Solar seminar room in the University of Balearic Islands with a new advanced radiant system

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Abstract

The use of Solar Energy in the Solar Seminar Room became more efficient with the combination with radiant systems for the highest renewable fraction, where solar thermal, photovoltaic, geothermal and auxiliary energy with heat pump systems (HP) have been used. The renewable energy is capable to cover all the energy consumption of the year. The net zero energy building needs low embodied energy in the materials with a high insulation. New radiant systems with capillary tube mats and clay in combination with calcium silicate has been used with solar heating and a geothermal system for buildings has been designed to achieve different values of the fraction of a primary energy saving using the Flat Plate Collectors (FPC) for Solar Thermal (ST) and other supply energies like solar photovoltaic (PV) or wind technology, and having the higher efficiency of the system with net zero energy.

Keywords: Solar energy, radiant system, Heat Pump, net zero energy building

1. Introduction

Radiant heating and cooling systems require considerably less energy consumption than conventional cooling systems. The radiant systems are ideal systems to replace heating and air conditioning in existing buildings or monument-protected buildings, because they have a lower cost in the retrofit and low impact on the construction of such buildings. The solar energy used in the project referred to in table 2. Results below are Flat Plate Collectors (FPC) and a Photovoltaics panel's polycrystalline (PV). FPC is working with less than 40ºC and arrives to high efficiency with high and sufficient comfort in the room. This became possible not only through the progress made in new renewable energy and advanced combisystems, but it has also been significantly improved by construction technologies and techniques. According to the thermal necessities and the weather conditions, the design has to be adapted in each area. Radiant cooling (floor, walls and/or ceiling) is not so often used but with the appearance of high efficiency aerothermal systems they have started to be installed with more frequency, though new constructions cover all thermal necessities (hot water, heating and cooling) with one system, especially at southern countries. The seminar room referred to below was built in the late 80s, and this new system has been tested in three more places, in a duplex residence in Mallorca and in a monument-protected building (the "Old Forge") in Ottersburg, Germany, and now in a flat in Palma.

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Table 1. Description of the composition of conventional materials (Hammond & Jones 2006).

Material	Embodied energy MJ per kg	€/m^2	CO_2 per kg kg/kg	Density kg /m^3	λ W/m K
Cement Mortar	1.09	18	0.18	1360	0.55
Expanded polystyrene	88.6	18	2.55	20	0.04
Autoclaved aerated concrete	1.3	33	0.7	1000	0.67
Plasterboard	6.75	4.4	0.38	900	0.25
Expanded polystyrene	88.6	6.8	2.55	20	0.04
Gypsum/ plaster	1.8	10	0.12	1120	0.3
	188.1	**90.2**	**6.48**	**4420**	

Table 2. Description of the composition of alternative materials (Hammond & Jones 2006)(Rossello-Batle et alt 2016)(skamol).

Material	Embodied energy MJ per kg	€/m^2	CO_2 per kg kg/kg	Density kg /m^3	λ W/m K
Mortar of lime and clay	1.8	90	0.13	1600	0.24
Straw bale	0.91	18	0	100	0.18
Clayboard	0.35	26.3	0.03	1500	0.18
Calcium Silicate	2	19	2.5	300	0.06
Clay	0.3	31	0.021	1900	0.59
	5.4	**184.3**	**2.68**	**5400**	

The systems with clay and straw are being used again in the construction, within the framework of the search for more sustainable systems, the use of ecological and traditional materials of km 0 and little embodied energy. They are very hygroscopic materials, so they keep the indoor humidity very stable throughout the year. Different radiant systems and materials could be used, in our case an assessment of the embodied energy variations was studied, but finally we have used the lowest impact in the materials to achieve similar insulation with low embodied energy. The proposed materials have 35 times less embodied energy, a 50% less of CO_2 emissions. These materials need more time to be installed and because they are not standard they became more expensive, but in the future the prices will be similar. The calcium silicate is more expensive than the polystyrene but has a high fire resistance and is more hygroscopic, helps to the system to be used for cooling without dehumidification system as recently has been shown (Moià et alt 2016).

2. Results

The system has been installed in the seminar room at the university campus in September 2015. It is composed of the new radiant systems with capillary tube mats in the room (figure 1), a well (geo-cooling system), Flat Plate Collectors, Air-Water Heat Pump, Storage Tank of 300L, PV with a Heat Pump, a ventilation system, the control and data logger systems, as showed at figure 4 (Moià et alt 2016).

Fig. 1: View of the capillary radiant system and top view of the seminar room

The results have been validated during a two-year data collection. These results are very promising and confirm the simulated results. The most important result is that during all the meetings and conferences the system has managed to keep the comfort temperature and control the humidity of the room (about 18ºC in winter and 26ºC at summer with 65% of relative humidity). The heat pump and solar system at winter never work more 40ºC. The large surface of the capillary tube mats helps that the system transfers heating and cooling with temperatures of the ceiling near to 18ºC.

