Seasonal Thermal Energy Storage in Existing Buildings – initial results from the EINSTEIN Project

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Topic: Sustainable and Low Energy Architecture

1. Abstract

This paper gives an overview of the initial results of monitoring from the EINSTEIN project.

EINSTEIN (Effective INtegration of Seasonal Thermal energy storage in ExIsting BuildiNgs) is a €9m EU project funded under the FP7 programme and involves 17 European partners.

The overall objective of EINSTEIN is:

"the development, evaluation and demonstration of a low energy heating system based on Seasonal Thermal Energy Storage (STES) systems in combination with Heat Pumps for space heating and domestic hot water (DHW) requirements for existing buildings to drastically reduce energy consumption in buildings."

The project ranges from the baselining of STES systems application in existing buildings, the subsequent development of a methodology and an evaluation tool and framework through to the demonstration of the concept in pilot installations.

A key element of the project is to adapt STES to be applied in existing buildings. This paper reports on the initial results of monitoring a STES which is integrated into a solar thermal heating system which is used to supply heat to a multiuse development in Lysekil, Sweden. The refurbished building being monitored has a heated floor area of 381 m² and comprises four shop units on the ground floor and two two-bedroom apartments on the first floor.

A 50 m² solar array in conjunction with a 3300 L buffer tank is used in combination with the seasonal thermal energy store of 23 m³ as the primary heat source for the building. This is supplemented with a connection with the district heating system in the town and electric heating.

This paper provides an overview of the Einstein project and the initial results of the monitoring of the installation described.

Keywords: STES, Retrofit, Solar Thermal, passivhaus

2. Introduction

Energy use in buildings accounts for approximately 40% of EU energy consumption. Due to this high energy use, one of the three main targets proposed by the European Economy Recovery Plan in 2008 is "to encourage Energy-efficient buildings, to promote green technologies and to develop energy efficient systems and materials in new and renovated buildings with a view to reducing radically their energy consumption and CO2 emissions".

In order to achieve these objectives, drastic measures are required. The improvement of energy efficiency of conventional generation technologies is not sufficient and a high proportion of energy demand supplied by renewable energy sources is essential. Taking into consideration that heat demand can represent up to 60-70% of total amount of energy consumption in a residential building (1), heating systems based on Seasonal Thermal Energy Storage (STES) have the potential to fulfil the objectives established in Europe for energy efficiency in a short timeframe. The fact that the concepts developed within this project are based on the innovative adaptation of existing technology is a significant aspect, as it enables the development of nearly zero energy buildings (one of the objectives of EPBD directive) within a relatively short timeframe.

It is planned that the previously stated objective of the EINSTEIN (2) project will be achieved by:

- Technological developments for STES systems adaptation for existing buildings
- Development of a novel, high-efficiency, cost-effective and compact heat pump suitable for existing buildings and optimized for higher temperature heat sources such as STES systems
- Development of a decision support tool that will help the planners to find the best technology to install in each particular case
- Development of integrated building concept: which passive and/or active measures (insulation, heat recovery, renewables…) and in which order should they be applied for the optimization of retrofitting.

As part of the EINSTEIN project, two pilot plants are being specifically constructed to demonstrate the integration of the developed heat pump with seasonal thermal energy storage in order to meet the heat demand of two existing buildings. The first pilot plant is located in Zabki, a suburb of Warsaw, Poland, and comprises a solar array of 151 m^2 coupled with a STES of 800 m^3 which complements a gas boiler of 95 kW in meeting the space and DHW heating demands of a public hospital. The second pilot plant is being built in Bilbao, Spain and comprises 70 m^2 of solar collectors and a STES volume of 175 m^3 in combination with a 190 kW gas boiler in order to meet the space heating demands of a public building. Both pilot plants are currently (July 2014) being commissioned and have commenced collecting summer solar heat for use during the winter of 2014/15.

In addition to the two pilot plants which are integrating the novel heat pump which is being developed, a third pilot plant is being monitored which does not have the tailored heat pump installed. A manufacturer of low-energy houses installed a STES in the autumn of 2013 in an unused basement of a development in Lysekil, on the west coast of Sweden. Monitoring the first year’s cycle of the performance of the STES commenced on the 17th of February 2014. The development comprises a 300m^2 new build of three apartments (the basement of which houses the STES) and a 381m^2 renovated building originally built in 1860 which comprises four commercial units and two apartments.

