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Solutions for optimizing the operation of energy recovery in ventilation systems

Soluții pentru optimizarea funcționării recuperării energiei în sistemele de ventilație

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Abstract. *Energy efficiency norms require effective insulation techniques for buildings in order to minimize energy consumption. The paper presents simulations, carried out throughout the year, regarding the efficiency of energy recovery units (ER) to ensure the quality of fresh indoor air. Indoor air energy recovery calculations were performed using plate and rotary heat exchangers in different operating scenarios. The evaluated parameters led to the stability of the optimization solutions in order to obtain a higher energy efficiency on the equipment. By comparing the obtained results, optimal measures and solutions were identified for energy efficiency in the operation of ER.*

Key words: outside air, ventilation, air conditioning, energy efficiency, energy recovery

1. Introduction

Due to the high consumption of primary energy for which the construction sector is responsible, which also has a negative impact on the environment (average annual increase in carbon emissions of approximately 2% [1]), the member states of the European Union have been obliged to adopt measures to energy efficiency of buildings. The gradual reduction of energy consumption has as its target the percentage of 11.7% until 2030, in relation to the year 2020 [2], [3]. A considerable percentage of energy consumption (around 50%), of total consumption in buildings, both in the residential and non-residential sectors, is due to HVAC (heating, ventilation and air conditioning) systems due to the high demand for thermal comfort. Of this percentage, ventilation accounts for 30% to 60% of energy consumption in buildings [1], [4], [5], [6], [7].

The new energy efficiency norms require construction techniques that insulate buildings better and better. Efficient buildings have very good thermal insulation and NZEB or passive buildings minimize primary energy consumption for heating/cooling and ventilation needs. Regarding the ventilation systems, which provide fresh air in buildings, the ventilation rates must be correctly set because insufficient ventilation is a critical factor that causes severe dissatisfaction in indoor environments. In the context of reducing energy consumption per building surface, which must be achieved through the objectives imposed by the EU, an important role is played by the recovery of the heat lost through the air exhausted by the ventilation systems. Heat recovery ventilation is known to be effective in saving energy and maintaining required ventilation rates. In this sense, an important aspect is the type of energy recovery capable of contributing to the reduction of energy consumption for heating and cooling spaces in buildings [8], [9], [10].

2. Efficiency of energy recovery

The contribution of heat recovery to energy savings should be studied depending on the destination of the building and the type of ventilation system. Therefore, the paper makes an analysis of the efficiency of energy recovery on energy savings considering several operating scenarios.

The heat recovery efficiency represents the use of waste heat for preheating fresh cold air and can take values between 0 and 100%. Achievable heat recovery efficiencies for common air handling equipment are estimated to be somewhere between 30 and 90%, while efficiencies above 60% are considered good and above 80% excellent [11].

The heat recovery efficiency η_t depending on the temperatures, (temperature differences) is calculated with the relation [12], [13]:

$$\eta_t = (t''_2 - t'_2) / (t'_1 - t'_2) \quad (1)$$

where:

t'_1 - extracted air temperature at the entrance;;

t'_2 - fresh air temperature at the entrance;

t''_2 - fresh air temperature at the exit.

This is where the efficiency grade (EG) comes in, where the fresh air heating is placed in relation to the required temperature and is calculated with the relation:

$$EG = (t''_2 - t'_2) / (t_{2N} - t'_2) \quad (2)$$

where:

t_{2N} - the required (maximum) temperature of the air introduced;

t'_2 - fresh air temperature at the entrance;

t''_2 - fresh air temperature at the exit.

The grade of efficiency is therefore important, especially in rooms with technological processes, where the temperature of the extracted air is often clearly higher than the required temperature of the input air. The degree of efficiency (EG) is higher than the recovery efficiency (ηt). Over the course of a year, significant differences appear between the annual degree of efficiency and the heat recovery efficiency depending on the temperature of the extracted/input air. So, it can be concluded that:

- the influence of the temperature difference between the extracted and introduced air with the energy used is considerable;
- for an extracted air temperature of 20ºC (input air temperature), as expected, the annual efficiency is the same as the heat recovery efficiency;
- the degree of annual efficiency increases with the exhaust air temperature and that the efficiency decreases at high values of heat recovery. The temperature of the air to be introduced would otherwise be too high.

Regarding the cost effectiveness of projects (high investment and high pressure loss) with high heat recovery efficiency, it is appreciated that they are not always advantageous.

3. Ventilation systems with heat recovery for a residential building. Case Study

The study carried out presents simulations regarding the efficiency of ER in order to ensure the quality of fresh indoor air. Indoor air heat recovery calculations using plate and rotary heat exchangers were performed, depending on the air flow rate and the number of operating hours of the ventilation system, and the feasibility of using heat exchangers was analyzed. Several operating scenarios were presented in which the parameters, which influence the energy efficiency of the energy recovery, were modified. In order to determine the optimization solutions in order to obtain a higher energy efficiency on the equipment, the following parameters were evaluated: the air speed in the free section and the pressure loss on the filter material. The scenarios were designed for different types of energy recovery and in different HVAC constructiv systems. For the case study, the realization of a separate installation was considered, which would provide fresh air all year round. Obviously, in winter, the outside air must be heated, either by an electric battery or by a battery supplied with hot water from the building's central heating boiler. In summer the fresh air can be cooled, either with a separate coil with direct expansion, or with a coil with water received by a water cooler (chiller), so that the rooms do not heat up undesirably. The actual cooling of the rooms is done with separate fresh air installation equipment either with direct expansion equipment ("splits") or using an installation with fan coils and the central water cooler.

The article analyzes only the air circulation produced by the installation that permanently introduces fresh air into a building intended as a residential building, and is composed of the following rooms: living room (29 m^2, 87 m^3); adult bedroom 1 (19 m^2, 57 m^3); adult bedroom 2 (18 m^2, 54 m^3); child's bedroom (17 m^2, 51 m^3); office

(17 m^2, 51 m^3); kitchen (14 m^2, 42 m^3); bathroom (9 m^2, 27 m^3); service bathroom (4 m^2, 12 m^3); entrance hall (6 m^2, 18 m^3); interior hall (9 m^2, 27 m^3).

Ensuring correct air circulation is done according to the following rules:

- rooms with continuous introduction of fresh air: living room, office, the three bedrooms which have a total area of 100 m^2 and a volume of 300 m^3;
- rooms with periodic evacuations of stale air: kitchen, bathroom and service bathroom;
- buffer rooms, for variable exhaust of stale air: hall and entrance.

The total flow of fresh air introduced is 900 m^3/h, distributed as follows: living room→260 m^3/h, bedroom 1 adults→170 m^3/h, bedroom 2 adults→160 m^3/h, children's bedroom→155 m^3/h, office →155 m^3/h.

At the same time, there are rooms from which stale air is evacuated depending on the period of their use. In these cases, the exhaust air flows can be variable: from everything to nothing. Thus, from the kitchen, through the hood (placed above the stove), either the maximum air flow of 210 m^3/h or nothing when the hood is not working. Either 135 m^3/h or nothing (fan off) can be evacuated from the bathroom, and 60 m^3/h or nothing (fan off) can be evacuated from the service bathroom. Under these conditions, everything that is not evacuated through the kitchen and/or bathroom and/or service bathroom will be evacuated through the suction holes located in the central hall and in the entrance, thus maintaining a continuous ventilation of the apartment.

To perform the calculations, the following climatic parameters were taken into account:

- Winter:
  - Outside air: temperature: -15°C; humidity: 70%;
  - Indoor air: temperature: 22°C; humidity: 50%;
- Summer:
  - Outside air: temperature: 36°C; humidity: 2570%;
  - Indoor air: temperature: 26°C; humidity: 50%;

Following the simplified calculation, the results were obtained:

- Winter → the introduction of fresh air into the building requires a thermal energy consumption of approx. 11.5 kW;
- Summer → the introduction of fresh air into the building requires a refrigeration energy consumption of approx. 3.5 kW.

To be able to make an accurate analysis of the electrical consumption of the ventilation equipment, it is necessary to know their technical characteristics. The comparison was made for a fresh air flow rate of 900 m^3/h. The simulation was carried out considering two ER types with plates, especially used for residential buildings:

- air-air ER Lossnay with plates LGH-100RVX (Fig. 1 a);
- air-air ER VAM1000FC with plates (Fig. 1 b).

The air flows circulation related to the two ER types of considered for the case study are shown in Fig. 1.

a) b)

Fig. 1 Types of energy recovery
a) Lossnay (https://torn-climatizare.ro/), b) VAM (https://c-control.com.ua/)

4. Results and discussion

- The results obtained were compared and optimal measures and solutions were identified for energy efficiency in the operation of ER. The simulations were carried out throughout the year, there being a difference between the winter and summer periods regarding the efficiency of the ER, and as well the investment recovery period was also taken into account. The simulations were carried out for the two types of ER, for the summer and winter periods, as follows:
- *for the type air-to-air ER with Lossnay LGH-100RVX plates,* the simulation of the efficiency of the ER was done with the help of the Lossnay Selection calculation program in which the calculation parameters were entered. For the summer/winter period, the results shown in Table 1 were obtained.

Table 1

Results obtained for the ER Lossnay LGH-100RVX

No.	Characteristic	Unit	Value	Unit	Value
		Summer		Winter	
1.	Selected Lossnay model & Fan Speed: LGH-100RVX x 1 unit				
	Heat exchange efficiency	%	68	%	80
	Enthalpy exchange efficiency	%	71	%	72.5
	Sound level	dB	47	dB	47
2.	*Selection Conditions*				
	Total supply air	m^3/h	900	m^3/h	900
	Power Supply	Hz	50	Hz	50
	External static pressure	Pa	150	Pa	150
	Pre heater(W)	-	-	W	4165
	After heater(W)	-	-	W	4165
3.	*Psychrometric Points*				
	Outdoor air (OA)-Summer (1) and Winter (1)				
	Dry bulb temperature	°C	36	°C	-15
	Relative humidity	%	25	%	70
	Absolute humidity	g/kg	9.3	g/kg	0.7
	Enthalpy	kJ/kg	60	kJ/kg	-13.2
	Outdoor air after Pre heater (OA')-Winter (2)				
	Dry bulb temperature	-	-	°C	-2.9
	Relative humidity	-	-	%	24
	Absolute humidity	-	-	g/kg	0.7

No.	Characteristic	Unit	Value	Unit	Value
		Summer		Winter	
	Enthalpy	-	-	kJ/kg	-1
	Room air (RA) - Summer (2) and Winter (3)				
	Dry bulb temperature	°C	26	°C	22
	Relative humidity	%	50	%	50
	Absolute humidity	g/kg	10.5	g/kg	8.2
	Enthalpy	kJ/kg	52.9	kJ/kg	43
	Supply air (SA) - Summer (3) and Winter (4)				
	Dry bulb temperature	°C	29.2	°C	17
	Relative humidity	%	40	%	45
	Absolute humidity	g/kg	10	g/kg	5.4
	Enthalpy	kJ/kg	54.9	kJ/kg	30.9
	Supply air after After heater (SA') - Winter (5)				
	Dry bulb temperature	-	-	°C	29
	Relative humidity	-	-	%	22
	Absolute humidity	-	-	g/kg	5.4
	Enthalpy	-	-	kJ/kg	43.1

- *for the type air-to-air ER with VAM1000FC plates,* the simulation of the efficiency of the ER was done with the help of the Daikin calculation program. The selection software uses data according to the JIS B 8628-2017 standard and shows the result for the specific air flow, ESP and temperature conditions. For the summer/winter period, the air flow characteristics in the rooms are shown in Table 2, the air conditioning characteristics in the rooms are shown in Table 3, the results obtained are shown in Table 4, The Psychrometric Points, for both cooling and heating are presented in Table 5. For the selection data it was considered: exhaust / Supply ratio – 1, additional resistance: supply side - 4.5Pa and exhaust side - 4.5Pa.

Tabel 2

Characteristics of air flow in rooms

Characteristic	Unit	**Value**
Room Airflow Conditions		
Total supply air	m³/h	900
Total exhaust air	m³/h	900
External Static Pressure (ESP)		
Design supply ESP	Pa	150
Altitude Selection		
Altitude	m	0

Tabel 3

Parametrii aerului condiționat în încăperi

No.	Characteristic	Unit	Value	Unit	Value
		Cooling		Heating	
1.	*Room Air Conditions (RA)*				
	Dry bulb temperature	°C	26	°C	22
	Wet bulb temperature	°C	18.6	-	-
	Relative humidity	-	-	%	50
2	*Ambient Air Conditions (OA)*				
	Dry bulb temperature	°C	36.0	°C	-15.0
	Relative humidity	%	25	%	70
3.	*Discharge* Temperature Setting				
	Temperature	°C	18	°C	25

No.	Characteristic	Unit	Value	Unit	Value
		Cooling		Heating	
4.	*Electric Heaters*				
	Inlet heater	kW	5.000	-	-
	Supply Temperature	-	-	°C	20.0
	Supply heater	-	-	kW	3.000

Tabel 4

Results obtained for the ER VAM1000FC

No.	**Characteristic**	**Unit**	**Value**	**Unit**	**Value**
		Cooling		**Heating**	
1.	**Efficiencies**				
	Temperature exchange efficiency	%	79.2	%	79.2
	Enthalpy exchange efficiency	%	65.2	%	70.4
2.	**Savings over Heat Exchanger**				
	Latent heat savings	kW	1.220	kW	3.382
	Sensible heat savings	kW	3.593	kW	6.321
	Total heat savings	kW	4.813	kW	9.703
3.	**Heaters**				
	Switch on inlet heater above	°C	59.5	-	-
	Switch on inlet heater below	-	-	°C	1.0
	Inlet heater (user settings)	kW	1.500	kW	3.788
	Inlet heater (calculated minimum)	kW	0.000	kW	3.788
	Supply heater (user settings)	-	-	kW	3.000

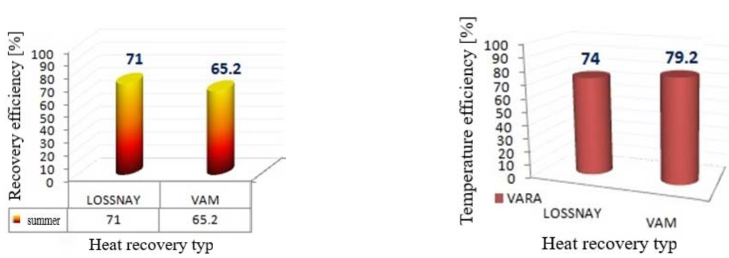
Table 5

Psychrometric Points

No.	Characteristic	Unit	Value	Unit	Value
		Cooling		Heating	
1.	Room Air (RA)				
	Dry bulb temperature	°C	26.0	°C	22.0
	Wet bulb temperature	°C	18.6	°C	15.4
	Relative humidity	%	49.8	%	50.0
	Absolute humidity	kg/kg	0.0104	kg/kg	0.0082
	Enthalpy	kJ/kg	52.8	kJ/kg	43.0
2.	*Exhaust Air (EA)*				
	Dry bulb temperature	°C	38.0	°C	1.4
	Wet bulb temperature	°C	21.0	°C	1.0
	Relative humidity	%	21.4	%	93.5
	Absolute humidity	kg/kg	0.0088	kg/kg	0.0039
	Enthalpy	kJ/kg	60.9	kJ/kg	11.2
3	*Outdoor Air (OA)*				
	Dry bulb temperature	°C	36.0	°C	-15.0
	Wet bulb temperature	°C	20.7	°C	-15.6
	Relative humidity	%	25.0	%	70.0

No.	Characteristic	Unit	Value	Unit	Value
		Cooling		Heating	
	Absolute humidity	kg/kg	0.0093	kg/kg	0.0007
	Enthalpy	kJ/kg	60.0	kJ/kg	-13.3
4.	*Supply Air (SA)*				
	Dry bulb temperature	°C	29.1	°C	25.2
	Wet bulb temperature	°C	19.9	°C	13.7
	Relative humidity	%	43.1	%	25.6
	Absolute humidity	kg/kg	0.0109	kg/kg	0.0051
	Enthalpy	kJ/kg	57.1	kJ/kg	38.4
5.	*Ventilation In (VI)*				
	Dry bulb temperature	°C	41.1	°C	-4.0
	Wet bulb temperature	°C	22.2	°C	-7.3
	Relative humidity	%	19.0	%	26.4
	Absolute humidity	kg/kg	0.0093	kg/kg	0.0007
	Enthalpy	kJ/kg	65.2	kJ/kg	-2.3
6.	*Ventilation Out (VO)*				
	Dry bulb temperature	°C	29.1	°C	16.6
	Wet bulb temperature	°C	19.9	°C	10.1
	Relative humidity	%	43.1	%	43.6
	Absolute humidity	kg/kg	0.0109	kg/kg	0.0051
	Enthalpy	kJ/kg	57.1	kJ/kg	29.6

Based on the results obtained, a comparative evaluation was made between the two types of ER, during the summer, in terms of the efficiency of the ER (Fig. 2 a) and the efficiency of the temperature exchange (Fig. 2 b).



a) b)

Fig. 2 Comparative evaluation for summer period - ER Lossnay vs. VAM

a) ER efficiency, b) temperature exchange efficiency

According to the graph in Fig. 4 it can be seen that the ER Lossnay will have a much lower energy consumption than the ER VAM.

In order to evaluate the yield during the winter, the internal temperature of 22°C was considered. Comparative graphs between the two ER types, in winter, the efficiency of the ER (Fig. 3 a) and the temperature exchange efficiency (Fig. 3 b).

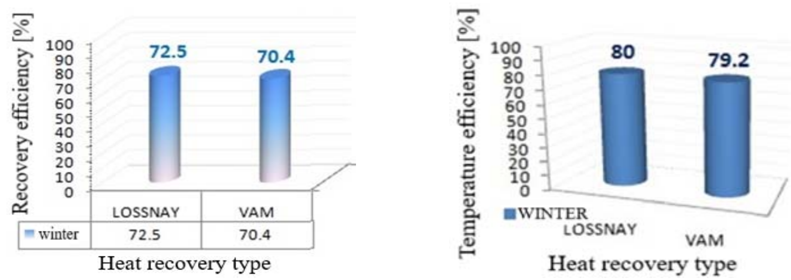


Fig. 3 Comparative evaluation for winter period - ER Lossnay vs. VAM
a) ER efficiency, b) temperature exchange efficiency

The investment cost calculation showed that the installation with ER Lossnay is 3780 Euros, and the one with ER VAM is 3655 Euros, resulting in a price difference of only 125 Euros. So, it can be said that the efficiency of the ER is proportional to its investment cost.

Another important indicator in the choice of the ER is the payback period of the investment, which was determined as the ratio between the cost of the equipment in lei and the cost of the energy saved in a year, in lei/year. For the two ER types , in Fig. 4 compares the payback of the investment in months.

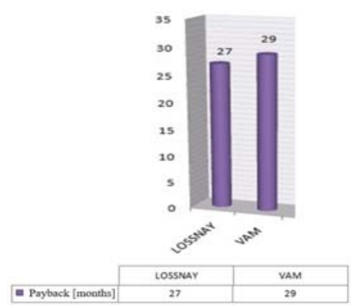


Fig. 4 Payback of investment- ER Lossnay vs. VAM

5. Conclusions

With the increasing demand for thermal comfort, HVAC systems and their related consumption have grown considerably, accounting for around 50% of energy consumption in buildings and around 10–20% of total energy consumption in developed countries, a trend that will . continues to rise in line with the expansion of built-up areas and related energy needs. From the analysis of the payback of the investment, it was found that a better heat recovery is done with the help of the ER Lossnay over the period of 27 months, this also takes into account its efficiency. The lower the efficiency of the equipment, the longer the payback period of the entire investment. The use of ER leads to the uninterrupted supply of clean air in buildings (especially residences, offices, commercial premises, etc.) which means maintaining a high standard of health. The continuous change of the contaminated air in the premises drastically reduces the development of airborne germs.

References

[1] L. Perez-Lombard, J.Ortiz, C. Pout, A review on buildings energy consumption information, Energy and Buildings, Vol. 40, pp. 394–398, 2008..

[2] A G. Marinescu, Eficientizarea energetică - impulsionată prin obligativitatea reducerii consumului anual de energie, Ziarul Bursa, 13 martie 20231

[3] European Council, Council adopts energy efficiency directive, 25 July 2023, Available online: ttps://www.consilium.europa.eu/en/press/press-releases/2023/07/25/council-adopts-energy-efficiency-directive/, Accessed: 30.09.2023..

[4] F. Babota, Mechanical ventilation systems with heat recovery for refurbishment projects and new buildings, Buletinul Institutului Politehnic din Iași Publicat, Tom LX (LXIV), Fasc. 2, 2014.