Table 3. – Approximate embodied energy and CO_2 emissions for the described ensemble.

	EE (kWh/m^2)	ECO$_2$ (kg/m^2)
Expanded clay concrete	61,6	18,1
Calcium silicate board	3,9	1,3
	EE (kWh/m^2)	**ECO$_2$ (kg/m^2)**
Polypropylene tubes	3,3	1,7

Table 4: Energy Consumption and CO_2 emissions

	Before	New system
Electricity kWh/year	3507	330
Kg CO_2/year	1708	0
Solar Thermal used	0	748

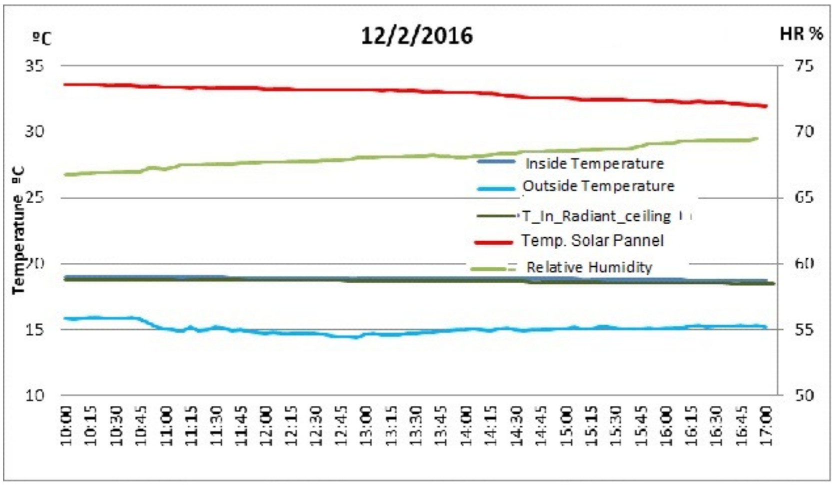

Fig. 2a: Temperatures of the system Heating-winter (12/2/2016)

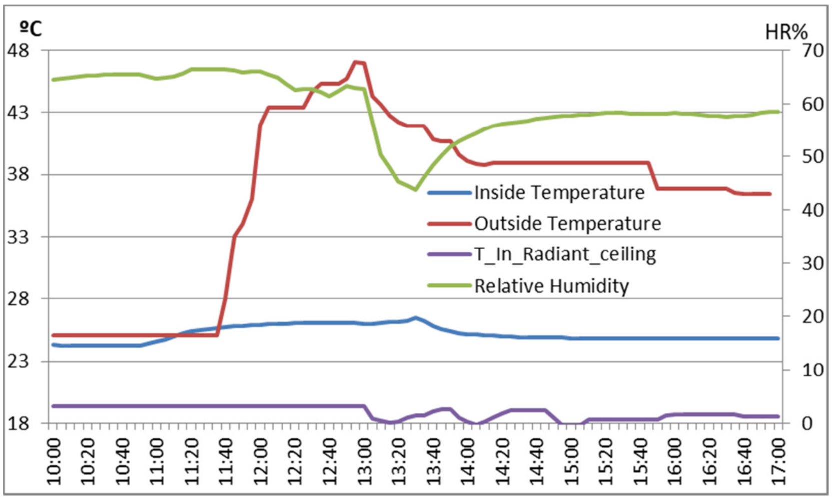

Fig. 2b: Temperatures of the system for Cooling-summer (21/7/2016)

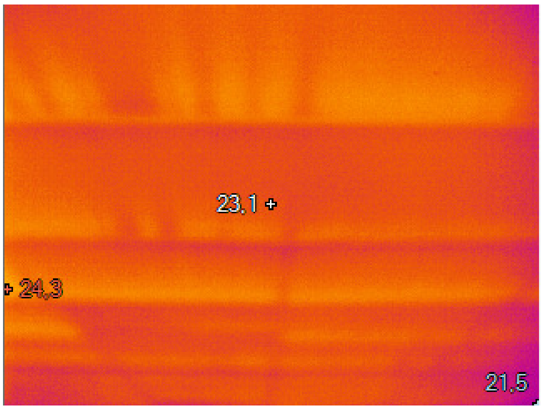

Fig. 3. Thermographic view of the radiant system in autumn

The heat transfer is very uniform in all the room (see figure 3), if the hydraulic circuits are well regulated; each panel has a capillary pipe every 2 cm, with a total of 50 capillaries. Each capillary has a diameter of 3.4 x 0.55mm, round distribution tube 20 x 2.0mm. The new system uses renewable energies during all the year, and a small quantity of electricity is needed for pumps and auxiliary systems. There are more components in the system but a good control and design allows a high reduction of the electric consumption, compared with the old system. As can be seen in Table 3 and Table 4, the installed power of the new system is 50% lower than before, including the chiller, only necessary for extreme external temperatures (less than 7ºC or higher than 32ºC). In this case the reduction is about the 85% at summer and 95% at winter.