Figure 1 below shows a photograph of the 50m^2 solar thermal collectors installed on the roof of the renovated building. Figure 2 gives a schematic of the DHW and space heating system showing the solar collection and wet heating system.

Figure 1 Solar panels on roof of Renovated building (© Lars Pettersson, Scandinavian Homes Ireland Ltd)

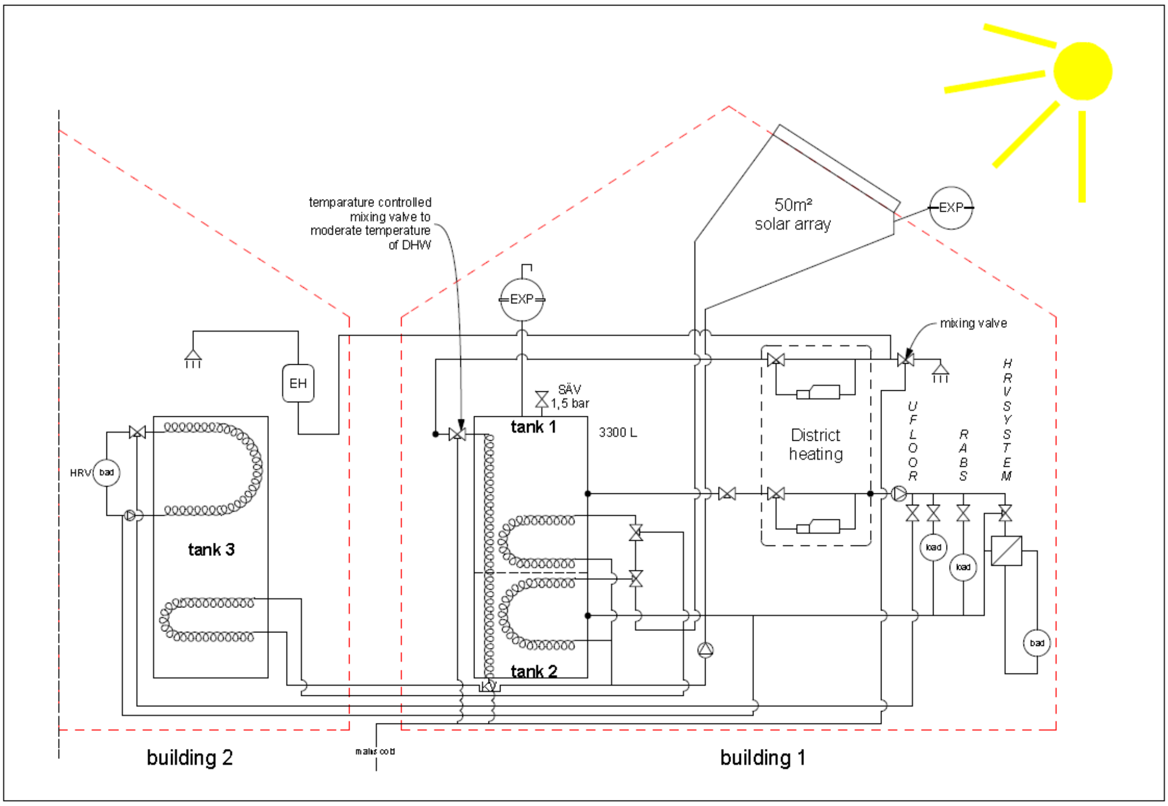

Figure 2 Schematic of heating system

The primary heating system for the renovated building (building 1) and new build (building 2) comprises:

- 50m^2 solar array comprising 10 panels of 1.8m^2 aperture (totalling 18 m^2) of evacuated tube collectors and 16 panels of 2m^2 aperture, (totalling 32m^2) of flat plate collectors.
- 3300 litre buffer tank located in building one is logically divided (although not physically) into two, based on thermal stratification considerations.
- 23m^3 STES installed in the basement of Building 2
- District Heating system backup