[5] A. Dodooa, L. Gustavssona, R. Sathrea, Primary Energy Implications of Ventilation Heat Recovery in Residential Buildings. Energy and Buildings, Vol.43, pp.1566–1572, 2011.

[6] M.W. Liddament, M. Orme, Energy and ventilation, Applied Thermal Engineering, Vol. 18, Issue 11, pp. 1101–1109, 1998.

[7] M. Orme, Estimates of the energy impact of ventilation and associated financial expenditures, Energy and Buildings, Vol. 33, Issue 3, pp. 199–205, 2001.

[8] S.M. Kim, J.-H. Lee, S. Kim, H. J. Moon, J. Cho, Determining Operation Schedules of Heat Recovery Ventilators for Optimum Energy Savings in High-Rise Residential Buildings. Energy and Buildings, Vol.46, pp. 3–13, 2012.

[9] Adriana Tokar, Dan Negoiţescu, Marius Adam, Dănuț Tokar, Arina Negoiţescu, The waste energy recovery, an energy-efficient solution for the industrial sector, E3S Web of Conferences, CLIMA 2019 Congress, Volume 111, eISSN: 2267-1242, Bucharest, Romania, May 26-29, 2019.

[10] Marius Adam, Adriana Tokar, Energy efficiency in HVAC system using air cooling by direct evaporation, Acta Technica Corviniensis – Bulletin of Engineering Tome XII, Fascicule 4, ISSN: 2067-3809, pp. 57-61, 2019.

[11] M. Adam, Optimizarea instalațiilor de ventilare climatizare în regim de răcire în scopul asigurării eficienței energetice și a confortului în clădiri de birouri, Teză de doctorat Universitatea Politehnica Timișoara, 2014.

[12] MDLPA, Metodologie de calcul al performanței energetice a clădirilor, indicativ Mc 001-2022, Monitorul oficial al României, Anul 191 (XXXV) — Nr. 46 bis, 2023.

[13] MDLPA, Normativ pentru proiectarea, executarea și exploatarea instalațiilor de ventilare și climatizare, indicativ I5-2022, Monitorul oficial al României, Anul 191 (XXXV) — Nr. 108 bis, 2023.

Analysis of advanced thermal insulation alternatives for a solar collector with PCM and nanomaterials

Analiza unor soluții avansate de izolare termică pentru un colector solar cu materiale cu schimbare de fază și nanomateriale

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Abstract. *Maximizing the quantity of heat delivered to the air is one of the difficulties dealt with by solar collectors used for air heating. In order to increase the quantity of heat delivered by the phase change materials with integrated nano materials, a thermal insulation solution is investigated in this work to reduce losses to the adjacent regions. A mobile insulating blanket that is fully mechanized is the solution. The time of day or the season determines where to set the insulating blanket.*

Key words: *aerogel; thermal insulation; solar collector*

1. Introduction

The construction industry is one of the largest energy consumers, accounting for over forty-five percent of total worldwide consumption of energy [1]. Furthermore, CO2 emissions around the world are increasing year after year, and global warming threats are becoming more serious each year. Greenhouse gas emissions are a direct result of rapid industrialization and urbanization. The utilization of renewable energy sources to provide indoor comfort and low energy consumption ought to be considered in such a scenario. Because of its abundance and accessibility, solar thermal energy is regarded as one of the most viable renewable energy sources [2]. The solar collector is one of the most widely deployed low-cost solar energy capture devices.

Solar water collectors are already a common solution for residential hot water and heating, whereas air solar collectors are used to warm fresh air, dry or heat the air inside a space. Employing a solar air collector instead of a solar water collector reduces expenses, has a reduced environmental impact, and eliminates the risk of freezing. Furthermore, by employing air solar collectors, outlet temperatures of up to 65 °C can be achieved, making them appropriate for a wide range of building applications [3-5].

Transpired solar collectors (TSC) are typically installed on large scale structures, such as industrial, office, or multi-family residential buildings, for ventilation and room heating during cold periods, and hot air from the system is typically bypassed during warmer periods [6-8]. Using PCMs in solar collectors can boost o operating hours and thermal stability while integrating nanoparticles in PCMs may also enhance thermal behavior related to the melting and solidification process and shorten the phase change period, resulting in a number of overall advantages. This novel type of materials are called nePCMs. The authors suggest a novel system: a transpired solar collector with nano-enhanced phase-changing materials and dynamic insulation. Throughout the day, the dynamic insulation is placed to the interior space, thus, during the coldest months of the year, the air is preheated as it passes over the transpired plate, which has a higher heat transfer rate due to the lobed perforations, and excess heat is stored in the highly efficient nePCMs. Inside, warm air is introduced. The dynamic insulation shifts to the exterior during the night, shielding the nePCMs, which can now transfer heat to the interior.

This paper focuses on insulating materials that can be used as dynamic insulation because the requirements they must meet are both thermal- in terms of the coefficient of thermal conductivity-, mechanical due to the fact that the insulating material is circulated by a roller, and also the mechanical properties and water absorption.

2. Methodology

Figure 1 depicts the novel solar collector system built by the team. The solar collector is constructed of perforated metal plates, a grid-type system in which nePCMs stored in spherical plastic recipients will be positioned.

Fig. 1. Solar collector with nePCMs

A moving roller on which the dynamic insulation will be shifted based on the time of day is placed on the top of the experimental stand. The challenges in developing this experimental stand included selecting the best phase change material for Romania's climatic conditions, selecting the right Nano material and the concentration with which it will be mixed with the phase change material, as well as selecting the type of insulation that will be carried by the mobile system.

To investigate the optimal solution in terms of thermal insulation, three types of material were analyzed: an Armacell Armaflex blanket (glass fiber polymer composite), an aerogel blanket and a ceramic fiber blanket.

A KERN ABJ 220 – 4NM analytical balance- Figure 2- with single cell technology was used to determine the density of the materials.

Fig. 2. Analytical balance

To investigate the optimal solution in terms of thermal insulation, three types of material were analyzed: an Armacell Armaflex blanket, an aerogel blanket and a ceramic fiber blanket.

The mechanical strength of materials is essential for the design of structures and components to ensure their safety and durability. There are several properties and parameters that characterize the mechanical strength of materials, the most important of which is tensile strength. This material property refers to its ability to resist tensile forces (stretching). This is measured by determining the maximum breaking stress of the material- Figure 3.

Water absorption represents the property of porous materials to absorb and retain water in open pores. It is calculated as the difference between the mass of water-saturated material (m2) and the mass of dry material (m1). The higher the open porosity and the finer the pores, the higher the water absorption. In capillary pores with a diameter between (1-10) μm, water penetrates by capillary rise, and in those with a diameter smaller than 1 μm by pressure. This is an important property of materials and can vary significantly between different types of materials. Water absorption can have a significant impact on the performance and durability of materials in various applications.

Fig. 3. Hegevald & Pesche machine

Thermal conductivity testing is an important part of evaluating the thermal performance of materials [9]. The majority of thermal conductivity testing equipment involves putting samples of certain size into a system consisting of a hot plate heated by an electrical resistance and a plate cooled, in most cases, by mains water. Thus, a temperature differential is maintained between the two opposite sides of the monitored material sample, and thermal conductivity is indirectly estimated by measuring the heat flow transported through the material under the respective conditions.

Thermal conductivity was measured using a P.A.Hilton H111N equipment for the materials under consideration. The tests were carried out on an experimental stand recognized by the Romanian National Accreditation Body (RENAR) at the Centre of the Department of Thermal Sciences, part of the Technical University of Civil Engineering Bucharest. The EA Multilateral Agreement (EA MLA) is a signed agreement between EA members that recognizes and respects the equivalence of the signing states' accreditation systems [10].

3. Results

From each type of material, a specific sample was cut to the dimensions required to be tested in each individual case. The materials under consideration have the following densities:

1. *Ceramic fiber blanket*
Mass, m = 18.4 g
Volume, V = (10 x 10 x 1.96) cm3 = 196 cm3
Density 0.094 g/cm3

2. *Glass fiber polymer composite*
Mass, m = 4.1 g
Volume, V = (10 x 10 x 0.7) cm3 = 70 cm3
Density, 0.0585 g/cm3

3. *Aerogel blanket*
Mass, m = 6.6 g
Volume, V = 10 x 10 x 0.7 = 70 cm3
Density, 0.094 g/cm3

The insulating materials used in this project were tested to tensile strength, and the results obtained are presented in the following. Figure 4 shows the appearance of the materials before and after tensile testing.

1. *Ceramic fiber blanket*
Initial length, Li = 100 mm
Final length, Lf = 115 mm
Section, S = (40 x 19) mm2 = 760 mm2
Maximum force = 2 daN
Tensile strength, ft = 0.026 N/mm2
Elongation, ε = 15%

2. *Glass fiber polymer composite*
Initial length, Li = 100 mm
Final length, Lf = 160 mm
Section, S = (40 x 7) mm2 = 280 mm2
Maximum force = 6 daN
Tensile strength, ft = 0.214 N/mm2
Elongation, ε = 60%

3. *Aerogel blanket*
Initial length, Li = 100 mm
Final length, Lf = 120 mm
Section, S = (40 x 7) mm2= 280 mm2
Maximum force = 18 daN
Tensile strength, ft = 0.643 N/mm2
Elongation, ε = 20%

The materials tested in this project have the following water absorption values:

1. *Ceramic fiber blanket*
Mass of dry material, m1 = 6.7 g
Mass of material saturated with water, m2 = 42.7 g
Mass absorption, Am = 537.3%

2. *Glass fiber polymer composite*
Mass of dry material, m1 = 0.5 g
Mass of material saturated with water, m2 = 0.6 g
Mass absorption, Am = 20%

3. *Aerogel blanket*
Mass of dry material, m1 = 0.6 g
Mass of material saturated with water, m2 = 0.6 g
It does not absorb water.

Fig. 4. Tested materials before and after tensile strength testing

The thermal conductivity ranges between 0.0323...0.0545 W/(mK) for the analyzed solutions. The lower the thermal conductivity, the lower the heat flow to the areas adjacent to the solar collector. In this regard, the best option is represented by the *aerogel blanket* having the lowest value. The highest value was obtained for *Glass fiber polymer composite.*

4. Conclusions

The most efficient material to be implemented in the solar collector with nePCMs and dynamic insulation (on rolls) in order to improve the energy efficiency by reducing the number of operating hours and operating costs is the aerogel blanket.

The aerogel blanket achieved the best results in the tests carried out, having the highest tensile strength, 0.643 N/mm2, not participating in the absorption of water vapor process and also having the lowest value of the coefficient of thermal conductivity, 0.0323 W/(mK).

The optimal solar collector insulation solution will be implemented in the experimental stand and the research team will carry out tests and will report the performance in operation in further research.

Acknowledgements

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References

[1] Ma, Z., et al., Nano-enhanced PCM for improved building performance. RSER, 2016. 58: p. 1256-1268.

[2] Khan, M., et al., Evaluation of solar collector designs with integrated LHTES: A review. SE, 2018. 166

[3] Goyal, R., et al. Effect of thermal storage on the performance of an air collector: A periodic analysis. JECM, 1998. 39(3–4): p. 193-202.

[4] Paya-Marin, M., Solar Air Collectors for Cost-Effective Energy-Efficient Retrofitting, in Cost-Effective Energy Efficient Building Retrofitting. 2017, Woodhead Publishing. p. 141-168.

[5] Wang, Experimental study on heating characteristics & parameter optimization of TSC. JAE, 2019.

[6] Brown, C., et al. Transpired Solar Collector Installations in Wales and England. EP, 2014. 48: p. 18-27.

[7] Croitoru, C., et al., Thermodynamic investigation on an innovative UTSC. JSE, 2016. 131: p. 21-29.

[8] Shukla, A., et al., A state of art review on the performance of TSC. RSER, 2012. 16(6): p. 3975-3985.

[9] https://www.en-standard.eu/csn-en-253-district-heating-pipes-bonded-single-pipe-systems-for-directly-buried-hot-water-networks-factory-made-pipe-assembly-of-steel-service-pipe-polyurethane-thermal-insulation-and-a-casing-of-polyethylene/ Accessed on 1th of September 2023

[10] https://www.renar.ro/index.php/en/oec/get_oec_details/43944 Accessed on 01 August 2023

An assessment of the operating efficiency of a condensing boiler fed by fuel with different amounts of hydrogen in the mixture

Evaluarea performanțelor în funcționare pentru o centrală în condensare alimentată cu procente diferite de hidrogen în combustibil

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Abstract. *The current trends converge towards minimizing the carbon footprint on the environment in the operation of all thermal equipment and need finding alternative solutions compared to what the market offers at the moment. Utilizing hydrogen in combustible mixtures with methane gas to fuel condensing boilers is one solution. The benefit is that it reduces carbon dioxide emissions into the atmosphere as only water vapor is produced when hydrogen undergoes combustion. The effects of adding hydrogen at percentages of 23%, 30%, 35% and 45%, respectively, to the combustible gas mixture are examined in the paper.*

Key words: *hydrogen; condensing boiler; carbon footprint*

1. Introduction

A practical option to decarbonize the energy sector is to incorporate hydrogen into natural gas pipes as mixes of hydrogen and methane. It makes use of already-built infrastructure, lowers greenhouse gas emissions, and provides a way to store extra renewable energy. To achieve a smooth transition, though, issues with safety, infrastructural improvements, and hydrogen generation must be resolved [1-3]. Hydrogen-methane mixtures could be a key component of a low-carbon, sustainable energy future as technology develops and renewable hydrogen becomes more widely available [4,5]. The compatibility of employing hydrogen-methane mixes with current natural gas distribution networks and pipelines is one of their main benefits. Hydrogen-methane mixtures are often employed with very slight alterations [7], but retrofitting pipelines for pure hydrogen can be expensive and time-consuming.

In Romania, using hydrogen in combustible mixtures is considered a way to ensuring the energy security by maximizing the potential of renewable resources and this is best reflected by the advance which legislation in this country has made through the introduction of the norm 237/2023. Romania may become a regional leader in energy security by "increasing and modernizing storage capacities compatible with the use of new gases and hydrogen". Also, according to the principle "energy efficiency first" one of the main objectives for 2030 is increasing the share of SRE and low-carbon fuels in the transport sector - including advanced biofuels, hydrogen, fuels made from waste [8].

Numerous investigations related to the operation of combustion equipment with methane hydrogen mixture were carried out in Romania by testing laboratory part of the Technical University of Civil Engineering Bucharest research team. This laboratory is accredited by the National Accreditation Body for performance testing of boilers in operation for the purpose of applying the European marking CE [9]. The current work exclusively examines, both theoretically and practically, how condensing boilers behave when fed fuel mixtures with a high hydrogen content are used.

2. Methodology

High-performance and precise measuring instruments, such as thermocouples, pressure sensors, flowmeters, and a flue gas analyzer, are employed on the experimental stand throughout the testing process-Figure 1. The testing team has been evaluating boilers for more than 10 years, and a routine test also offers safety tests for boilers using gas type G222, also known as flame return limit gas according to the regulations. This gas contains a percentage of 23% hydrogen mixed with methane and the purpose of the test is to evaluate if the flame of the burner has a tendency to stick to its surface or even to go further backwards.

The team intensified testing with this type of gas and also looked into how the equipment behaves at even higher percentages of hydrogen, like 30 or 35%, due to the current preoccupations about implementing hydrogen obtained from renewable sources mixed with methane in the distribution networks of gaseous fuels [10-12].

In this direction, the laboratory has concluded a collaboration protocol with the Delgaz Grid company, on the basis of which numerous equipment will be tested when operating with high percentages of hydrogen in the combustible, in order to determine whether the operation is appropriate.

The methodology aims to determine how the main parameters vary when the percentage of hydrogen in the fuel mixture increases. The main direct effect is on the reduction of the fuel’s heat of combustion, since hydrogen has a lower heat of combustion compared to methane at the same unit of volume. Thus, when such mixtures are used, in order to maintain the same thermal load of the equipment it is necessary to increase the fuel flow rates.

Due to the fact that burning hydrogen only produces water vapor, the principal benefit associated with present-day environmental protection concerns is the reduction of carbon dioxide emissions.

Fig. 1. Experimental stand

3. Results

The assessment of the heat released from fuel combustion was carried out up to a maximum percentage of 40% hydrogen in the mixture, which represents a maximum limit considered according to the research carried out to date, so that no significant interventions and changes are made in the natural gas distribution networks. Table 1 presents both net calorific value and gross calorific value due to the fact that the condensing boilers, which are mandatory according to Romanian norms operate with the gross calorific value.

Table 1

Mixtures' burning performance

Combustible mixture	Net calorific value [kJ/m3]	Gross calorific value [kJ/m3]
G20 (methane)	36,879	40,970
20% hydrogen+ methane	30,798	34,340
G222 (23% hydrogen+ methane)	29,930	33,480
30% hydrogen+ methane	28,297	31,551
35% hydrogen+ methane	27,047	30,157
40% hydrogen+ methane	25,796	28,763

In the following table, the volume of air required for the combustion of a unit volume of fuel (1 m3), the resulting volume of combustion gases, the way in which the fuel flow changes, as well as the value of carbon dioxide emissions, assuming as a benchmark a condensing boiler having a thermal power of 28 kW and an air excess of 1.3. This particular values were chosen based on the research team's experience.

Table 2

Mixtures' burning features

Combustible mixture	Necessary air volume [m3]	Flue gases volume [m3]	Flow [m3/h]	Carbon dioxide [m3/h]
G20 (methane)	12.38	13.38	2.82	2.82
20% hydrogen+ methane	10.51	11.42	3.37	2.7
G222 (23% hydrogen+ methane)	10.24	11.12	3.47	2.67
30% hydrogen+ methane	9.59	10.44	3.67	2.57
35% hydrogen+ methane	9.126	9.95	3.84	2.5
40% hydrogen+ methane	8.66	9.46	4.03	2.42

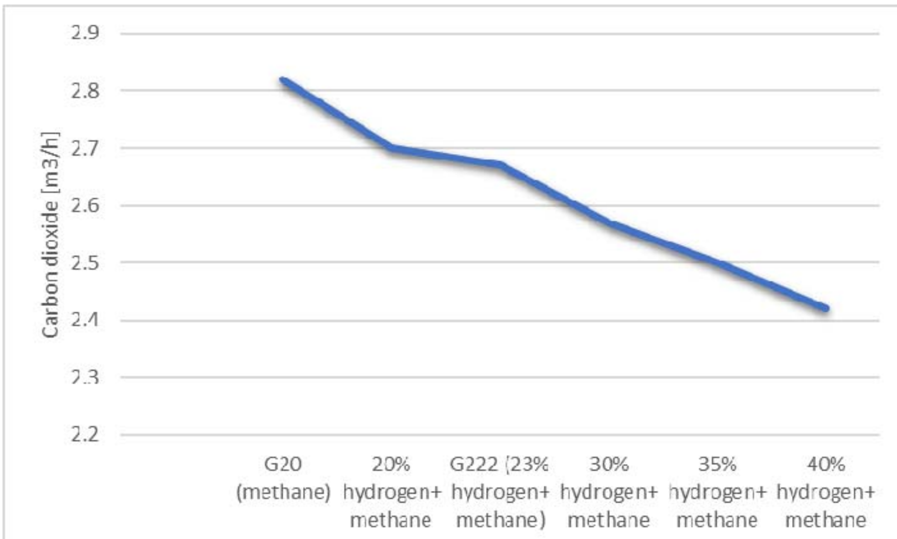

Fig. 2. Carbon dioxide emissions

4. Conclusions

The research team emphasizes the following essential points that must be taken into consideration in the process of adopting hydrogen in the distribution networks of consumer gas supply, as a result of the experience gained from the theoretical as well as experimental evaluations of numerous combustion equipment.

The higher the percentage of hydrogen introduced into the mixture, the more the heat of combustion of the fuel mixture will decrease, thus to ensure the same thermal load of the equipment in operation, the fuel flow must be increased.

The positive impact envisaged with the introduction of hydrogen is maintained even with this increase in fuel flow, i.e., the amount of carbon dioxide emissions in the environment notably decreases, which is highlighted in Figure 2.

The assessments presented solely address the thermal performance and emissions of the equipment; they do not cover the functionality and behavior of the gas distribution networks when injecting the mixtures.

The idea that the hydrogen to be used in combustible mixtures must be obtained from renewable energy sources and with a minimal carbon footprint possible in all stages of production, must be reinforced, along with the highlighting of the benefits brought in terms of the reduction of harmful emissions in the atmosphere, so that, looking at the overall picture, the effect is positive.

