INNOSTORAGE – USE OF INNOVATIVE THERMAL ENERGY STORAGE FOR MARKED ENERGY SAVINGS AND SIGNIFICANT LOWERING CO_2 EMISSIONS

Beneficiaries:

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D7.2 - Report on Staff Exchanges

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Contents

1 Objectives

The exchange was planned as a further step in translating the experimental experience with the radiant wall into useful models for enhancing integration of renewable energies in buildings. The main objectives of the exchange were:

- To Integrate an experimentally validated radiant wall model with PV and air-to-water heat pump models in a full room model.
- To develop control concepts for exploiting PV panels with radiant wall peak load shifting capacity.
- To optimize the system design in different climatic areas.

2 Introduction

The main goal of the study was to combine PV, radiant walls, and an air-to-water heat pump for maximizing the renewable energy contribution to building heating and cooling. First, the PV provides the energy to make the system work. However, the panels only provide electricity during the day and their power profile is proportional to the available solar radiation. Still, the cooling and heating demand follow different daily profiles, which means that a conventional cooling/heating system would not be able to use exclusively PV electricity, thus requiring energy from other sources. A solution to this issue is to use thermal energy storage, being radiant walls one option for short term heat storage. This technology consists of pipes embedded in heavy weight walls and envelopes so that the thermal mass of the building structure can be used for thermal storage. By using the thermal inertia, the radiant walls can store heat when energy is available while maintaining comfort temperature in the building during occupancy periods. This peak load shifting capacity can be used to better exploit the energy provided by the PV, as the heating or cooling system can operate while renewable electricity is available and store heat in the walls. However, heating and cooling with peak load shifting is complex, as it is necessary to understand the dynamics of the system. Moreover, it is also important to forecast the production of the PV panels and the heating and cooling demands. This requires well designed control strategies and clear and simple models of all the components of the system.

3 Description of work

The work mainly consisted in developing a model and simulating different control concepts. The project took a previously validated model of the radiant wall, which had to be integrated to a room model that could simulate the cooling load. This involved developing the model of the room, together with the models of the roof and the ground. Furthermore, all the models were programmed from the beginning, and thus debugging and verification was required.

SEVENTH FRAMEWORK PROGRAMME

MARIE CURIE ACTIONS

Later, the objectives of the simulation required developing models for the heat pump and the solar panels, as well as the control concepts to be applied. This part involved a literature review and selection of the best method.

Finally, all the simulated data was interpreted and prepared for a research paper.

4 Materials and Methodology

All the modelling was developed in C++ and compiled with DevC++. The radiant wall, the floor, and the ground were modelled with finite volume model (FVM) methodology. These were linked together with the star-network methodology from Seem [1]. On the other side, the active systems were simplified. First, the PV panels were modelled horizontal with constant efficiency. Second, the heat pump was modelled with a regression curve of the data provided by a producer [2], assuming that the temperature at the evaporator remained constant, and thus assuming constant supply temperature. The weather data was obtained from the experimental measurements of the Puigverd the Lleida (Spain) test site [3,4], using the data from whole 2016 summer in order to have months with low cooling load and months with high cooling loads.

Three control concepts were defined. The first concept was “no control”, which simply implied to maintain the set-point range of 24-26ºC during the whole day, without taking in account the solar production or the electricity cost. A second set of control concepts was “peak load shifting” and considered shifting the load to off-peak periods with low outdoor temperature (between 0:00 and 8:00), increasing the heat pump efficiency and reducing the operation cost, this concept had a reduced set-point temperature of 21-22ºC during a pre-cooling period form 5 am to 7 am. The last set of control concepts were “solar” strategies that involved exploiting the energy produced by the PV panels. Three strategies were applied within this concept, “base solar” simply reduced the set-point from 10 am to 6 pm, and in contrast “solar following” only reduced the set-point in this period if the PV panels produced enough energy to feed the energy demand of the heat pump (minimum PV output power around 1500 W). The last control was a hybrid between peak load shifting and solar improved, in which a forecast of the following day was used to define if pre-cooling was required early in the morning.

5 Results

The energy use for all controls is shown in Figure 1. Solar concepts used overall more energy than base set-point concept or peak-load shifting concept. This was caused by the solar concepts having longer periods at low set-point. However, solar strategies had low to null imported energy when considering that the heat pump directly consumed the energy provided by the PV panels. Moreover, the criterion of activating the heat pump only if enough power was supplied by the PV resulted in less energy use and less imported energy.

