HEATING AND SAVING

heating system at low temperature:
aluminium radiators
compared to radiant floor panels

energy requalification
of the exempt buildings


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Heating and saving

Heating system at low temperature: aluminium radiators compared to radiant floor panels

Use of aluminium radiators in combination with condensing boiler and heat pumps in the energy requalification of the exempt buildings

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Analysing energy performance of 2 low temperature heating systems: system with radiant floor panels system with aluminium radiators

This study aims to clarify energy consumption and real possible savings by comparing a heating system with radiant floor panels (also known as underfloor heating) to one with aluminium radiators.
Popular opinion as to the advantages of radiant panels is often supported by theories that rarely arise in the reality of energy requirements and actual heating system operating conditions.
Therefore, an important premise is necessary:
the quantity of heat necessary to heat a building depends solely on its construction characteristics (thickness of walls, degree of heat insulation, characteristics of window and door frames). This quantity of heat is the same whatever the type of system as only influencing the efficiency with which it is supplied to the environment measurable with emission and regulation efficiency.
The result of this simple technical physics remark is that in theory (that is with the system working always at nominal conditions), at the same operating conditions, consumption in the same building is identical whether a radiator or panel system is used, apart from very small differences in emission and regulation efficiency as set out here below. In reality systems mainly operate at variable loads, that is, depending on regulation: in the same conditions energy consumption will be lower for systems with a better regulation efficiency. In fact, the main task of a system is not only that of providing the necessary heat but above all adjusting this quantity of heat as quickly as possible to variations in thermal loads. Therefore, it is best to use systems with the lowest possible heat inertia. Heat inertia expresses the ability of a heating system to adapt quickly to those thermal load variations it is subject to during the course of the day. Regulation efficiency expresses in numerical form how quickly systems adapt to instant thermal load variations.
Aluminium radiator systems heat the air within the room immediately, and only

subsequently the structures of the building and are therefore defined as low heat inertia systems and thus with high regulation efficiency.
Radiant panel systems must heat the structure of the building (floor) that is part of it before releasing heat to the surrounding environment. Therefore radiant panel systems are defined as having high heat inertia and therefore lower regulation efficiency.
Once radiator systems reach the temperature set, they stop supplying heat almost immediately, whilst panel systems continue owing to the significant quantity of heat accumulated in the floor structure; the heat accumulated within the internal floor structure must first be absorbed before any effect of the regulation system can be felt.

In practice, a climate characterised by significant variations in temperature during the course of the day combined with sufficiently high sunlight makes the supply of heat from south/south west facing windows significant; other sources of free heat include household appliances (computers, TVs, washing and cooking equipment) and the possible presence of people. All these sources of heat cause the room temperature to rise suddenly. Regulation systems intervene to shut or stop this flow of heat to those terminals within the room.
Homes heated with radiant panels do not respond as quickly as they should to these increases in temperature due to their heat inertia. Even with powered valves controlled by thermostats in each room the resulting effect is an uncontrolled increase in the internal temperature. Therefore, it is practically impossible to take advantage of free heat, moreover there is a feeling of discomfort (temperature increases) and also the danger that, should this free heat suddenly disappear, the system is unable to deliver heat with the necessary speed, thus causing the temperature to fall.
A home heated with radiators is able to make the most of sources of free heat thanks to its low heat inertia thus saving on energy and a greater feeling of well being for occupants.
In conclusion sufficiently high sunlight of south/south west facing windows and walls, heat emitted from household appliances and the presence of people must be considered as good sources of free energy that can only be exploited by a low heat inertia system that instantly reacts to variations thus reducing energy requirements and as a result consumptions.

System efficiency can be quantified assessing the efficiency with which the necessary heat (emission efficiency) is supplied and prompt response to thermal load variations (regulation efficiency): using low heat inertia systems guarantees maximum regulation efficiency.
Legislative Decree 311 related UNI standards confirm that radiant panel systems have a

lower regulation efficiency than aluminium radiator systems. The lower this value is the higher the consumption.
The high heat inertia of radiant panel systems makes it almost impossible to switch them on and off (in fact the standard provides for this system to work 24 hours a day).
If we assume that average household use during the week is limited to a few hours a day, the most intelligent and economically advantageous way to use energy would be that of maintaining a comfortable temperature only in those hours of actual need.
An aluminium radiator system guarantees high emission and regulation efficiency, low heat inertia and the ability to program the system to switch on and off during the course of the day.
This is impossible with a panel system: the time to get it running is so high that it is hardly ever switched off. Data provided by "Altroconsumo" shows an almost 8% increase in energy consumption per degree in temperature.

The following is a list of all those factors that influence the energy requirements of a building, more precisely a building-plant system:

- Type of building
- Production efficiency
- Emission efficiency
- Regulation efficiency
- Distribution efficiency
- Circulation pump power absorption
- Hours in operation per year.

Emission and regulation efficiency and circulation pump power absorption depends on type of system. Other factors remain unchanged if the building and heat production system are the same.
Therefore, let us analyse those efficiency values shown in the new UNI TS 11300 standards, now the reference for analysing building energy consumption.

emission efficiency (η_e) in rooms under 4 m in height

Type of supply terminal	Average annual thermal load W/m³ᵃ		
	< 4	4 - 10	> 10
	η_e		
Radiators on insulated external wall (*)	0,95	0,94	0,92
Radiators on internal wall	0,96	0,95	0,92
Convector fans (**) values referred to T average water = 45°C	0,96	0,95	0,94
Convectors	0,94	0,93	0,92
Inlets on hot air systems (***)	0,94	0,92	0,90
Buried insulated floor panels	0,99	0,98	0,97
Buried floor panels (****)	0,98	0,96	0,94
Ceiling panels	0,97	0,95	0,93
Wall panels	0,97	0,95	0,93

a) The average annual thermal load, expressed in W/m³, is obtained dividing the annual useful heat requirements expressed in Wh, calculated according to UNI EN ISO 13790, by the conventional emission terminal operating time, expressed in hours, and gross heated volume of the room or area expressed in cubic metres.

(*) Efficiency indicated refers to a water delivery temperature of 85°C.
Efficiency increases by 0,01 for reflecting wall.
Efficiency reduces by 0,04 for non insulated external wall (U > 0,8 W/m² K).
Efficiency increases by 0,03 for water delivery temperature < 65°C.

(**) Power consumption is not considered and must be calculated separately.

(***) As for hot air heating systems values refer to systems with:
- air vents positioned no higher than 2 m from floor;
- inlets and vanes of an appropriate size for room capacity and characteristics;
- correct operating conditions, appropriately sized generators, correct suction flow rate;
- air tight envelope and cover.

(****) Data provided does not bear in mind heat lost by floor to the ground; these losses must be calculated separately and used to adjust efficiency value.

regulation efficiency (η_{rg})

type of regulation	characteristics	low heat inertia systems	high heat inertia systems	
		radiators, convectors, convector fans, radiant panels and hot air	panels built into building structures and thermally de-coupled	panels buried into building structures and not thermally de-coupled
only climatic (adjusted with external probe)		$1 - (0{,}6\ \eta_u \gamma)$	$0{,}98 - (0{,}6\ \eta_u \gamma)$	$0{,}94 - (0{,}6\ \eta_u \gamma)$
only room with regulator	On Off	0,94	0,92	0,88
	PI o PID	0,99	0,97	0,93
	P banda prop. 0,5°C	0,98	0,96	0,92
	P banda prop. 1°C	0,97	0,95	0,91
	P banda prop. 2°C	0,95	0,93	0,89
climatic + room with regulator	On Off	0,97	0,95	0,93
	PI o PID	0,995	0,99	0,97
	P banda prop. 0,5°C	0,99	0,98	0,96
	P banda prop. 1°C	0,98	0,97	0,95
	P banda prop. 2°C	0,97	0,96	0,94
only area with regulator	On Off	0,93	0,91	0,87
	PI o PID	0,995	0,99	0,97
	P banda prop. 0,5°C	0,99	0,98	0,96
	P banda prop. 1°C	0,98	0,97	0,95
	P banda prop. 2°C	0,94	0,92	0,88
climatic + room with regulator	On Off	0,96	0,94	0,92
	PI o PID	0,995	0,98	0,96
	P banda prop. 0,5°C	0,98	0,97	0,95
	P banda prop. 1°C	0,97	0,96	0,94
	P banda prop. 2°C	0,96	0,95	0,93

nota γ supply/loss ratio
η_u supply usage factor defined in UNI/TS 11300-1.

Limiting our analysis to buildings no more than 4 m in height and average annual thermal load between 4 and 10 W/m^{3a} emission efficiency for a radiator on an insulated external wall is of 0,94 + 0,03 (low temperature systems), that is 0,97. It can reach 0,98 positioning a reflecting panel behind the radiator. Whereas emission efficiency of a radiant floor panel system insulated by the structure is of 0,98. Therefore there is no real difference between the two systems or equal to 0,01.

Regulation efficiency analysis is more significant. The standard distinguishes between low heat inertia systems, radiators, and high heat inertia systems, radiant panels.

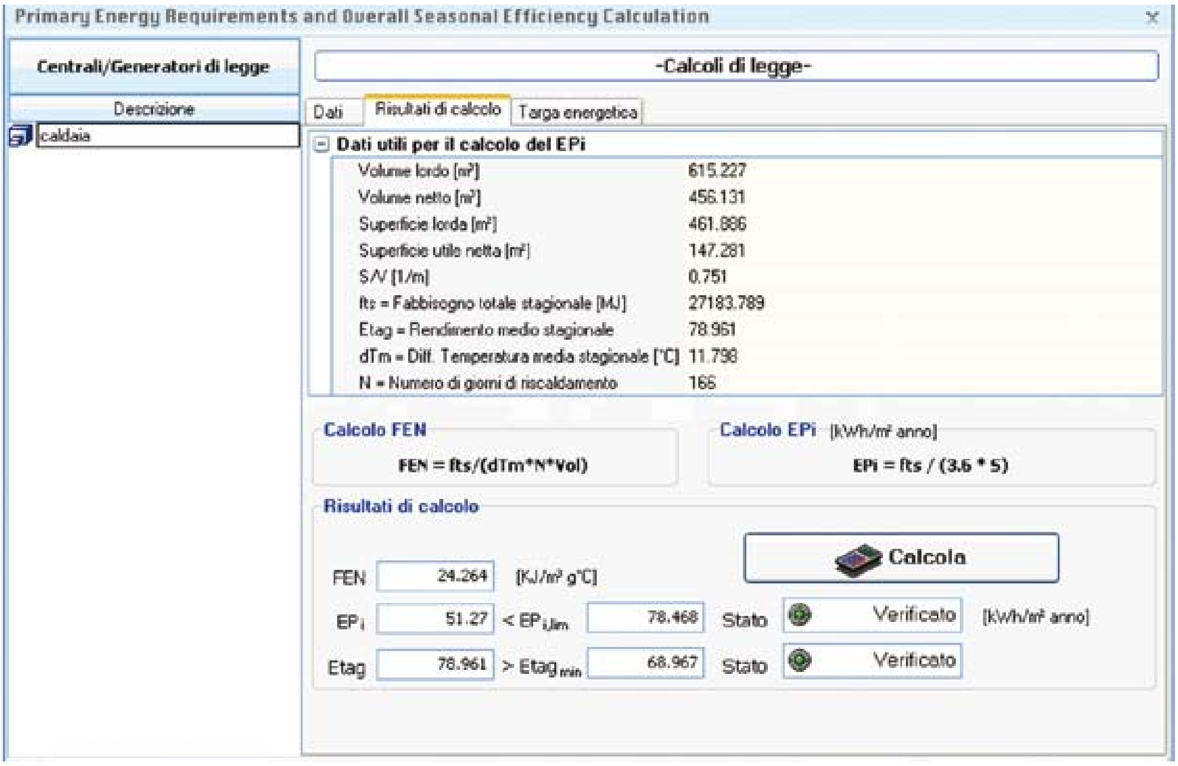
In all cases radiant panel efficiency is lower than that of radiators. The same quantity of energy is absorbed by radiator and panel systems assuming parameters to determine building-plant system consumption to be almost identical; moreover, it is realistic to expect a lower consumption percentage for radiator systems.
The results obtained comparing the energy performance of the two heating systems through a thermo-technical and energy performance calculation software (MC4 Software) confirm that noted.
The newly built construction used for the simulation is a semi-detached house arranged on two levels with building envelope structures in accordance with minimum requirements set out in Legislative Decree 311.
In detail:

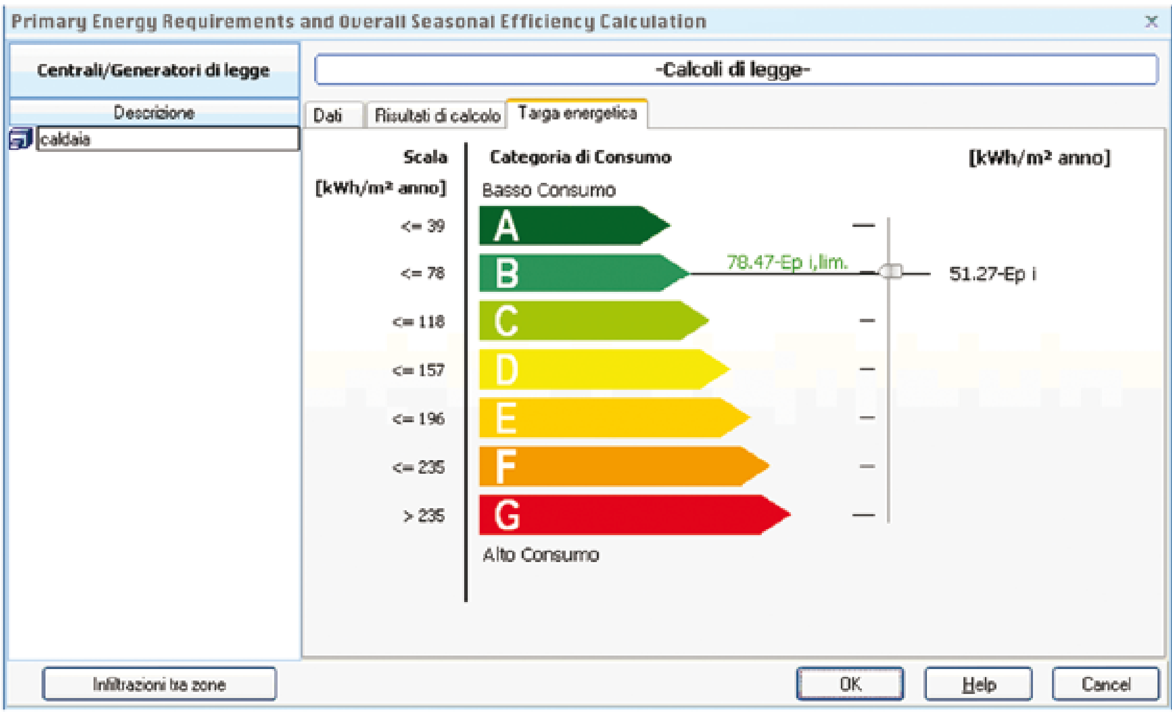
- Reference province: Florence
- Altitude above sea level 40 m
- Latitude 43,41
- Wind area 2
- Degrees day 18/21
- Climatic zone D
- Gross volume 615,22 m^3
- Net volume 415,13 m^3
- Gross surface area 461,89 m^2
- Net useful surface area 147,28 m^2
- Gross surface area/Gross volume 0,751
- Difference in average seasonal temperature 9,798°C
- Number heating days 166

Operating conditions: continuous over 24 hours optimised switch on (as set out in inspections in accordance with Law 10 and subsequent amendments).

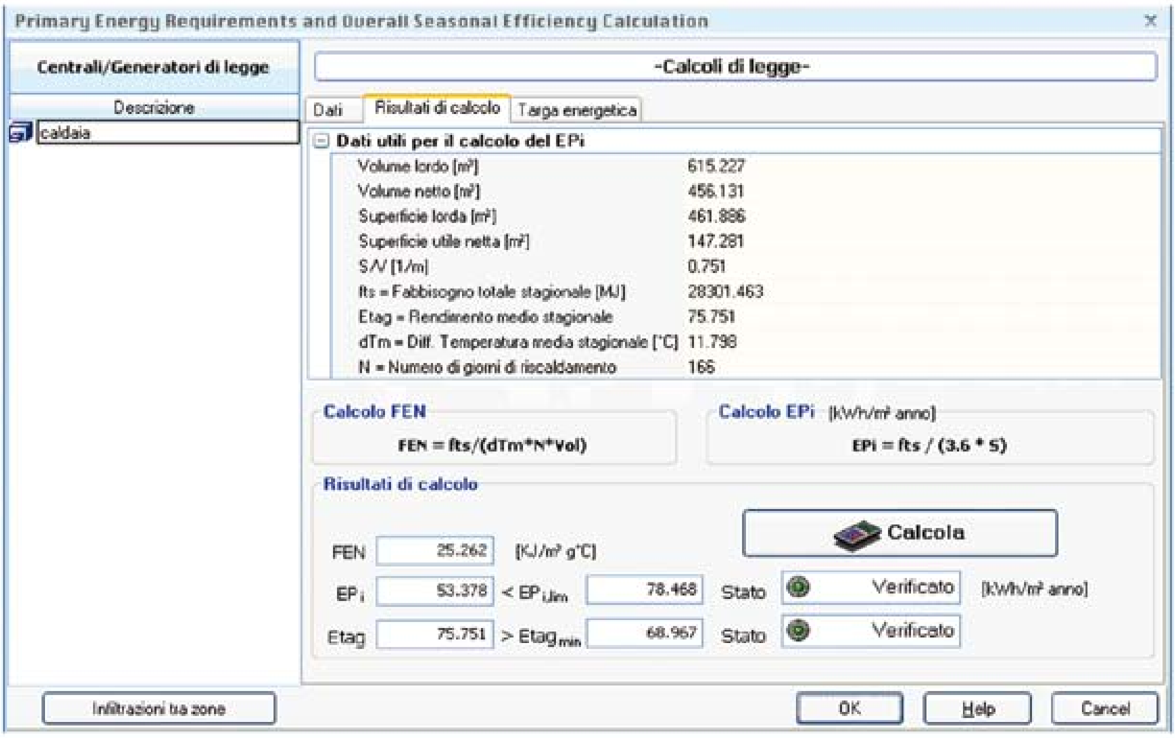
Main calculation results

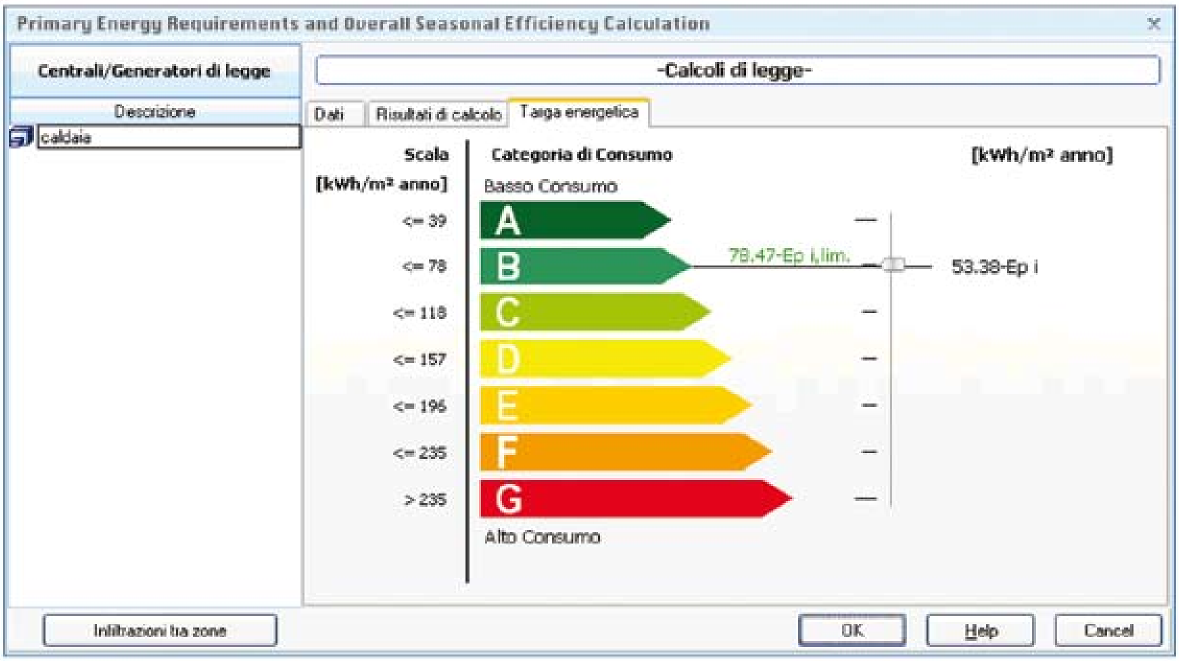
Radiator system:
Standard Energy Requirements (FEN): 24,264 kJ/m³g °C
Primary Energy Requirements EP_i: 51,27 kWh/m²year (EP_{lim} 78,47 kWh/m²year)
Overall efficiency: 79,67 (minimum overall efficiency 68,97)





Radiant panel system:
Standard Energy Requirements (FEN): 25,262 kJ/m³g °C
Primary Energy Requirements EP_i: 53,378 kWh/m²year (EP_{lim} 78,47 kWh/m²year)
Overall efficiency: 75,75 (minimum overall efficiency 68,97)





Result analysis

The data analysis shows a small difference in energy consumption with the radiator system requiring 2,11 kwh/m² year less compared to the floor panel system. The very small difference confirms that said above: building consumption depends on building construction characteristics and not the system installed.

A true comparison

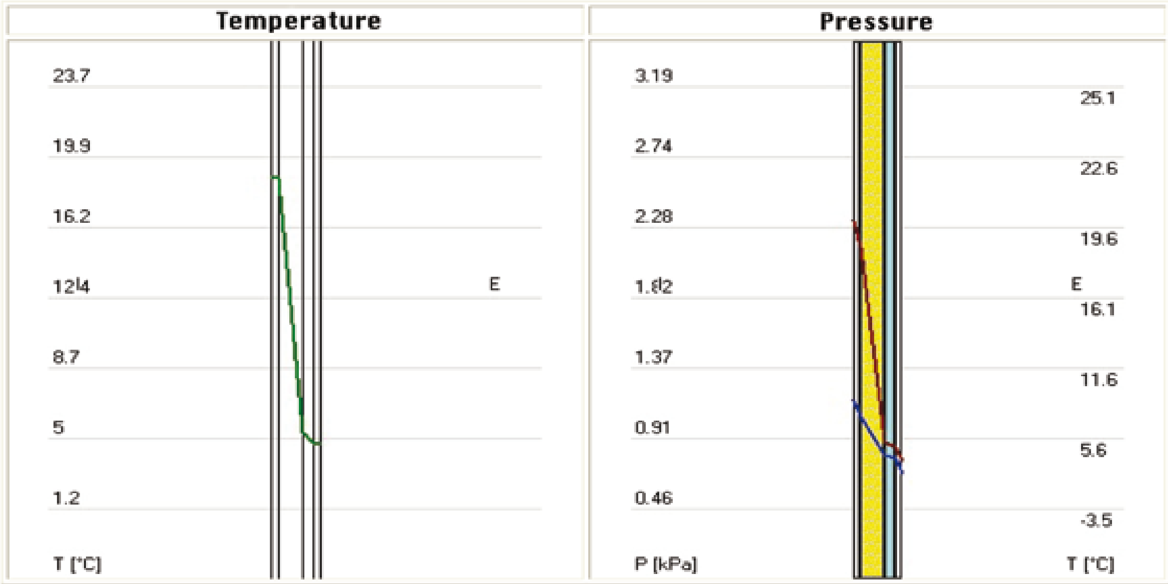
These theoretical remarks encouraged Global technical staff to carry out a practical comparison.
Two identical test rooms, one heated with aluminium radiators, the other with radiant panels, were constructed within an unheated industrial building. (Photo 1)

fhoto 1

They are built with three internal double plaster board walls with rock wall insulation; reinforced concrete external wall with insulating sheet; insulated, reinforced concrete floor and footing; double plaster board ceiling with rock wall insulation.

