DIFFERENT STRATEGIES FOR ORGANIZING THE ENERGY COMMUNITY

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ERA-Net Smart Energy Systems

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CONTENTS

INTRODUCTION

The climate change, pandemic and the conflict in Ukraine have caused the European energy system to experience an unprecedented crisis. In 2022, due to the geopolitical situation in the world, the EU revised the foundations of its energy policy in order to move from fossil fuels to renewable energy as quickly as possible and to become energy independent from Russian fossil fuels. In May 2022, average retail gas prices for end users in the European Union (EU) capitals increased by 84% [1] and the average retail electricity price for households rose by 30-33 % [2] compared to May 2021. Net zero energy is a very relevant concept today, but it has been used more at the scale of buildings, and moving to the level of energy communities will provide significant benefits in energy efficiency [3]. One of the solutions to the global energy challenge is through the establishment of clean-energy communities. Until 2016, there was no legal framework in Europe to regulate the energy communities. The Clean Energy for All Europeans Package [4], specifically the Renewable Energy Directive [5] and the Electricity Market Directive [6] provide guidelines for energy communities: Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs). The EU has set a deadline (1-2 years) for the implementation of these principles in the legislative bases of the EU member states. The restructuring processes of the EU energy sector mean not only the transition from fossil to renewable energy resources, but also the need to review how energy is produced and supplied. Within this, renewable energy communities are becoming increasingly important. Renewable energy communities are a form of cooperation between various stakeholders of the local society (households, small and medium-sized enterprises, farms, individual traders, the municipality and its institutions) in order to jointly create the infrastructure for the use of renewable energy resources with the aim of producing energy mainly for their own consumption (for their members).

Several countries in Europe are currently experimenting with community-owned renewable energy systems. There are more than 3,500 renewable energy communities in the EU [7] designed to bring clean, cheap and secure energy to the people. Some energy communities supply electricity from wind or solar energy or provide heating of buildings with boilers that use local biomass as fuel, or use solar collectors to prepare hot water for households. Some participate in energy supply, distribution and trading processes. Based on the literature analysis [8], [9], [10] it can be concluded that the creation of energy communities is a current topic and they can increase the energy efficiency and independence of autonomous renewable (RES) based energy systems.

RES has become a main goal for the creation of smart sustainable communities, cities and for reduction of the impact of climate change [11]. Different RES systems can be combined for energy production: wood biomass cogeneration systems combined with a heat pump and with a PV system [12]. Passive solar energy can be used to improve the energy efficiency of buildings [13]. Currently, the most widely used PV products are rooftop solar PV systems because most of the governments are financing such kind of projects. In addition, PV is one of the cleanest RES in terms of energy production, having several positive impacts on the power grid (peak load reduction etc.)[14].

LATVIAN CONVENTIONAL DWELLINGS BUILDING STOCK

At the beginning of 2021, there were 810,992 conventional occupied dwellings (apartments or private houses) in Latvia. A significant period of construction in terms of volume for multi-apartment buildings was until 1941, when 44.5% of the total was built, but the proportion of buildings built during the Soviet era (until 1992) is even higher, with a percentage of 51% (Table 1). As can be seen, only 4.4% were built during the restored free state, which is a significant drop. From the end of the 1950s to the beginning of the 1990s, the construction of typical residential houses was widespread in Latvia with insufficient thermal insulation in the sense of the currently valid Latvian regulatory acts [15]. The number and area of these buildings are summarized in the Table 2. Alongside cities microdistricts, small towns that were constructed around large factories or other important buildings (for example, Aizkraukle was built in the 1960s around Plavina HPP). The most common building series in the regions of Latvia are 103, 316 and 464 [16] – the buildings have a thin rectangular shape and a limited number of floors: two, three, four or five. Building series 602, 467 and 119 were also built in cities - the buildings have a rectangular shape, the number of floors - from five to sixteen. New series of mass-built apartment buildings were no longer created in Latvia after 1985. One of the reasons for this was the change of the state apparatus in 1991, which largely interrupted the design and construction system of existing residential areas and their apartment buildings [17]. Most of the inhabited conventional dwellings are apartments in multi-apartment buildings (73% or 592.5 thousand), while 25% or 198.5 thousand are individual houses (2021).