References

[1] Glanville, P.; Fridlyand, A.; Sutherland, B.; Liszka, M.; Zhao, Y.; Bingham, L.; Jorgensen, K. Impact of Hydrogen/Natural Gas Blends on Partially Premixed Combustion Equipment: NO_x Emission and Operational Performance. *Energies* **2022**, *15*, 1706

[2] Schaffert, J.; Fischer, P.; Leicher, J.; Burmeister, F.; Flayyih, M.; Cigarida, H.; Albus, R.; Görner, K.; Mili, P.; Carpentier, S.; et al. Impact of Hydrogen Admixture on Combustion Processes—Part II: Practice. Deliverable D2.3 as Submitted from the THyGA Project. 2020.

[3] Suchovsky, C.J.; Ericksen, L.; Williams, T.A.; Nikolic, D.J. *Appliance and Equipment Performance with Hydrogen-Enriched Natural Gases*; Canadian Standards Association: Toronto, ON, Canada, 2021.

[4] Altfeld, K.; Pinchbeck, D. *Admissible Hydrogen Concentrations in Natural Gas Systems—Gas for Energy 03/2013*; DIV Deutscher Industrieverlag GmbH: München, Germany, 2003; ISSN 2192-158X

[6] Ingersoll, J.G. The Renewable Hydrogen–Methane (RHYME) Transportation Fuel: A Practical First Step in the Realization of the Hydrogen Economy. *Hydrogen* **2022**, *3*, 84–111

[7] Hodges, J.P.; Geary, W.; Graham, S.; Hooker, P.; Goff, R. *Injecting Hydrogen into the Gas Network—A Literature Search*; HSE Books: Norwich, UK, 2015

[8] https://legislatie.just.ro/Public/DetaliiDocument/272306 Accessed on 01 October 2023

[9] https://www.renar.ro/index.php/en/oec/get_oec_details/43944 Accessed on 01 August 2023

[10] Berrada, A.; Laasmi, M.A. Technical-economic and socio-political assessment of hydrogen production from solar energy. *J. Energy Storage* **2021**, *44*, 103448

[11] Karayela, K.; Javanib, N.; Dincercb, I. Green hydrogen production potential for Turkey with solar energy. *Int. J. Hydrog. Energy* **2022**, *47*, 19354–19364.

[12] European Commission. Available online: https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en

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Revista Română de Inginerie Civilă, Volumul 15 (2024), Numărul 2

Thermal modules for apartments: an efficient solution for heating and domestic hot water

Module termice pentru apartamente: o soluție eficientă pentru încălzire și apă caldă menajeră

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Abstract. *In a residential building, the integration of thermal modules from the design phase can bring multiple benefits in terms of energy efficiency and thermal comfort. The article deals with a brief comparison between the traditional heating system and the decentralized system with apartment thermal modules by making the preparation of the thermal agent for heating and domestic hot water more efficient. The study was carried out following the new nZEB requirements regarding the obligation for all new buildings and those undergoing renovation to ensure a percentage of at least 30% from renewable sourcess.*

Key words: energy efficiency, thermal comfort, domestic hot water, heating

1. Introduction

In a world of climate change and the emphasis on sustainability, apartment owners and developers of residential buildings are starting to look for efficient and environmentally friendly solutions to provide heating and hot water in their homes. This is where the apartment modules come in, innovative technologies that bring with them a series of benefits for modern homes. They not only offer increased energy efficiency, but also individualized control, convenience, and adaptability to renewable energy sources.

In some countries, the thermal module concept is becoming a common way to achieve heating and domestic hot water (DHW) in residential buildings. A number of parameters can be addressed and evaluated to reveal the qualities and performance of the thermal module in relation to traditional concepts for heating and hot water installations. This paper aims to analyze the main parameters regarding the advantages and disadvantages, the quality (comfort) and the performance of the thermal mode, covering the distribution system and the equipment.

2. Component elements

Apartment modules, also known as individual heating plants, represent a significant change from traditional central heating systems. These compact and independent devices are designed to provide home heating and hot water in each apartment individually. Unlike centralized systems that require transporting hot water over long distances, apartment modules work directly in each housing unit, reducing energy losses and associated costs.

The apartment thermal module is completely thermally insulated, compact and easy to operate. Specially designed for two-pipe systems in residential buildings fed from a centralized heating source on the block (boiler or heating system)

The heat exchanger for preparing hot water with a special, innovative design, Micro Plate type, ensures a very good and uniform flow through the exchanger, thus ensuring a uniform and efficient coverage of the entire heat exchange surface, as well as a maximum flow turbulence for a increased heat transfer. The exchanger ensures minimum pressure losses, for minimum energy consumption required for pumping water in the entire system. All these characteristics of the exchanger must be ensured to guarantee a long life, increased reliability and a reduced impact on the environment.

The hydraulic part allows the flow from the primary and secondary circuits to pass through the heat exchanger only when the consumption of hot water is started and blocks the flow immediately after the consumption ceases.

The thermostatic part controls the temperature of domestic hot water. Due to the automatic hydraulic control of the heat exchanger, it is largely protected against limescale and bacteria formation.

Primary circuit:

- differential pressure regulator
- impurities filter
- immersion sheath for temperature sensor, for thermal energy meter
- ball valves.
- bypass loop for keeping the primary agent warm
- radiant floor pumping and mixing group

Secondary circuit:

- the heating circuit must be designed for direct heating
- the multifunctional controller type TPC-M

Domestic hot water is prepared instantly in the heat exchanger on the principle of countercurrent flow.The temperature is precisely regulated, without oscillations compared to the set temperature, the assurance of this regulation being achieved by the multifunctional controller with direct action and differential pressure regulator.

The multifunctional controller ensures an extremely fast operation to protect the exchanger from lime deposits as well as against the formation of bacteria. Also, the pressure regulator within the controller ensures taking over the temperature and flow variations on the primary side to ensure a constant temperature all the time, regardless of the desired domestic hot water flow rate [1].

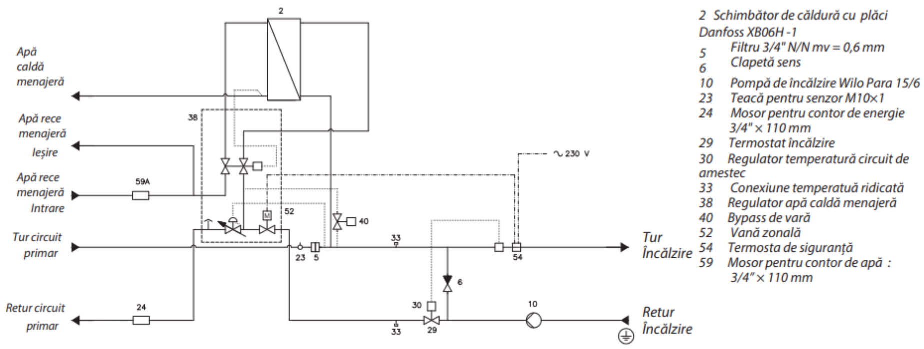

Fig. 1. Functional scheme of the thermal mode

3. Comparison between the traditional system and the one with thermal modules

Reference for the comparison of the traditional system without thermal modules and the one with thermal modules is based on a modern way of making distribution systems with fewer pipes for saving money and energy [2]. Pipeline distribution systems are shown in Fig. 2, where the main differences can be seen in the number of pipes installed. In the traditional system we have a route of 5 pipes (2 for heating, 1 for domestic hot water, 1 for domestic hot water recirculation and 1 for cold water) compared to the system with thermal modules with a route of 3 pipes (2 for heating and 1 for cold water). Since decentralized DHW is prepared in the apartments, the DHW distribution pipes and DHW recirculation on the columns are eliminated.

The system with thermal modules also comes with a major advantage by reducing the technical space by approximately 10-15 m^2, due to the fact that domestic hot water storage will be eliminated [3].

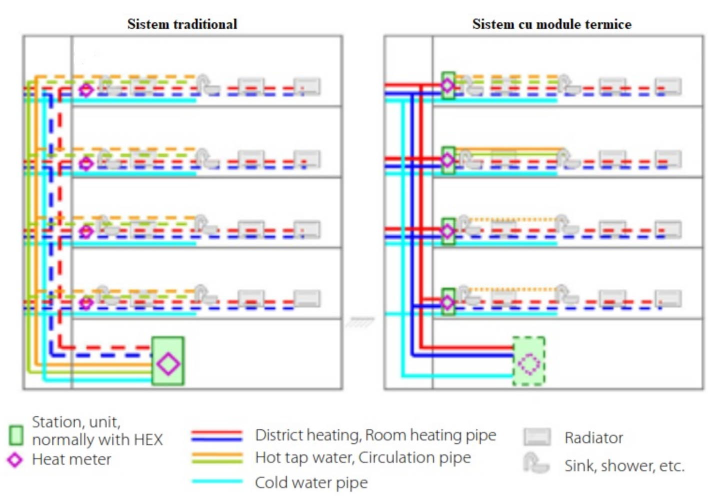

Fig. 5. Column distribution scheme for the traditional system and the system with thermal modules

According to the measurements made in Denmark, in over 2500 homes, an energy saving of 15-30% was obtained compared to the traditional system [4]. The analysis assumed the measurement of all thermal energy deliveries in the apartments. The main contribution to saving energy comes from the distribution of domestic hot water. It is assumed that half of the annual distribution energy loss is net loss (summer time), it does not contribute to heating the building. The winter temperature is identical for the two concepts, because for this period the heating system defines temperature levels.

This economy is also achieved by insulating the pipes, and the Danish standard [5] takes into account the heat loss constants (W/m), depending on the temperatures, the annual operating time and the diameter of the pipe.

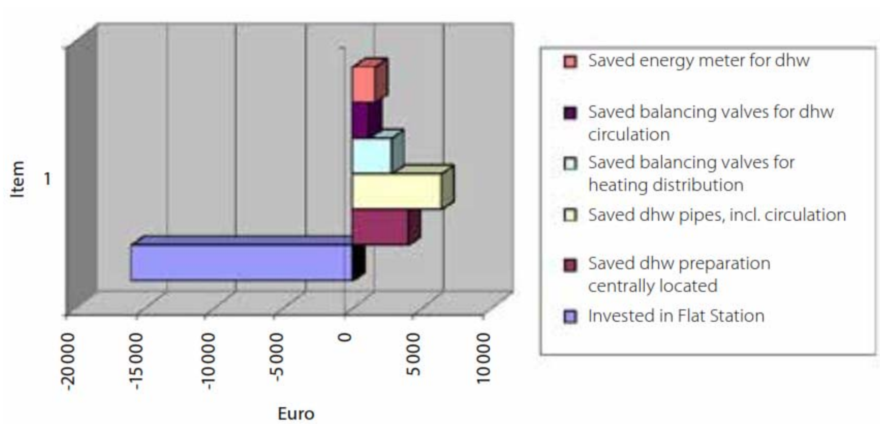

Fig. 3 The investment value of a block with 4 apartments

An example of investment comparing the traditional system with the one with thermal modules included in Fig. 3. This comparison is made of a block in Denmark, built with a basement and 4 levels, consisting of 24 houses, which has been modernized.

4. The advantages and disadvantages of using thermal modules

4.1. The advantages of the owners who use thermal modules

Homeowners who choose to use thermal modules in their homes can benefit from several advantages. Here are some of them:

- *Energy savings and low costs*: Thermal modules are designed to provide heating and hot water on demand, meaning that energy is only used when needed. This can lead to reduced energy consumption and, consequently, heating and hot water costs compared to traditional district heating systems.[6]
- *Individual control*: Owners using thermal modules have individual control over the temperature in their own apartments. This means they can adjust the

temperature according to personal preference, which can increase comfort and energy efficiency.

- *Flexibility in installation*: Thermal modules can be installed near each apartment or housing unit, which means that there is no need for long pipes or complex distribution systems. This makes installation and maintenance easier and less expensive.
- *Reliability*: Typically, thermal modules are reliable and durable equipment that require less maintenance compared to other types of central heating systems.
- *Adaptability*: Thermal modules can be used with different energy sources, such as gas, electricity or renewable energy sources, depending on the preferences and local conditions of the owners.
- Reduction of heat loss: Being installed near housing units, thermal modules can reduce heat loss in long pipes and distribution systems, which contributes to energy efficiency.
- Instant hot water: Thermal modules can provide hot water instantly, meaning there is no need to wait for the water to heat up, which adds a level of comfort.
- Reduction of dependence on fossil fuels: If renewable energy sources are used to power the thermal modules, owners can reduce dependence on fossil fuels and help protect the environment.onclusion.

4.2. Disadvantages of owners who use thermal modules

Here are some of the potential disadvantages of thermal modules, which owners should consider when deciding to use them:

- *Higher initial costs*: The initial cost of purchasing and installing thermal modules can be higher compared to traditional district heating systems. This can be a barrier for some owners.
- *Individual responsibility for maintenance*: Owners using thermal modules are usually responsible for the maintenance and repairs of their individual equipment. This can add additional costs and responsibilities.
- *Variability in quality*: The quality of thermal modules can vary by manufacturer and model. It is important to choose high-quality equipment to avoid problems and costs related to frequent repairs.
- *Electricity consumption*: Some thermal modules use electricity to operate, which can increase your electricity bills. However, there are thermal modules that work with renewable energy sources or with energy efficiency, which can reduce electricity consumption.
- *Vulnerability to individual failures*: If a thermal module fails in an apartment or housing unit, this can affect the comfort and hot water supply for that apartment specifically, while the rest of the building remains unaffected.
- *Limitations in cooling systems*: Thermal modules are usually designed for heating and hot water preparation, not for cooling. Owners who also want to

integrate cooling into the thermal modules may require additional solutions, such as the installation of additional cooling units.

- *Potential incompatibilities with existing systems*: In some cases, the installation of thermal modules may require modifications or upgrades to the existing building infrastructure, which may add additional costs.

5. Conclusions

In conclusion, apartment thermal modules represent a modern and efficient solution for heating and hot water in contemporary homes. They bring numerous advantages, from energy savings to individualized control and reduced environmental impact. With ever-developing technologies and increasing environmental concerns, the adoption of apartment modules can significantly contribute to achieving sustainability goals and increasing the quality of life in housing.

- *Outstanding energy efficiency*: Apartment thermal modules are an energy efficient solution for heating and hot water in homes. They provide heat and hot water on demand, eliminating energy losses associated with long-distance transport, resulting in significant energy savings and reduced costs.
- *Individual control*: One of the major advantages of apartment modules is individual control over temperature. Each owner can adjust the temperature according to their preferences, ensuring that they feel comfortable in their own home.
- *Flexibility in energy source*: Modules can run on different energy sources, including natural gas, electricity or renewable sources, giving owners options adapted to the environment and available resources.
- *Reducing dependence on fossil fuels*: By using renewable energy sources, the modules contribute to reducing the carbon footprint and protecting the environment.
- *Additional convenience and comfort*: The modules provide hot water instantly, eliminating the wait for the water to heat up, which adds a level of comfort to users.
- *Simplification of maintenance*: As the modules are installed in each individual apartment, maintenance and repairs become simpler and more cost-effective compared to centralized systems.
- *Potential for sustainability*: Integrating modules with renewable energy sources and building automation systems paves the way for a more sustainable and comfortable future for homes

References

[1] http://www.danfoss.com/Products/Categories/Group/HE/District-Heating-Substations/Substations-Direct-Heating/Flat-Stations. Accesat 28.09.2023 ora 14:10
[2] Comparing Distributions Systems in Blocks of Flats, by Kristjansson H.,SDDE 2009, Slovenia

[3] Cost considerations on Storage Tank versus Heat exchanger for htw preparation, by Thorsen J.E., The 10th International Symposium on District Heating and Cooling 2006
[4] The Installation of Meters Leads to Permanent Changes in Consumer Behaviour, by Gullev L., Poulsen M., "News from DBDH", #3/2006
[5] DS 452, Code of practise for thermal insulation of technical service and supply systems in buildings, 2. revision, Dansk Standard, 1999
[6] A new Low-Temperature District Heating System for Low-Energy Buildings, by Olsen P.K., Lambertsen H., Hummelshøj R., Bøhm B., Christiansen C.H., Svendsen S., Larsen C.T., Worm J., The 11th International Symposium on District Heating and Cooling 2008

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Comparative analysis on the energy use of different refrigeration systems for supermarket application

Analiză comparativă a utilizării energiei diferitelor sisteme frigorifice pentru aplicații în supermarketuri

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Rezumat. *Această lucrare investighează oportunitatea utilizării căldurii recuperarte de la sistemele frigorifice, din supermarket-urile de capacitate medie, pentru climatizare. Consumul de energie electrică pentru sistemul de aer condiționat și frigul tehnologic din supermarket-uri reprezintă o pondere importantă din consumul total de energie electrică din acestea. Eficiența energetică a supermarket-urilor poate fi îmbunătățită prin optimizarea proiectării componentelor, recuperarea caldurii din sistemele frigorifice, adoptarea de soluții tehnologice inovatoare, integrarea sistemului HVAC de temperatură medie și joasă cu instalațiile frigorifice. Acest studiu are ca scop evaluarea consumului de energie a unui sistem frigorific pentru frig tehnologic si climatizare care utilizează agentul frigorific R410A. Sunt analizate 2 sisteme frigorifice:*
- Solutie clasică: instalație pentru frig tehnologic ZEAS+ instalație de climatizare cu VRV;
- Soluția propusă: instalatie pentru frig tehnologic cu recuperare de căldură pentru instalația de climatizare CONVENIPACK
Soluțiile investigate permit o economie anuală de energie mai mare de 17% față de soluția de bază pentru climatele avute în vedere.

Cuvinte cheie: eficienta energetica, recuperare caldura, sistem frigorific comercial

Abstract. *This paper investigates the opportunity of utilizing the heat recovery from refrigeration systems in supermarkets with medium requirement capacity for air conditioning. The electricity consumption for air conditioning and refrigerated cases in medium supermarkets represents an important share of the total electricity consumption. The energy efficiency of supermarkets can be improved by optimizing components design, recovering energy, adopting innovative technology solutions, integrating the HVAC system with medium temperature and low-temperature refrigeration plants. This study is aimed at investigating the energy consumption of a refrigeration system for commercial refrigeration and air conditioning that uses the refrigerant R410A. Two refrigeration systems are analyzed:*
- traditional solution: system for commercial refrigeration using equipment type ZEAS + air conditioning equipment type VRV IV;

- new proposed solution: system for commercial refrigeration with heat recovery using equipment type Conveni-Pack for air conditioning.
The results obtain shape the potential for improving energy efficiency and environmental impact over traditional system in climates from Romania. The investigated solutions allow an annual energy saving higher than 17% to the baseline solution for the considered climates.

Key words: *energy efficiency, heat recovery, commercial refrigeration system*

1. Introduction

The European Green Deal sets in stone our green transition ambitions, including our climate targets towards net-zero by 2050 [1, 2, 3].
Conventional supermarket refrigeration systems are responsible for considerable CO_2 emissions due to the direct effect of refrigerant leakage and the indirect effect of high energy consumption [4].

Conventional supermarket refrigeration systems are also responsible for considerable CO_2 emissions due to the direct effect of refrigerant leakage and the indirect effect of high energy consumption. The new systems not only operate at higher efficiency, but also reduce refrigerant charge and refrigerant leakage. The IEA [4] reports that 3-5% of total electricity consumption in industrialized countries stems from supermarkets. Conventional supermarket refrigeration systems are also responsible for considerable greenhouse gases emissions. These emissions are due to the direct effect of refrigerant leakage and indirect CO_2 emissions related to the energy consumed [5, 6, 7]**.**

The EU's Eco-design Directive 2009/125/EC is designed to encourage the market to use more efficient products. It also helps manufacturers to agree a better definition of efficiency for remote condensing units. Since 01/07/2016 refrigeration units also need to comply to this system of minimum efficiency requirements. In this catalogue the seasonal data is marked with the seasonal flower [8]. The new F-gas regulation comes into effect on January 1st 2015 and requires a phased reduction of HFCs from 2015 to 2030 based on a quota system, and with bans on high GWP refrigerants in certain sectors.

In the past refrigeration and deep freeze systems have traditionally been separated from air conditioning and heating systems. Changing the initial project from store with a new solution combines them into an all-in-one-system which covers all your refrigeration and climate control needs.

Heat rejected from the refrigeration system can be recovered and used for supermarket heating. Using the equipment with 100% recovery of heat from the refrigeration showcases and evaporators inside store generated the energy efficiency and cost is saving. The total heat is used by the indoor air conditioning units to heat the retail space and delivery comfort thermal without additional cost.
Space cooling and refrigeration equipment are responsible for numerous environmental impacts, particularly with respect to overall contribution to GHG

emissions (Greenhouse Gas) [9]. Overall GHG emission for the commercial refrigeration systems have a highest value for the refrigerant leakage rate 35,8% and for energy consumption is 64.2%. [10, 11, 12].