Building envelope structures of two rooms are as follows:

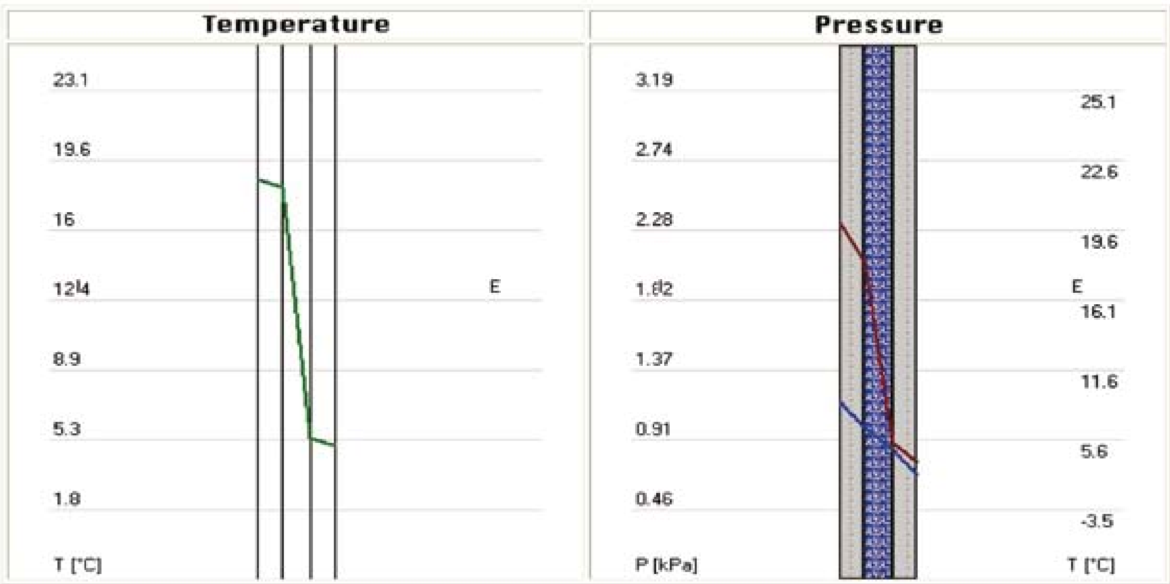
Structure: plaster board/rock wool wall



NORMAL TRANSMITTANCE CALCULATION

Theoretical transmittance:	[W/m²°C]	0,533
Increased safety (0[%]):	[W/m²°C]	0,533
Rounding:		
Transmittance adopted:	[W/m²°C]	0,533

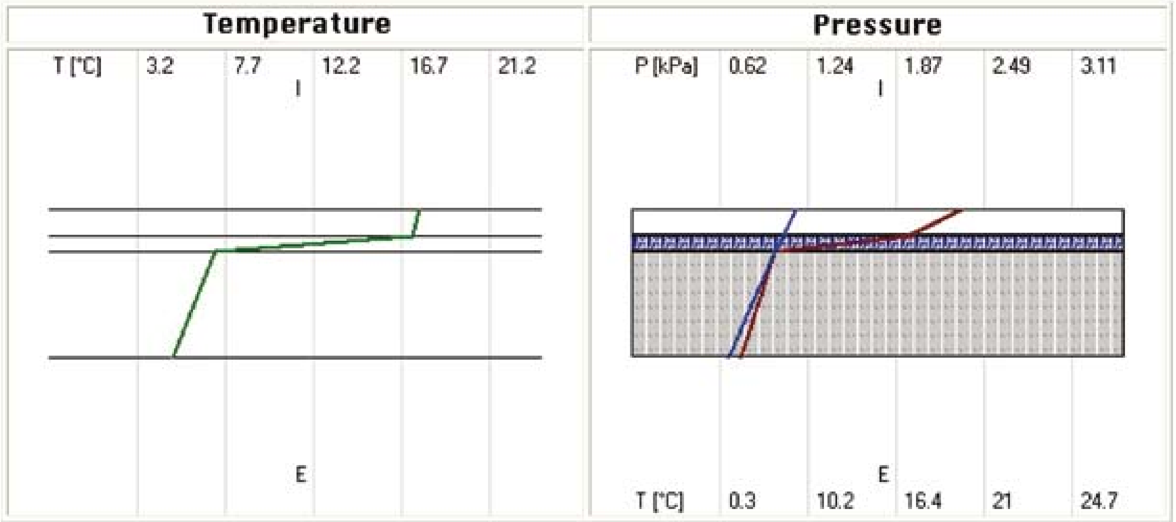
Structure: warehouse wall



NORMAL TRANSMITTANCE CALCULATION

Theoretical transmittance:	[W/m²°C]	0,695
Increased safety (0[%]):	[W/m²°C]	0,695
Rounding:		
Transmittance adopted:	[W/m²°C]	0,695

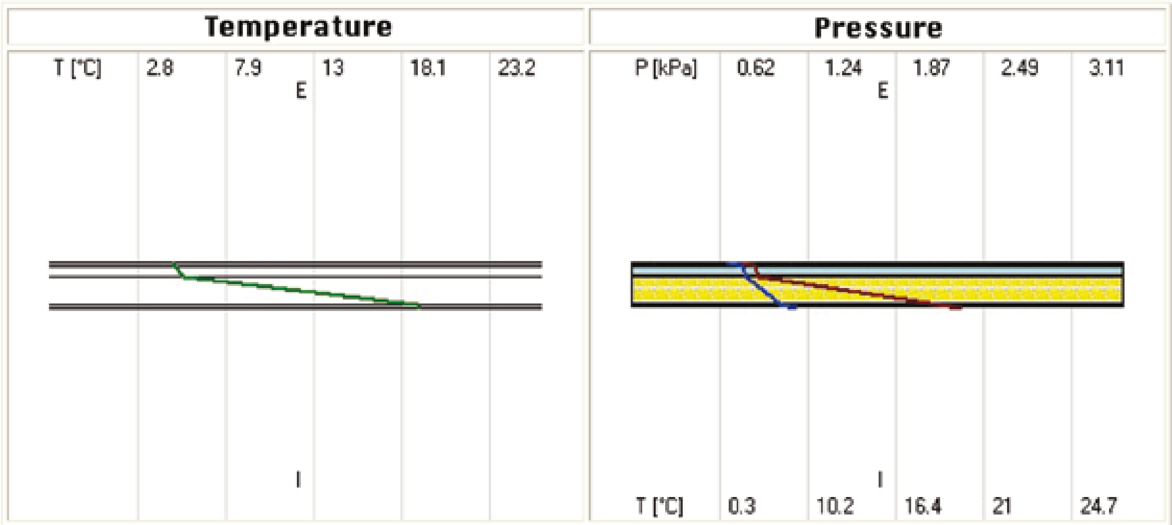
Structure: floor



NORMAL TRANSMITTANCE CALCULATION

Theoretical transmittance:	[W/m²°C]	0,903
Increased safety (0[%]):	[W/m²°C]	0,903
Rounding:		
Transmittance adopted:	[W/m²°C]	0,903

Structure: ceiling



NORMAL TRANSMITTANCE CALCULATION

Theoretical transmittance:	[W/m²°C]	0,542
Increased safety (0[%]):	[W/m²°C]	0,542
Rounding:		
Transmittance adopted:	[W/m²°C]	0,542

Clearly structures are highly dispersing. This choice was made so that dispersion would be approximately the same as a class B 70 m² building.

Systems

Heat generator: Rhoss THAEYT 107 water/air heat pump with primary storage and circulator. Maximum delivery temperature of 45°C for both systems.

System layouts of two rooms are those shown in figure 5 (radiators) and figure 6 (radiant panels).

Detail radiator header

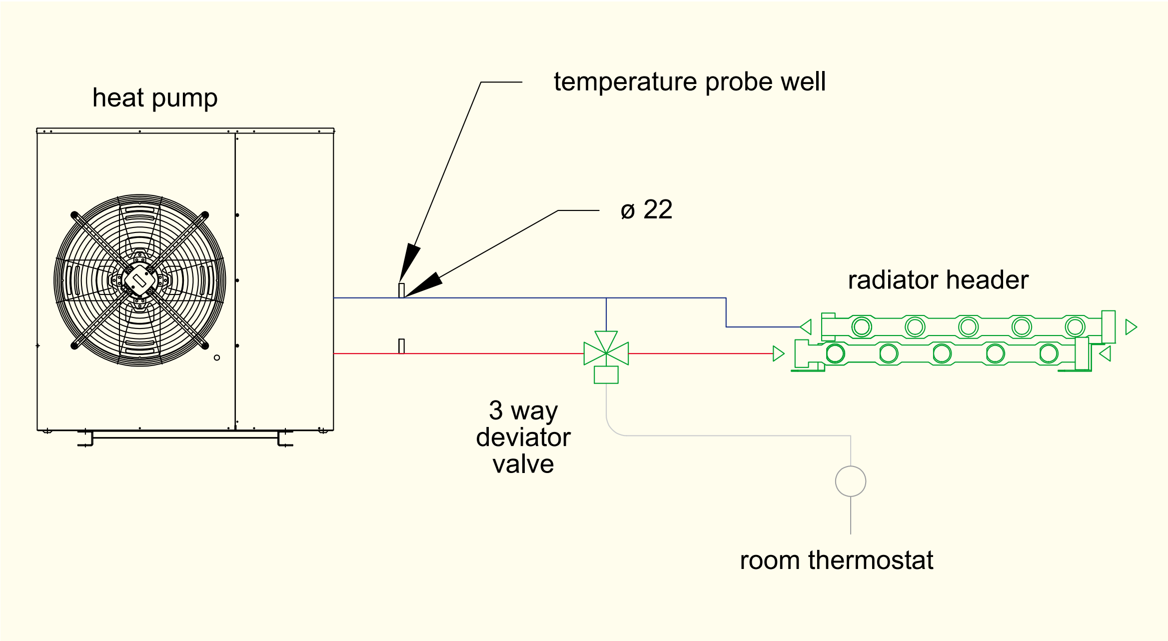


fig. 5

Detail radiant panel header

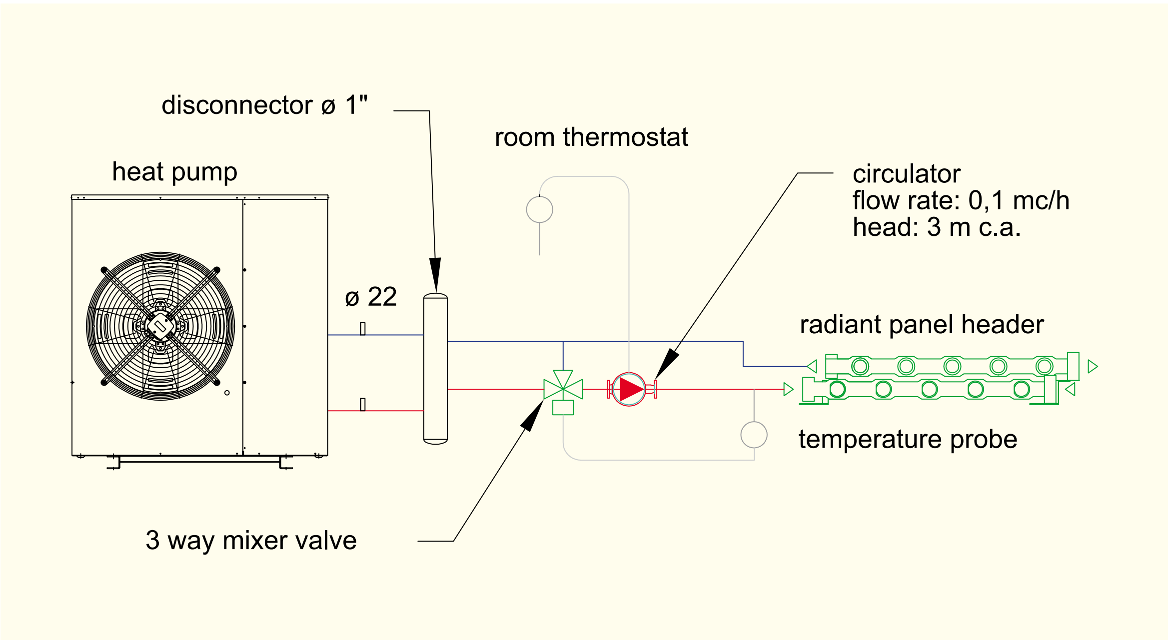


fig. 6

Both rooms are regulated by daily and weekly timer-thermostat, programmable on various temperature intervals. Thermostat is set to 20°C for both rooms.
Thermostat acts on secondary circulator in radiant panel system whereas in the case of the radiator system it acts either on the primary pump or three way diverter valve depending on the type of tests carried out.
Both rooms are equipped with an automatic continuous data acquisition system. At 5 minutes intervals it logs:

- Power consumption
- Instant power absorbed
- Temperature within rooms
- External temperature
- Water delivery and return temperatures of two systems

Description of data acquisition system

This system consists of one or more GPC data acquisition boards that, linked by a standard RS485 or Ethernet network, report back to a personal computer that collects and processes data. They are true data loggers equipped with their own memory, able to acquire and store data for weeks at a time.
GPCs can be interfaced with instruments that measure power and environmental parameters, existing or dedicated real time alarm management PLCs and electric, water and gas meters. They can be connected to remote sites and controlled centrally via local networks, standard telephony and GSM.