It can be concluded that Latvia's housing stock is rapidly aging. The aging of buildings and the deterioration of their technical condition lead to a decrease in the energy efficiency of the housing stock. According to the Ministry of Economy of the Republic of Latvia, 23,000 buildings need to be renovated in the multi-apartment building sector.

Table 1

Type of multi-apartment buildings and commissioning by years.

	Before 1941	1941-1960	1961-1979	1980-1992	1993-2002	2003-2014	2015-2019	Total
Apartment buildings with wooden exterior walls	8622	1472	472	77	20	34	7	10704
Multi-apartment 1-2 storey buildings	5257	2833	3057	638	91	226	26	12128
Multi-apartment 3-5 storey buildings	2644	918	5350	3385	243	597	63	13200
Multi-apartment 6-9 storey buildings	674	32	361	657	52	195	36	2007
Multi-apartment buildings of 10 or more floors	0	0	172	264	23	72	9	540

Table 2

Characteristics of typical residential buildings.

Typical building series	**Area, thousand m^2**	**Number**	**Average area, m^2**
103	4208,66	1503	2800
467	1897,54	563	3370
602	1608,87	299	5381
318	1021,23	420	2431
104	899,19	355	2533
464	472,26	124	3809
316	426,06	173	2463
119	217,96	37	5891
Total	10751,77	3474	309

NEARLY ZERO-ENERGY BUILDING (NZEB) DEFINITION IN LATVIA

According to the European Commission Regulation (EU) No. 244/2012 (January 16, 2012), which supplements the European Parliament and Council Directive 2010/31/EU of May 19, 2010 on the buildings energy efficiency, as amended by Directive 2018/844 of May 30, 2018 and Regulation 2018/1999 of December 11, 2018, a long-term strategy for buildings developed in Latvia as an EU member state, which promotes the renovation of the national stock of residential and non-residential buildings (both public and private) so that it becomes highly energy-efficient and decarbonized by 2050, promoting cost-effective conversion of existing buildings into nearly zero-energy buildings (NZEB).

In Latvia, the requirements for a NZEB are determined by the Cabinet of Ministers. Now in force Cabinet of Ministers regulations no. 222 "Building energy efficiency calculation methods and building energy certification regulations" (April 16, 2021) issued in accordance with the articles of the "Law on the Energy Performance of Buildings" and defined in Section III "Requirements for a nearly zero-energy building and the use of high-efficiency systems".

Regarding zero-energy buildings, Article 2, point 2 of Directive 2010/31/EU states that the energy required for NZEB should be covered to a large extent from renewable energy sources (RES), including energy produced on-site or nearby from RES. Regulation of the Cabinet of Ministers No. 383 "Regulations on Energy Certification of Buildings" (July 9, 2013) determined that nearly zero-energy buildings at least partially ensure the use of RES, however, detailed requirements for the part of renewable energy resources were not specified. Regulations No. 383 no longer in force, from April 16, 2021 in force regulations No. 222 "Building energy efficiency calculation methods and building energy certification regulations", which, in relation to at least partial use of RES, no longer provide for the mandatory use of RES, but determine the minimum permissible values of non-renewable primary energy that can be achieved. As a result, according to the regulations, the need for the proportion of RES use must be determined individually in each project from the general conditions for achieving the indicators of non-renewable primary energy. This, in turn, means that in cases where centralized heat supply with a high percentage of RES is used as a heat carrier in the building, there will be no need to duplicate the use of RES, especially in densely built-up areas where the installation of RES can be technically difficult.

