not available
C23	Assess air supply openings in relation to extract openings.	0		
C24	Assess the controllability of a sample number of terminal units	0		
C25	Check filter changing or cleaning frequency.	10		
C26	Assess the current state of cleanliness or blockage of filters.	4		
C27	Note the condition of filter differential pressure gauge.	3		
C28	Assess the fit and sealing of filters and housings.	25		
C29	Examine heat exchangers for damage or significant blockage	4		
C30	Examine refrigeration heat exchangers for signs of leakage	4		
C31	Note fan type and method of air speed control	2		
C32	Check for obstructions to inlet grilles, screens and pre-filters.	4		
C33	Check location of inlets for proximity to sources of heat	2		
C34	Assess zoning in relation to internal gain and solar radiation.	5		
C35	Note current time on controllers against the actual time	10		

C36	Note the set on and off periods	6		
C37	Identify zone heating and cooling temperature control sensors	5		
C38	Note zone set temperatures relative to the activities and occupancy	4		
C39	Check control basis to avoid simultaneous heating and cooling	6		
C40	Assess the refrigeration compressor(s) and capacity control	480		240 min per unit
C41	Assess control of air flow rate through air supply and exhaust ducts	10		
C42	Assess control of ancillary system components e.g. pumps and fans	10		
C43	Assess how reheat is achieved, particularly in the morning	0		not available
C44	Check actual control basis of system	8		
	TOTAL TIME TAKEN (minutes)	**1'024**		
	TOTAL (seconds/m^2)	**17.55**	Area (m^2)	3500

Actions based on system inspection checklist

ECO	DESCRIPTION	ITEM	ACTION
E2.6	Apply night time over ventilation	PI6, PI12, C5, C6, C7	Modify control strategy
E4.5	Replace electrical equipment with Energy Star or low consumption types	PI22	S.E.[1]
E4.6	Replace lighting equipment with low consumption types	PI22	S.E.
O1.1	Generate instructions ("user guide") targeted to the occupants	PI7, PI8, PI9, PI10, P4	S.E.
O1.3	Train building operators in energy – efficient O&M activities	PI1, PI2	S.E.
O1.4	Introduce an energy – efficient objective as a clause in each O&M contract	PI1, PI2	S.E.
O2.3	Shut off auxiliaries when not required	PI7, PI8, PI9, PI10, P4	Modify control strategy
O3.1	Shut chiller plant off when not required	PI7, PI12, PI21, C8	Re-programming schedule
O3.5	Maintain proper starting frequency	PI7, PI12, PI21, C8	Modify control strategy

[1] Self explanatory

	and running time of (reversible) chillers		
O3.20	Apply indirect free cooling using the existing cooling tower (free chilling)	PI7, PI12, PI21, C8	Modify cool water circuits
O4.3	Shut off coil circulators when not required	PI7, PI12, PI21, C8	Modify control strategy
P2.5	Improve central chiller / refrigeration control	PI7, PI12, PI21, C8	Installing external RH measurement

Overall conclusions

Considering the operation strategy of the plant, according to ECO O 3.1 it seems reasonable (and underestimated) **a percentage of 10% of savings** on cooling production consumption, if the system was shut down when not needed, during Summer season.