Global radiator installation

The GLOBAL RADIATORI company system consists of 1 GPC board programmed to acquire data from field instruments.
Both the TecSystem temperature measuring device, model NT538, equipped with 8 PT100 temperature probe channels and Revalco 1RAEMC485 three-phase multimeters (one per heat pump) are connected to this GPC.
Measuring instruments communicate with GPC through a 2 cable RS485 serial interface using the Modbus RTU protocol.
The GPC, in which system configuration resides, knows which measuring channels it must acquire, continuously interrogating the measuring device channels in sequence and taking an average sample of each channel every 2,5 seconds.
Measurements sampled in this way are stored within the GPC and averaged over 5 minute intervals; in practice the GPC memorises the average measurements of each channel every 5 minutes. The PC, acquiring data from the GPC, converts it from the original format, as produced by the measuring instruments, into the user format of each channel (temperatures, voltages, current etc.) feeding the system history file.

Description of tests

Trials were carried out between 02/10/09 and 05/01/09.
The following tests were carried out:
- System on continuously
- System on intermittently over two time bands
- System on intermittently over three time bands
- Starting with system switched off.

Thermostats in both rooms are set to 20°C.

In the case of the radiator system tests were even carried out with different types of regulation. Some tests were performed acting on the primary pump supply, others controlling three way valve opening and closing. During the last test period the heat pump of the panel system was set to a maximum delivery temperature of 40°C whilst radiator heating pump setting remained at 45°C.
The following shows the overall energy consumptions measured during the entire period and consumptions for each of the above-mentioned operating tests. Moreover, graphs show temperatures measured within two rooms.

Total test results

Total energy consumption from 02/10/2009 to 05/01/2009
MONITOR 2003 - SUMMARY FROM 02/10/2009 TO 05/01/2009

code	description	value
C.046 -	panels: power on	861,898 kWh totalizer
C.048 -	radiators: panel on	638,999 kWh totalizer

BUILDING WITH RADIANT PANEL SYSTEM USED 34,88 % MORE

Energy consumption from 02/16/09 to 02/20/09 system on continuously
Radiators regulated switching circulating pump on/of
MONITOR 2003 - SUMMARY FROM 02/16/2009 TO 02/20/2009

code	description	value
C.046 -	panels: power on	87,400 kWh totalizer
C.048 -	radiators: panel on	79,00 kWh totalizer

BUILDING WITH RADIANT PANEL SYSTEM USED 10,60 % MORE

Energy consumption from 02/24/09 to 03/03/09. Times in operation 05,00/08,00 - 17,00/23,00
Radiators regulated switching circulator on/of
MONITOR 2003 - SUMMARY FROM 02/24/2009 TO 03/03/09

code	description	value
C.046 -	panels: power on	115,900 kWh totalizer
C.048 -	radiators: panel on	82,900 kWh totalizer

BUILDING WITH RADIANT PANEL SYSTEM USED 39,80 % MORE

Energy consumption from 03/04/09 to 03/18/09. Times in op. 5,00/8,00 - 12,00/14,00 - 17,00/23,00
Radiators regulated with three way valve and circulator always on
MONITOR 2003 - SUMMARY FROM 03/04/2009 TO 03/18/09

sigla	description	value
C.046 -	panels: power on	179,000 kWh totalizer
C.048 -	radiators: panel on	154,000 kWh totalizer

BUILDING WITH RADIANT PANEL SYSTEM USED 16,20 % MORE

Energy consumption from 03/19/09 to 04/08/09. Times in op. 5,00/8,00 - 12,00 /14,00 - 17,00/23,00
Radiators regulated with three way valve and circulator always on
MONITOR 2003 - SUMMARY FROM 03/19/2009 TO 04/08/09

sigla	description	value
C.046 -	panels: power on	221,700 kWh totalizer
C.048 -	radiators: panel on	178,200 kWh totalizer

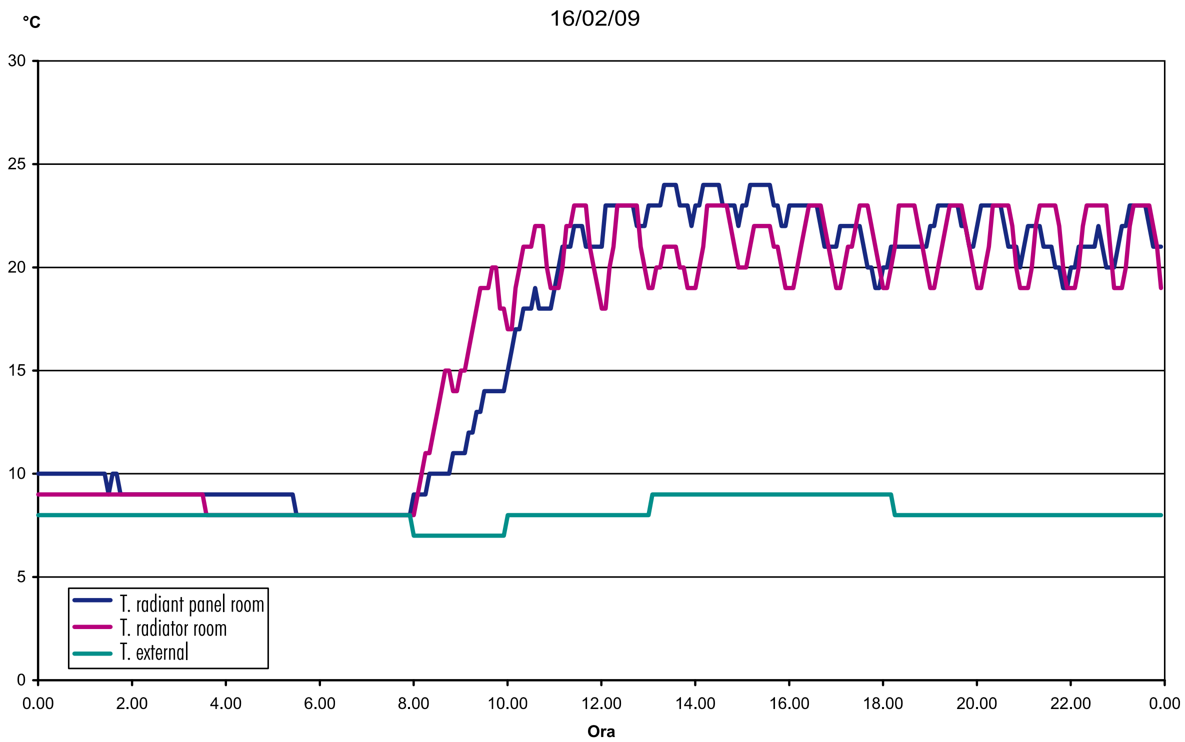
BUILDING WITH RADIANT PANEL SYSTEM USED 24,40 % MORE

Energy consumption from 04/09/09 to 05/01/09. Times in op. 5,00/8,00 - 12,00/14,00 - 17,00/23,00
Radiant panels: delivery T 35°C T heat pump set point 40°C
Radiators: delivery T 45°C T heat pump set point 45°C switching circulator on/off
MONITOR 2003 - SUMMARY FROM 04/09/09 TO 05/01/2009

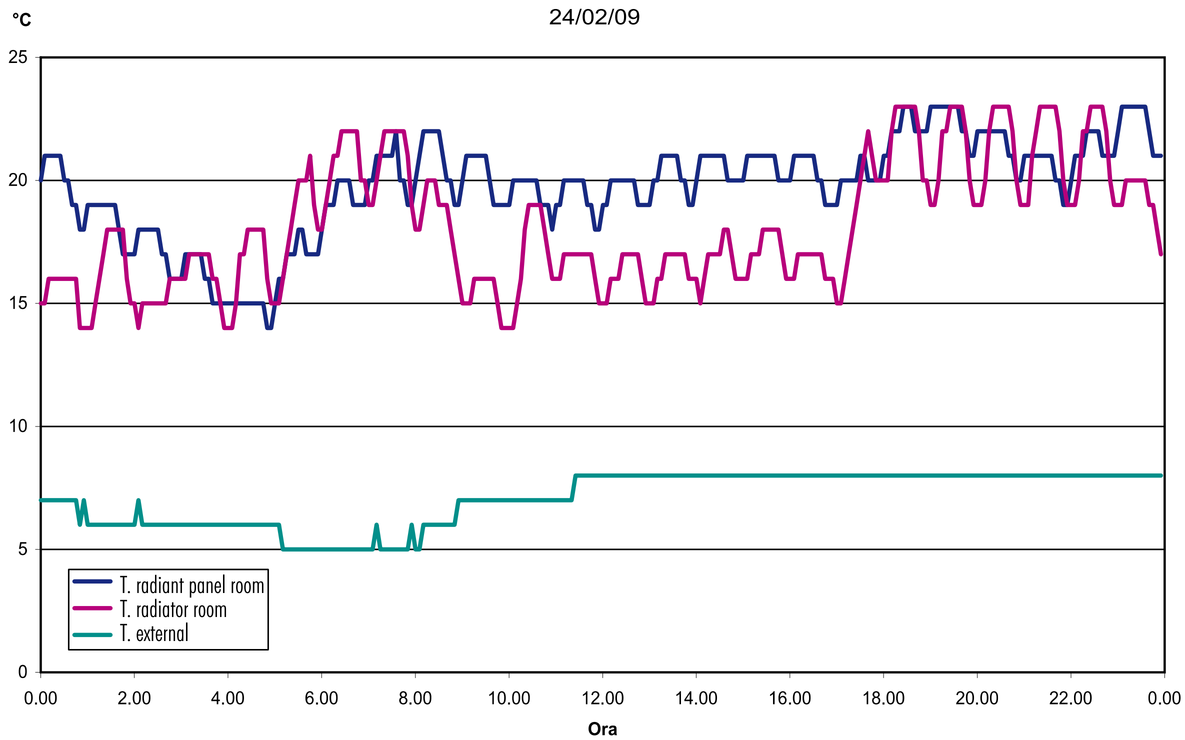
sigla	description	value
C.046 -	panels: power on	169,900 kWh totalizer
C.048 -	radiators: panel on	50,100 kWh totalizer

BUILDING WITH RADIANT PANEL SYSTEM USED 3,40 TIMES MORE

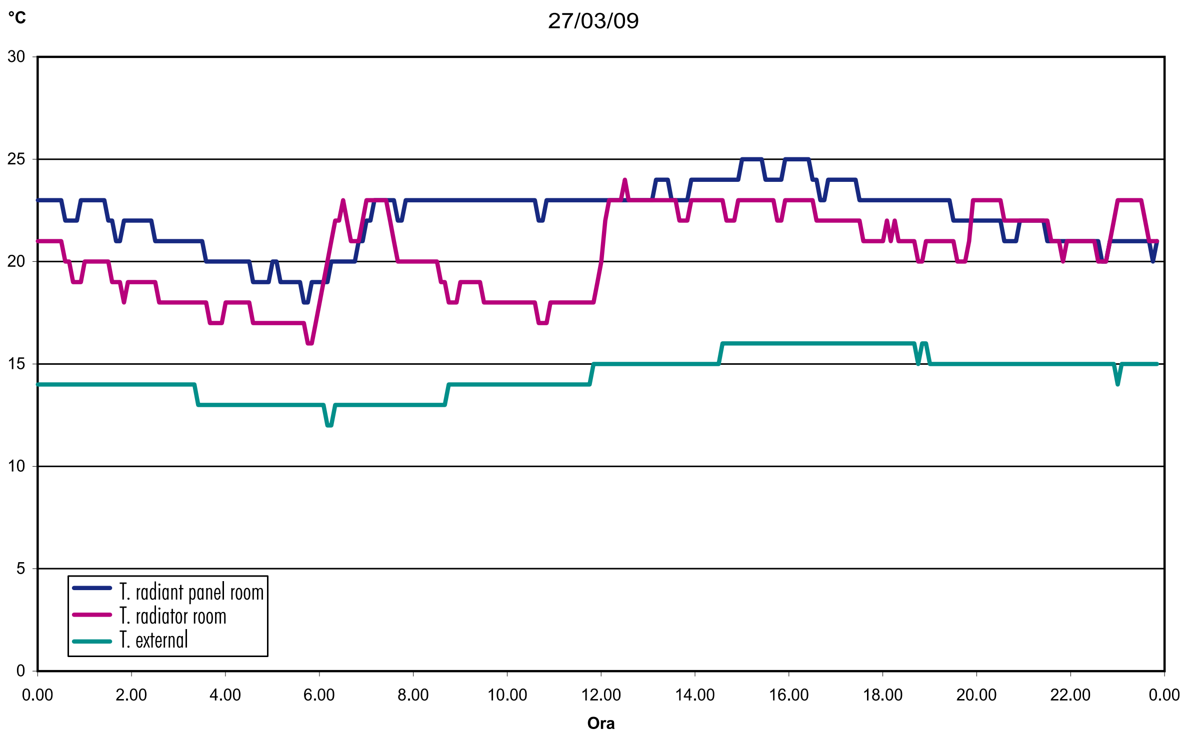
Test results: radiator and panel internal room temperature trend, external temparature



