SOLAR THERMAL INTEGRATION INTO A DISTRICT HEATED SMALL HOUSE

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ABSTRACT

According to the EU's objective, all newly constructed buildings should be nearly zero-energy houses since the beginning of 2021. The requirements for zero-energy solutions implicate an on-site renewable energy generation and storage, often including solar. A new model of district heating (DH) substation including solar heating panels and a storage tank was developed using IDA-ICE energy simulation software toolkits. The domestic hot water (DHW) and space heating were heated by solar panels connected to the storage tank and the whole process was simulated throughout the year in Finnish climate. Simulations showed that solar collectors may help to save approximately half of the energy for DHW heating needs whereas the effect on the space heating was marginal. Saving is approximately 200-400 kWh per square meter of the collector area and decreases with increasing of the total collector area. The variation of the storage tank volume does not show to have significant influence on the annual energy gains as long as the required temperatures for DHW are maintained. Solar thermal integration will affect also the return temperature of the primary side which is most visible during the summer time.

INTRODUCTION

A common method for calculation of thermal solar systems for space heating and domestic hot water (DHW) heating is the European standard EN 15316-4-3 [1], normally applied on monthly basis. There are also dedicated calculation tools for more detailed analysis of solar heating components and systems [2]. These methods do not take the properties of district heating system into account. Therefore the building energy simulation software IDA-ICE [3] was used in this study to combine the detailed building simulation model with a detailed district heating substation model, including solar heating.

METHODS

Figure 1 shows one of the two single family houses used in this study in IDA-ICE program, which is used mainly for studying building indoor climate and energy consumption. Table 1 shows the energy use of the two buildings, house 2 having higher energy consumption. The buildings have a water based floor heating system, with maximum supply water temperature of 38 °C.

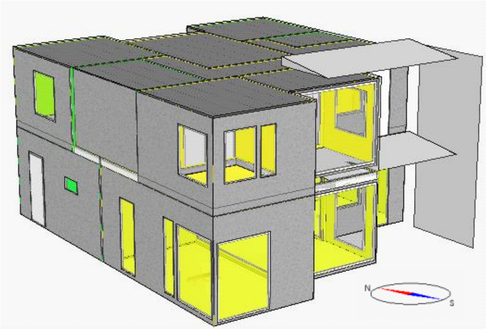

Fig. 1 House 2 in thermal simulation model IDA-ICE.

Table 1. Energy consumption of the two houses in this study.

	House 1	House 2
Space heating, kWh	6 401	17 982
DHW use, litres per day	133	220
DHW heating, kWh	2 820	4 675
DHW circulation, kWh	2 190	2 190
Total heating, kWh	11 410	24 845

Normally in IDA-ICE program the heating water and DHW are heated in a boiler, which ensures fast and robust simulation. Instead of a boiler, a district heating substation model (Figure 2) was constructed utilizing heat exchangers and control components already available in IDA-ICE.

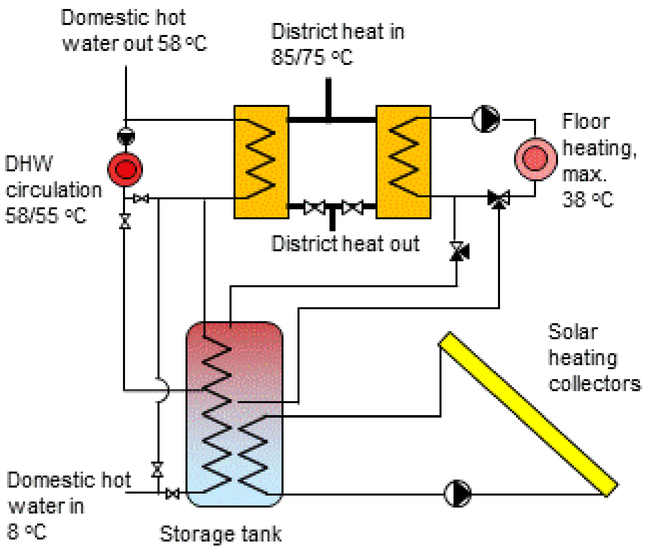

Fig. 2 Solar heating system incorporated into the district heating substation.

