

Net zero emissions for a seminar room in the University of Balearic Islands

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Abstract. In this study the energy retrofit of a seminar room in the University of Balearic Islands was evaluated. This room was built in the late 80s and it was equipped with halogen lights and Compact Fluorescent Light Bulbs (CFLs). The climate system consisted of an air to air heat pump system. Development of modern net zero-energy buildings (NZEB) became possible with the combination of solar thermal, photovoltaic and geothermal energy systems. This kind of combination was used to improve the energy efficiency of the room evaluated in this paper, together with the installation of an innovative radiant heating and cooling ceiling system. Although renewable energy can cover all the annual energy consumption, a small fraction of auxiliary energy is provided by heat pump systems (HP).. Solar heating combined with geothermal systems for buildings have been designed to achieve different values of the fraction of a primary energy saving using 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.

Key words

Solar Thermal, Heat Pump, Photovoltaic, geothermal, combisystems.

1. Introduction

Article 9 of Directive 2010/31/EU of 19 May 2010 on energy performance of buildings establishes that “Member States shall ensure that by 31 December 2018 all new buildings occupied and owned by public authorities are nearly zero-energy buildings” [1]. It requires a new building concept and a big effort by the construction sector, including engineers, architects and ESCO. This new type of buildings will be obtained reducing the energy demand, using renewable energies and more efficient systems.

Radiant cooling systems require usually less energy consumption than conventional cooling systems. Radiant ceiling systems are ideal for cooling in existing buildings, because the cost of the retrofit. Recently, reductions in electric PV costs and mature technology of heat pumps have provided a new model: solar-electric assisted heat pump [2]. This system comes with fewer drawbacks than

solar thermal energy, a smaller price tag for residential applications. Nevertheless, the best system would be a combination of both. Development of modern net zero-energy buildings (NZEB) became possible not only through the progress made in new renewable energy and construction technologies and techniques, but it has also been significantly improved by the combination of all the techniques and advanced combisystems.

Some research groups are studying the best combination to archive this goal. According to thermal necessities and weather conditions, the design needs to be adapted in each area [3]. Radiant cooling (floor or ceiling) is not so often used but with the appearance of high efficiency arothermal 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 [4]. The building considered in this study, was previously the first Rectorate of the University, and the seminar room was built in the late 80s.

2. New Design

Firstly, the seminar room had an old Air-Air Heat Pump, Roca-York, with fibber ducts and light ventilation, according to the standards of the 80's. See Figure 1.



Fig. 1. Old Heat Pump and control system

The old lights with halogens, CFLs and incandescence had an electric power of 2037 W, with a very heavy transformer (230 V to 12 V). The new light system installed in the room has a power of 738 W, and are lineal LEDs. Using the Spanish official software (CALENER) [5] the room was simulated and different technology and strategies to

reduce the energy consumption were assessed. CO₂ emissions obtained for the room showed the worst letter in the Spanish label (G), with an indicator for global emissions of 118,39 kgCO₂/m². An F label was obtained for heating and cooling, with a maximum consumption of 72,48 and 8,36 kWh/m², respectively, and maximum emissions of 80,89 and 8,07 kgCO₂/m².

The old system in this seminar room was replaced by an innovative radiant heating and cooling ceiling system composed by:

- Calcium silicate insulation boards (2-3 cm), highly higroscopic, used as thermal insulation and as support of the rest of the system elements (dry bulk density: 200-350 kg/m³; thermal conductivity<0,06W/m K). These plaques allow water absorption at temperatures below the dew point. When the system is not operating, they release the stored water. It has been demonstrated that this material can absorb several times its own weight in water.
- A mesh of capillary tubes made of polypropylene, which allows thermal diffusion at a low temperature over a large area.
- A clay finish is used to cover the ensemble.

An embodied energy assessment is not the goal of this study. Nevertheless, in Table I, values for the embodied energy and CO₂ emissions for the materials included in the described ensemble are shown. They are observed to be lower values in comparison with other materials used in buildings.