EXAMPLE FOR 9-STOREY APARTMENT BUILDING (CASE 1)

TRNSYS software was used to determine the potential of solar energy use in urban area for development the energy community organization solutions for Latvia, based on best European practice examples. Based on the typical residential buildings' analysis of Latvia, apartment buildings of series 467 were chosen as one of the simulation variants – Case 1, as they are the second dominant type of apartment building in terms of area and number (see Table 2). The geometry of its external building envelop is a pitched roof, more suitable for installing solar collectors and PV. Also, they are mostly 9-story buildings, which are equipped with an elevator, and PV input can mostly cover the electricity consumption of the proposed energy community for the common needs.

Case 1 - the TRNSYS model was created for evaluating the potential of using solar collectors and forecasting the system efficiency, as well as for the effective selection of system parameters and elements (size, number of solar collectors, etc.)

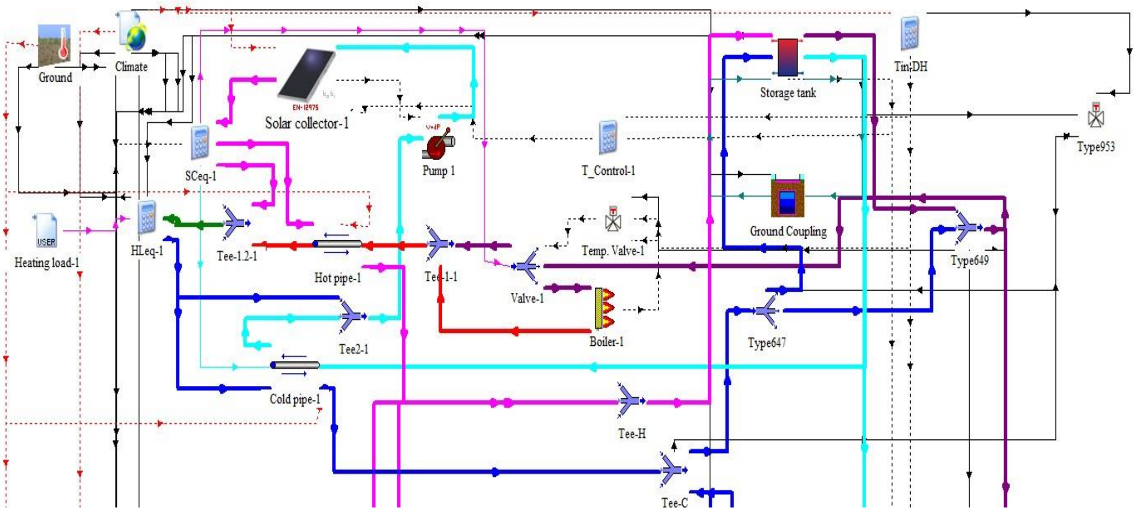

Figure 1. TRNSYS model (fragment).

The developed model consists of 3 identical parts that correspond to 3 large heat energy consumers - 3 multi-apartment buildings. The basic elements of system each

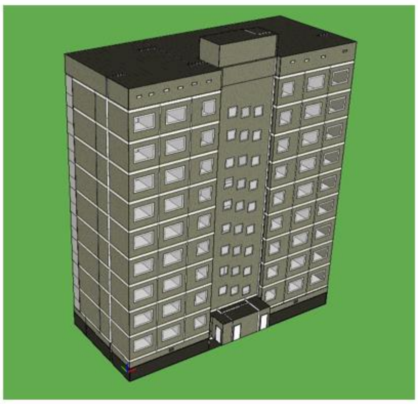

Figure 4. IDA ICE modelled multi-apartment building.