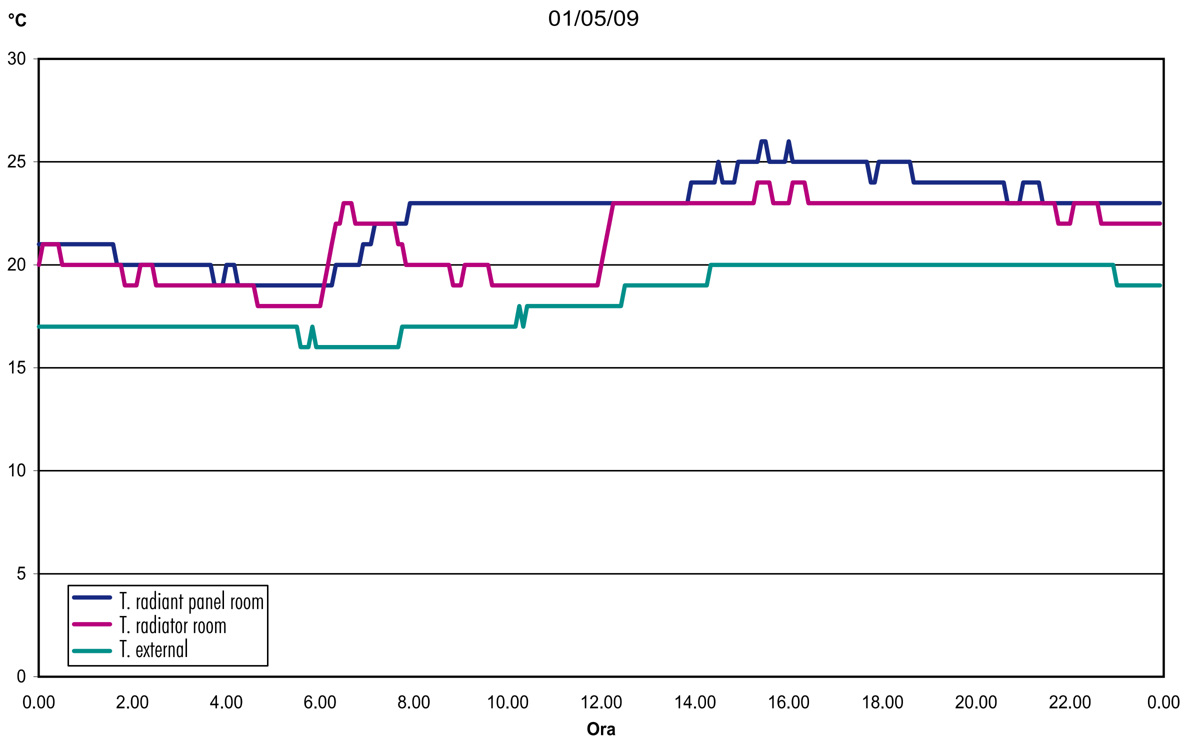
graph 1: internal temperature trend starting from system switched off



graph 2: times in operation 5,00/8,00 - 17,00/23,00



graph 3: times in operation 5,00/8,00 - 12,00/14,00 - 17,00/23,00
(radiators working with mixer valve)



graph 4: times in operation 6,00/8,00 - 12,00/14,00 - 17,00/23,00
(radiant panel delivery T 35°C T heat pump set point 40°C)

Description of tests Winter 2009-2010

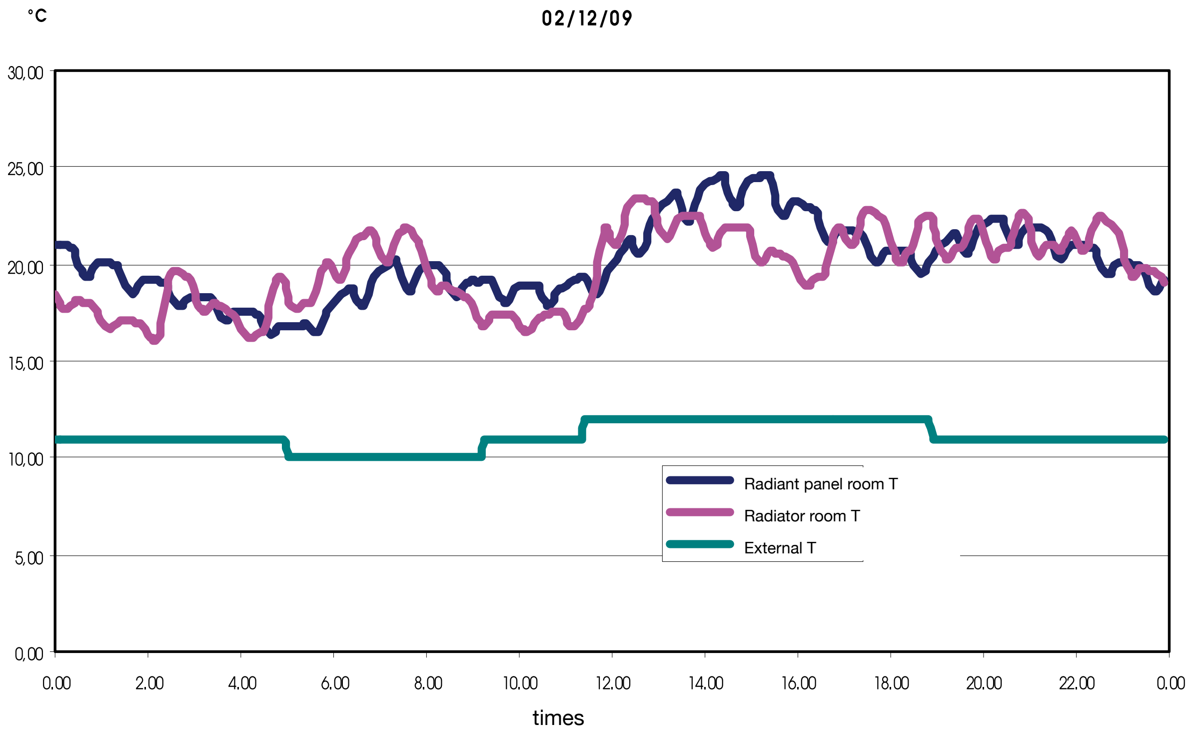
Trials were carried out between 11/10/09 and 03/24/10.
The following tests were carried out:

- System on continuously
- System on intermittently over three time bands
- Switching radiators on/off on heat pump
- Switching radiant panels on/off on heat pump

Radiant panel heat pump set point temperature 35°C
Radiator heat pump set point temperature 35°C
Radiator heat pump set point temperature 40°C
Thermostats in both rooms are set to 20°C.

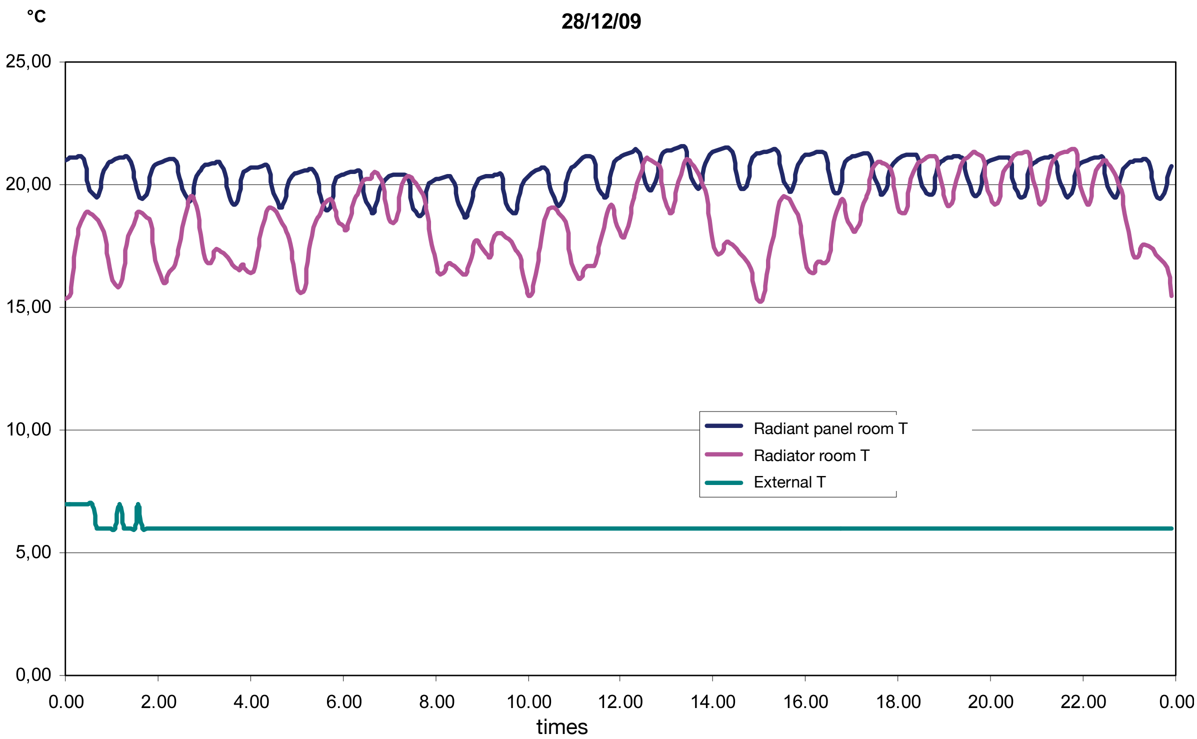
The following shows the overall energy consumptions measured during the entire period and consumptions for each of the above-mentioned operating tests. Moreover, graphs show temperatures measured within two rooms.
It should be noted that having chosen to use an operating temperature of 40°C for the heat pump of the radiator system, its efficiency and consequently consumptions are penalised in a percentage varying between approx. 13% and 21%, as shown below.

External T 0°C		
T set point 35°C	T set point 40°C	Difference
Cop. 2.82	Cop. 2.5	12.8 %
External T 7°C		
T set point 35°C	T set point 40°C	Difference
Cop. 3.34	Cop. 2.92	14.4 %
External T 10°C		
T set point 35°C	T set point 40°C	Difference
Cop. 3.81	Cop. 3.15	20.9%
External T 15°C		
T set point 35°C	T set point 40°C	Difference
Cop. 4.32	Cop. 3.68	17.4%



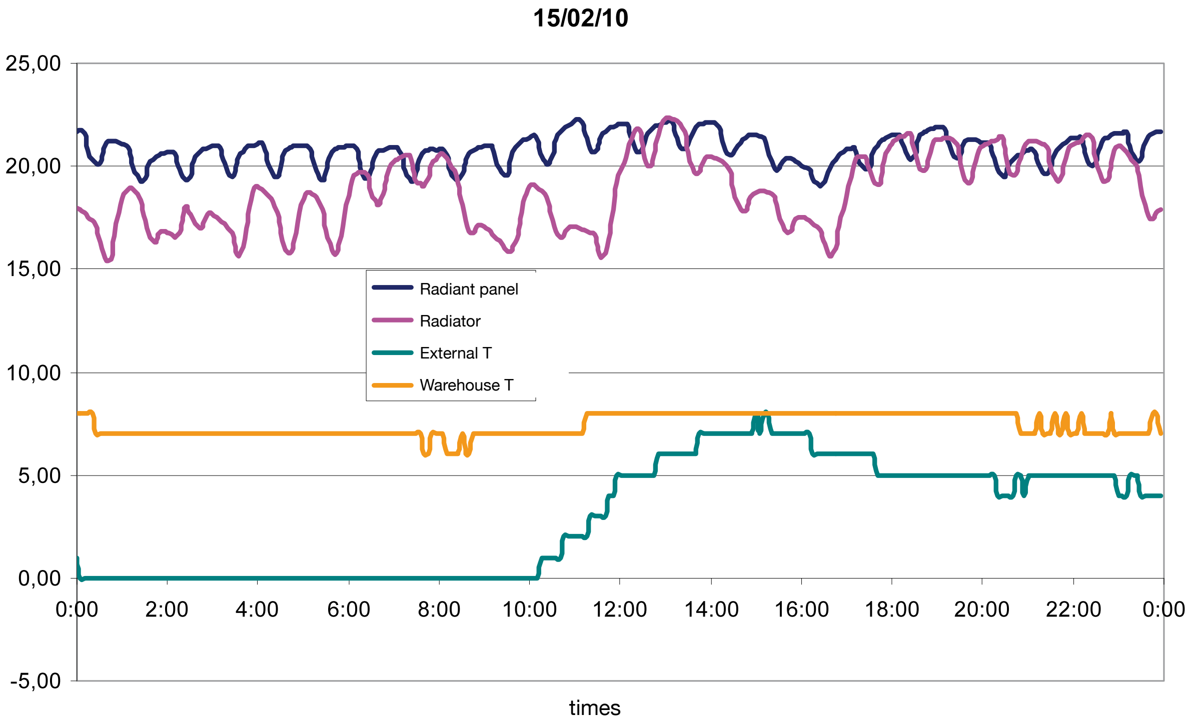
graph 5: times in operation 6,00/8,00 am - 12,00/2,00 pm - 5,00/11,00 pm
Panels: delivery T 35°C, heat pump set point T 35°C - Radiators: heat pump set point T 40°C