The solar collectors supply heat to the heat exchanger coil in the middle of the buffer tank (“tank 1“) until it reaches the target temperature of 62°C and then diverts heat to the heat exchanger coil at the bottom of the buffer tank (“tank 2“) until it reaches 52°C. Once tank 1 and tank 2 have achieved their target temperatures, the solar fluid is fed to the Seasonal Thermal Energy Store (tank 3). The STES performs the function of providing a significant load to reduce the incidence of solar collector stagnation. It also supplies space heat to the new building (building 2 which comprises 3 apartments of 300 m2 in total). In addition to supplying the space demands of building 1 and building 2, the heating system also provides the domestic hot water requirements of the four commercial units and five apartment units.

In sizing the STES dynamic modelling was performed and a tank size of 50 m^3 was recommended. However for commercial reasons a 23 m^3 STES tank was installed in the basement of building 2 in an existing space which could accommodate the STES without further modifications. This significantly increased the potential for overheating, but also significantly reduced the costs of the STES.

3. Initial Results

Figure 3 below gives the temperature profiles of the buffer tank and the STES for the period 17th of February 2 23rd of July 2014.

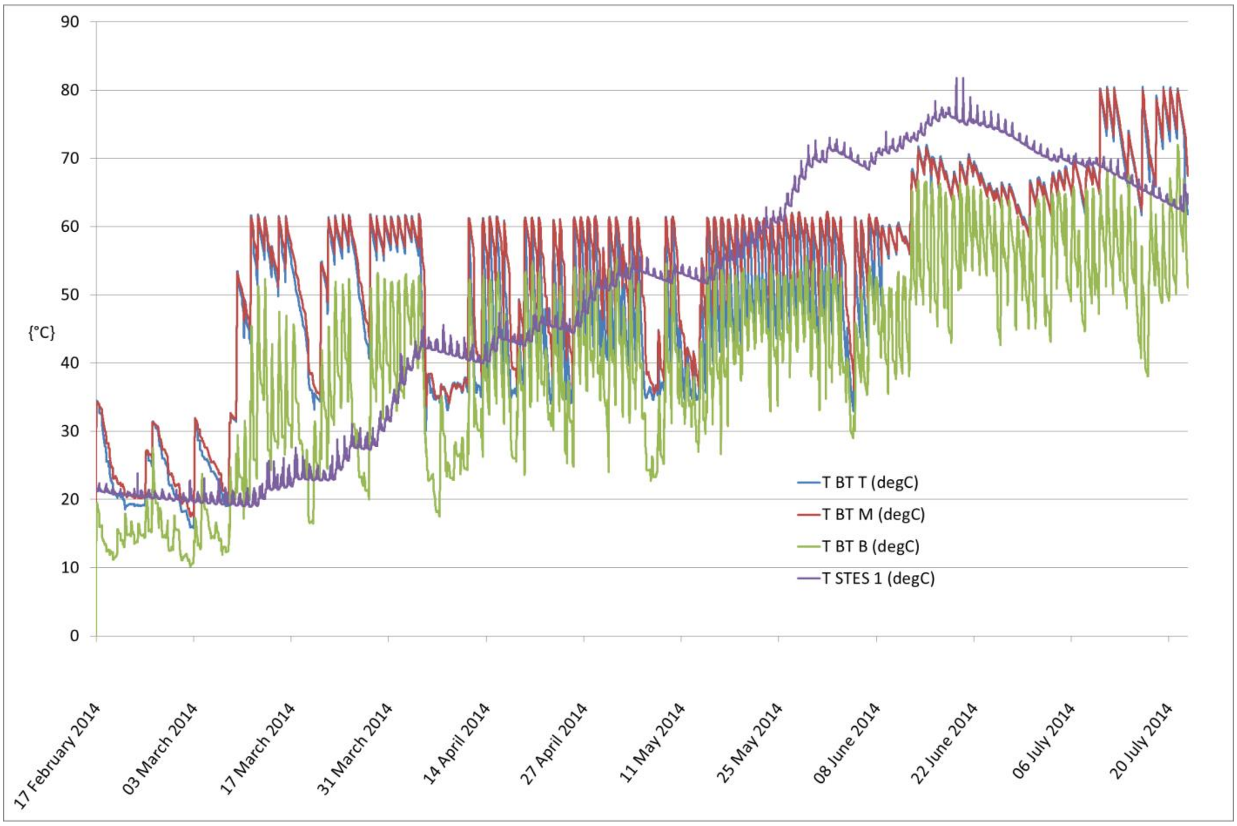

Figure 3 temperature profile of the buffer tank (measured at three locations) and the STES