A solar collector model and a stratifying water heat storage model were also added, along with necessary control systems. The south facing collector has a tilt of 45° and its efficiency is shown in Figure 3. The water heat storage is 1.6 meters high and is insulated with 50 mm of polyurethane.

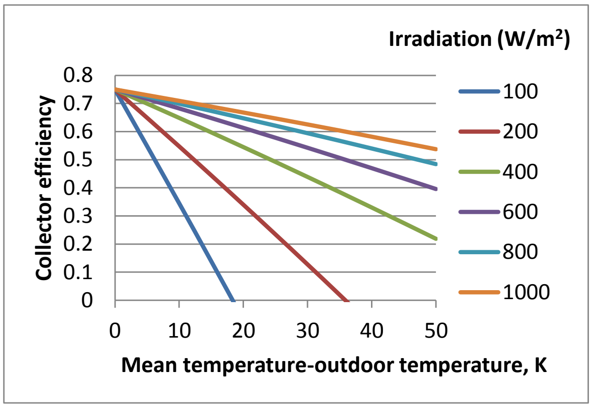

Fig. 3 Efficiency of the solar collector, depending on solar irradiance and collector temperature difference.

Domestic hot water consumption schedule was prepared using a stochastic model which puts more weight on evenings and mornings, as well as on weekends [4]. The weather file is the one represented in the Finnish building code, to be used in southern Finland simulations (Helsinki-Vantaa reference year 2012).

By combining the building and system models it is possible to simulate the performance of the combined solar and district heating system, taking into account the heating load in each room and domestic hot water consumption at each time instant. The variation of district heating water temperature and pressure could be also taken into account, by using data exchange with a DH network model, but this was not realized in present simulations. Instead, the DH water temperature was defined to be 75 °C in summer and 85 °C in winter.

RESULTS

The heating power (Figure 4) is small in both houses from late April to late September. On the other hand the heat supply from the solar collector to the storage tank concentrates to the same period, as shown in Figure 5. This means that solar energy can cover only a small part of the heating energy load of the building. This situation can be slightly improved by increasing the solar collector area and the tank volume, as can be seen in Table 2.

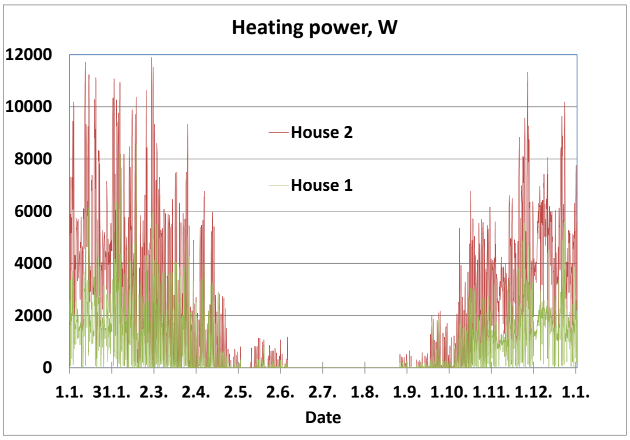

Fig. 4 Heating power of the two houses throughout the year, hourly averages.