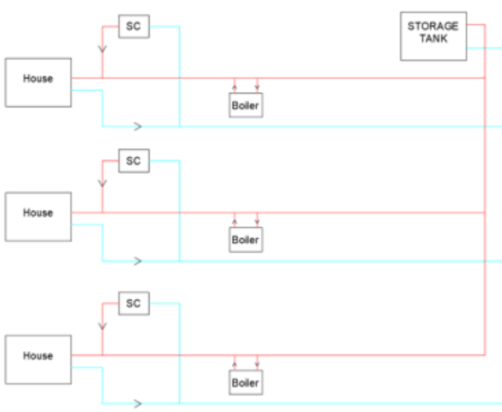

Figure 3. Simplified scheme.

part is: solar collector field, boiler and return/forward two-way pipelines (Figure 3). Two-way pipelines are necessary in order to be able to deliver the excess thermal energy, which occurs when the solar collectors produce more energy than is demanded from the consumer at that moment, to the single, common, underground storage tank. In turn, it returns heat later when the water in the solar collectors fails to reach the programmed minimum temperature, however, if the temperature in the storage tank is also not sufficient, then part of this flow is directed to the boiler, which raises it to the required values before mixing again.

In order to bring the simulated situation closer to the real conditions, the model uses TRNSYS internal climate of Riga, in addition, the heat load (equal to each of the 3 buildings) was received from the IDA ICE simulation results, where a typical 9-story apartment building of the 467 series was modeled (see Figure 4), but the forward (T1) and return (T2) temperature schedules, which regulate the operation of the model, were accepted in accordance with the data of JSC "Rīgas Siltums" and the selected location (see Figure 5).

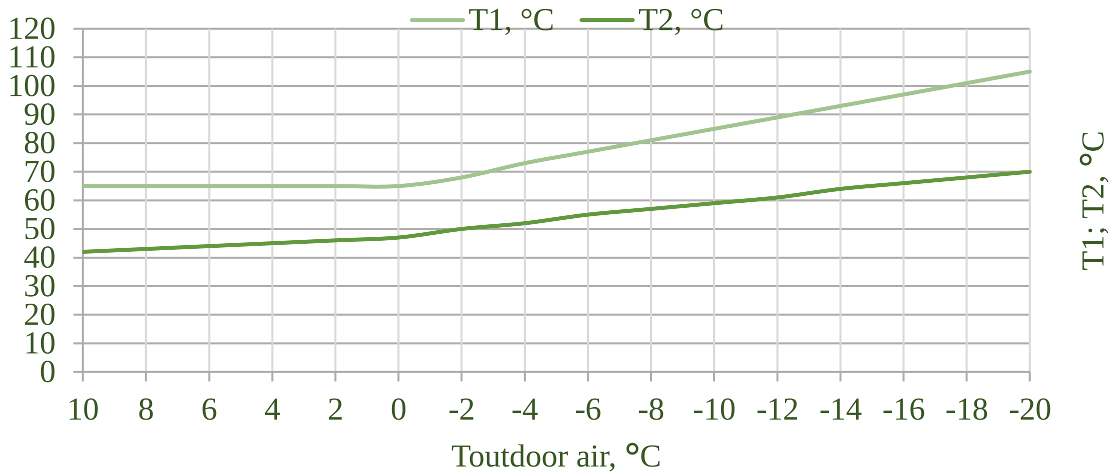

Figure 5. The selected temperature schedule (boiler house "X", "X1", "X2", "X3", "X4" in the pipelines of the heating networks on the border of JSC "Rīgas Siltums" ownership).

Table 3 summarizes the values adopted in the developed model.

Table 3

Input data

Installation angle of solar collectors	45 °
Orientation of solar collectors	South
The area of solar collectors (for one consumer)	500 m^2
The volume of the storage tank	100 m^3

Storage tank dimensions (X*Y*Z)	5*5*4 m
U-value of the storage tank walls	0,36 W/(m^2*K)
Pipeline insulation thickness	35,15 mm
U-value of pipe insulation	0,026 W/(m^2*K)

continuation of Table 3

Outer diameter of pipelines	33,7 mm
Internal diameter of pipelines	28,5 mm
Pipeline length to 1st building	100 m
Pipeline length to 2nd building	200 m
Pipeline length to 3rd building	500 m

During the simulation, the energy balance graphs of the system were obtained, which describe the operation of the system.

Figure 6 shows the energy balance of the proposed system: a graph of the energy consumption of three apartment buildings and the amount of energy generated in the boilers. The amount of energy generated in the boilers exceeds the building's consumption during the winter months and November to compensate for heat losses (or energy losses) and the part of the energy that is in the pipelines on the way to the objects at that moment (energy accumulations in pipelines).