Given that this is the 1st year of operation of the STES, system optimisation is being carried out.

Due to the high temperatures being reached in the STES, on 13th June the target temperature of tank 1 in the buffer tank was changed from 61°C to 72°C, and the target temperature of tank 2 was also increased. On 10th July these temperatures were increased further.

There are two temperature spikes on the 20th 21st of June where the STES increased in temperature by approximately 7°C in one-day. As can be seen from figure 3 the STES started losing heat from around 22 June, due to stagnation.

From the graph below, which plots the amount of heat collected in the buffer tank, the STES, and the total solar heat collected in the previous seven-day period, it is clear that after the peak which occurred on 1 June, there was a significant decline in the amount of heat which is collected on a per week basis, from a peak of over 900 kwh (which occurred in the week to 2 May, and in the weeks which finished on 29th , 30th , 31st of May, and 1st and 2nd of June) to between 500 and 600 kwh for the whole period up to 20 June, and has now significantly decreased again to between 255 and 300 kwh for all of the weeks which finished between the 12th and 22nd of July. Following system interventions, the STES temperature has started to increase at the time of writing (31st July).

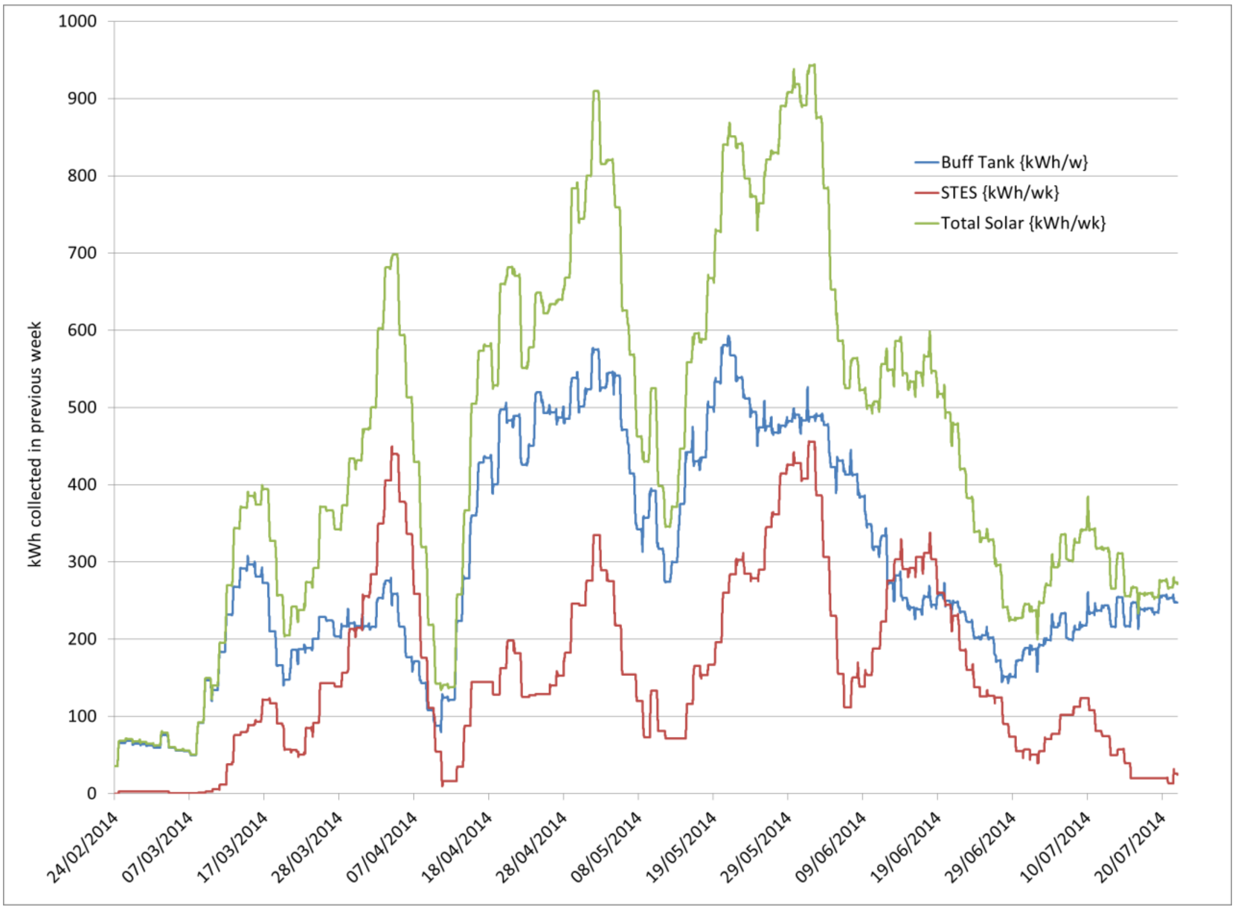

Figure 4 Solar Heat collected by Buffer Tank, STES and in total for rolling 7 day period

4. Heating Loads and Solar Fractions

It is noted that the figures presented in this paper provide an incomplete picture of the performance of the installation given that the figures represent the recorded performance over only 163 days of operation. In addition, no input has been recorded from the STES given that it's operating temperature was 20°C at the commencement of the monitoring period.

Table 1 below gives the energy consumption and solar fractions for both space heating and domestic hot water for building 1 between the period 17th of February to 23rd of July. Table 2 gives the same figures for building 2.

Heat Load	Total {kWh}	Solar {kWh}	DH [kWh}	Electric {kWh}	SF
Space Heating	11766.1	4818.3	5959.0	988.8	41.0
DHW	1061.0	866.4	194.6	0.0	81.7

Table 1 Building 1 Space and Domestic Hot Water Consumption and Solar Fractions