2. The ambient conditions

A supermarket operating in Iasi was considered for this analysis. The refrigeration system simulated in this study is a classical R410A vapor compression refrigeration system type ZEAS without heat recovery. Average temperature variation Considering the latest year under observation (2022) in Iasi (Figure 1) implies that the refrigeration systems perform well in January/February and the load is extreme during July/August.

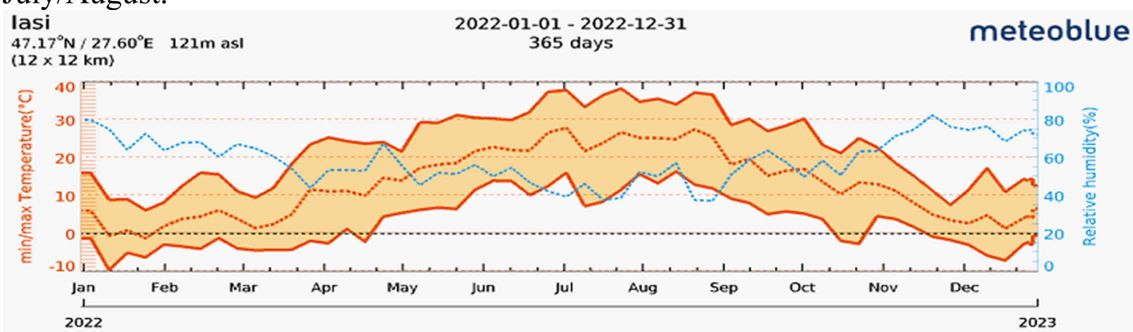

Fig. 1. Outside temperature for one year (2022) in Iasi [13].

The use of indicators or indexes such as heating degree days (HDD) and cooling degree days (CDD) can contribute to the correct interpretation of energy consumption for cooling and heating buildings [14]. Considered the annual report from EUROSTAT in the five years ago for Iasi the highest HDD values was in 2021 (3078.36) and the highest CDD values was in 2022 (128.26), table 1. This means that in 2022 was more days for cooling than in the past and this depends on ambient temperature during the cold and warm season. The evolution on the CDD has an upward trend with an increase of approx. 22.9% compared to the year 2021.

Tabel 1

Cooling and heating degree days – annual data.

TIME	2018	2019	2020	2021	2022
CDD					
Romania	84.67	123.62	96.36	137.94	145.61
Iasi	58.71	114.20	100.98	104.40	128.26
HDD					
Romania	2,748.49	2,568.23	2,665.91	2,993.60	2,751.22
Iasi	2,951.93	2,622.68	2,566.66	3,078.36	2,762.26

Weather-related energy consumption for heating and cooling in supermarket indicators such as HDD and CDD can contribute to monitoring energy demand for cooling and heating under climate change. Considering the data provided table 1 the decrease in energy consumption will be observed in this paper, where the authors propose a new technical solution.

2.1. The traditional solution

The system is assumed to be located in Iasi, therefore, weather data for this location has been used and the store opened during 24h. There are two levels of temperature for display cabinets and cold storage rooms: medium and low temperatures (MT and LT) for chilled and frozen food. The initial description of the supermarket is presented in table 2, the data are based on an audit energetically. In the summer-time, the air – conditioning set point is 26°C, while in the winter time the set point for ambient heating is 20°C, the relative humidity is set to 50%.

Table 2

Initial description of the store (commercial refrigeration)

Supermarket area	400 m^2
Power for display cabinet (MT)	12.9 kW
Power for display cabinet (LT)	2.14 kW
Power for cold room (MT)	3 kW
Power for freezer room (LT)	3 kW

The cooling load of the refrigerated display fixtures depends on space air temperature and relative humidity. Space heating is required in the sales area, offices and back rooms for customer and personnel thermal comfort with distribution system, delivery temperature 30-50°C, using eco-friendly options.

The space heating demand was calculated using the SR EN 12831-1:2017 Q_{SH} = 15kW and the cooling demand is Q_{SC} = 9kW using the national regulation I5:2022. Refrigeration solution for medium and low temperature applications with variable load conditions and high energy efficiency requirements uses the equipment type ZEAS condensing units. The scheme of refrigerant circuit is presented in figure 2. With the booster it is possible to have medium and low temperature cooling in a single system, reducing the piping requirements from 4 to 2 pipes compared with conventional system. In tables 3 and 4 is presented the report with list of equipment, piping diagram (figure 3) design using Xpress software refrigeration professionals for ZEAS condensing units and VRV IV.

Table 3

List of equipment

Model	Quantity	Description
LREQ12BY1	1	MT condensing unit
LCBKQ3AV19	2	Booster unit
Evaporator	1	Freezing room
Evaporator	1	Cooling room
Freezer display cabinet	1	Freezing
Refrigerated display cabinet	6	Cooling

Tabel 2

The cooling load for equipment

	Model	$t_{evaporation}$ [°C]	Q_{load} [kW]	$Q_{evaporator}$ [kW]
Sistem_1	LREQ12BY1 MT condensing unit		25.10	24.80
POS IV.1	Freezer display cabinet	-34	2.14	3.40
Freezing room	Evaporator	-28	3.00	4.53
POS III.5	Refrigerated display cabinet	-7	2.15	2.15
POS III.3		-7	2.15	2.15
POS III.4		-7	2.15	2.15
POS III.2		-7	2.15	2.15
POS III.1		-7	2.15	2.15
POS II.1		-7	2.15	2.15
Cooling room	Evaporator	-6	3.00	3.00

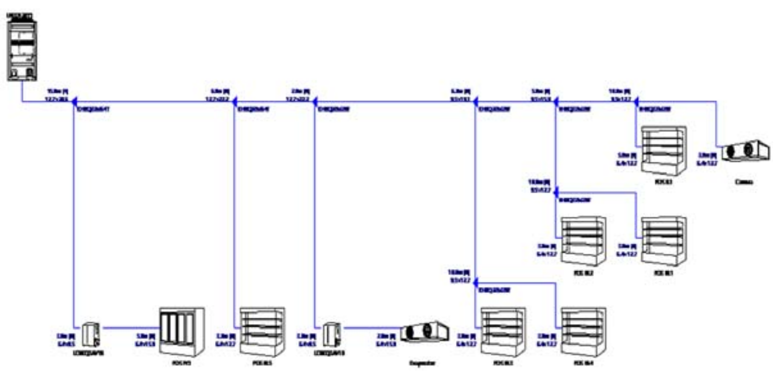

Fig. 2. Scheme of technological cooling refrigerant for traditional system (ZEAS).

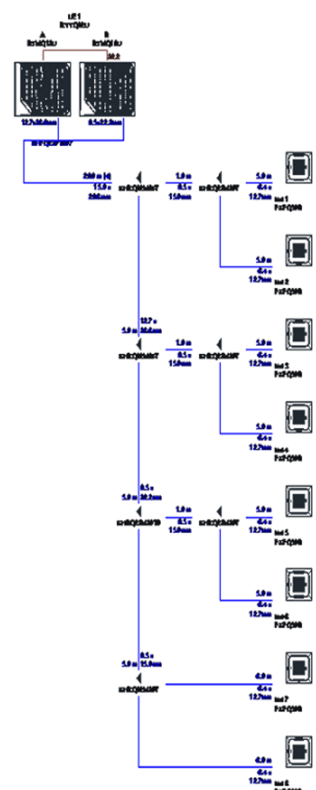

Fig. 3. The piping diagrams for air conditioning system (traditional system).

For air conditioning system (AC) it's using the VRV IV technologies system type RYYQ-U in combination with internal round flow cassette type FXFQB with technical specification in table 5. This AC system is reversible this means can have the possibility to heating and cooling on during the year.

Tabel 5

Air conditioning system components

Model	Quantity
RYMQ12U (VRV IV Continuous Heating)	1
RYMQ10U (VRV IV Continuous Heating)	1
FXFQ50B - Round Flow Round flow cassette (IU)	8

2.2. The new propose solution

Supermarkets present a unique space conditioning challenge because of the interaction between the Heating, Ventilation and Air Conditioning (HVAC) system and the refrigerated display cases. The display cases provide significant sensible cooling and increase the latent load fraction on the HVAC system. The energy consumption of the HVAC systems in retail food stores can be between 15% and 25% of the total energy consumption depending on the system design, geographic location and controls.

The heat recovered from the refrigerated and freezer display cabinets can be used to provide heating for the supermarket. In spring or autumn, heat recovered from freezer display cabinets can be used to heat the store and the excess is discharged to the environmental. In winter, heat is extracted from the outside air and combined with the heat recovered from the freezer cabinets and used to heat the internal air for achieve thermal comfort. Heat recovery from the refrigeration system is one of the most efficient ways to increase the total efficiency of the refrigeration system and to decrease the heating purchase demand. This solution AC system introduced in this paper is based to integration of AC into refrigeration system, a recent technology, solution more efficiency than the old system. In tables 6 and 7 is presented the report with list of equipment, piping diagram (figure 4 and 5) design using Xpress software refrigeration professionals for Conveni-Pack with heat recovery [15, 16].

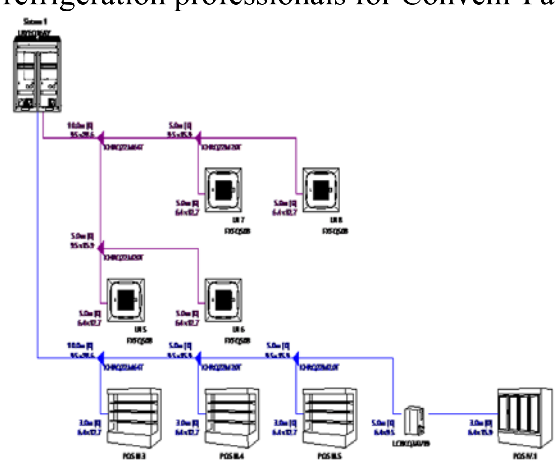

Fig. 4. The piping solution for new system-part 1.

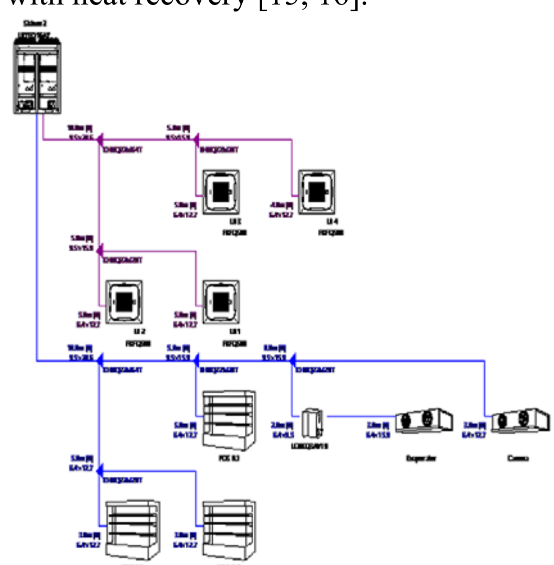

Fig. 5. The piping solution for new system–part 2.

Tabel 6

List of equipment

Model equipment	Quantity	Description
LRYEQ16AY	2	Heat pump condensing unit
FXFQ50B	8	FXFQ-B - Round Flow - Round flow cassette (IU)
LCBKQ3AV19	2	Booster unit
Evaporator	1	Freezing room
Evaporator	1	Cooling room
Freezer display cabinet	1	Freezing
Refrigerated display cabinet	6	Cooling

For new system part 1 the following values results: the heating capacity delivered to the shop is 25.2 kW and the cooling capacity actually delivered to the shop is 13.52 kW after equipment selection. The maximum available heat recovery capacity is 19 kW, enough to cover the heat requirement.

Tabel 7

The cooling load for equipment – new system part 1+2

Model equipment	$t_{evaporation}$ [°C] Set point		Q_{load} [kW]		$Q_{evaporator}$ [kW]	
	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2
LRYEQ16AY Heat pump condensing unit	-	-	13.99	11.10	19.58	19.58
FXFQ50B	-	-	-	-	6.30	6.30
FXFQ50B	-	-	-	-	6.30	6.30
FXFQ50B	-	-	-	-	6.30	6.30
FXFQ50B	-	-	-	-	6.30	6.30
Freezer display cabinet	-	-34	-	3.00	-	3.44
Refrigerated display cabinet	-	-7	-	2.15	-	2.15
Refrigerated display cabinet	-	-7	-	2.15	-	2.15
Refrigerated display cabinet	-	-7	-	2.15	-	2.15
Evaporator	-28.0	-	3.00	-	4.51	-
Refrigerated display cabinet	-7	-	2.15	-	2.15	-
Refrigerated display cabinet	-7	-	2.15	-	2.15	-
Refrigerated display cabinet	-7	-	2.15	-	2.15	-
Evaporator	-6	-	3.00	-	3.00	-

For new system part 2 the following values results: the heating capacity delivered by the indoor units is 25.2 kW and the cooling capacity actually delivered by the indoor units is 22.95 kW after equipment selection. The maximum available heat recovery capacity is 14.57 kW, enough to cover the heat requirement.

3. Methodology

The comparison between the two commercial refrigeration systems refers to the energy efficiency. Each systems was selected from DAIKIN's products. The efficiencies of each system were mapped and simultaneously compared to one another, showing how each system performs in varying climatic conditions throughout the year taking into account the input data. This level of modeling using software Pack Calculation Pro allowed for the simulation of monthly consume of electricity in each system but and power usage throughout the year to ensure cooling capacity demand. The total monthly consumes electricity for systems include compressors, fans from evaporators and condensers. For the systems analyzed, their parameters are input into Pack Calculation Pro. This included type of refrigerant system, refrigerant, type of compressor, location, schedule for supermarket, type condenser and the cooling capacities.

A complete comparison of the energy usage and energy efficiency of the two systems was collected. The baseline environment weather data there is in library of software, information allow for an accurate analysis of system performance over the course of a year. When run during a year, the peak loads for each solution were calculated and exported in graph. The program allowed to simulate when cooling systems would run based on outdoor conditions, but with the constant maintenance of the evaporation temperature. If a parameter needed to be changed, it could update all systems at once.

4. Result for energy efficiency

Improving the energy efficiency of space cooling and refrigeration systems can mitigate energy related emissions, which is particularly important given the high proportion of total emissions associated with electricity consumption of cooling services. The electricity consumed for the compressors was calculated using CoolPack, Excel spreadsheet and Pack Calculation Pro programs [17, 18].

The monthly electrical energy consumption results are present here are for 300square meter store. Figures 6 and 7 show the annual energy consumption for the initial and the proposed solution analyzed in this paper. One can see that the trend of the energy consumption is the same for one year. In figure 8 is presented a comparison between both solutions analyzed here. The high energy consumption in the initial solution with 17.8% then new solution results from experimental data.

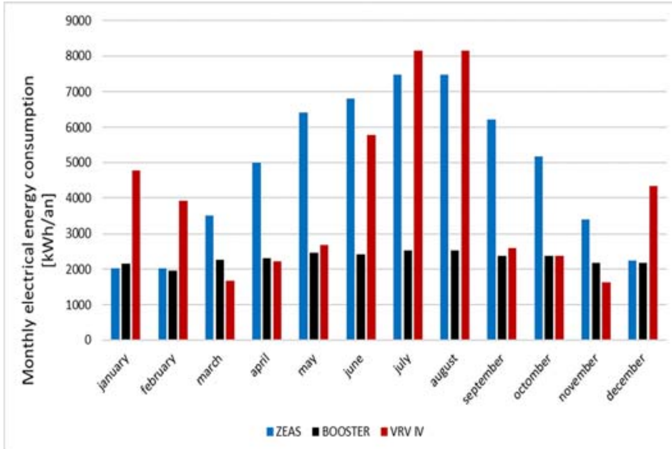

Fig. 6. The monthly electrical energy comsumption for traditional system.

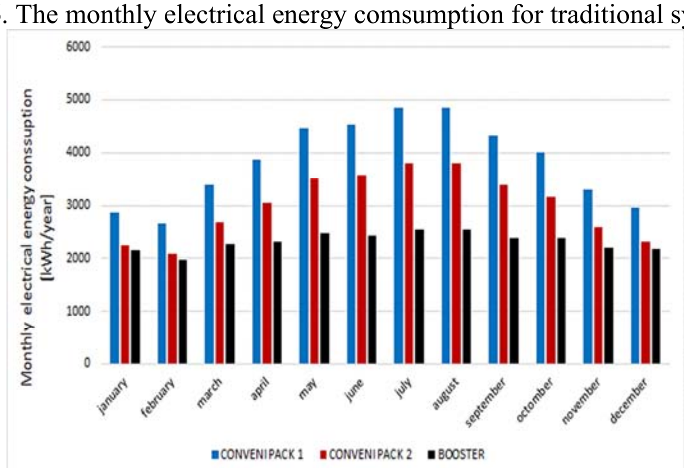

Fig. 7. The monthly electrical energy comsumption for new system.

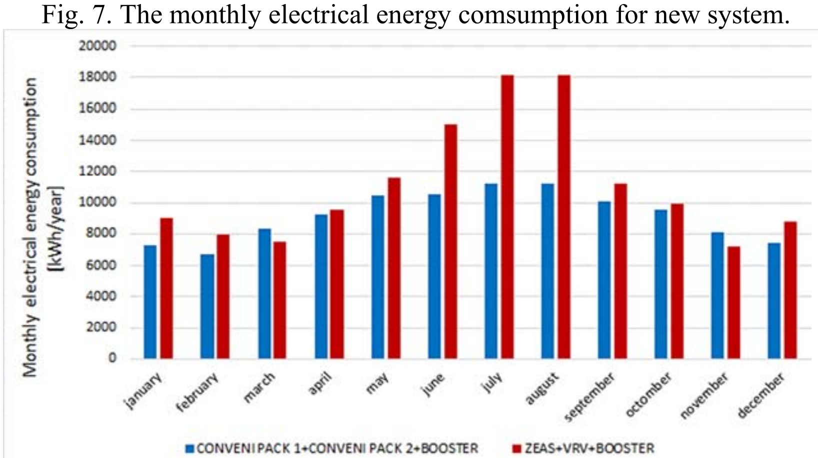

Fig. 8. The monthly electrical energy comsumption traditional system vs. new solution.

5. Discussion

Overall, there is a reduction in the total energy use for refrigeration system and air conditioning. In the last decades, an important demand of electric energy is observed worldwide to respond to the industry's development. Large food stores as supermarkets are energy-intensive buildings. The energy saving of the proposed solutions is 17.8% in the case of initial solution. During the wintertime and summertime, the integration between the refrigeration units and the air conditioning system, resulting from recovery heat of the condensation heat, leads a very low energy consumption for Conveni-Pack. The refrigerant charge is lower with 44% for new solution, dropping from 40.79 kg to 22.8 kg. Cold production is responsible for 17% of the world energy consumption. Refrigeration is necessary to maintain cold temperature in display cabinets or cold storage rooms to preserve food. This study aims to assess energy performances of two refrigeration system architectures in a supermarket: without and with heat recovery for air conditioning system.

6. Conclusions

In this paper, a comparative study for two different commercial refrigeration system configurations is performed for medium-size supermarket, with refrigerant system for commercial refrigeration and air conditioning/heating system. The evaluation was carried out for Iasi weather file, where maximal monthly temperature is equal 36°C and CDD increasing with 22.9% for 2022 then 2021. The baseline model that was used is a real case study supermarket which has as a reference refrigeration system. The model is validated against real monitoring data for both energy and environmental conditions. From the alternative refrigeration systems configurations considered, the Conveni Pack system with heat recovery was found to be the more energy efficient system not only in terms of energy performance but in terms of refrigerant charge. This system concluded to a 17.8 % reduction in the total annual energy use of the case study store. Calculations show that the proposed solution offer a benefit in term of energy efficiency over the reference traditional solution. The new systems can limit the refrigerant charge, drop with 44% and annual leak rate decrease in close connection and can also save energy and provide better operational control. The low charge of the new system it has an impact on the footprint environmental.

As a final remark, the new solution should be proposed also for different climatic zone from Romania with consideration of their significant energy consumption. The future step is to continue this study for other towns with different outdoor conditions and also to calculate the total emissions CO_{2eq} over the lifetime of the system.

The technological advancements described above can produce important benefits as regards energy costs and the environment.

References

[1] https://commission.europa.eu/document/41514677-9598-4d89-a572-abe21cb037f4_en
[2] https://www.eea.europa.eu/help/glossary/eea-glossary/eco-design
[3] https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/eu-legislation-control-f-gases_en
[4] IIR 37th Informatory Note of Refrigeration Technologies, Advantages in supermarket refrigeration, March 2018.