Energy losses and accumulations in pipelines are highest in winter months (up to 10947 kWh January) and lowest in summer months (up to 6187 kWh) due to heat losses in the ground.

The amount of energy produced in the solar collectors is obviously higher in May (29802 kWh), when it drops in the summer (18166 kWh in July), 16593 kWh in September, after which there is another drop to 0 kWh in November and December. In general, with given parameters, the amount of energy produced in solar collectors is greater than the energy consumption of buildings in the months from May to August. Currently, the solar fraction of the system, as a percentage of the amount of energy produced by solar collectors from the total amount of energy consumption, is 22.5 %.

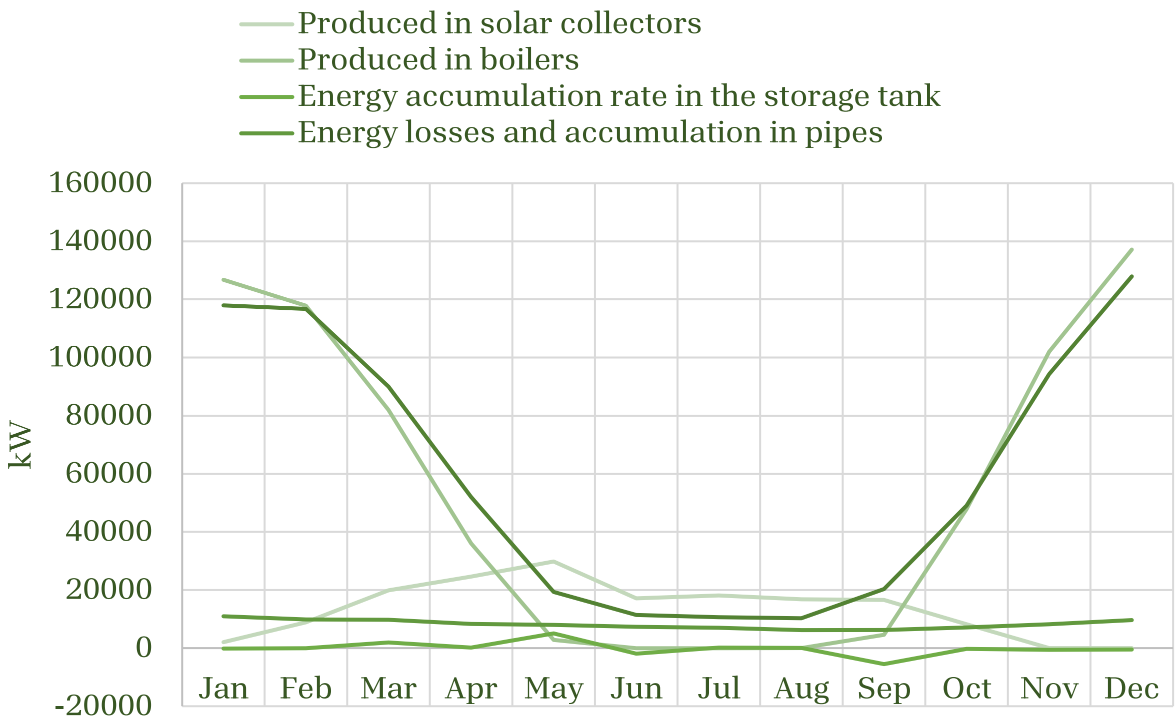

Figure 6. System energy balance.

