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Expanding the prosumer concept to enhance the efficiency of district heating systems. A case study

Extinderea conceptului de prosumer pentru a spori eficiența sistemelor de termoficare. Un studiu de caz

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Abstract. *Considering the fact that the energy sector producing both thermal and electrical energy has a contribution to the increase of greenhouse gas emissions, the need to diversify energy production sources and equipment such as biomass power plants, installations that recover secondary fuel and thermal energy resources, solar installations and heat pumps is a major priority. The study carried out presents a solution for the integration of renewable energy sources (RES) for the production of electricity that will then be used both in the own thermal energy supply facilities, following that the surplus electricity will be used for the production of hot water that can be delivered in the district heating system.*

Key words: district heating, RES, photovoltaic system, air-water heat pump

1. Introduction

It is well known that the energy sector in general and in particular the energy sector for the production of thermal energy needed for heating buildings has a considerable contribution to the increase of greenhouse gas emissions.

Therefore, it is necessary to diversify the sources, integrate biomass power plants, installations that recover secondary fuel and thermal energy resources, solar installations, and heat pumps. The variation of sources, but also of consumption, will attract on the one hand the need to store the given energy and transform some networks from unidirectional to bidirectional. The selection of thermal energy sources that ensure a quality supply for consumers will have an important role in optimizing the operation of thermal networks and transforming classic networks into smart networks. In this context, this study addresses the advantages of smart thermal networks related to the local integration of renewable energy sources (heat pumps and photovoltaic panels), turning consumers into prosumers of thermal and electrical energy. The problem of variability and fluctuation in renewable energy sources can only be solved using storage. It is estimated that thermal energy storage in the construction and industrial sectors can provide an annual energy saving of up to 7.8% and a 5.5% reduction in CO_2 emissions [1].

On the other hand, there are also changes regarding the requirements that the sources must ensure, emphasizing the ecological aspect at the expense of the economic aspect. For this reason, a mix of conventional and renewable sources is inevitable in the energy sector. The development of energy solutions that integrate renewable energy into energy production systems and thermal energy has been of major interest to energy producers and distributors in recent years [2].

Considering the desired transition, from the 3rd generation district heating (DH) systems to the 4th and 5th generations, which involves reducing the temperature regime of the transported thermal agent, it supports the increase of RES integration opportunities in the heating and transformation systems of consumers with energy production potential in prosumers [3]. The reduction of the temperature regime is considerable considering the fact that 3rd generation DH systems network supply temperatures range in the order of 80–120^{0}C and for the so called low temperature district heating (LTDH) networks the normal supply temperatures range is around 45 – 55 ^{0}C, which leads to a considerable reduction of energy losses during transport [4]. At the same time, the reduction in temperature favors the integration of renewable heat sources in heating networks, which, according to the International Energy Agency (IEA), should increase to 14% by 2025 and up to 22% by 2030 [5, 6].

The need to transition heating systems to RES is also evident from the increase in CO_2 emissions, which, in 2022, will increase by 1.5% compared to 2021; compared to 2010, the increase is 25%, which makes centralized heating systems account for 4% of global CO2 emissions. From this point of view, in Fig. 1, it can be seen that the biggest contributor to the intensity of CO_2 emissions is China, while Europe, even though it is the third largest contributor, participates in about half of China's emissions, which means that in Europe, the transition to RES is starting to prove effectiveness.

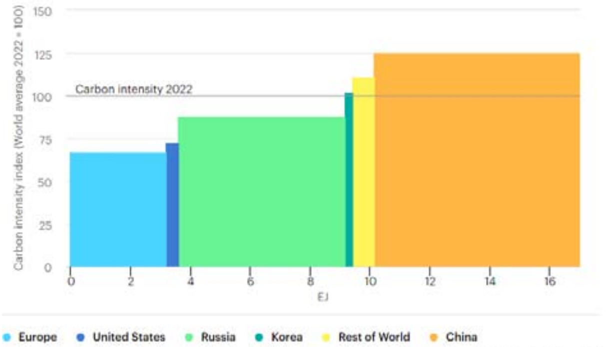

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Fig. 1. CO_2 emission intensity index for heat production in centralized systems by region in 2022. [6]

For this reason, through a case study, the paper proposes an analysis of a combined thermal and electrical energy production model that integrates an air-water heat pump and a photovoltaic system in a thermal point of the district heating network in Timișoara located on an educational building supplied with heat from the thermal point. The photovoltaic system is dimensioned both for the educational building's own consumption and for supplying electricity to the heat pump and possibly the pumping system.