Heat Load	Total {kWh}	Solar {kWh}	DH [kWh}	Electric {kWh}	SF
Space Heating	4575.5	240.9	297.9	4036.7	5.3
DHW	2121.7	1712.2	384.5	25.0	80.7

Table 2 Building 2 Space and Domestic Hot Water Consumption and Solar Fractions

As can be expected, the space heating load for building 1 significantly exceeds that for a building 2 given that the building is larger and is renovated rather than new and also the combined commercial/residential usage profile. The DHW consumption also reflects that there are 2 apartments in building one compared with the 3 apartments in building 2.

The space heating solar fraction for building 2 is significantly below that for building 1 given the losses in the transmission of heat between the output of the district heating system in building 1 and the load in building 2. The electric contribution towards space heating is thus seen to be significantly higher in building 2. When the solar heat from the STES (which is located in the basement of building 2) becomes operational in the winter of 2014/2015, it is expected that a significantly increased solar fraction will be achieved for space heating.

The space heating solar fraction is almost 40% in building 1, and the contribution from the electric heating is seen to be less than 10% of the overall space heating demand.

For both building one and building 2 the solar fractions for DHW exceed 80%. This reflects the large solar array of 50 m² feeding the combi tank of 3300 L.

5. Conclusion

This paper gives an overview of the EINSTEIN project and the initial results from a building being monitored as part of the project. Following optimisation of the system which will be carried out in the summer of 2014, the contribution made by the solar installation including the STES will be assessed for the winter period 2014/2015.

To date, the Swedish installation has shown that by combining a large solar array with a relatively small diurnal store, (in this case 50 m^2 with a store of 3300 L), DHW solar fractions in excess of 80% have been achieved, and the space heating solar fraction for the renovated building has exceeded 40%. The STES provides a large load during the summer months in order to avoid stagnation of the solar array. Further optimisation and monitoring is required to fully demonstrate the potential of the Swedish system.

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