Table I. – Approximate embodied energy and CO₂ emissions for the described ensemble [6].

| | EE (kWh/m ²) | ECO ₂ (kg/m ²) |
|---------------------------------|--------------------------|---------------------------------------|
| Expanded clay concrete | 61,6 | 18,1 |
| Calcium silicate plaques | 3,9 | 1,3 |
| | EE (kWh/m) | ECO ₂ (kg/m) |
| Polypropylene tubes | 3,3 | 1,7 |



Fig. 3. View of the seminar room, before and after the retrofit.

In summer a geo-cooling system is utilised, making use of an existing and very old well near the building, with a constant temperature of water of 17°C during all the year, enough for the radiant system. In winter solar collectors provide water with a temperature from 25°C to 35°C, with a high efficiency. This system doesn't need any auxiliary dehumidifier system, because of the calcium silicate hygroscopic panels. Other radiant systems need to be switch off or auxiliary equipments when they have condensation problems. This new system avoids any extra consumption in extreme conditions. See Figures 2 and 3.

A new efficient air to water heat pump has been installed, this is used as auxiliary system in extreme days. The energy savings and consumption using this new system are shown in Table II.

Table II. – Energy Consumption and CO₂ emissions

| | Before | New system |
|-----------------------------|-------------|------------|
| Electricity kWh/year | 3507 | 330 |
| Kg CO2/year | 1708 | 0 |
| PV prod. kWh/year | 0 | 423 |
| Solar Thermal used | 0 | 748 |

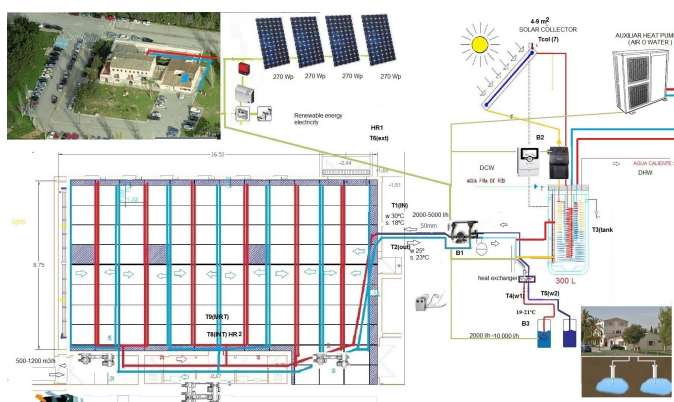


Fig. 2. Design of the system.

3. Simulated and real Results

The system was completely installed in the seminar room in September 2015. As indicated previously, it is composed by a new radiant ceiling system (see Figure 4), a well (geo-cooling system), Flat Plate Collectors, Air-Water Heat Pump, Storage Tank of 300L [7], Photovoltaics panels polycrystalline (PV) [8] with an inverter for the grid, a ventilation system (with heat recovery), the control and data logger systems.

The initial results are very promising and would validate the simulated results, obtained using various software tools (TRANSOL, GREENIUS, CALENER). These results will be validated during one year of collecting data. The radiant system reduce working temperatures of the system (17-22°C at summer and 28-33°C at winter) and do not need any fan to transfer the heat, if we compare this with the fan coil, that they need to work (7-12°C at

summer and 40-45°C), only this fact makes increase the efficiency of the heat pump a 30%.

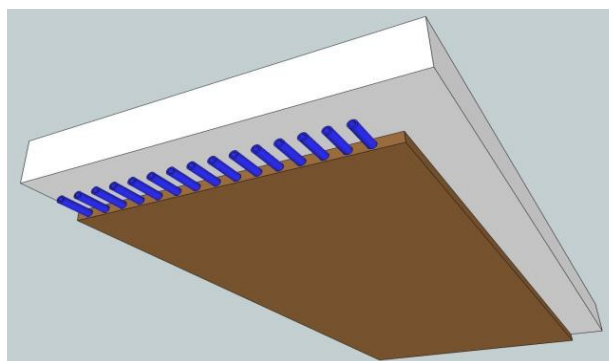


Fig. 4. View of the hygroscopic radiant panel [7]

The heat transfer is very uniform in all the room, if the hydraulic circuits are well regulated, each panel has a capillary pipe every 2 cm, with a total of 50 capillaries. Each capillary have 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 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 III, the installed power of the new system is 50% lower than before, including the chiller, only necessary for emergency days. In these case the reduction it's the 85% at summer and 95% at winter. See Figure 4.