[5] IEA, Annex 26: Advanced supermarket/heat recovery systems – Final Report **Volume 1, 2,** 74 pages, Executive Summary + Country report 2003.
Available on: <https://info.ornl.gov/sites/publications/Files/Pub57707.pdf> (Accessed 15/02/2018)
[6] *GE YT., TASSOU SA*., ,, Performance and optimal design of supermarket refrigeration systems with supermarket model "SuperSim", Part I: Model description and validation, *International Journal of Refrigeration.* 2011, **vol 34**, pages 527-539. Avalable on: <http://bit.ly/RIF-GeTassou> (Accessed 14/02/2018).
[7] *TASSOU SA., GE YT., HADAWEY A., et al*., Energy consumption and conservation in food retailing, Applied Thermal Engineering, **vol. 31**, pages 147-156, 2011.
[8] *DEVIN E., MICHINEAU T., MOULINS F., et al.,* Etude sur le confinement des fluides frigorigènes*,* Rapport Final, N de convention: 1481C0048. Paris, Cemafroid, IRSTEA and ADEME, 81 pages, 2015.
[9] https://www.daikin.eu/en_us/product-group/refrigeration/zeas.html
[10]. *Miller SA, Keoleian GA*., Framework for analyzing transformative technologies in life cycle assessment. Environ. Sci. Technol*.* 49(5):3067–75, 2015.
[11]. *Makhnatch P,Mota-Babiloni A, Rogstam J, Khodabandeh R.*, "Retrofit of lower GWP alternative R449A into an existing R404A indirect supermarket refrigeration system" **Int. J. Refrig. 76**:184–92, 2017.
[12]. *Yabin Dong, Marney Coleman, Shelie A. Miller* - Annual Review of Environment and Resources*,* Greenhouse Gas Emissions from Air Conditioning and Refrigeration Service Expansion in Developing Countries, 2021. 46:59–83, https://doi.org/10.1146/annurev-environ-012220-034103.
[13] https://www.meteoblue.com/en/weather/historyclimate/weatherarchive/iasi_romania_675810?fcstlength=1y&year=2022&month=4
[14] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Heating_and_cooling_degree_days_-_statistics#Heating_and_cooling_degree_days_by_EU_Member_State
[15] https://www.daikin.eu/en_us/product-group/refrigeration/conveni-pack.html
[16] Service manual CONVENI PACK – DAIKIN.
[17] softeware Pack Calculation Pro - v5.3.7, Feb.2023.
[18] software CoolPack – v1.5.0.

External temperatures BIN intervals evaluation procedure proposal

Propunerea procedurii de evaluare a intervalelor BIN temperaturi exterioare

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Abstract. *The external temperatures BINs are a couple of components, the external air temperature, t_e, representative of a relatively small range of values and the duration of appearance of these external temperature values within each month of a year. The establishment of these couples assumed an analysis of the behavior of the outside temperature throughout the whole year but also during each month of the year and also of daily oscillations within each month. It resulted as a representative number of 5 BINs per month and in this hypothesis the monthly BINs were established. It turned out that the locality in Romania has a distinct importance in the effective establishment of the BINs, which is why they are different depending on: locality, month of the year, average monthly outdoor temperature and the amplitude of the daily oscillation of the outdoor temperature. The external temperature BINs are useful in energy analysis studies on buildings for utilities such as space heating and the preparation of daily hot water, an example being the implementation of an air-water or air-air heat pumps.*

Key-words*: external temperature BIN, energy analisis studies*

1. Introduction

The establishment of BINs of outdoor air temperatures represents a sorting of outdoor air temperatures depending on their values and the duration of their occurrence. The BIN is therefore a two elements component - the value of the external temperature and the duration of its occurrence. The outside temperature we are referring to is an average value within a range of several degrees. The BINs are established separately for each month of the year, thus resulting in a detailed identification of the cold and warm periods within each month of the year. An important utility of this type of sorting can be in the case of evaluating the energy performances of the heating systems of buildings and the preparation of hot water related to them. The use of non-conventional heating and hot water preparation systems that include air-water or air-air heat pumps was also considered.

2. Procedure description

It should be mentioned from the beginning that the establishment of the BINs is based on 3 data strings, namely the number of days in each month, n_{zl}, the monthly average outdoor temperatures, t_{em}, and the monthly average amplitudes of the diurnal oscillation of the outdoor temperature, a_{te}. Based on these 3 types of data, the outside temperature field is evaluated for each month of the year, establishing the weight of high, medium and low temperatures. More precisely, the monthly outdoor temperature field was divided into 5 zones: the area of extreme high outdoor temperatures, the area of moderate high outdoor temperatures, the area of monthly average outdoor temperatures, the area of moderately low outdoor temperatures and the area of extremely low outdoor temperatures. More, the difference between the maximum external temperature of the month and the minimum outdoor temperature of the month was divided into 5 equal intervals. For each of these 5 intervals of the monthly outdoor temperature fields, the average representative value of t_{emz} and the duration in hours related to the respective zone, n_{hz}, were established. In this way, each of the months of the year contains 5 BINs (pairs of values: (t_{emz}, n_{hz})). The sum of the number of hours within the 5 monthly BINs is equal to the number of hours related to the respective month. The zonal average outdoor temperatures within a month, considered with the weight corresponding to the number of zonal hours, led by summation to the monthly monthly average outdoor temperature, t_{emp}. Given that two of the monthly data series: the monthly average outdoor temperatures, t_{em} and the monthly average amplitudes of the diurnal oscillation of the outdoor temperatures, a_{te}, are different from locality to locality, the set of annual BINs also differs being locally dependent. These being the principles of establishing the monthly BINs, an automatic calculation program that evaluates the 60 annual BINs for 3-5 representative cities in Romania, such as, for example: Resita, Slatina, Zalau, Bistrita and Sfantu Gheorghe.

3. Software tool:

The table of BINs presented in fig. 1 below, refers to the city of Sfantu Gheorghe and, as can be seen, contains a first group of 4 columns, the first of which are the names of the months and the last 3 on the right, Entry Data, referring to the number of monthly days, N_{zile}, at the average monthly external temperature, t_{em}, and at the average amplitudes of daily external temperatures, a_{te}. Using the evaluation tool requires selecting the locality from the list of localities accessible from the cell to the right of the Location cell. The series of monthly average outdoor temperatures, tem, and the average amplitude of the diurnal outdoor temperature oscillation are automatically loaded.

Sfantu Gheorghe Z5				Rezultate - BIN-uri (cupluri - temperatura exterioara- durata, - teB-NoreB)									
	Input Data			BIN 1		BIN 2		BIN 3		BIN 4		BIN 5	
Month	Nzile	tem	amp	teB1	NoreB1	teB2	NoreB2	teB3	NoreB3	teB4	NoreB4	teB5	NoreB5
Jan	31	-0.27	3.48	-3.3749	59.52	-1.82084	178.56	-0.26677	267.84	1.287288	178.56	2.84135	59.52
Feb	28	-0.86	4.80	-5.90219	53.76	-3.37923	161.28	-0.85628	241.92	1.666674	161.28	4.189628	53.76
Mar	31	4.57	6.32	-2.18146	59.52	1.195434	178.56	4.572325	267.84	7.949217	178.56	11.32611	59.52
Apr	30	7.64	5.93	1.244291	57.6	4.440722	172.8	7.637153	259.2	10.83358	172.8	14.03001	57.6
May	31	12.80	6.57	6.048251	59.52	9.423776	178.56	12.7993	267.84	16.17483	178.56	19.55035	59.52
Jun	30	15.13	6.37	8.95511	57.6	12.04021	172.8	15.12531	259.2	18.2104	172.8	21.2955	57.6
Jul	31	18.16	6.12	12.4762	59.52	15.3179	178.56	18.15961	267.84	21.00132	178.56	23.84302	59.52
Aug	31	17.27	6.56	10.96796	59.52	14.12079	178.56	17.27362	267.84	20.42644	178.56	23.57927	59.52
Sept	30	12.87	5.69	6.522825	57.6	9.69644	172.8	12.87006	259.2	16.04367	172.8	19.21729	57.6
Oct	31	8.28	5.76	1.851914	59.52	5.065688	178.56	8.279462	267.84	11.49324	178.56	14.70701	59.52
Nov	30	3.77	5.00	-2.15068	57.6	0.808237	172.8	3.767153	259.2	6.726069	172.8	9.684984	57.6
Dec	31	-1.30	3.25	-5.12138	59.52	-3.21254	178.56	-1.3037	267.84	0.605145	178.56	2.513987	59.52
Montg	Nzile	tem	amp	teB1	NoreB1	teB2	NoreB2	teB3	NoreB3	teB4	NoreB4	teB5	NoreB5

Fig.1

The following 10 columns refer to the resulting BINs and for each month separately, on the corresponding line of the month, the values of the 5 BINs composed of (t_{eB1}, N_{oreB1})...(t_{eB5}, N_{oreB5}) are observed. Fig. 2 presents an annual global picture of the outdoor temperature values related to the BINs for each month of the year. You can see the high values of the group of 5 external temperatures of the BINs in the summer months and the low values of the winter months, and also within each month the differences between the external temperatures of the 5 BINs.

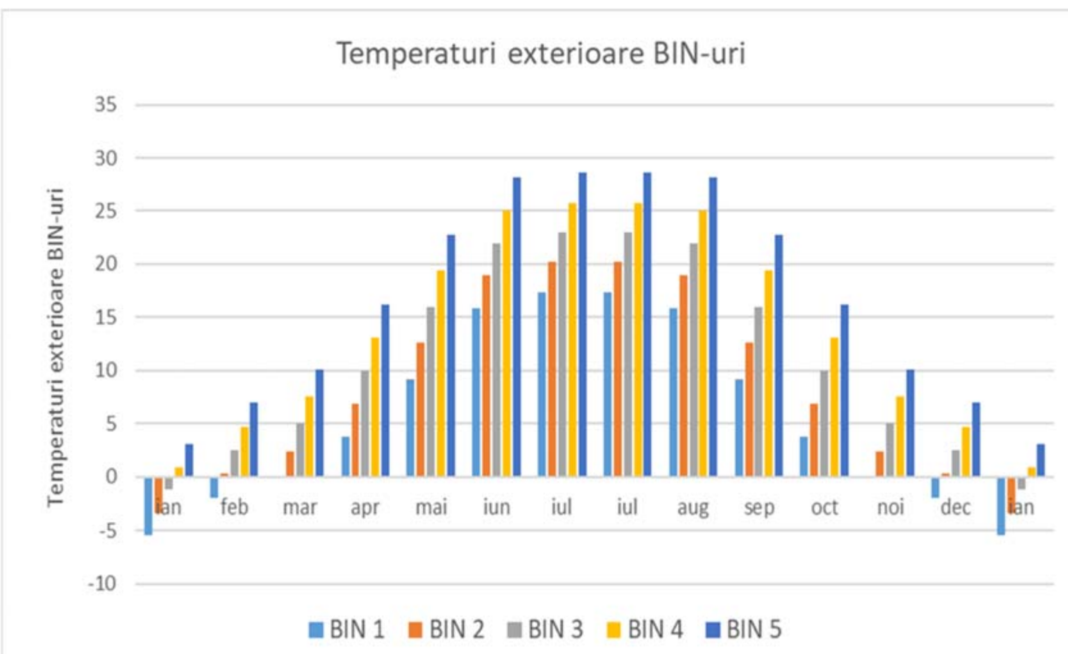

Fig. 2

In fig. 3 graphically shows the number of hours related to the 60 BINs in a year. It is observed that the number of hours related to extreme monthly BINs is approx. 50 hours, the number of hours related to moderate BINs approx. 180 hours, and the number of hours related to median BINs approx. 260 hours, which means a total of approx. 720 hours per month.

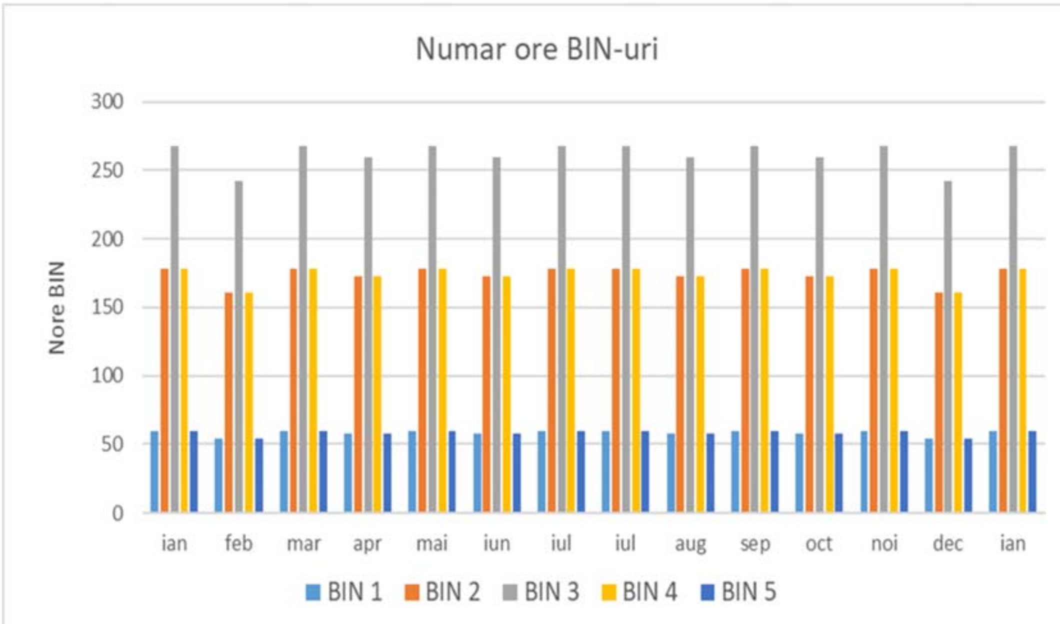

Fig.3

4. Discussions

The tool described in the work, contains only 5 representative cities from Romania: Resita, Slatina, Zalau, Bistrita and Sfantu Gheorghe. The average monthly outdoor temperatures can be extracted from SR 4838/2014 for a number of over 200 localities in Romania. Regarding the values of the amplitudes of the diurnal external temperature oscillations, a corresponding processing of a database that the authors own was undertaken. The external temperature BINs are useful in several types of works aimed at the energetics of buildings for several types of utilities. The integration of heat pumps in the non-conventional source system represents only one of the possible uses of BINs for outdoor temperatures.

Referance

1. Revised Mc001 - Methodology for energy certification of buildings from 2022;
2. The standard of degree days - SR 4839 from 2014

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.

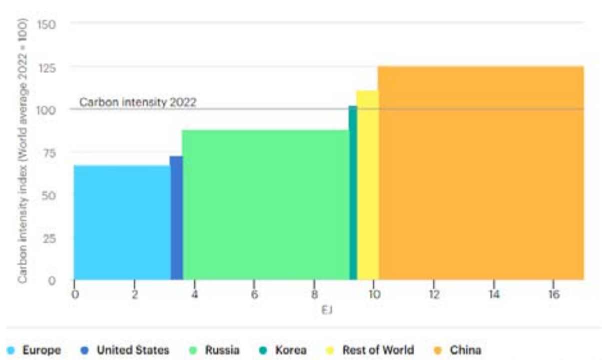


Fig. 1. CO_2 emission intensity index for heat production in centralized systems by region in 2022. [6]

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].

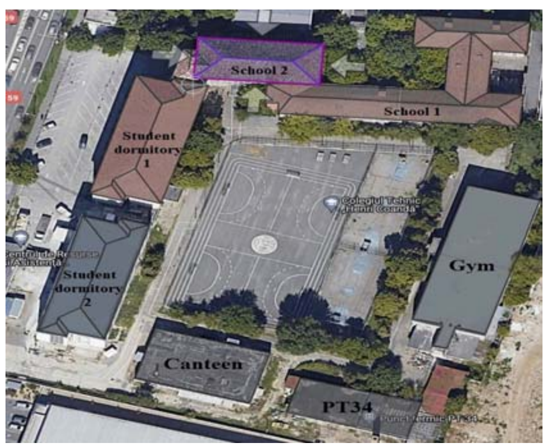


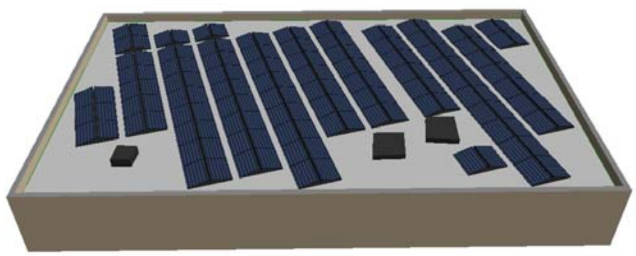
Fig. 1. Situation plan of the studied buildings [7]

Table 1

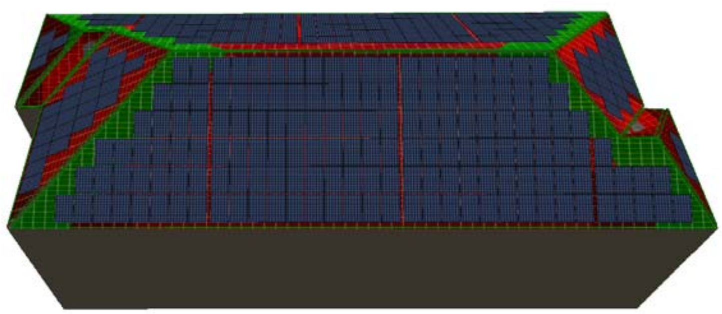
The input data of the studied buildings

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**

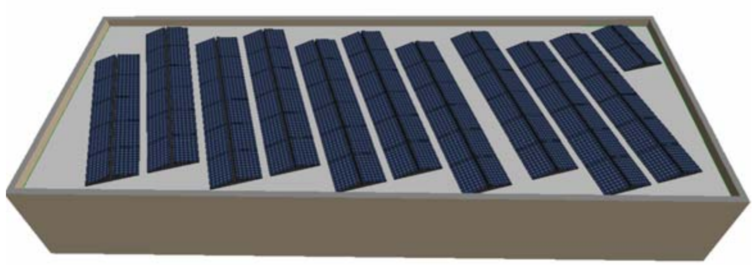
This study proposes the integration of RES of the electricity produced with the help of photovoltaic panels mounted on the roofs of buildings presented in the situation plan. The electricity produced is used in the first phase to ensure their own electricity consumption. In Fig. 2 you can see the location 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.



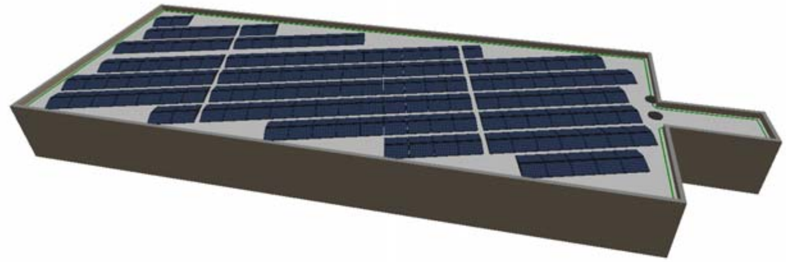
a) Canteen



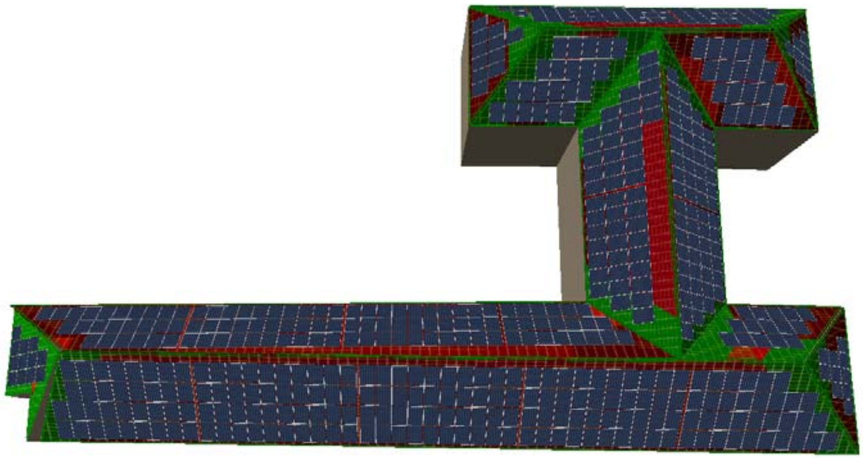
b) Student dormitory 1 and 2



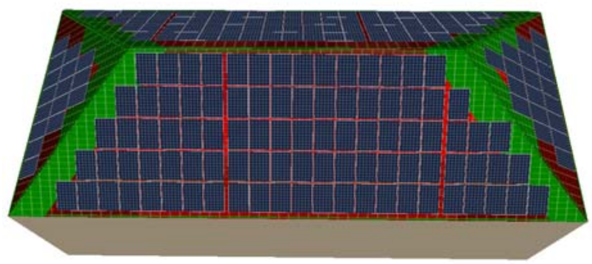
c) PT34



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	-

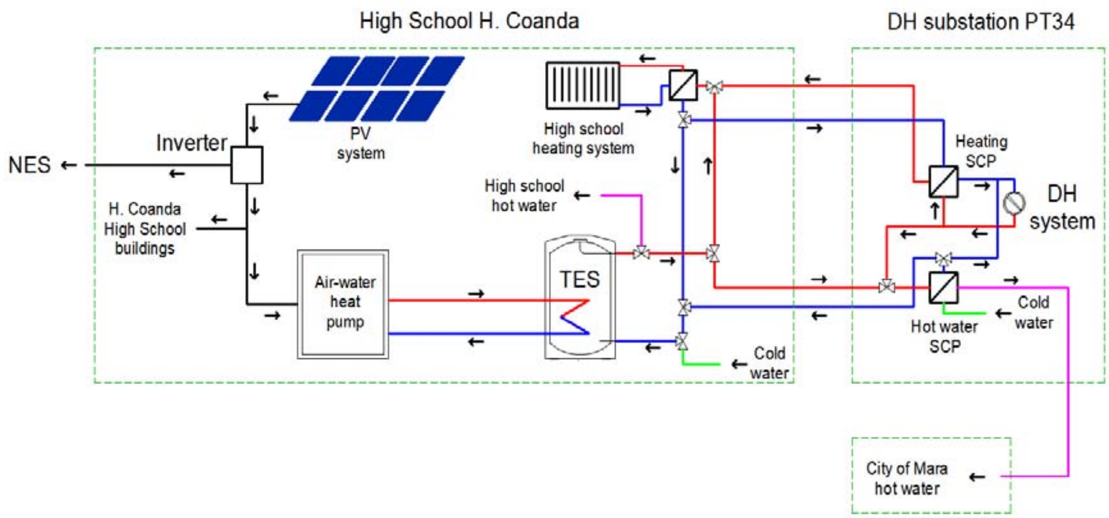


Fig. 3. Functional scheme of the thermal and electrical installation

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.