Additionally, few differences were observed between “solar following” and “solar predictive” concept. This was mainly caused by the criterion used to enable pre-cooling. Consequently, the energy use of “solar following” and “solar predictive” was mainly driven by the solar charging mode, which was common in both strategies. However, “solar predictive” control could have less operation cost in case many cloudy and warm day are expected or in case the installed capacity of the PV panels is not enough to feed the heat pump regularly.

On the other side “no control” and “peak load shifting” concepts had similar energy use during the hottest month of summer, from June to August. However, “peak load shifting” had higher energy use in May and September, when the cooling load was lower. This was caused by the pre-cooling period, which in the hot summer was useful for shifting the peak load, as it provided similar cooling than the cooling load of “base set-point” strategy. However, when the heat gains were lower, the pre-cooling provided more cooling than the required for maintaining the comfort range during the rest of the day. Moreover, the “peak load shifting” strategy could no exploit the energy provided by the PV panels, importing almost all energy from the grid.

When considering the operation cost of each strategy Figure **2** shows that operation cost of solar strategies is very low as a result of the very low imported energy when considering self-consumption. The reduction between the case with and without self-consumption in “solar” strategies is above 93% of cost savings. On the other side, “base set-point” only reduced 57% of the operation cost with PV panels, while peak-load shifting strategies had savings below 10%. Comparing “solar” strategies to “base set-point” with PV panels, the results showed that “solar” strategies saved above 77% of the operation cost, and thus “solar” strategies better exploited the PV production.

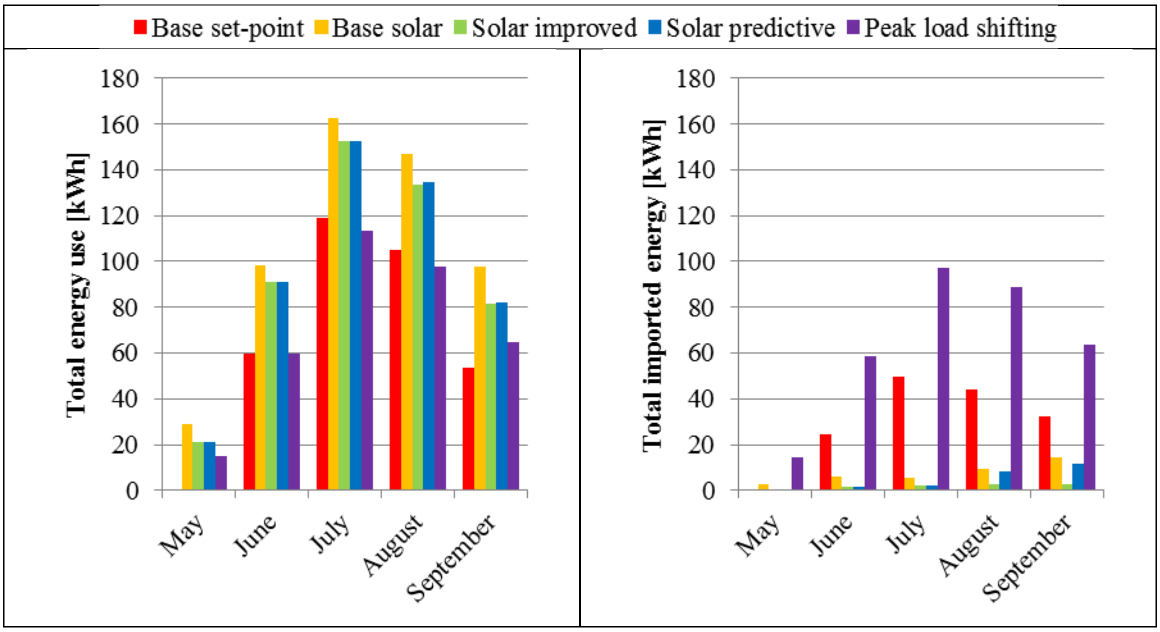

Figure 1. Total energy use (left) and imported energy if self-consumption is considered (right) for all control strategies