Energy consumption: panels 8.4 kWh, radiatori 8.2 kWh, difference 2,4%.
Lower radiator heat pump efficiency: approx. 20%. **Total savings achievable: 24,4 %**



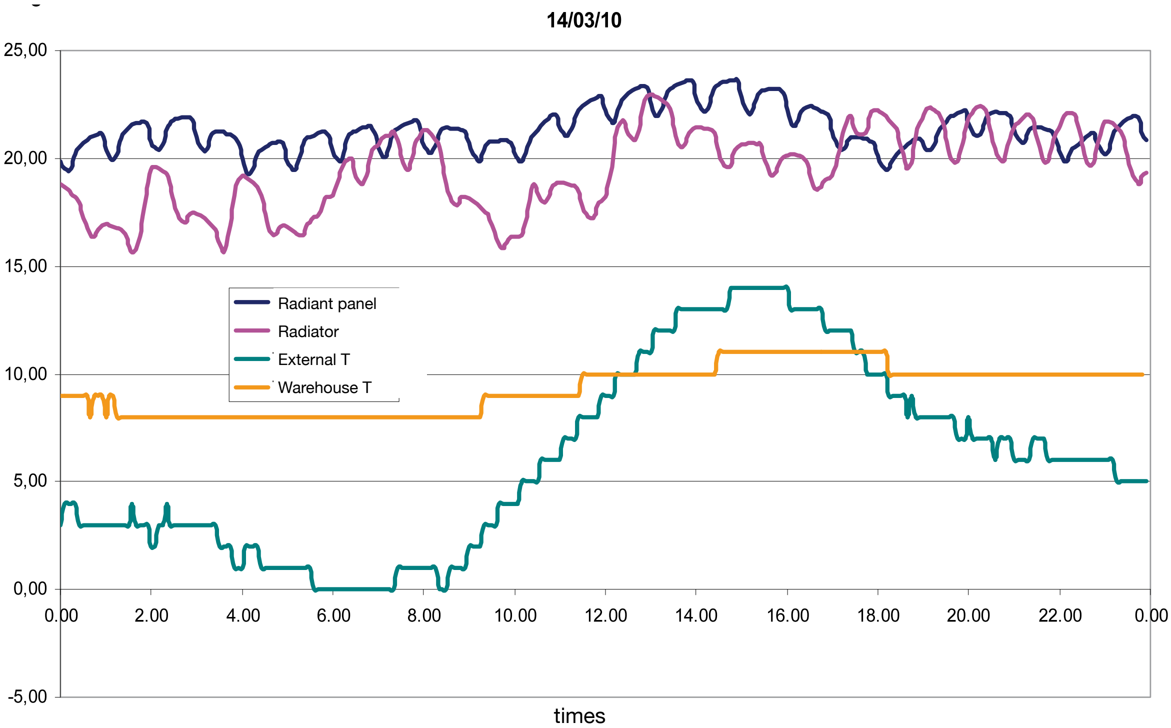
graph 6: times in operation Radiators 6,00/8,00 am - 12,00/2,00 pm - 5,00/11,00 pm. Panels continuously.
Panels: delivery T 35°C, heat pump set point T 35°C
Radiators: heat pump set point T 40°C

Energy consumption: panels 20.2 kWh, radiators 16.4 kWh, difference 23%
Lower radiator heat pump efficiency: approx. 14%. **Total savings achievable: 37 %**



graph 7: times in operation 6,00/8,00 am - 12,00/2,00 pm - 5,00/11,00 pm
Panels: delivery T 35°C, heat pump set point T 35°C. Radiators: heat pump set point T 40°C

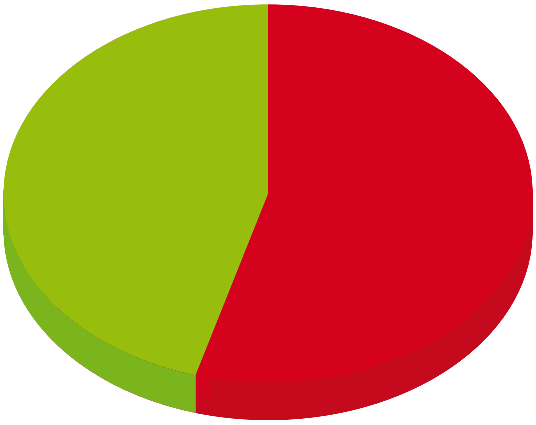
Energy consumption: panels 14.9 kWh, radiators 13.1 kWh, difference 13,7%.
Lower radiator heat pump efficiency: approx. 14%. **Total savings achievable: 27,7 %**



graph 8: times in operation 6,00/8,00 am - 12,00/2,00 pm - 5,00/11,00 pm
Panels: delivery T 35°C, heat pump set point T 35°C. Radiators: heat pump set point T 40°C

Energy consumption: panels 11.1 kWh, radiators 9.2 kWh, difference 21,7%.
Lower radiator heat pump efficiency: approx. 21%. **Total savings achievable: 42,7 %**

Test campaign summary 2009

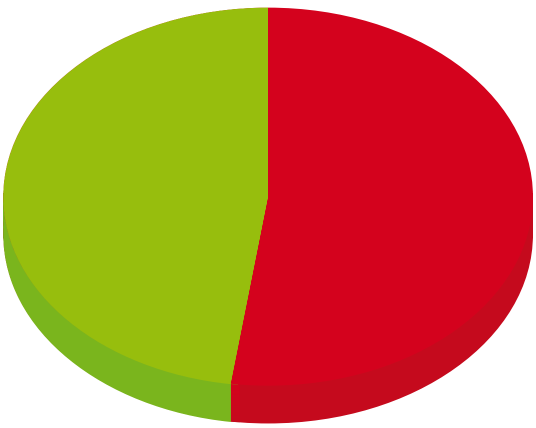


ENERGY CONSUMPTION WITH GLOBAL RADIATOR SYSTEM: **638.999 kWh**

ENERGY CONSUMPTION WITH RADIANT PANEL SYSTEM: **861.898 kWh**

difference: **34.9%**

Test campaign summary 2009/2010



ENERGY CONSUMPTION WITH GLOBAL RADIATOR SYSTEM: **1591.4 kWh**

ENERGY CONSUMPTION WITH RADIANT PANEL SYSTEM: **1756.7 kWh**

difference: **10.4%**

TOTAL LOWER RADIATOR HEAT PUMP EFFICIENCY: **16.5%**

Total savings achievable: 26,9 %

Of particular interest is the analysis of the graphs relating to the internal temperatures of the two rooms both in the heating test starting with the system switched off and intermittent operating tests. The delayed response of the floor system compared to that of the radiators is clear, the latter reaching room temperature more quickly. The radiant panel heated room temperature is generally higher than that of the other room despite both having the same set point temperature and a more refined regulation. In particular, temperatures are high even during intermittent operation when the system is switched off. In practice this corresponds to situations when the building is uninhabited and thus there is no need for heating. Lastly, the graph referring to a day with high external temperatures requiring heat at only precise times of the day (graph 4) is of great significance: the floor heated room temperature is out of control, much higher than that of the room with radiators.

The results of the second test campaign (winter 2009-2010) confirm the data obtained in the previous winter. Despite the deliberate penalisation of the heat pump efficiency, the radiator system, under any operating conditions, consumed less and less energy than the radiant panel system.

The comparison of the temperature profiles inside the two test rooms should also be highlighted: while the room heated with the radiators always easily maintains the set point, the room with the radiant panels tends to have temperatures that are out of control. This is more evident as the thermal loads decrease (i.e. as the outside temperature increases) and as the daily temperature range increases (corresponding to mid-season). This last consideration also clearly suggests the unsuitability and economic convenience of radiant panel heating for new civil buildings in class A/A+, characterized by very low thermal loads and very low heat inertia.

Conclusions

We have seen how the energy consumption of a radiant panel heated room is higher in all operating conditions: as expected the more limited differences are noted during continuous operation, where the greater consumption is mainly attributable to the power absorption of the second circulator in the radiant panel system; whereas the more significant differences were noted during intermittent operation, in particular during late winter/early spring days, when external temperatures increase and the day/night temperature range is greater.
The greater economy of the radiator system, highlighted by both those graphs showing temperatures starting from zero (1) and those with operating temperatures (2, 3, 4), is due to the high heat inertia of radiant panel systems that cannot adjust quickly to changing thermal loads, thus resulting in an increased internal room temperature (there is no need to remind you that an increase in room temperature corresponds to increased consumptions).

Therefore, it is best to use radiator systems rather than those with radiant floor panels for applications characterised by appreciable variations in internal and external load (typical of our climate with temperature ranges between night and day even higher than 10° C).

Therefore, considering the theoretical values (building energy requirements, emission and regulation efficiency, heat inertia) and practical results obtained from the above-mentioned tests, it would be correct to say that the best energy efficiency is obtained using radiator systems.

It is clearly preferable to install radiator systems rather than radiant floor panels to achieve energy savings while maintaining a high environmental comfort.

Low temperature radiator systems continue to be the best building-plant compromise for all applications characterised by appreciable load variations such as those of all civil utilities: household heating, schools, offices, hotels limited to winter heating.

Lastly, we include a few excerpts from the report prepared by the "Sergio Stecco" Energy Department of the Faculty of Engineering of Florence University resulting from the Research agreement stipulated with Global having as subject "Comparing performance of radiant panels and radiators" based on the analysis of data obtained with the above-mentioned system.

[...]

The aim is that of making sure comparison between two heating systems has been carried out properly and that the results provide a decisive answer in terms of performance of the two systems. In particular, we are interested in assessing the actual thermal energy consumption of the two systems during intervals and days that are:

- truly representative of periods of varying lengths;
- comparable in terms of useful effect, that is, comparable in terms of temperature in relation to hourly thermal profile set.

[...]

Criteria for selecting representative data of different series of tests

24 hour use is necessary to analyse and compare the performance of the two heating systems. Therefore, they were analysed separately according to the room temperature profile set by the timer-thermostat. Overall, five different operating regimes were adopted during the various measuring periods:

1) *on continuously* from 02/16/09 to 02/20/09;

2) *on during the following hours: 05.00 - 08.00, h 17.00 - 23.00* and radiators regulated switching circulator on/off from 02/24/09 to 03/03/09;

3) *on during the following hours: 05.00 - 08.00, h 12.00 – 14.00, 17.00 - 23.00* and radiators regulated by three way valve and circulator always on from 03/04/09 to 03/18/09;

4) *on during the following hours: 05.00 - 08.00, h 12.00 – 14.00, h 17.00 - 23.00* and radiators regulated by three way valve and circulator always on from 03/19/09 to 04/08/09;

5) *on during the following hours: 05.00 - 08.00, h 12.00 – 14.00, h 17.00 - 23.00* with: radiant panels having delivery T 35 °C and heat pump set point 40°C and radiators having delivery T 45°C heat pump set point 45°C circulator on/off from 04/09/09 to 05/01/09

[...]

In this first series of tests, the lack of certain data lead to the need to hypothesise and simplify in order to estimate consumption and performance of the two heating systems tested.

- Firstly the mass of data available, that was relatively high as measurements were carried out for 3 months over a 24 hour period with sampling at 5 minute intervals, was reduced and verified. A data selection criterion was then prepared that, depending on the thermal profiles recorded within the two rooms, identified typical days characteristic of the various periods and system operating regimes, set and regulated by the timer-thermostat. This resulted in ***5 representative days (typical***

days) being identified. These were used to assess and compare consumption as well as calculate heat loss for both rooms for the two different systems under examination.