2. Case Study

The case study was carried out on the buildings of the educational unit "Colegiul Tehnic Henri Coanda Timișoara" and the DH substation PT34, as shown in Fig. 1. In Table 1, the input data of each building are presented, namely the built-up area of the building (A_d), the considered heat requirement (Q_{nec}), the annual thermal energy required for heating (Thermal E_{nec}) and the electrical consumption of the studied buildings (Electrical Drowning). The simulation was performed using the calculation software Polysun SPTX Constructor [7].

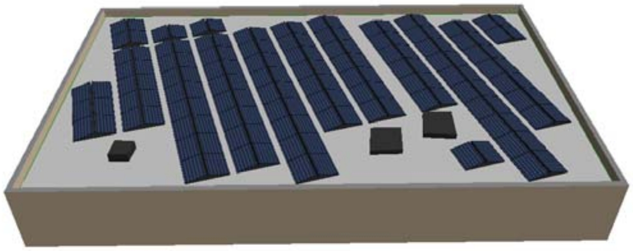
Fig. 1. Situation plan of the studied buildings [7]

Table 1

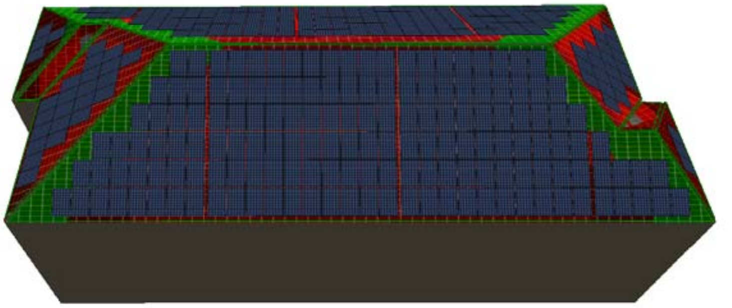
The input data of the studied buildings

Building	A_d (m^2)	Q_{nec} (kW)	Thermal E_{nec} (MWh)	Electrical E_{nec} (MWh)
Canteen	556.00	69.50	7.50	18.00
Student dormitory 1	3,050.00	381.25	33.80	24.00
Student dormitory 2	3,050.00	381.25	33.80	22.00
PT 34	165.00	-	-	7.00
Gym	951.00	118.88	12.50	25.00
School 1	4,192.00	524.00	46.50	50.00
School 2	1,628.00	203.50	18.50	20.00
Total	**13,592.00**	**1,678.38**	**152.60**	**166.00**

This study proposes the integration of RES of the electricity produced with the help of photovoltaic panels mounted on the roofs of buildings presented in the situation plan. The electricity produced is used in the first phase to ensure their own electricity consumption. In Fig. 2 you can see the location of the photovoltaic panels on the studied buildings. Table 2 shows the output data resulting from the simulation performed by mounting 1956 EvoloCells 400 MIB 400 W photovoltaic panels on a total roof surface of 13,592 m^2.