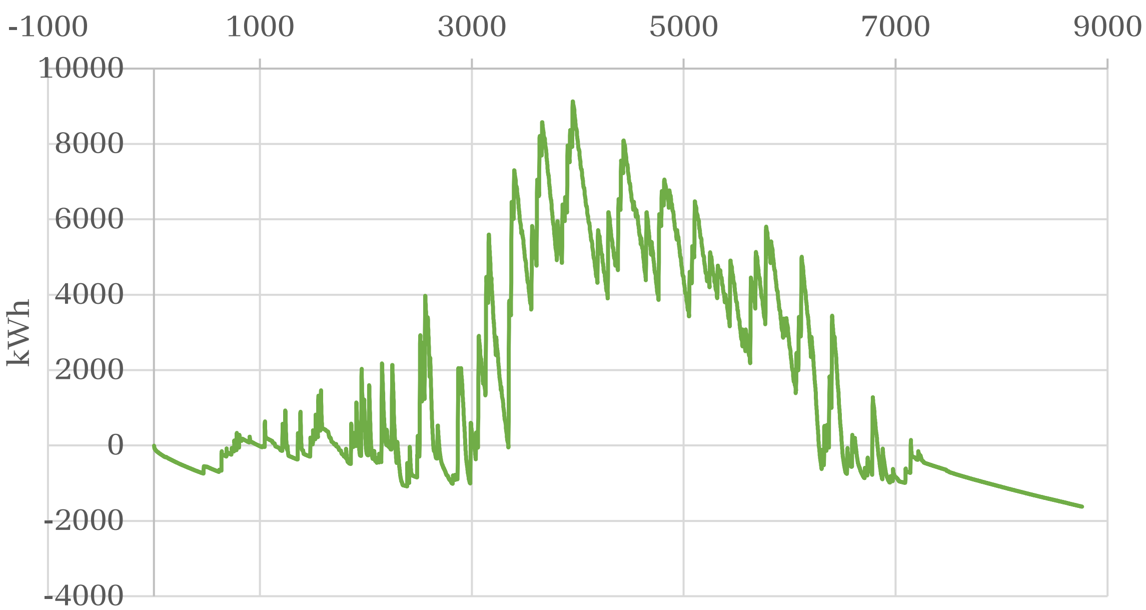

Figure 7. Cumulative graph of accumulated energy in the storage tank.

Figure 7 demonstrates the accumulated energy in the storage tank. It can be seen that during the summer period there is energy storage with peaks and troughs of up to more than 8000 kWh, but during the rest of the year the amount of energy regularly drops to negative values, which may be related to the reduction below the initial amount of energy possessed by the volume of water in the storage tank.

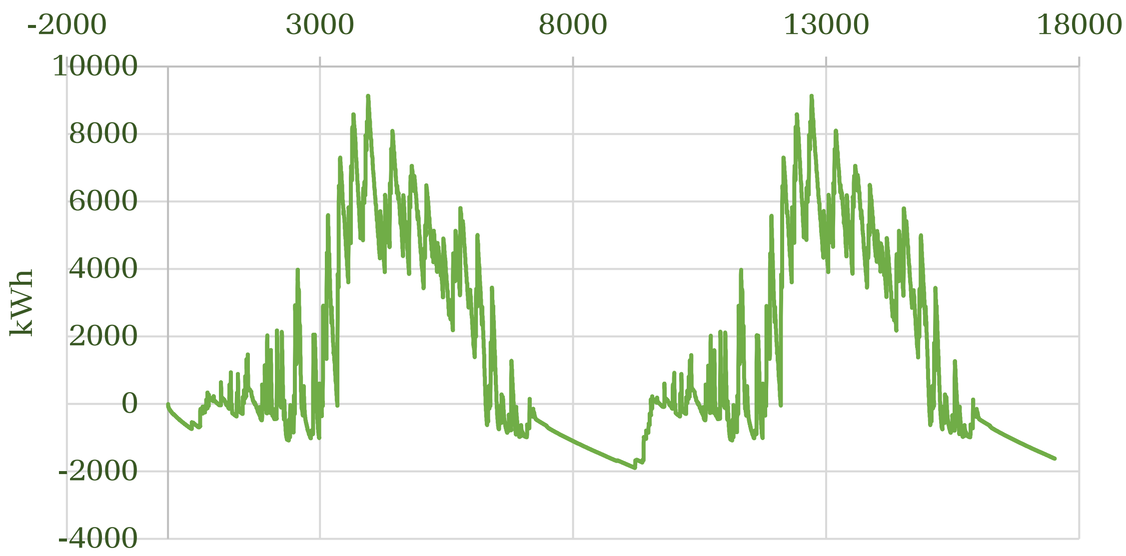

Figure 8. Cumulative graph of accumulated energy in the storage tank (2 years).