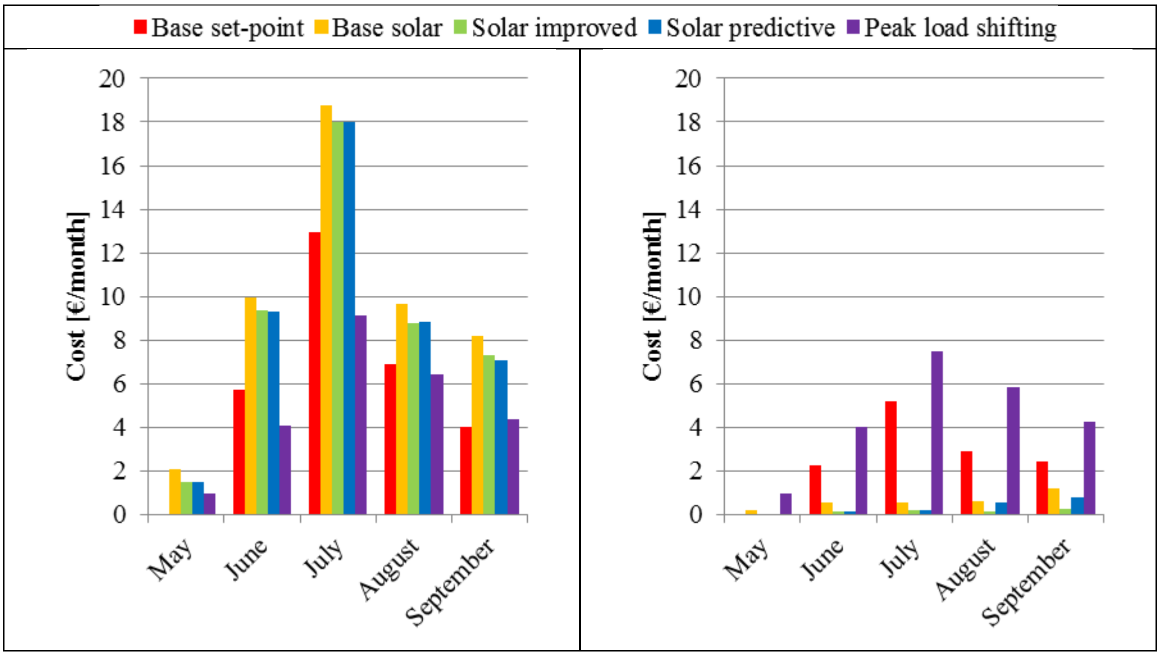

Figure 2. Operation cost without self-consumption (left) and with self-consumption (right) for all control strategies

6 Outcomes or future work

On the short term, the results obtained provided valuable information for writing a scientific paper regarding the advantages of "solar" control concepts in domestic buildings. This paper was in progress at the date of this report and was due to submission in mid-June.

On the mid and long term, the model had further potential for research on optimization of the radiant wall, both in design and control strategies. First follow-up research was planned to focus in office and commercial buildings, as first results suggested different control concepts could be required for different types of occupancy and intensity of internal gains. Furthermore, the first results studied one climate during the summer period, consequently, research on different climates and during heating period would complement the initial research. Finally, the conclusions regarding the "solar" control concepts pointed to different variables that strongly influenced the performance of the system. Detailed study of the most important parameters would lead to optimization of the control strategies, which could apply advanced control such as fuzzy logic or neural networks among others.

7 References

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8 Assessment

The secondment resulted in a successful and fruitful exchange. The experimental expertise of GREA Innovacio Concurrent was brought together with the simulation and demonstration experience of UNISA, forming a good synergy which will have immediate results and strengthen the long term collaboration.

GREA Innovacio Concurrent is still mainly an experimental focused group, in which simulation has started to grow recently, moreover, the group has plenty of experimental information valuable for models validation that can be further implemented in building design optimization or in HVAC integrated with renewables control development. On this area, UNISA had plenty of experience in simulation and demonstration. Consequently, the collaboration between the two institutions resulted in a positive feedback in which the experimental knowledge made reliable the demonstration research, which was adequately oriented and focused to meaningful issues.

At a personal level the exchange was enriching as it was an opportunity to learn about a different energy paradigm. Australia faces a completely different situation than Europe regarding energy policies, with energy efficiency in buildings being the last concern while most efforts are focused in renewable energies integration and implementation. The theoretical knowledge has been reinforced by living there, as the issue could be experimented through the architecture and lifestyle of the country. Furthermore, the exchange has shown the challenges and issues of a different research institution, which faces different requirements, recruitment, and financial situations, and thus having a different behaviour. Most significant in this point was the different relationships stablished between researchers and the richer cultural and national background. Finally, the exchange in an English speaking country was greatly useful for consolidating and improving the language skills, especially in the oral and written expression, which were key to write the last papers and the thesis as well as to oral defence.