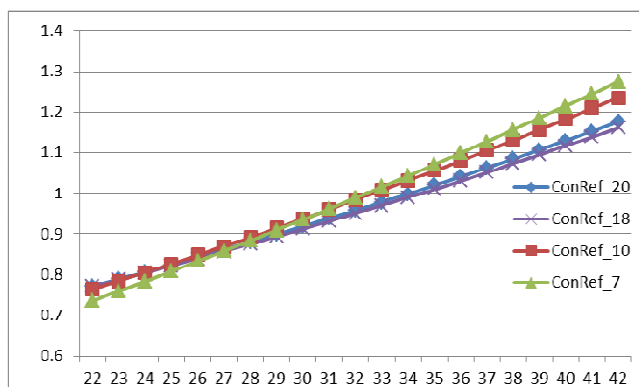


Fig. 3. Unitary electric consumption from a heat pump in different condensation/evaporation temperatures, using Calener simulation [5].

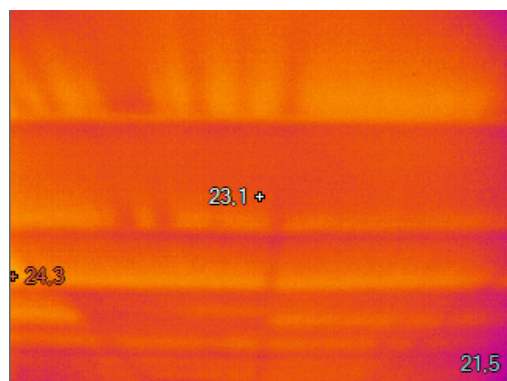


Fig. 5. Termographic view of the radiant system

A new control system will be installed, with data logger and a webserver.

Table III. – Electrical power

| | Before | | New system | |
|------------------------------|------------|-------------|------------|-------------|
| | Winter | Summer | Winter | Summer |
| Heat Pump/Chiller* | 9.3 | 10.3 | 4 | 3.61 |
| Pump from the well | | | | 1.2 |
| Solar Pump | | | 0.04 | |
| Secondary Pump | | | 0.06 | 0.06 |
| Dehumification | 0.3 | 0.3 | | |
| Ventilation | 0.3 | 0.3 | 0.4 | 0.4 |
| Total | 9.9 | 10.9 | 4.5 | 5.27 |
| Total without chiller | 9.9 | 10.9 | 0.5 | 1.66 |

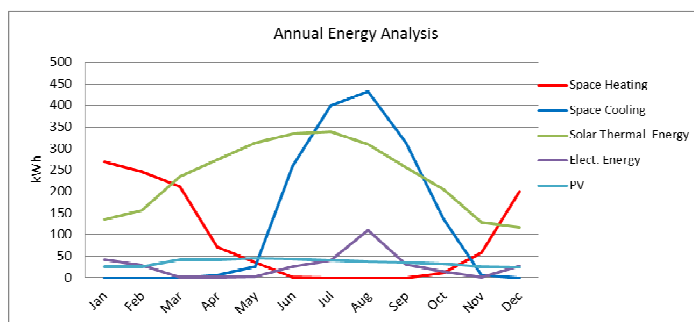


Fig. 4. Annual Energy Consumption and Mix of Renewable sources

4. Conclusion and future analysis

With the new system evaluated in this study between 85-95% of the installed power has been reduced. The reduction of the energy consumption will be 90%.

Radiant cooling energy systems allow savings near 30% compared to conventional ones (Fan coils or split) and they can work with optimal temperatures for geothermal and solar thermal energy.

Using the properly mix of renewable energies the evaluated seminar room will be a real NZEB.

The electricity production has higher emissions in the Balearic Islands than in the mainland's, over double, due to the use of coal in a big percentage, about 840 gr/kWh. To reduce the impact of the small quantity of electricity consumed, a PV system will be installed, and a Net metering contract will be made with the electrical company to compensate the electric consumption. An excess will be produced in summer with and a lower production in winter..

A small wind turbine of 500 W will be as well installed, as a demonstrative system, even the expected working hours would be less than 10% of the equivalent time. The test would be useful for future installations in other locations with more wind and less solar radiation. From the simulated results it is clear that in summer solar thermal collectors have an over production. A seasonal storage will be dimensioned according to the results obtained of the real test.

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