In order to find out the maximum drop of accumulated energy in the storage tank and the time of their withdrawal, a 2-year refining simulation was carried out. Summary of the results Figure 8 shows that the observed decline begins in November (when the solar collectors no longer produce thermal energy), but in the second half of January there is a return to the values of 1 year.

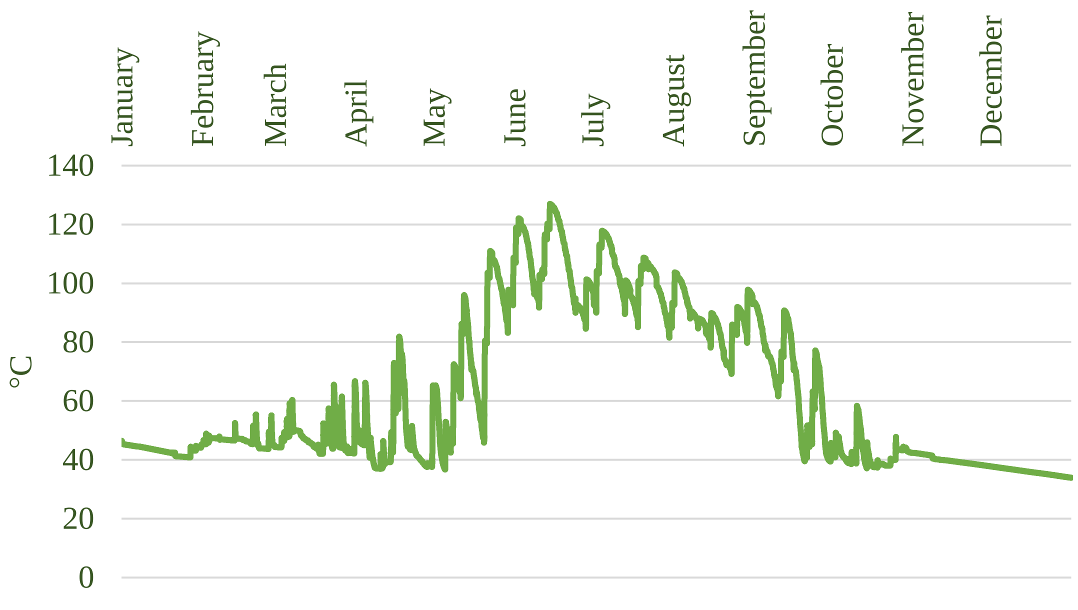

Figure 9. The temperature in the center of the storage tank.

Figure 9 confirms that due to the high temperature that the water flow after the solar collectors tends to reach in summer (outflow temperature is not controlled) the temperature in the storage tank also rises above 120 °C, while the lowest temperature observed in the center of the storage tank is slightly below 40 °C despite the fact that the minimum return temperature according to Figure 4 is 42 °C. This situation can be explained by heat loss in pipelines from the object to the storage tank. The steady drop in temperature starting in November is also visible in Figure 6 and may be due to the termination of operation of the solar collectors during the specified period.