References

[1] E. Guelpa, V. Verda, Thermal energy storage in district heating and cooling systems: A review, Applied Energy, vol. 252, 2019.

[2] L. Brand, A. Calvén, J. Englund, H. Landersjö, P. Lauenburg, Smart district heating networks – A simulation study of prosumers' impact on technical parameters in distribution networks, in Applied Energy, vol. 129, pp 39-48, 15 Sept 2014.

[3] H. Li, J. Hou, T. Hong, N. Nord, Distinguish between the economic optimal and lowest distribution temperatures for heat-prosumer-based district heating systems with short-term thermal energy storage, in Energy, vol. 248, 1 Jun 2022.

[4] L. Brange, J. Englund, P. Lauenburg, Prosumers in district heating networks – A Swedish case study, in Applied Energy, vol. 164, pp 492–500, 2016.

[5] F. Ochs, M. Magni, G. Dermentzis, Integration of Heat Pumps in Buildings and District Heating Systems - Evaluation on a Building and Energy System Level, Energies, vol. 15, no.11, 2022.

[6] IEA, District Heating. 2021, Available online: https://www.iea.org/reports/district-heating, accessed on 28 September 2022.

[7] ***, PolySun SPTX Constructor software from Vela Solaris

[8] D. Muntean, A. Tokar, Reducing operating costs in district heating systems by optimizing functional parameters. Comparative studies, in 14th International Conference on Hydroinformatics, vol. 1136, 2022.

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Research regarding the eco-efficiency of an air-water heat pump

Cercetări privind eco-eficiența unei pompe de căldură aer-apă

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Rezumat. *Studiul privind sistemul frigorific din această lucrare a fost realizat la Universitatea Tehnică de Construcții București (U.T.C.B) - Complexul Laboratoare Colentina. Tema aleasă își propune să contribuie la baza teoretică și la cercetarea practică în ceea ce privește dezvoltarea și utilizarea agenților frigorifici ecologici.*
În ultimii zece ani, s-au făcut numeroase cercetări în domeniul agenților frigorifici alternativi ecologici, la nivel internațional, ținând cont de restricțiile severe ale legislației prevăzute de lege: Protocolul de la Kyoto, Regulamentul (UE) 517/2014, Acordul de la Paris / 2015, Amendamentul Kigali / 2016 / Protocolul de la Montreal. În acest sens, cercetarea are în vedere implementarea legislației UE în domeniul sistemelor frigorifice, pompelor de căldură și aerului condiționat.

Cuvinte cheie: *Pompa de căldura, agent frigorific ecologic, COP/EER*

Abstract. *The study on refrigeration systems in this paper was made at the Technical University of Civil Engineering of Bucharest (U.T.C.B) - Colentina Laboratories Complex. The chosen topic is aiming to contribute to the theoretical basis and practical research in terms of development and use of ecological refrigerants.*
In the last ten years, a lot of research has been done in the field of ecological alternative refrigerants , at international level, taking into consideration the severe legislation restrictions stipulated by law: Kyoto Protocol, Regulation (EU) 517/2014, Paris Agreement / 2015, Kigali Amendment / 2016 / Montreal Protocol. In respect of this, the research, considers the implementation of EU legislation in the field of refrigeration systems, heat pumps and air conditioning.

Key words: Heat Pump, Ecological Refrigerant, COP/EER

1. Introduction

The ecological refrigerants proposed in this scientific work are chemicals obtained by mixing in different proportions of various current ecological refrigerants with one or more natural or synthetic substances that have zero values of ozone depletion potential (ODP) and low global warming potential (GWP).

In the last ten years, a lot of research has been done in the field of ecological alternative refrigerants, at international level, taking into consideration the severe legislation restrictions stipulated by law: Kyoto Protocol, Regulation (EU) 517/2014, Paris Agreement / 2015, Kigali Amendment / 2016 / Montreal Protocol. In respect of this, the research, considers the implementation of EU legislation in the field of refrigeration systems, heat pumps and air conditioning.

The results of the simulations from this paper performed with the help of the high-performance program EES (Engineering Equation Solver) for the refrigerants: R134a, R1234yf, MV3T, MV3TN in the case of an air-water heat pump (Figure 1).

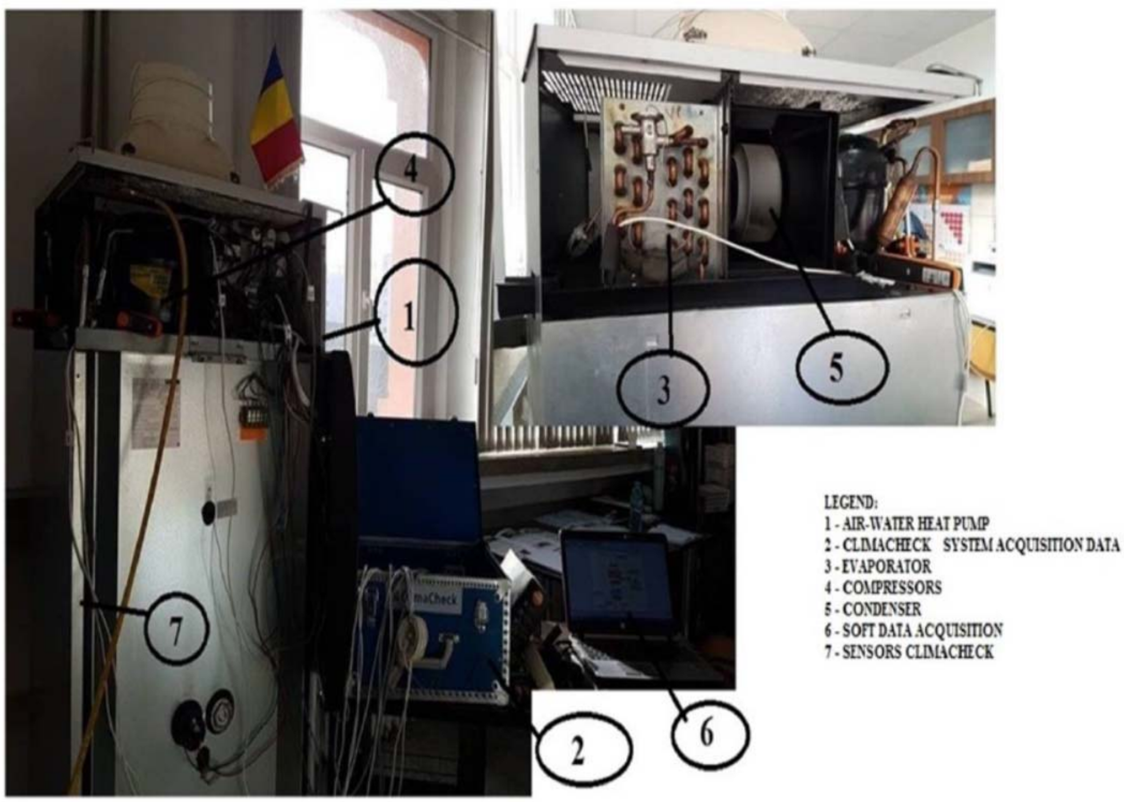


Fig. 1. Air water heat pump experimental stand

2. Ecological And Energy Efficiency Analysis

The ecological refrigerants proposed in this scientific work are chemicals obtained by mixing in different proportions of various current ecological refrigerants with one or more natural or synthetic substances that have zero values of ozone depletion potential (ODP) and low global warming potential (GWP).

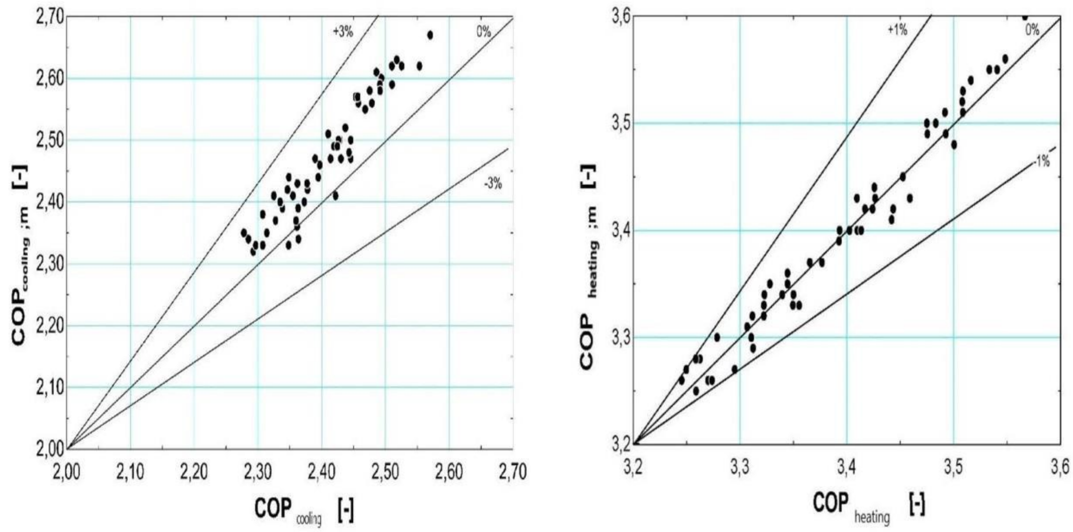
The results of the simulations from this paper performed with the help of the high-performance program EES (Engineering Equation Solver) for the refrigerants: R134a, R1234yf, MV3T, MV3TN in the case of an air-water heat pump.

The comparative study (Figure 2) of these facilities followed the coefficient of performance (COP/EER). Also the TEWI factor (Total Equivalent Warming Impact – in respect with EN 378-1 as it was shown in the Table).

Table 1

The theoretical results for factor TEWI of the ecological alternatives

Refrigerant	R134a	R1234yf	MV3T	MV3TN
GWP [-]	1430	4	717	560
L [kg/s]	0,0624	0,0580	0,0601	0,0596
n [an]	15	15	15	15
m [kg]	0,78	0,725	0,751	0,745
α_{rec} [-]	0,8	0,8	0,8	0,8
E_{annual} [kWh /an]	1153,62	1153,62	1153,62	1153,62
β [kg/kWh of CO2]	0,28985	0,28985	0,28985	0,28985
GWPx Lx n	1338,48	3,48	646,40	500,75
GWP x m(1 - α_{rec})	223,08	0,58	107,73	83,46
n x E_{annual} x β	5015,65	5015,65	5015,65	5015,65
TEWI [kg CO_2]	6577,21	5019,71	5769,78	5599,86
TEWI [tons of CO_2]	6,577	5,019	5,769	5,599



Calculated vs. measured cooling COP and heating COP of the best MV3T refrigerant used in the experimental stand AIR-WATER HP

Fig. 2. Coefficient of performance (COP/EER)

3. Concluzion

In conclusion, from an ecological point of view, the refrigerant must be chosen so that according to the regulations of the current legislation, it has zero ODP and GWP low and TEWI as small as possible.

In the Figure 2 it can be observed the validation of the calculated vs. measured cooling and heating COP of the best MV3T refrigerant used in the experimental stand AIR-WATER HP.

References

[1] Mioara Vinceriuc, „Research regarding the contribution of refrigeration, air conditioning and heat pump systems to global warming", PhD Thesis, Technical University of Civil Engineering of Bucharest, 2021

[2] Kyoto Protocol to The United Nations Framework Convention on ClimateChange , United Nations Frame Work Convention on Climate Change, 1997

[3] Regulation (EU) no 517/2014 of the European Parliament and of the council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014R0517

[4] The Montreal Protocol on Substances that Deplete the Ozone Layer (2000), Secretariat for the Vienna Convention for the Protection of the Ozone Layer & the Montreal Protocol on Substances that Deplete the Ozone Layer.

[5] Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer Kigali, 15 October 2016

[6] *** https://earthobservatory.nasa.gov/world-of-change/Ozone/show-all.
[7] *** https://svs.gsfc.nasa.gov/31201
[8] Calm, J. C., G. C. Hourahan, A. Vonsild, D. Clodic, and D. Colbourne - 2014 Report of the refrigeration, air conditioning, and heat pumps technical options committee, Ch. 2: Refrigerants. United Nations Environment Programme (UNEP) Ozone Secretariat, Nairobi, ozone.unep.org/en/assessment-panels/technology-and-economic-assessment-panel, 2015
[9] Ţârlea G. M., Vinceriuc M., Zabet I., Ţârlea A., R513A AND R1234yf ALTERNATIVE REPLACEMENT OF R134a REFRIGERANT, autori publicata la a XVII-a Conferinta nationala de Termotehnica, cu participare internationala, noiembrie 2016, Universitatea Transilvania Brasov, categoria B+.
[10] Ţârlea G. M., Vinceriuc M. Alternative ecologice ale agentului frigorific R134a, Revista de Instalatii , I.S.S.N. 2457 – 7456, AIIR 2018, Editura Matrix Rom; NR 4/2018;
[11] Ţârlea G. M., Vinceriuc M., Zabet I., Ţârlea A., Water-Air Heat Pump Ecological and Energy - Efficiency Study Case SME Cluj 2017
[12] The National Institute of Standards and Technology (NIST) - Refprop version 8.0, USA, 2007
[13] EN378- Refrigerating systems and heat pumps - safety and environmental requirements, 2016, European standard
[14] Vinceriuc M., Ţârlea G , Tarlea A., Air-Water-Heat Pump with low GWP refrigerant, Paper presented at CLIMA 2019 - the REHVA HVAC World Congres and publish in Romanian Journal of Civil edited by MATRIX ROM Volumul 10 (2019), Numărul 3, ISSN 2068-3987, pp. 296-298, Proceedings of CLIMA 2019;
[15] Mioara Vinceriuc, Gratiela TARLEA- Mathematical And Experimental MV3TN Heat Pump Validation, 2nd Conference of the UTCB Doctoral School, 25th of October 2019, Hydrotechnics Faculty, https://sd.utcb.ro/dsc-2019/programme/
[16] Air-Water Heat Pump Modelling, Gratiela Tarlea, Mioara Vinceriuc, Ion Zabet- 50-International Hvac&R Congress And Exhibition (KGH), 2019, Belgrad; [17] ASHRAE – HVAC Systems & Equipment, 2020
[18] AHRI - Specification for fluorocarbon refrigerants. Standard 700-2011. Air-Conditioning, Heating, and Refrigeration Institute, Arlington, VA, 2011

Energy storage a necessity for a low-carbon energy system

Stocarea energiei este o necesitate pentru un sistem energetic cu emisii scăzute de carbon

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Abstract. *As in 1973, the energy issue occupies the first page of the agenda of energy experts, social planners, politicians and, last but not least, consumers. The impact of renewable energy sources (wind and solar) on the energy infrastructure was analysed, while aiming to reduce carbon footprints. Demographic growth, urbanization, the targets imposed by Net Zero Emissions tend towards the massive forcing of energy towards renewable energy conversion and storage systems.*

Key words: storage, the oil crisis, greenhouse gases, renewable energy sources,

1. Introduction

The large amounts of greenhouse gases emitted into the atmosphere led to the need for the transition to a clean energy for which climate objectives were set worldwide. The Net Zero Emissions by 2050 scenario proposes the path towards the massive integration of renewable energy sources (RES) and considerable increase in total electricity demand [1].

The main sources considered are solar photovoltaic and wind, but the hourly and seasonal variability of their SRE energy production make it necessary to approach energy storage to ensure the maintenance of grid stability, flexibility, and reliability in the face of increasing demand. In a market economy where the low selling price of electricity can lead to the disconnection of certain production capacities, maintaining the stability of electric power systems puts pressure on energy specialists.

With all the advantages of modern computing technologies and/or artificial intelligence, the following of the load curve in economic conditions is achieved with a certain inertia.

In the "new oil crisis" the stability of the electrical energy systems is threatened on the one hand by the "big plantations", on the other hand by the domestic consumers who have "tasted" energy independence and installed photovoltaic systems with powers greater than their own needs (prosumers).

In order to maintain the stability of the NES, the national energy system coordinator (NESC) has the possibility of disconnection/connection, in case of necessity of the large production capacities, but has no lever of intervention on the prosumers.

Due to the underdevelopment of electricity distribution networks that make it difficult for the development of the built environment, during the day when electricity consumption is reduced, the line voltage increases. In these conditions, the protection systems of the inverters disconnect, the prosumers not being able to capitalize on their surplus of produced energy, generating dissatisfaction on their part and at the same time a challenge for specialists looking for solutions to integrate RES into the energy mix.

The large targets for RES integration, until 2050, in the EU energy system require the flexibility of national power systems [2]

The technical-economic benefits that RES energy conversion systems provide cannot be fully exploited without the existence of conventional systems capable of ensuring the stable operation of the NES. Maximizing the use of RES conversion systems implies the possibility of using the electricity produced when the weather conditions are favourable [3-6].

Therefore, energy storage is a crucial technology for the energy system of the future without greenhouse gas emissions (GHG) [2].

The article reviews energy storage systems and proposes, based on data provided in real time by Transelectrica, an analysis of electricity storage both in terms of energy balance and especially in terms of GHG reduction [7].

2. Electrical energy storage systems

Economic growth and the quality of life, demographic growth and urbanization force the electrical energy systems to adapt on the fly in order to be able to meet the growing demand for energy. We are practically witnessing the integration in NES of some hybrid conversion systems (conventional and renewable), whose stable operation is conditioned by the stochastic nature of renewable energy sources. Solar and wind systems play an important role in the energy mix, whose operation at accepted technical parameters is determined by weather conditions.

The need to store electricity, to ensure continuity of supply, has been known since the beginning of the 20th century. To ensure electricity during the night (when the power plants were closed) lead accumulators were used [5, 8].

Continuity in supply and safety in operation, adaptation to climate change is not possible without the integration of storage solutions. Storage must be looked at from several perspectives, but especially from the point of view of energy mixes.

Improperly used, the term electrical energy storage apart from storage in high-capacity capacitors and magnetic superconductors, storage involves the conversion of electrical energy into other forms of energy, Fig. 1 [5]. The return of stored electrical energy in such systems is influenced by the efficiency of the conversion system chosen.

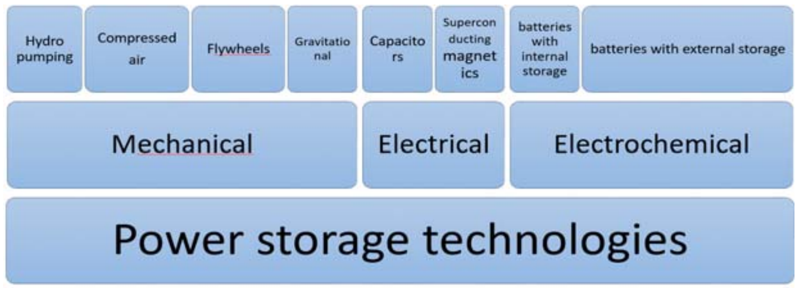

Fig. 1. Power storage technologies [5]

Part of the hybrid energy systems (HRES) that integrate renewable energy resources, the capacity of the storage systems is dimensioned according to the type of fluctuations in the energy system as a result of the RES integration, the storage time and last but not least the lifetime and the size of the storage system storage.