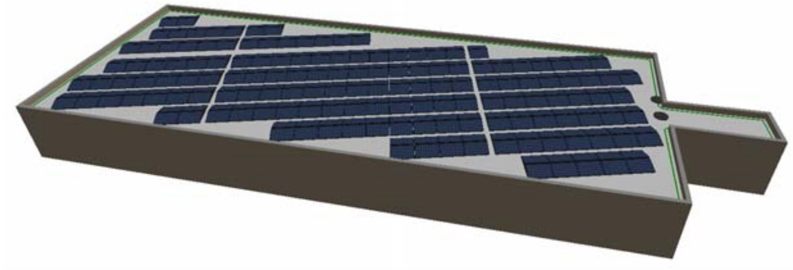


a) Canteen

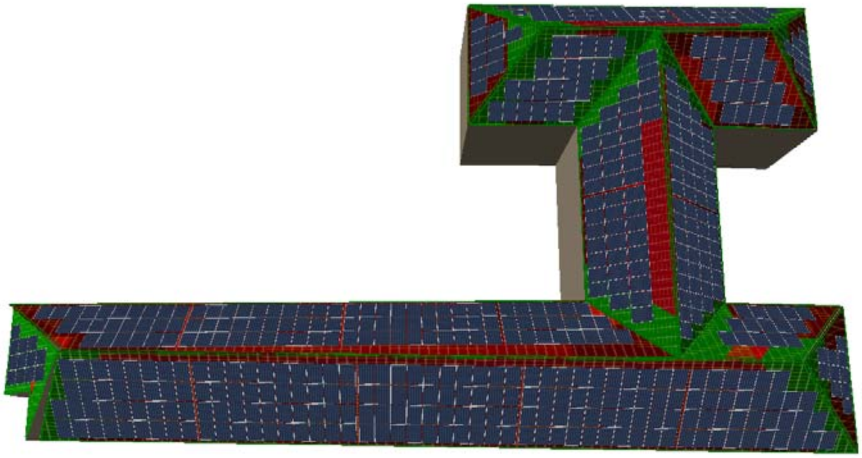


b) Student dormitory 1 and 2

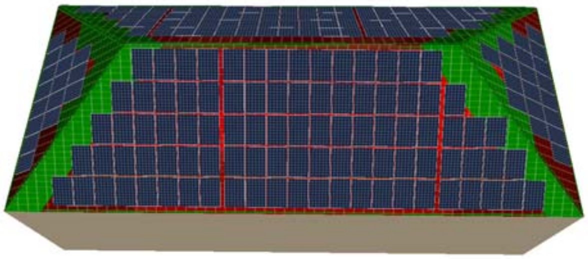
c) PT34



d) Gym



e) School 1



f) School 2

Fig. 2. The placement of photovoltaic panels on the studied buildings [8]

Table 2

The output data of the studied buildings

Building	Nr. of panels	PV inst. [MW]	PV prod. [MWh/an]
Canteen	154	61.60	67.60
Student dormitory 1	333	133.20	142.60
Student dormitory 2	297	118.80	124.35
PT 34	122	48.80	53.96
Gym	294	117.60	130.04
School 1	552	220.80	218.43
School 2	204	81.60	82.54
Total	**1,956**	**782.40**	**820.00**

Considering the considerable surplus of annual electricity produced after ensuring the own consumption of electricity necessary for the operation of educational buildings (approximately 654 MWh), this study proposes the installation of six air-water heat pumps, each with a heating capacity of 200 kW. The thermal energy produced by the heat pumps using the electricity from the photovoltaic system of the educational institution can be used first of all for the preparation of hot water consumed in the own buildings as well as for heat supply in their heating installations, resulting on the heating side a hybrid system that uses as primary thermal energy the one from the DH system with input of energy from RES. In table 3 you can see the production of the photovoltaic system (PV prod), the consumption of electricity for lighting (El. Enec), the preparation of hot water for consumption (Hw Enec) and the input of thermal energy for the heating system (Heat. Enec) and surpluses of solar electricity produced (S. Epv).

Table 3

Monthly production and consumption of electricity

Month	Elec. E_{nec} (MWh)	Heat E_{nec} (MWh)	Hw E_{nec} (MWh)	PV prod. (MWh)	S Epv (MWh)
Jan	20.00	90.64	21.74	24.07	-108.31
Feb	18.50	73.11	20.14	36.44	-75.31
March	18.00	57.95	22.25	64.84	-33.36
April	17.00	27.79	20.90	88.45	**22.76**
May	16.00	9.28	20.49	106.31	**60.54**
June	9.50	1.62	18.61	111.35	**81.61**
July	1.00	0.03	18.17	115.98	**96.78**
Aug.	1.00	0.00	17.58	101.20	**82.62**
Sept.	10.00	7.88	17.07	70.83	**35.88**
Oct.	17.00	30.90	18.31	50.99	-15.23
Nov.	18.00	56.08	18.80	30.87	-62.01
Dec.	20.00	81.72	20.68	18.73	-103.67
Sum	166.00	437.00	234.74	820.00	-17.69

Even after the use of the solar electricity produced to cover the various types of energy required for the functioning of the buildings, it can be seen in table three that there are some months in the summer period that remain with a considerable surplus of electricity produced. The classic solution is for this electricity surplus to be delivered to the NES, but here the problem of its load level arises, as there is a possibility that this surplus cannot be taken over. Our proposal is that the energy not consumed in the summer months be used for the production of domestic hot water, which will then be introduced into the DH system's distribution network. In the studied situation, this option is easy to implement also due to the fact that DH substation PT34 is located in close proximity to educational buildings.

