BUILDING ENERGY AUTONOMY INCREASETHROUGH THERMAL STORAGE: NUMERICAL ANALYSIS AND EXPERIMENTAL CHARACTERIZATIONOF A HOT WATER PCM STORAGE SYSTEM

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Introduction

In central Europe 80% of the building energy needs corresponds to thermal energy. Renewable energy cannot meet these needs due to the time shift between production and thermal needs. Thermal storage is one solution to efficiently use the renewable energy. In this paper we analyze the impact of thermal storage on the building heating and domestic hot water autonomy in the case of local renewable energy production. To be relevant, various building types have been investigated. We proposed earlier a PCM storage solution [1] that solved the efficient heat extraction challenge for building heating [2, 3]; in this paper we show the first results of a PCM storage system for domestic hot water.

Building energy autonomy simulations

Three types of middle size buildings with different insulation properties and representative of the Swiss real estate have been compared: 1) buildings built before 1970, buildings with 2) medium and 3) high energy efficiency (that follow the Swiss “minergie” standard). Their respective thermal needs for hot water and building heating was 150, 80 and 45 KWh/m2. All considered buildings were equipped with 300 m2 photovoltaic (PV) panels and a heat pump with a COP of 3.3. By using the monthly average solar power of the city of Bern, we found the average solar thermal energy production and the monthly heating energy needs for each building type (figure 1a). This figure displays the total thermal energy needs during the day from 6:00 to 18:00 and during the day+night. With energy storage solar power can be used at night-time and thermal energy autonomy is achieved when the daily PV production is sufficient. This is visible in figure 1a when the total required energy (continuous lines for each building type) is below the PV driven heat pump thermal energy production. The most energy efficient buildings become totally autonomous, while buildings with medium energy efficiency remain dependent on the grid energy in December and January. The less efficient buildings built until 1970 show an energy autonomy from March to October.

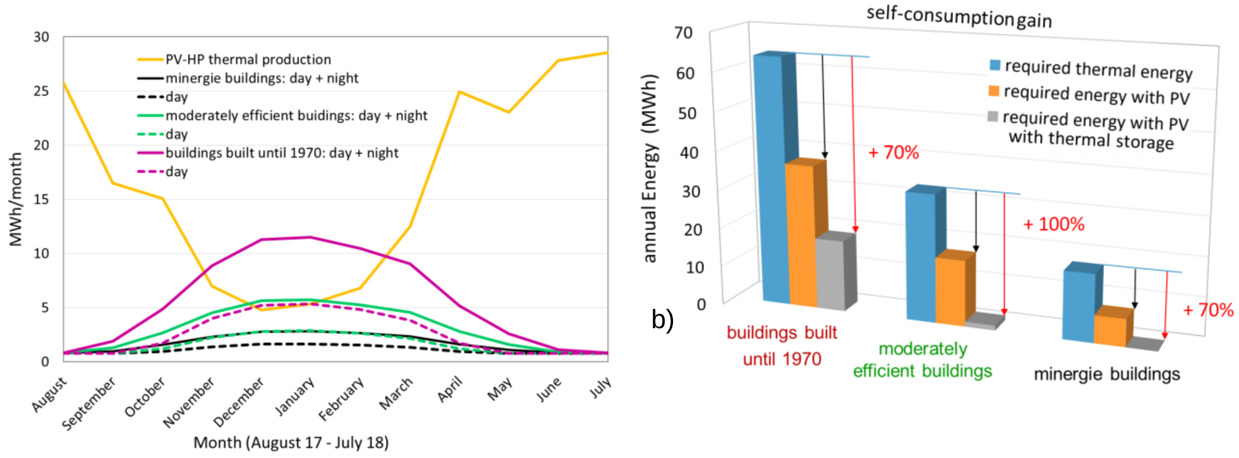

Figure 1: a) Monthly PV driven thermal energy production and thermal needs for differently insulated buildings. b) For all buildings equipped with PV panels, thermal storage increases the self-consumption of the thermal needs by at least 70% as shown by the red and black arrows.

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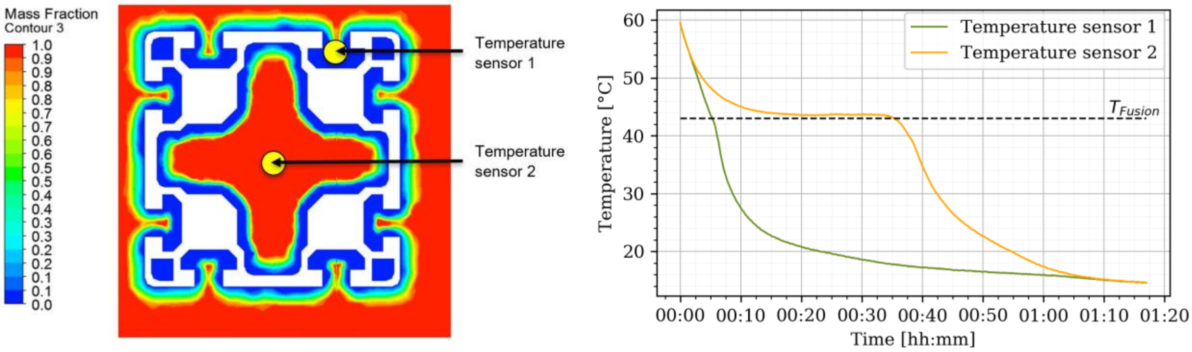
A summary of the energy autonomy with and without heat storage is given in figure 1b. For each building type, the thermal energy needs and the self-consumption with and without PCM heat storage are displayed. The gain in energy autonomy due to heat storage is indicated by the arrows. Interestingly the maximal gain is obtained for the old buildings. Even if the most energy efficient buildings become autonomous all year long, their absolute energy autonomy gain remains lower.

PCM Storage system for domestic hot water

As hot water is a major energy consumer for all types of buildings, we simulated, planed and realized a thermal storage prototype for domestic hot water. The 226x266x1900 mm device contains 50 liters of Rubitherm RT44HC PCM with fusion temperature: Tfusion of ~43°C. The simulated discharge is shown in figure 2a with a cross-section of the inner part of the device. The metallic structure and the discharge (or charge) water circuit are displayed in white. The liquid PCM (red) gradually changes its color according to its solidification. The image shows an homogenous solidification process taking place at a specific distance of the cooling surfaces. This indicates that the discharge (charge) power strongly depends on the size of those surfaces.



a) b)

Figure 2: a) Distribution of PCM solid (blue) and liquid (red) phases after 10 minutes of discharge.
b) PCM temperature during discharge for the two temperature sensors displayed in figure 2a.

Preliminary measurements have been realized during the discharge process with water flow of 28 l/m and an initial PCM temperature of 60°C. The temperature of the two points displayed in figure 2a are shown as a function of the discharge time in figure 2b. At short distances (< 1cm) from the metallic surface, the solidification process takes place after 5 minutes of cold water (T< T_{fusion}) flow. The temperature curve of the PCM central part (temperature sensor 2) shows a solidification process only appearing after 10 minutes but lasting for about 25 minutes. This indicates that the PCM solidification can provide large heating power > 10 KW but only for 5 min and after 20 min the power drops to 5 kW. This maybe due to the structure with part of PCM located too far from the metallic surfaces. The integration of the heating power shows a PCM storage capacity of about 4 kWh.

References

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