Fig. 2 shows the electrical energy storage systems ordered by power density (kW/kg), energy density (kWh/kg) that it can store, but also according to the time in which the storage system can return in SEN electrical energy stored [5].

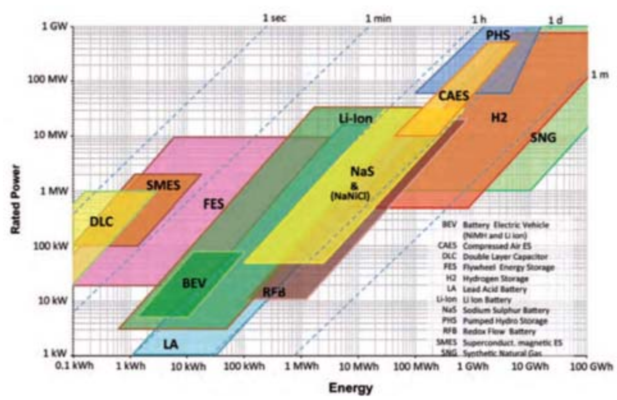

Fig. 2. Graph of the return of energy stored in storage systems

The choice of storage technologies must be analyzed both from an economic, constructive point of view, of the function of returning electricity, of occupied land surfaces, but especially after an analysis of the impact on the environment.

Currently, with all the obstruction from environmental activists, the most widely used storage technology is pumped storage (SEHP). Presenting the advantage of seasonal storage, these systems can compensate for day-night consumption, compensate for production gaps in the RES, and ensure a maximum of one hour, frequency regulation in the power system (SE) [9, 10].

Although our country has an important hydrographic network, with important hydroelectric energy production capacities, no SEHP has been realized until now [9].

Energy storage in compressed air (SEAC), in containers but especially in underground caverns [11], due to the fact that it can transfer large amounts of energy at high flow rates is proposed by Stal Laval and is recommended for the integration of RES energy production systems (especially wind and solar energy) [9].

In order to maintain voltage and frequency (ensuring the quality of electricity), without backup generators, energy can be stored in inertial (inertial) systems - SEV. These systems can provide a fast response of charge-discharge cycles [9].

Gravitational storage systems (SESGs) can store large amounts of potential energy, for long periods of time, and return this energy as needed by the SE.

Electrochemical storage Fig. 3, refers to storage in batteries, capacitors/supercapacitors and fuel cells, [9,12], represents one of the most common solutions with applicability, from simple to complex. They can be used from powering a trivial light source to balancing intermittent energy production from RES [9].

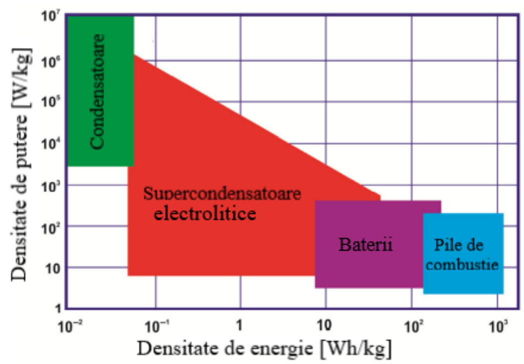

Fig. 3. Electrochemical storage systems [11]

A possibility of realizing a storage system is presented in Fig. 4 [12].

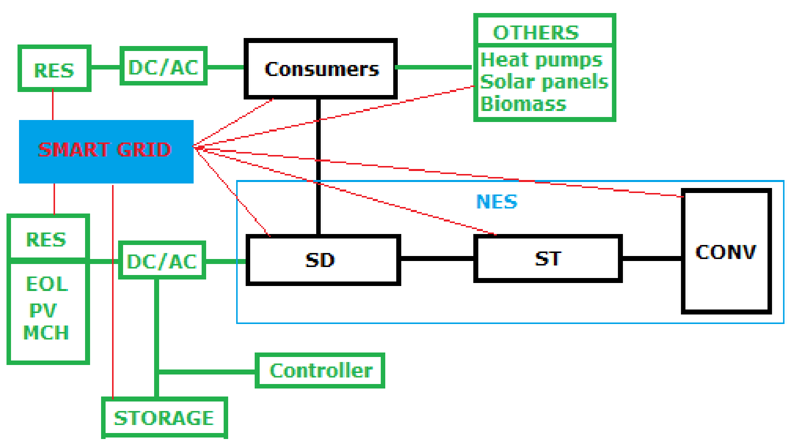

Fig. 4. Storage energy system proposed [13].
RES - Renewable energy sources; EOL - Wind energy; PV - Photovoltaic energy, MCH – Microhydro plants; AC - Alternative current; DC - Continuous current; SD - Distribution system; ST - Transportation system; CONV - Conventional energy source; NES - National energy system

3. Analysis of the national energy system during the period 01.06.2023 - 30.08.2023

Based on the data provided by Transelectrica S.A., available online, the load curve and electricity production (wind, solar, hydroelectric) during the period 01.06.2023- 30.08.2023 was represented, Fig. 5, 6, 7.

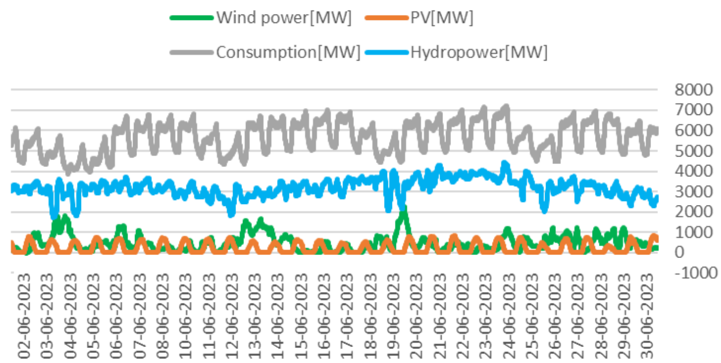

Fig. 5. The variation of consumption and production of electricity from.RES June 2023

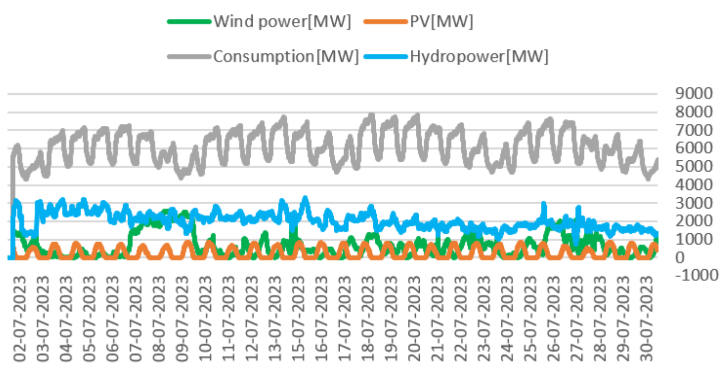

Fig. 6. The variation of consumption and production of electricity from.RES July 2023

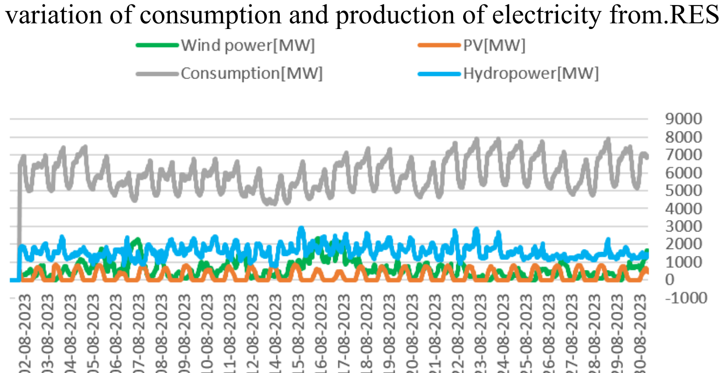

Fig. 7. The variation of consumption and production of electricity from.RES August 2023

The variation of the balance of energy during the period 01.06.2023- 30.08.2023 was drawn, Fig. 8, 9, 10.

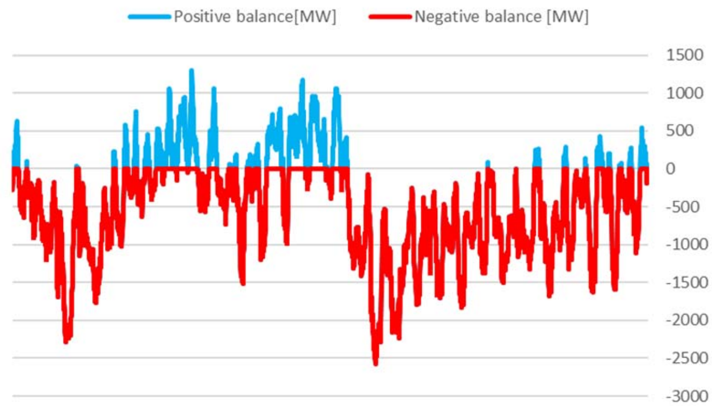

Fig. 8. Balance of energy. June 2023

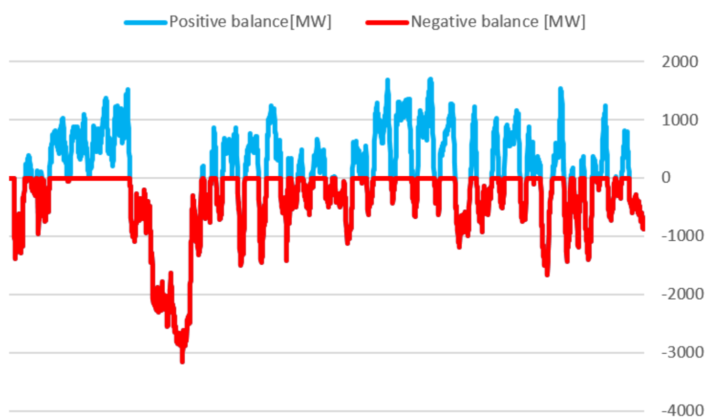

Fig. 9. Balance of energy. July 2023

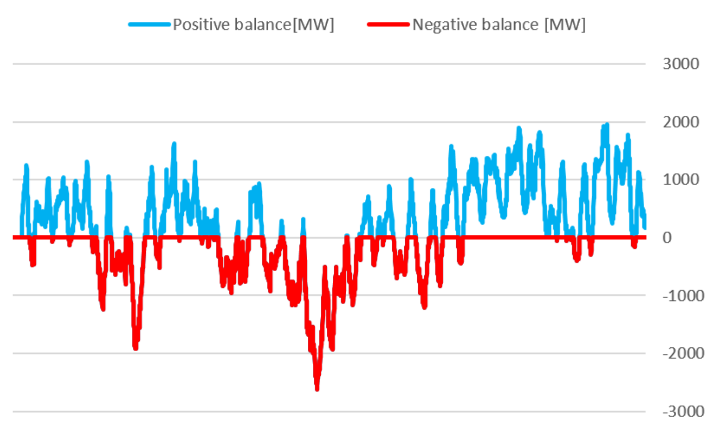

Fig. 10. Balance of energy. August 2023

The production of electricity using fossil fuels has been graphed, Fig. 11, 12, 13.

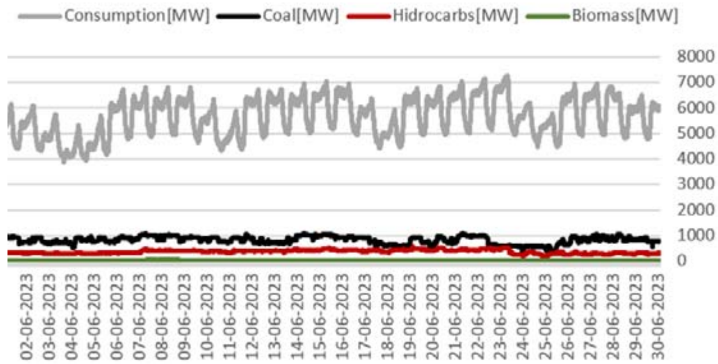

Fig. 11. Variation of electricity consumption and production from conventional energy sources. June 2023

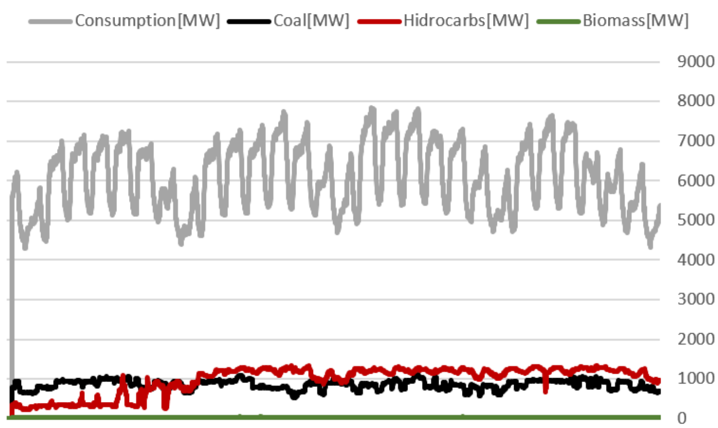

Fig. 12. Variation of electricity consumption and production from conventional energy sources. July 2023

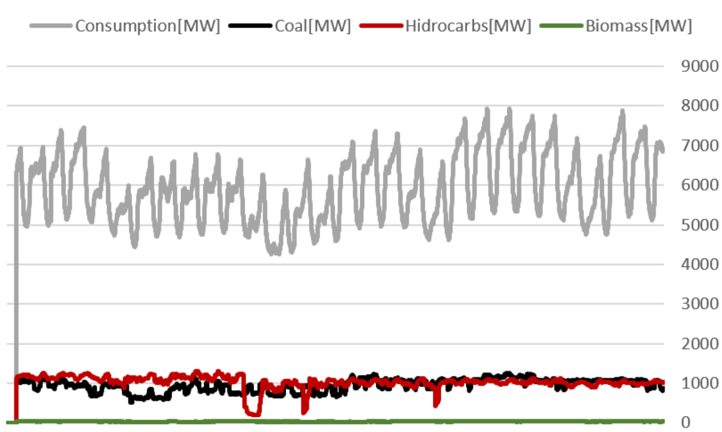

Fig. 13. Variation of electricity consumption and production from conventional energy sources. August 2023

The amount of greenhouse gases as a result of the production of electricity using fossil fuels has been graphed, Fig. 14, 15, 16.

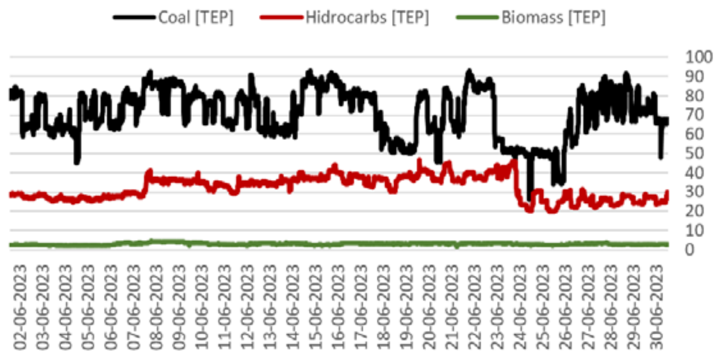

Fig. 14. Greenhouse gas emissions expressed in TEP. June 2023

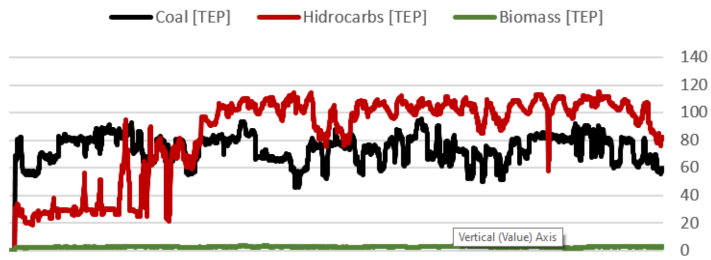

Fig. 15. Greenhouse gas emissions expressed in TEP. July 2023

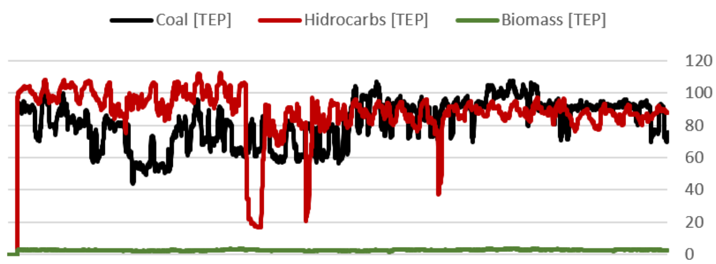

Fig. 16. Greenhouse gas emissions expressed in TEP. August 2023

The amount of greenhouse gases produced by electricity production systems using fossil fuels was calculated, after the adoption of energy storage solutions.

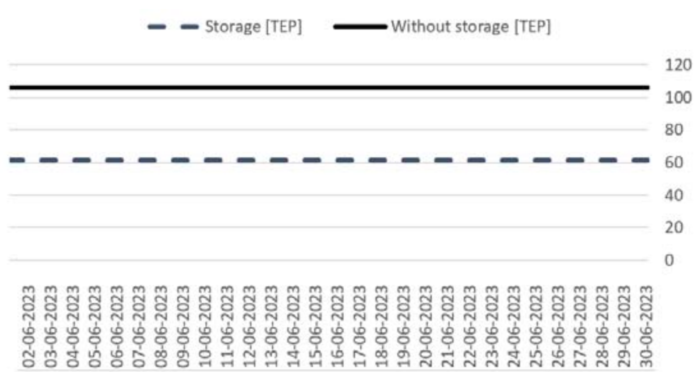

Fig. 17. Average greenhouse gas emissions expressed in TEP. June 2023

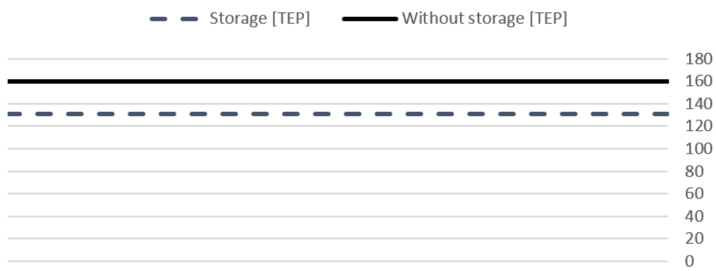

Fig. 18. Average greenhouse gas emissions expressed in TEP. July 2023

Fig. 19. Average greenhouse gas emissions expressed in TEP. July 2023

4. Conclusions

Starting from the national energy mix [7]., the paper analyzes the energy balance, emphasizing the need to reduce electricity consumption by modernizing and making the existing equipment more efficient.

Analysing the contribution of solar energy and wind energy in the energy mix, a low level of implementation of these renewable resources is found, the production share being owned by hydropower, Fig. 5-7. From the same graphs, it can be seen that during the studied period, the photovoltaic systems had a relatively similar operation.

In June, the degree of use of hydrocarbons was below the level of coal use, in July and August the use of hydrocarbons exceeded the level of June.

Even if the energy balance is negative, Fig. 8-10, (electricity production is higher than consumption), the management of NES is worrying because important amounts of energy are imported in periods of the year when energy from RES should cover a good part of consumption.

Analysing the energy balance in the period June 1-August 30, 2023, Fig. 17-19, it is noted the need to implement some storage systems in the national energy mix that would lead to a decrease of GHG by 41.6% in June, by 18.4% in July and by 12.1% in August.

Based on the above observations, it can be stated that grid-scale storage plays an important role in the net-zero scenario by 2050.

References

[1] IEA, Net Zero Emissions by 2050 Scenario (NZE), Available online: https://www.iea.org/reports/global-energy-and-climate-model/ net-zero-emissions-by-2050 - scenario-nze, accessed on 10 September 2023.

[2] Parlamentul European și Consiliul Uniunii Europene, Directiva 2009/28/CE a Parlamentului European și a Consiliului din 23 aprilie 2009 privind promovarea utilizării energiei din surse regenerabile, de modificare și ulterior de abrogare a Directivelor 2001/77/CE şi 2003/30/CE, Jurnalul Oficial al Uniunii Europene, L 140/16, 2009.

[3] D. Tokar, A. Tokar, M. Adam, "Experimental stand for the study of energy conversion and storage", Romanian Journal of Civil Engineering, vol. 3, pp. 245-253, 2020.