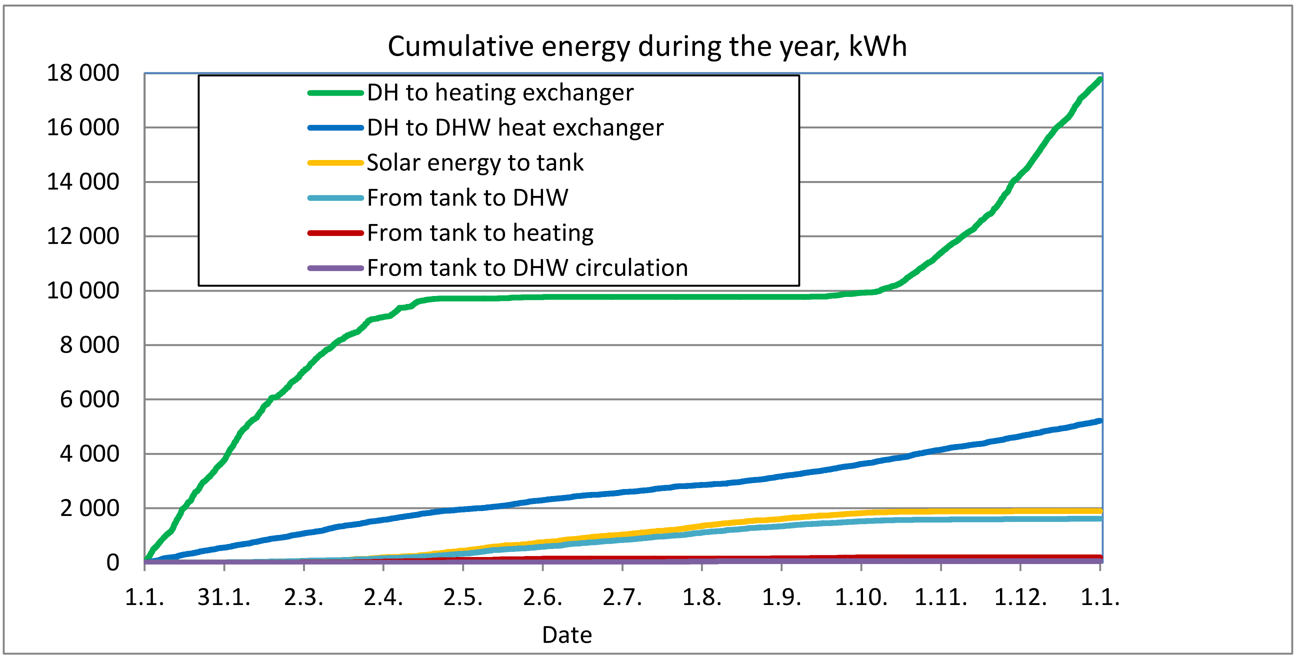

Fig. 5 Cumulative energy intake from solar collectors, solar tank and district heating in house 2. Solar collector area 6 m^2 and solar tank volume 400 litres.

Table 2. Yearly energy intake from solar tank, from district heating and energy savings. Different solar collector and tank sizings in house 2.

Solar collector area	Storage tank volume	From tank to heating	From tank to DHW	From tank to DHW circulation	District heat to DHW heat exchanger	District heat to heating exchanger	District heat saving	Saving per collector area
m^2	litres	kWh	kWh	kWh	kWh	kWh	kWh	kWh/m^2
3	200	68	1166	18	5681	17914	1259	420
6	400	193	1616	58	5220	17790	1843	307
6	800	241	1610	19	5267	17741	1845	307
12	800	389	2010	149	4764	17593	2496	208
12	1200	425	2027	109	4791	17558	2504	209
0	0	-	-	-	6871	17982	-	-

Table 3. Yearly energy intake from solar tank, from district heating and energy savings. Different solar collector and tank sizings in house 1.

Solar collector area	Storage tank volume	From tank to heating	From tank to DHW	From tank to DHW circulation	District heat to DHW heat exchanger	District heat to heating exchanger	District heat saving	Saving per collector area
m^2	litres	kWh	kWh	kWh	kWh	kWh	kWh	kWh/m^2
3	200	42	999	67	3988	6335	1090	363
4	300	64	1143	108	3838	6294	1281	320
6	400	138	1319	161	3608	6241	1564	261
6	800	80	1326	188	3662	6213	1537	256
12	800	304	1550	280	3240	6121	2051	171
-	-				5011	6401		

Increase of the tank volume does not however bring additional district heat savings because the solar heat supply for DHW decreases at the same time. Savings per collector area decreases along with installed collector area, ranging from 170 to 420 kWh per square meter, when the results for the less energy consuming house 1 (Table 3) are also taken into account.

Figure 6 shows the solar collector heating power and Figure 7 shows the temperatures in the storage tank in a week in June. Tank temperatures rise during the first days but decrease during the last two days because of less sunshine. On three days the tank temperature exceeds 58 °C, i.e. is high enough to heat the DHW circulation as well as the consumed hot water up to 58 °C. This situation is quite rare and therefore the energy gain from the tank to DHW circulation is quite low, see Tables 2 and 3.