- Basically heat consumption for the two rooms was not assessed according to the type of heat generator but obtaining, on the basis of the operating maps of the two heat pumps, at the water delivery and return temperatures and temperature within the warehouse and prior eliminating circulator power absorptions, the COP and from this the thermal power emitted minute by minute within the two systems. The results highlighted a ***lower heat consumption for radiators***, ranging ***from 5%*** when running at constant temperatures (optimal regime for panels) to ***40%*** for intermittent use. The differences between the power and heat consumptions of the two systems increase as the hotter seasons approach, when the reduced need for heat increases the relative weight (on power consumptions) of circulators. Moreover, when power consumption incidence is on similar levels for both systems (cases 3 and 4 with circulator always on even for radiators), reduction in heat consumption is greater for the radiator system. The ***1°C uncertainty*** as to the temperatures measured leads to errors ***in heat consumption estimates of 4 – 5%*** that, in some cases, is equivalent to the difference between the two systems.

[…]

- ***The average temperature of the radiant panel heated room was higher*** than that of the room with radiators in all tests except when systems are on continuously (1). This is because of the greater heat inertia of panels. This is why panels take a lot more time to heat a room initially at a low temperature than radiators: see for example figure 22 showing the two systems being switched on at 5 from an initial temperature of around 15°C for the room with radiators and 17°C for that with panels.

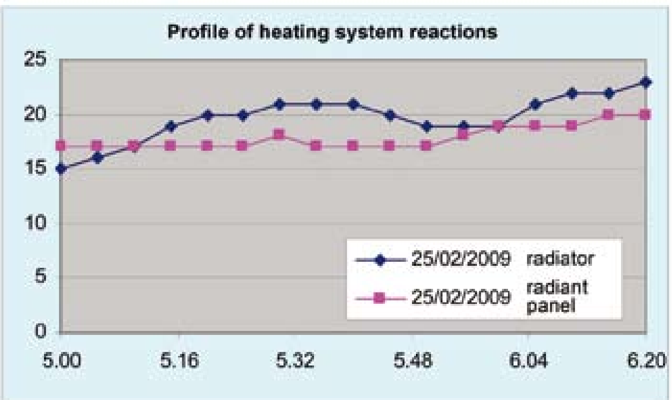


fig. 22

This also explains why the panel system generally uses more power than radiators in those hours when it is not always on. Therefore the radiator heating system is more efficient in all those cases when system is not continuously on over 24 hour period.

Previous observations show that it is advantageous to use radiators even when, due to existing constraints, it is not possible to maximize the heat generation performance/efficiency, as often happens in the case of the energy upgrading of existing buildings.
Efforts should be made to ensure that the system upgrading actions are not invasive to the occupants of the building, i.e. that they do not make it compulsory to abandon the house. The best solution is therefore to work with the existing type of system which, in most cases, is represented by the radiator system. The recommended modification is the replacement of the old cast iron radiators with new aluminum radiators, obviously keeping the overall dimensions unchanged.
Below it is shown how, in the simplest case of upgrading, i.e. the replacement of the heat generator with a condensing boiler, it is possible to optimize the efficiency simply by installing an external temperature probe for the variable temperature control of the boiler. Most of the existing building stock consists of buildings in Energy Class F or G, with annual primary energy requirements of 150-200 kW/m^2.

The most common type of heating system consists of a gas boiler (standard generator) and radiators (control terminals) sized with ΔT 50°C or 60°C.

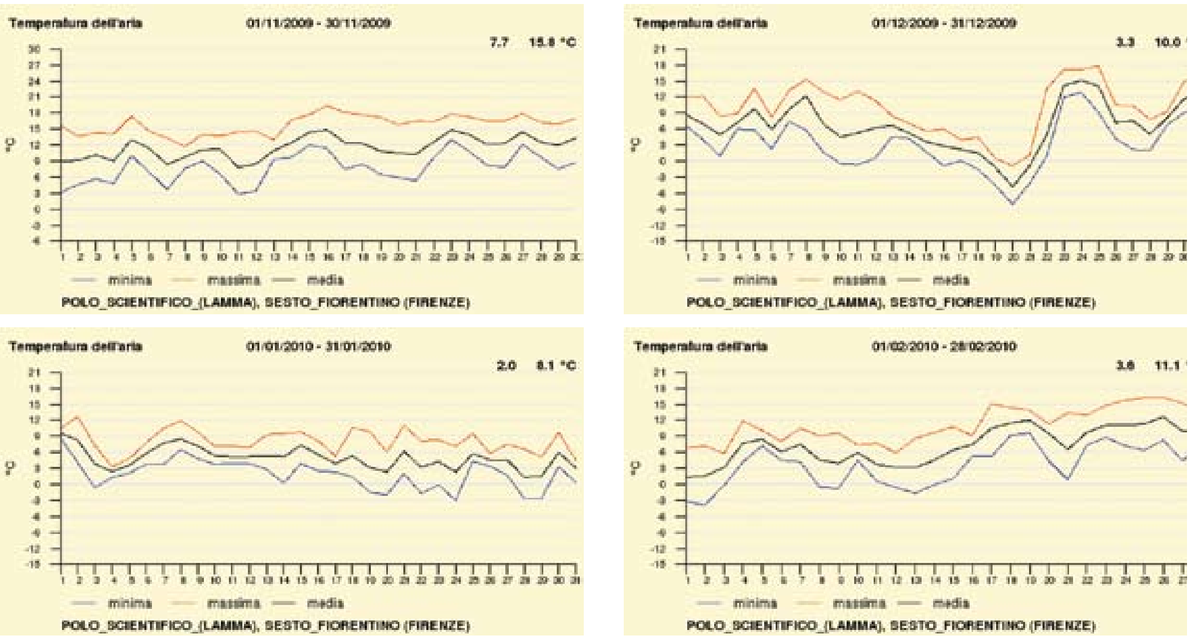
It is not necessary to install radiant panels as supply terminals In order to optimise the efficiency of condensing boilers or heat pumps.
The use of Global aluminium radiators allows to maintain the system unchanged, optimizing the efficiency without increasing the number of elements. The low heat inertia allows "start&stop" operation, reducing consumption.
Below is an example:

place **Firenze** • gross volume heated **400 m³**
net useful surface area **76 m²** • urface/volume **0,98**
energy class **E**
approximate primary energy **110 kW/m2 /year**
traditional **Global Vox 800 system 54 elements**

External T	Internal T	Power required	ΔT	Delivery T	Return T
0°C	20°C	9650 W	50°C	75°C	65°C
0°C	16°C	7720 W	42°C	63°C	53°C
6°C	20°C	6755 W	38°C	63°C	53°C
6°C	16°C	4825 W	30°C	51°C	41°C
8°C	20°C	5790 W	35°C	60°C	50°C
8°C	16°C	3860 W	25°C	46°C	36°C
12°C	20°C	3060 W	25°C	50°C	40°C
12°C	16°C	1930 W	20°C	41°C	31°C
16°C	20°C	1930 W	20°C	45°C	35°C

As the outside temperature increases or during the regime of attenuation (keeping the internal temperature at 16°C), the energy requirements of the building decreases. The installation of an external temperature probe allows to automatically control the delivery temperature of the system and maximize the efficiency obtaining further energy savings.

Average monthly increase in external temperature: winter 2009/2010*



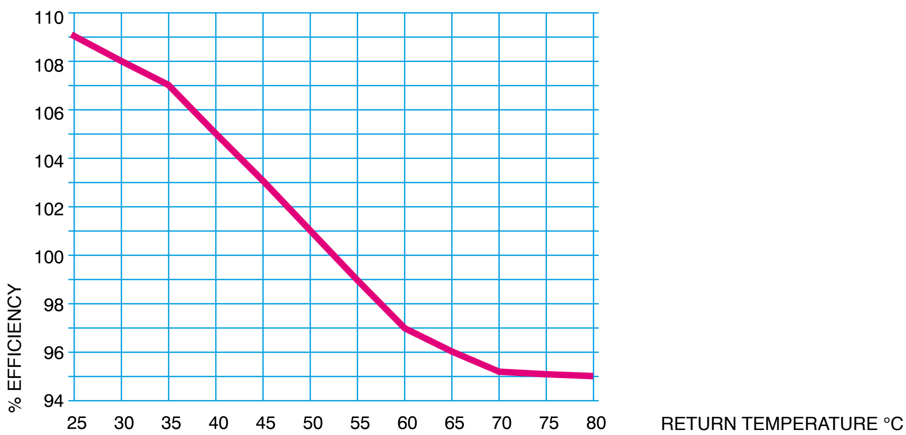
*data by Lamma Weather Forecast, Florence Station

The weather data show the variations in the external temperature during the winter of 2009/2010; in the same period the operating time of the plant is divided as follows:

TIME	RETURN TEMPERATURE	EFFICIENCY
10%	> 60°C	97%
24%	tra 50 e 60°C	101%
45%	tra 45 e 35°C	103%
21%	< = 35°C	107%

The average annual boiler efficiency is **104%**

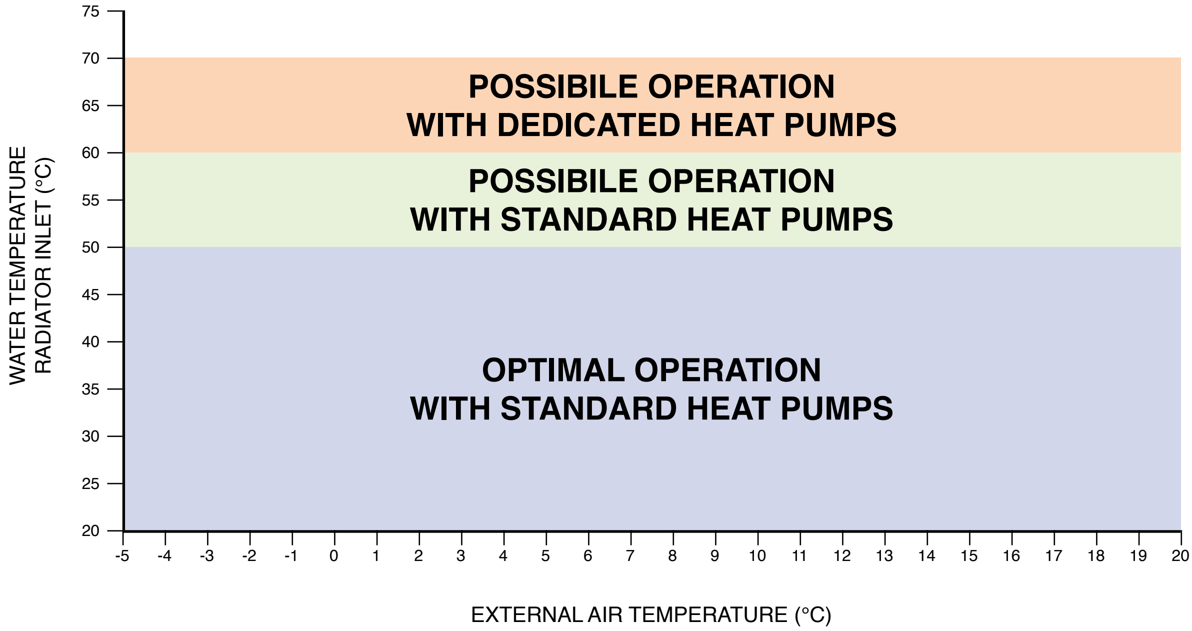
The graph shows the average efficiency values of condensing boilers: when the water return temperature value decreases, the energy efficiency of the boiler increases.



The condensing boiler therefore operates under identical conditions in radiant panel systems and in those with aluminium radiators. The low heat inertia of Global radiators also allows the use in "start&stop" mode further improving the economy of the system with savings of more than 30% compared to radiant floor panel systems. In the case of upgrading also concerning the building envelope, it is possible to estimate a reduction of the power required approx. 20%-50%: by keeping the existing terminals (same overall dimensions) it is possible to further increase the efficiency of the condensing boiler in order to reach the theoretical maximum.

The same considerations apply to heat pumps, whose efficiency is linked to the delivery temperature in a similar way to that seen for condensing boilers.

It's worth noting that:
HEAT PUMPS, EXACTLY LIKE CONDENSING BOILERS, CAN OPERATE WITH RADIATOR SYSTEMS.