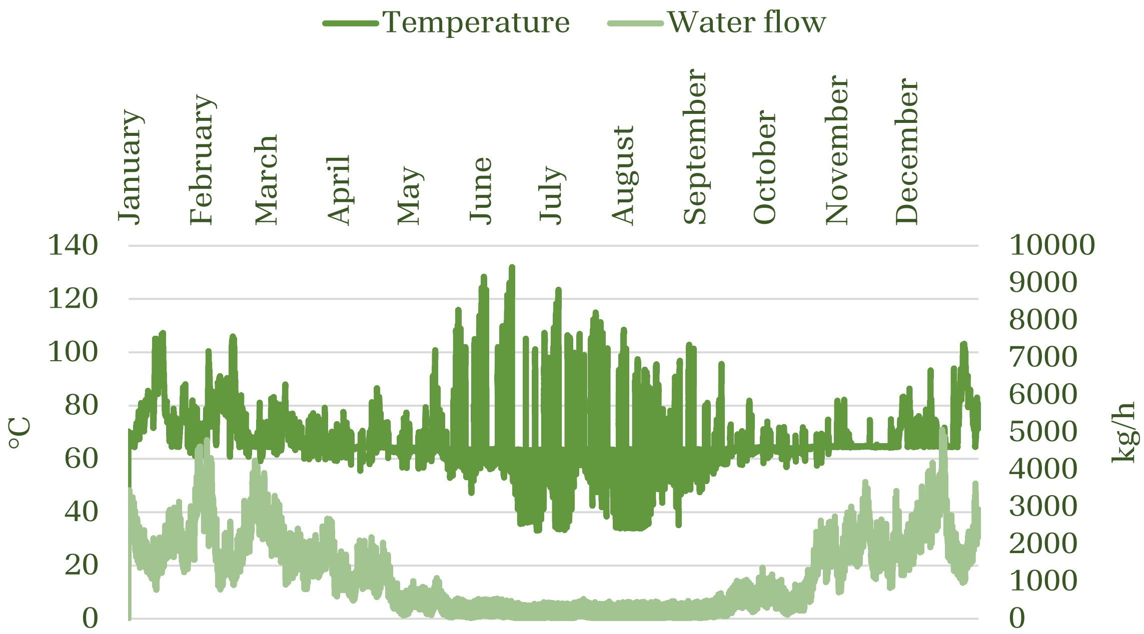

Figure 10. Water flow and temperature (to building 1).

Figure 10 shows the amount of water flow to one of the buildings in the lowest summer period when no heating is used, and the water flow temperature varies according to a set schedule with several dips below the minimum required summer temperature of 65 °C.

EXAMPLE FOR RESIDENTIAL DISTRICT (CASE 2)

To validate the developed model and test the methodology, a residential district with a common boiler house was selected, providing heat supply only to this area (see Figure 11). Ten multi-apartment residential buildings, as well as one preschool educational institution and a minimarket are connected to the district's centralized networks.

Description of multi-apartment residential buildings:

- building 1, building 2 and building 3: series 467, panel, 5 floors, 80 apartments, 4 sections;
- building 4, building 5, building 7 and building 10: series 467, panel, 5 floors, 60 apartments, 3 sections;
- building 6, building 8: series 318, brick, 4 floors, 32 apartments, 4 sections;
- building 9: series 316, brick, 4 floors, 32 apartments, 4 sections.

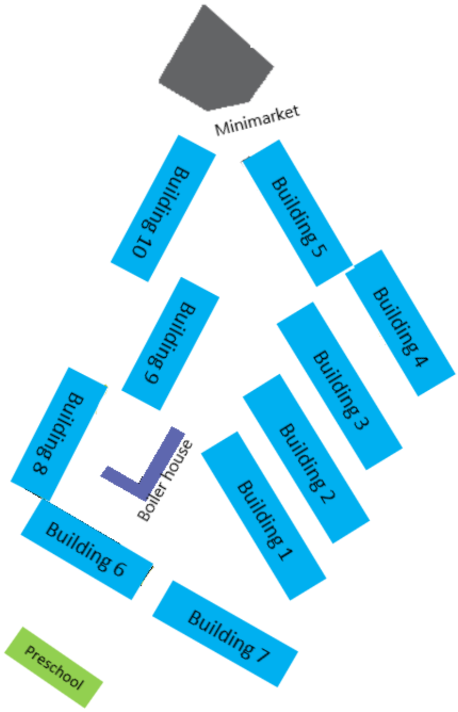

Figure 11. The basic scheme of analyzed district.

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