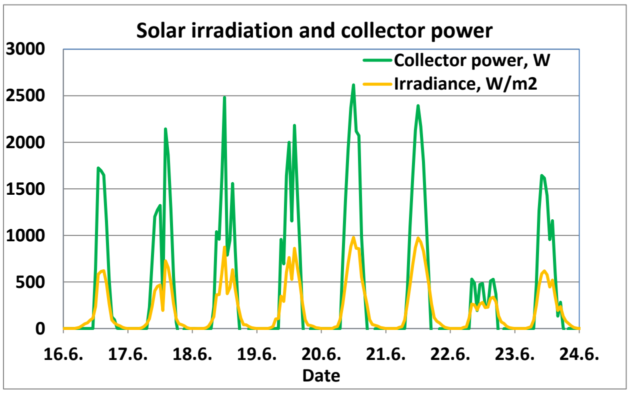

Fig. 6 Solar radiation and solar collector power during a summer week. House 2, solar collector area 6 m^2 and solar tank volume 400 litres.

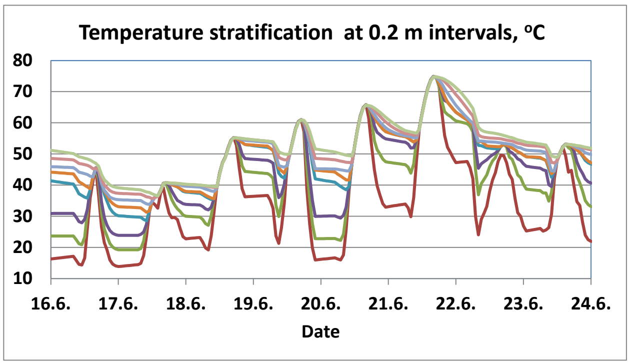

Fig. 7 Temperatures in the storage tank at 0.2 m intervals in summer week, temperature increases from bottom to top. House 2, solar collector area 6 m^2 and solar tank volume 400 litres.

DHW heating up from 8 °C is a very favourable task for the solar system due to the low temperature level. Most of the solar energy is used for this purpose. The energy saving due to solar system is approx. 55% of consumed DHW heating need when a 6 m^2 collector is used in house 1 and a 12 m^2 collector is used in house 1. Economically it may be appropriate to exclude the space heating and DHW circulation heating altogether from the solar system.

Integration of solar heat into district heating has also an impact on district heating return temperatures, from April to September (Figure 8). In summer the return temperature is approx. 3 degrees higher in a combined solar and district heat system.

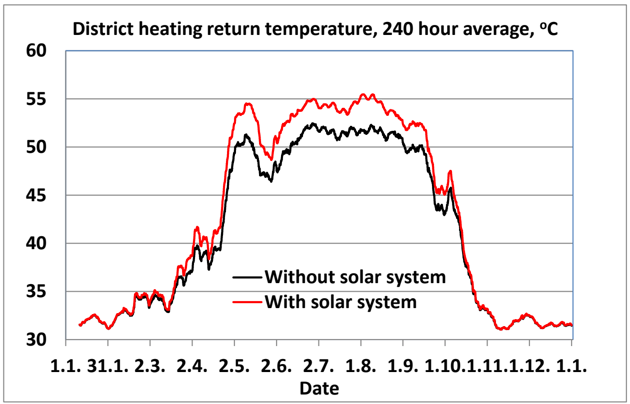

Fig. 8 District heating primary side return temperature with and without solar system, 240 hour sliding average. House 2, solar collector area 6 m^2 and solar tank volume 400 litres.

CONCLUSIONS

A new model of district heating substation including solar heating panels and a storage tank was developed using IDA-ICE energy simulation software toolkits. Simulations showed that solar collectors may help to save approximately half of the energy for DHW heating needs in Finnish climate, whereas the impact on the space heating energy was marginal. Solar thermal integration with district heating will affect also the return temperature of the primary side which is most visible during the summer time.

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