In the previous studies, the authors Daniel Muntean and Adriana Tokar [8], proposed that from DH substation PT34, the neighboring residential neighborhood "City of Mara" would be fed through a dedicated route with a length of 300 m. The current study proposes the use of surplus solar electricity for the preparation of domestic hot water with the help of heat pumps and its introduction into the DH system to supply the "City of Mara" residential district.

Table 3 summarizes the solar energy surplus (S Epv) for the summer months, the electrical energy required for the production of domestic hot water that is delivered to the "City of Mara" residential district (Hw Enec "City of Mara") and the electrical energy delivered in NES (Elec. In NES). In Fig. 3 presents the proposed functional scheme of the solar electricity production facility, of the facility for preparing the thermal agent needed for heating and domestic hot water preparation and its integration into the DH system so that the beneficiary of the studied buildings becomes a prosumer of thermal and electrical energy.

Table 3

Electrical and thermal energy introduced into the system

Month	S Epv (MWh)	Hw Enec "City of Mara" (MWh)	Elec. in NES (MWh)
April	22.76	52.24	-
May	60.54	51.22	**9.32**
June	81.61	46.54	**35.08**
July	96.78	45.43	**51.35**
Aug.	82.62	43.95	**38.67**
Sept.	35.88	42.66	-

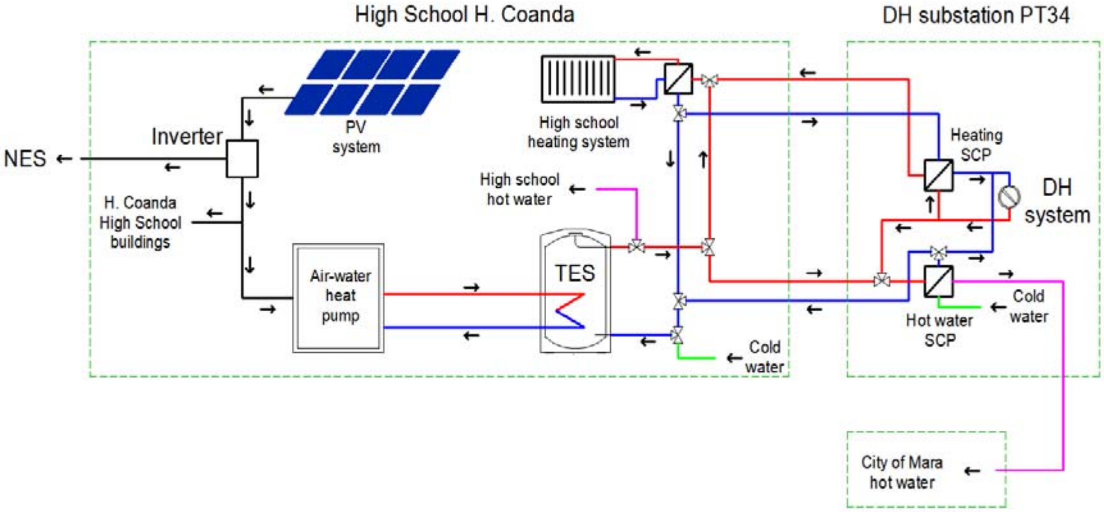


Fig. 3. Functional scheme of the thermal and electrical installation

In the autumn - winter months when the solar electricity is less, the thermal installation will primarily produce the hot water needed for the buildings belonging to the beneficiary and heat input for the heating installation. In the months of spring and summer, the surplus of solar electricity will be used for the production of hot water for consumption, which will be delivered to the DH system to supply the "City of Mara" residential district. In both modes of operation, the hot water produced is stored in a storage tank (TES). The remaining surplus of electrical energy that is not converted into thermal energy is delivered to the NES.

3. Conclusions

The integration of RES into energy production and supply systems, both thermal and electrical, has become a necessity these days caused by both the problematic energy context and the need to reduce environmental pollution.

Beneficiaries of buildings, be they residential or public institutions, must look at the need to use RES as an opportunity to become from consumers to prosumers of thermal and electrical energy.

From the point of view of heating networks, adaptation to climate change and security of heat supply can be achieved by switching to the next generation of heating systems and implementing smart heating networks.

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