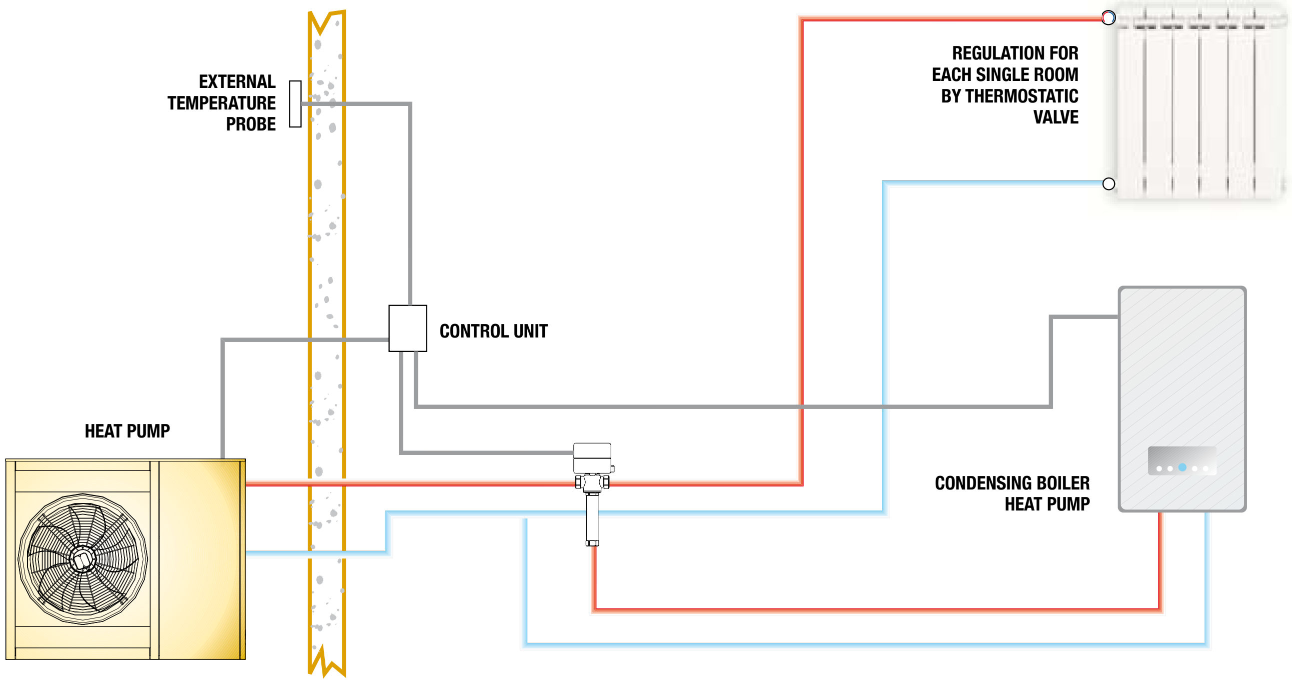
The graph shows that even in the case of a simple heat generator replacement, i.e. without reducing the required thermal output, it is possible to maintain the radiators by using heat pumps. We must then consider that in most cases the radiators present in old buildings are oversized compared to the actual need; by carrying out a careful analysis of the thermal loads and replacing the old radiators with new aluminium radiators, it is possible to keep the overall dimensions unchanged and to use standard heat pumps maximizing the efficiency.

As shown above with the help of an external probe, the heat pump adapts the water delivery temperature to the actual heating requirements. In addition, the performance comparison has shown that even when the heat pump operates at lower efficiency, the radiator system is able to consume between 3 and 23% less energy than the radiant floor heating system.

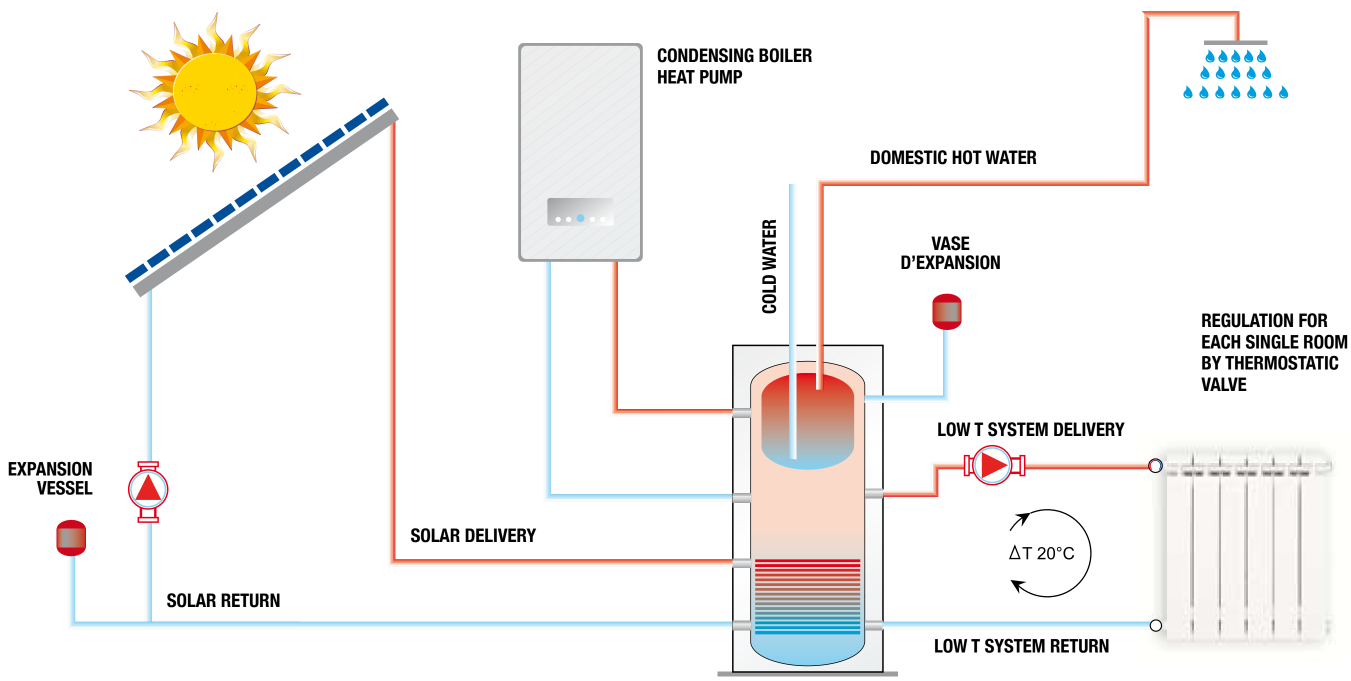
If, on the other hand, an external thermal insulation composite system is also carried out, which, as we have seen, can reduce the thermal output demand by up to 50%, it is possible, always with the same overall dimensions, to operate at the maximum efficiency of the heat pump at all operating speeds, in this case obtaining savings of more than 30% compared to the floor radiant system.

Below are some types of systems:

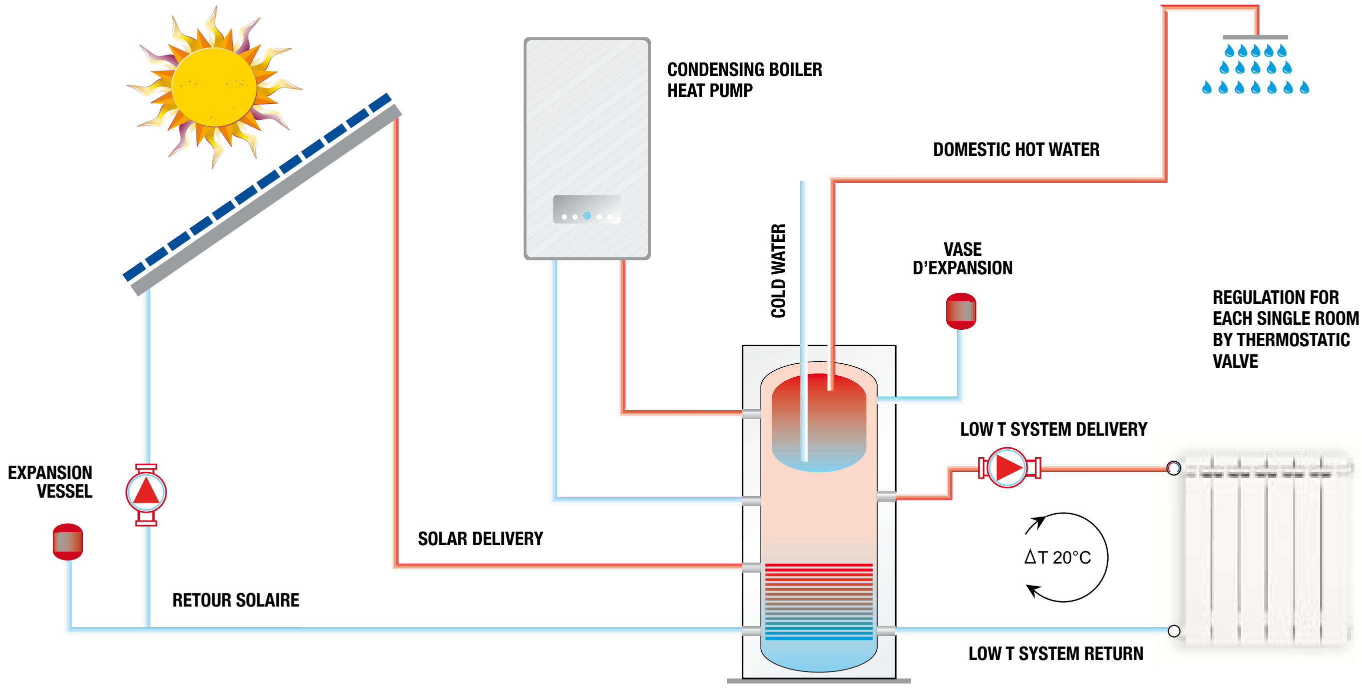
Low temperature hybrid heating system with Global radiators
Heat pump and condensing boiler



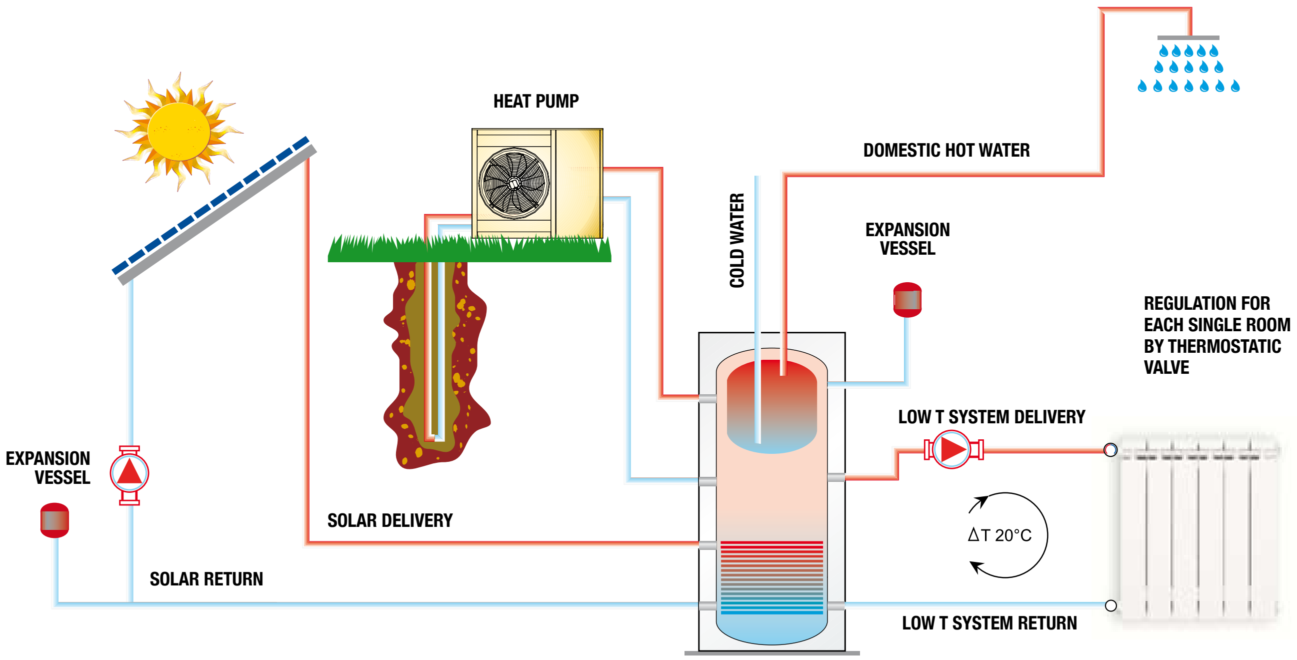
Low temperature heating system with Global radiators
Heat pump and solar system integration



Low temperature heating system with Global radiators
Condensing boiler and solar system integration



Low temperature heating system with Global radiators
Geothermal heat pump and solar system integration



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