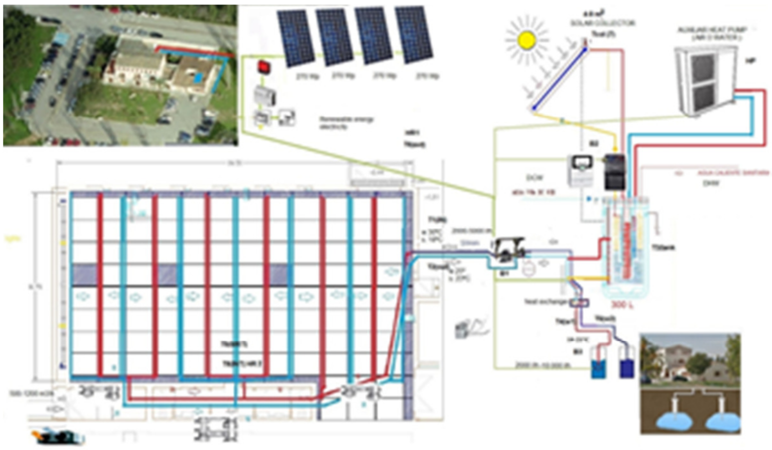

Fig. 4. Design of the system

The radiant system reduces the working temperatures of the system (17-22ºC in summer and 18-33ºC in winter) and don't need any fan to transfer the heat, if we compare this with the fan coil, they work with temperatures lower at summer and higher in winter, the design temperatures of the fancoils usually are 7-12ºC in summer and 40-45ºC in winter. Only this fact makes increasing the efficiency of the normal FPC and the heat pump about 30%. The new system uses renewable energies during all the year and the little auxiliary energy will be covered by a PV Heat Pump system.

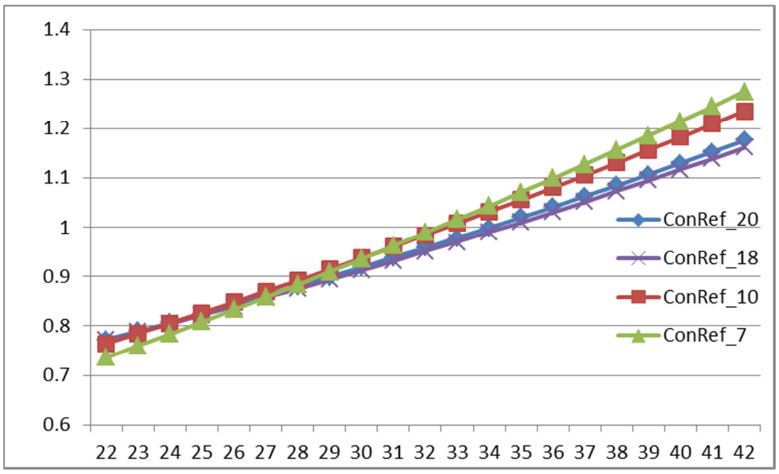

Fig. 5. Unitary electric consumption from a heat pump in different condensation (22-42ºC)/evaporation (7-20ºC) temperatures (Moià et alt 2016).

From the real results from October until April, the FPC is used for the heating system, with some support of a heat pump during the coldest days (January-February). The only problem is at summer when the solar thermal collectors have an over production, during 3 months they have stagnation problems. In order to avoid this in the future there will be installed a seasonal storage, according to the results it will be dimensioned for storage of the energy for the winter.

The cooling ceiling is working with 17ºC and doesn't need any dehumidification, due to the calcium silicate, which avoids condensation when it is working below the dew point and recovers all the latent moisture, once the system is off and the ventilation on.

3. Conclusions

With the new system a 90% of the energy costs have been reduced. Radiant cooling energy savings have per se a 30% saving compared to conventional systems (Fan coils or split) and can work with optimal temperatures for geothermal and Solar thermal energy. PV will provide the little energy consumption of the new system.

• The system cools with a minimum impulse temperature of 17ºC, so the savings compared to systems with fan coils (7ºC) are also proven.

• The system heats the room with a flow temperature of 18ºC, so in winter the savings are much higher than other systems and the system is therefore ideal to combine with solar thermal energy.

• The system maintains greater comfort in the relative humidity inside, helping to regulate it both in winter and in summer.

• The materials used have lower embodied energy than the conventional materials.

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