[4] D. Tokar, A. Tokar, M. Adam, Experimental Study for the Analysis of the Potential Energy Conversion of Wastewater Discharged from Installations and Equipment's of the Civil and Industrial Buildings, in IOP Conf. Series: Materials Science and Engineering, no. 022076, vol. 1203, pp 1-11, 14-18 Jun 2021.

[5] D. Tokar, C. Stroita, A. Tokar, A. Rusen, "Hybrid System that Integrates the Lost Energy Recovery on the Water-Water Heat Pump Exhaust Circuit", in IOP Conf. Series: Materials Science and Engineering, no.042002, vol. 603, pp 1-9, 17-21 Jun 2019.

[6] D. Tokar, A. Dorca, D. Muntean, A. Tokar, M. Adam, Proposals for energy storage in natural environments, in Modern Science and Energy 2022, Barriers between energy and the environment in civil engineering and installations, Edition a XLI – a, Cluj-Napoca, pp. 10-11 November 2022

[7] Generation and Consumption, Avilablel online: https://www.transelectrica.ro/ widget/web/tel/sen-grafic/-/SENGrafic, accessed on 10 September 2023.

[8] F. T. Tănăsescu, " Energy storage systems, a solution for optimizing the operation of electrical networks to which renewable/intermittent sources are connected ", in *Proceedings ASTR*, Ed AGIR, 2014.

[9] D. Tokar, Contributions regarding functional energy optimization of renewable energy conversion systems, Doctoral Thesis.

[10] International Hydropower Association, Let's get flexible – Pumped storage and the future of power systems, Hydropower Pro, 2020

[11] Chen H., Zhang X., Liu J., Tan C., Energy Storage - Technologies and Applications. Chapter 4. Compressed Air Energy Storage, Intech Publishing House, pp. 101-112, 2013.

[12] Suresh S., Marlinda A.R., Chowdhury Z.Z., Wahab Y.B.A., Hamizi N.A, Shahid M.M., Mohammad F., Podder J., Johan M.R., Advances in Supercapacitor and Supercapattery, Chapter 2. Fundamental Electrochemical Energy Storage Systems, pp. 27-43, 2021.

[13] D. Tokar, D. Foris. A. Tokar, T. Foris, Sustainable development of disadvantaged regional by renewable energy sources integration, Proceedings of the 2019 International Conference "Economic Science for Rural Development" No 51, pp. 237-244, 9-10 May 2019, Jelgava.

Concepția sporirii calității măsurării volumelor de gaze naturale cu contoare G1,6÷G25 prin optimizarea verificării lor metrologice

Design improving the quality of natural gas volume measurement with G1.6÷G25 meters by optimizing their metrological verification

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Rezumat. *În lucrare este prezentată analiza situației actuale și a sarcinilor în vederea organizării eficiente a măsurărilor fiscale a volumelor de gaze naturale furnizate consumatorilor casnici și comunal-menajeri în contextul exigențelor de reducere pierderilor de gaze naturale în rețelele de distribuție ale SA ”Moldovagaz”. În acest sens se prezintă studiu erorilor echipamentelor de măsurare exploatate în intervalul de sarcini termice reduse a aparatelor de utilizare, care plasează măsurările în plaja de incertitudine după 3 ani de la verificarea metrologică reglementară, iar după 5 ani și 7 ani – condiționează erori cu ”minus” în valoare de până la 10% și respectiv 20% din volumul măsurat, fapt care condiționează pierderi de gaze naturale operatorilor sistemelor de distribuție.*

În această ordine de idei se caută scenarii de optimizare a activității laboratoarelor metrologice astfel încât instalațiile să se exploateze la sarcina nominală (10 mii contoare/ an), raza de transportare a contoarelor pentru verificarea metrologică să se plaseze în limita până la 70 km, iar durata lor de exploatare intre două verificări succesive reglementate să nu depășească 5 ani.

Pe marginea soluției propuse sunt structurate concluzii, care includ aspectele tehnice și avantajele economice de optimizare a activității de verificare metrologică a contoarelor consumatorilor finali casnici și comunal-menajeri.

Cuvinte cheie: *măsurare volum gaze, verificare metrologică*

Abstract. *The paper presents the analysis of the current situation and the tasks for the effective organization of the fiscal measurements of the volumes of natural gas supplied to household and utility consumers in the context of the requirements to reduce natural gas losses in the distribution networks of JSC "Moldovagaz". In this sense, a study of the errors of the measuring equipment operated in the range of reduced thermal loads of the devices of consumption is presented, which places the measurements in the range of uncertainty*

after 3 years from the regulatory metrological verification, and after 5 years and 7 years - conditions errors with "minus" in the amount of up to 10% and 20% respectively of the measured volume, a fact that conditions natural gas losses for distribution system operators.
In this line of ideas, scenarios are being sought to optimize the activity of metrological laboratories so that the installations are operated at the nominal load (10 thousand meters / year), the transport radius of the meters for metrological verification is placed within the limit of up to 70 km, and their duration of operation between two successive regulated checks not to exceed 5 years.
Conclusions are structured on the edge of the proposed solution, which include the technical aspects and the economic advantages of optimizing the activity of metrological verification of the meters of final household and utility-household consumers.

Key words: *gas volume measurement, metrological verification*

Introducere

Analiza activității curente a laboratoarelor pentru verificarea metrologică a contoarelor G1,6÷G25 demonstrează că sistematic, din an în an, se înregistrează restanțe la îndeplinirea graficelor de verificare metrologică, fapt care condiționează funcționarea unui număr mare de contoare (14%÷22%), exploatate anual în plaja cu erori negative, care generează pierderi de gaze operatorilor sistemelor de distribuție (OSD). În acest sens [1] prevede măsuri complexe de reducere a pierderilor de gaze naturale în rețelele de distribuție la nivelul normativ aprobat de Agenția Națională de Reglementare în Energetică (ANRE).

Potrivit informației publicate în studiul [2], în practica companiilor de transport și distribuție gaze din SUA este utilizată noțiunea „gaz, care nu a fost luat la evidență", cu următoarea structură:

- eroarea sistemelor de măsurare gaze – 63%;
- eroarea în practica contabilă legată de livrarea gazelor naturale consumatorilor finali – 27%;
- scăpări de gaze prin neetanșeitățile tubulaturii sistemului de distribuție– 5%;
- consumuri frauduloase – 2%;
- altele – 3%.

Respectiv, un factor semnificativ (63%) în formarea pierderilor de gaze naturale în rețele de distribuție constituie eroarea echipamentelor de măsurare gaze naturale. Pierderile de gaze naturale respective sunt cauzate de următorii factori:

- *pragul înalt de pornire a contoarelor de uz casnic, care nu înregistrează volumele de gaze naturale minime consumate de aparatele de utilizare.* Valorile debitului de pornire (pragul de sensibilitate) pentru contoarele de gaze cu membrană G1,6÷G6 sunt următoarele: 0,0032 m^3/h pentru G1,6; 0,005 m^3/h – pentru G2,5; 0,008m^3/h – pentru G4 și 0,012 m^3/h – pentru G6 [3];

- *eficiența scăzută a măsurărilor: pierderi datorită nepornirii contoarelor în cazul sarcinii reduse sau funcționării lor în diapazonul cu erori considerabile* *(intervalul de incertitudine a măsurărilor dintre pragul de pornire și debitul minim de măsurare Q_{min}.* Spre exemplu, consumatorii foarte des folosesc arzătorul de putere redusă al aparatelor utilizatoare la flacăra mică pentru prepararea diferitor bucate în regim de coacere, arderea flăcării pilot la încălzitoare de apă și mini centrale termice, etc. Conform caracteristicilor din pașapoartele tehnice al încălzitoarelor de apă și mini centralelor termice debitul minim al gazului la arderea flăcării pilot constituie 0,037 m^3/h, iar potrivit standardului [4] pentru mașini de gătit puterea nominală a arzătorului de sarcină redusă poate fi reglată în diapazonul 0,21 kW (0,022 m^3/h) – 1,05 kW (0,11 m^3/h), însă debitul minim (Q_{min}) al majorității contoarelor exploatate (G4), conform [3], de la care începe normarea erorilor este 0,04m^3/h. În cuantumul de consum până la 0,04 m^3/h contorul funcționează în plaja măsurărilor cu eroare incertă.

Studiile realizate referitor la dinamica erorii contoarelor de gaze Schlumberger și Premagaz de tip G1,6 la debitele Q_{max}, 0,2Q_{max} și Q_{min} [5], demonstrează, că cu cât durata de exploatare a contorului de gaze este mai îndelungată, cu atât eroarea acestuia este mai semnificativă în sensul „-”, adică contoarele înregistrează volume de gaze mai mici, decât cele real trecute prin contor.

Un alt studiu, publicat în [6], demonstrează că odată cu creșterea perioadei de exploatare a contorului, caracteristicele metrologice ale acestuia se modifică cu următoarea legitate:

- după trei ani de exploatare eroarea contorului coboară în plaja cu minus, dar rămâne în limita valorilor de eroare admisibilă;
- după cinci ani de exploatare eroarea de asemeni este în plaja cu minus, dar deja depășește valoarea admisibilă, în unele cazuri ajungând la „-10%”;
- după șapte ani de exploatare eroarea de măsurare în unele cazuri depășește „-20%”.

Pentru a minimiza influența factorului menționat la formarea pierderilor de gaze este necesară asigurarea exactității măsurării echipamentelor de măsurare instalate la consumatorii finali, care poate fi obținută prin verificarea lor metrologică în perioada reglementată.

În plus obiectivului prioritar de reducere a pierderilor de gaze al OSD stabilit în [1], prin Hotărârea [7] ANRE a pus în aplicație începând cu 01.01.2023 *Modul de determinare al consumului tehnologic și a pierderilor de gaze naturale în rețelele de distribuție*, conform căruia normativul sumar al pierderilor de gaze în anul 2023 este de 15,02 mil m^3 sau cu 29,3% mai mic comparativ cu pierderile efective înregistrate în anul 2022 (21,24 mil m^3), fapt care constituie o problemă greu realizabilă pentru toți 12 OSD și care pune noi sarcini în vederea eficientizării măsurării volumelor de gaze livrate consumatorilor finali.

1. Situația actuală în vederea respectării graficului verificării metrologice ale echipamentelor de măsurare gaze naturale la consumatorii casnici și comunal-menajeri

Verificarea contoarelor cu pereți deformabili de tip G1,6÷G25 se efectuează în 11 laboratoare metrologice ale OSD, în care sunt utilizate 19 instalații de verificare, inclusiv: Chișinău-gaz – 1/7, Ialoveni-gaz – 1/2, Bălți-gaz – 1/2, Florești-gaz – 2/2, Găgăuz-gaz – 3/3, Edineț-gaz – 1/1, Orhei-gaz - 1/1, Cimișlia-gaz - 1/1.

Luând în considerație, că laboratoarele metrologice ale OSD nu sunt desemnate conform Legii [8] cu dreptul de emitere a buletinelor de verificare metrologică și de aplicare a marcajelor metrologice, OSD au contracte cu alte persoane juridice desemnate în acest sens.

OSD dispun de personal calificat, care asigură procesul de recepție și pregătire a contoarelor și instalațiilor etalon pentru verificarea metrologică a contoarelor. Verificarea metrologică se efectuează de către verificatorul delegat de persoana juridică desemnată, cu care este încheiat contractul, respectiv care este invitat pentru procesul de verificare când în laboratorul OSD se acumulează cantității de contoare suficiente pentru a organiza verificarea metrologică reglementată.

În prezent în sistemul de distribuție gaze naturale al SA „Moldovagaz" se exploatează circa 776 mii contoare casnice, verificarea metrologică a cărora este în responsabilitatea OSD.

Reieșind din termenul reglementat de verificare conform [9] (o dată în cinci ani) și numărul total de contoare exploatate, anual sunt supuse verificării metrologice circa 120-133 mii.

Pentru a determina în ce măsură este utilizată capacitatea prescrisă de uzina producătoare a instalațiilor etalon a fost efectuată analiză privind cantitatea de contoare verificată în laboratoare în perioada 2018-2022, cât și cea raportată la o instalație de verificare, tabelul 1.

Tabelul 1. Informația privind activitatea laboratoarelor metrologice ale OSD afiliate SA „Moldovagaz" în perioada anilor 2018-2022.

Laboratorul OSD/ OSD care este deservit	Numărul de laboratoare/ instalații de verificare	Cantitatea de contoare verificate anual					Nr. mediu de contoare verificat anual	Nr. mediu de contoare verificat anual pe instalație
		2018	2019	2020	2021	2022		
Chișinău-gaz/ Stefan Vodă-gaz	1/7	51711	55024	45561	68824	58673	55959	7994
Bălți-gaz/ Ungheni-gaz	1/2	12006	15177	16406	10500	13676	13553	6777
Ialoveni-gaz	1/2	15544	15358	13007	16599	14652	15032	7516
Florești-gaz	2/2	6689	6966	6424	5684	6141	6381	3190
Gagauz-gaz/ Taraclia-gaz. Cahul-gaz	3/3	15762	15563	15588	12826	11561	14260	4753
Edineț-gaz	1/1	7452	7625	5578	6055	6174	6577	6577
Orhei-gaz	1/1	6569	6003	8086	7558	6005	6844	6844
Cimișlia-gaz	1/1	3713	4530	5098	4580	3974	4379	4379
Total	11/19	119446	126246	115748	132626	120856	122984	6473

Din informația prezentată rezultă că sarcina laboratoarelor metrologice nu este uniformă, media anuală de verificare pe o instalație în perioada de 5 ani fiind de 6473 contoare, numărul minim – 3190 contoare, iar cel maxim –7994 contoare. În laboratoarele a 5 OSD numărul contoarelor verificate a fost peste valoarea medie anuală, cele mai bune rezultate fiind înregistrate în SRL „Chișinău-gaz" și SRL „Ialoveni-gaz", iar în 3 laboratoare cantitatea contoarelor verificate a fost sub media anuală cu cel mai scăzut rezultat în laboratorul Vulcănești (SRL „Găgăuz-gaz"), urmat de 2 laboratoare din SRL „Florești-gaz". Activitatea respectivă scăzută este funcție de organizarea insuficientă a logisticii procesului de verificare și nu de operativitatea personalului laboratoarelor.

Totodată, costurile verificării metrologice a contoarelor ale fiecărui OSD diferă și depind de:

- costurile de demontare/montare a contoarelor;
- costurile de logistica (transportarea contoarelor tur - retur pentru verificarea metrologică);
- costurile serviciilor de laborator;
- costul serviciilor verificatorilor;
- ale costuri aferente.

Din analiză rezultă, că cele mai mici costuri de verificare per contor sunt înregistrate de 8 OSD care dispun de laboratoare proprii, iar ceilalți 3 OSD suportă costuri cu până la 70% supra în raport cu primii. Diferența costului verificării metrologice în laboratoarele diferitor OSD este cauzată de sarcina de verificare diferită, cheltuielile operaționale și de întreținere a personalului la cantitatea de contoare verificate.

De rând cu acestea, discrepanța de sarcină de verificare generează următoarele probleme:

- în laboratoarele în care sarcina de verificare este mai mică, personalul și instalația etalon nu sunt solicitate permanent, iar verificatorul este invitat pe măsura acumulării în stoc a cantității de contoare necesare pentru o vizită, ceea ce lungește staționarea contoarelor demontate în laborator;
- în laboratoarele în care sarcina de verificare este excesivă, personalul și instalația etalon sunt suprasolicitate și respectiv se înregistrează întârzieri de verificare a contoarelor în raport cu termenul limită de 60 de luni. Prin urmare, în zonele de operare a OSD respectivi se înregistrează o cantitate mare de contoare neverificate, utilizate în procesul de măsurare la consumatorii casnici.

Costul mediu de verificare metrologică a unui contor în laboratoarele metrologice ale OSD în anul 2022 a constituit 63,28 lei, iar cel așteptat pentru anul 2023 este de 108,37 lei.

2. Optimizarea procesului de verificare metrologică a contoarelor G1,6÷G25 în vederea executării în termenii reglementați a procedurilor tehnologice prescrise

În scopul optimizării procesului de verificare a contoarelor în termenii reglementați [9] și prin urmare, reducerea impactului utilizării contoarelor cu erori inadmisibile în evidența gazelor distribuite, fapt care influențează volumul pierderilor de gaze, este necesară reorganizarea funcționării laboratoarelor cu reconfigurarea logisticii de transportare a contoarelor pentru verificare. În acest sens, pentru organizarea verificării contoarelor G1,6÷G25 în flux continuu cu o sarcină zilnică corespunzătoare capacității nominale a instalațiilor etalon, s-au propus spre examinare două scenarii de reorganizare a laboratoarelor metrologice în raport cu structura organizatorică existentă, (fig.1):

1. Scenariu I prevede centralizarea verificării echipamentelor de măsurare în 5 laboratoare metrologice zonale, tabelul 2.

2. Scenariu II prevede centralizarea verificării echipamentelor de măsurare în 6 laboratoare metrologice zonale, tabelul 3.

Fig.1. Locația laboratoarelor de verificare metrologică a contoarelor de gaze naturale.

Tabelul 2.

Scenariul 1 privind reorganizarea laboratoarelor pentru verificarea metrologică a contoarelor

Laboratorul zonal	Nr. de instalații distribuite (reieșind din încărcare medie de 10000/an)	Numărul contoare verificate anual	Cheltuieli de verificare a contoarelor			Zonele de operare din care se vor prelua contoare pentru verificare metrologică (OSD, filiala OSD)
			total	inclusiv de logistică (combustibil)	inclusiv de verificare în laborator	
Chișinău	5 (+3 rezervă)	57 140	4 672,837	66,396	4 606,441	Chișinău-gaz, Ungheni-gaz, Orhei-gaz
Bălți	3 (+1 rezervă)	23 450	1 885,833	114,575	1 771,258	Bălți-gaz, Florești-gaz, Edineț-gaz
Anenii Noi	2 (+1 rezervă)	19 102	1 546,044	26,443	1 519,601	Ialoveni-gaz, Ștefan Vodă gaz
Comrat	1 (+1 rezervă)	8 747	1 710,318	29,778	1 680,539	Găgăuz-gaz (fil. Comrat și Vulcănești), Cahul-gaz (fil. Cantemir), Cimișlia-gaz,
Ceadâr Lunga	1 (+1 rezervă)	12 417		20,825		Găgăuz-gaz (fil. Ceadâr Lunga și Vulcănești), Cahul-gaz (fil. Cahul), Taraclia-gaz
Total	12 (+7 rezervă)	120 856	9 835,857	258,017	9 577,840	

Tabelul 3.

Scenariul II privind reorganizarea laboratoarelor pentru verificarea metrologică a contoarelor

Laboratorul zonal	Nr. de instalații necesare (reieșind din încărcare medie de 10000/an)	Numărul contoare verificate anual	Cheltuieli de verificare a contoarelor			Zonele de operare din care se vor prelua contoare pentru verificare metrologică (OSD, filiala OSD)
			total	inclusiv de logistică (combustibil)	inclusiv de verificare în laborator	
Chișinău	7 (inclusiv 2 pentru contoare G10-G25)	54442	4 431,269	15,365	4415,904	Chișinău-gaz, Ungheni-gaz (fil. Călăraşi, fil. Nisporeni), Ialoveni-gaz (fil. Ialoveni și fil. Strășeni)
Bălți	3 (inclusiv 2 pentru contoare G10-G25)	16982	1 347,633	33,157	1314,476	Bălți-gaz, Florești-gaz (fil. Florești și fil. Soroca), Ungheni-gaz (fil. Ungheni)
Edineț	2 (inclusiv 1 pentru contoare G10-G25)	9009	713,573	39,377	674,196	Edineț-gaz, Florești-gaz (fil. Drochia)
Orhei	2 (inclusiv 1 pentru contoare G10-G25)	9629	782,821	17,399	765,422	Orhei-gaz, Ialoveni-gaz (fil Criuleni)
Anenii Noi	2 (inclusiv 1 pentru contoare G10-G25)	9630	783,163	17,783	765,380	Ialoveni-gaz (fil. Anenii Noi, Coșnița), Ștefan Vodă gaz (fil. Căușeni și Ștefan Vodă)
Comrat	3 (inclusiv 1 pentru contoare G10-G25)	21164	1 749,358	68,819	1680,539	Găgăuz-gaz, Cahul-gaz, Cimișlia-gaz, Taraclia-gaz (toate filialele acestora)
Total	19 (inclusiv 8 pentru contoare G10-G25)	120 856	9 807,816	191,898	9 615,918	

În Scenariile elaborate s-au luat în calcul urătoarele aspecte:

1) Distanța de transportare a contoarelor de la sediul filialelor până la laboratoarele metrologice centralizate.

În acest scop la baza calculelor au fost puse datele statistice privind verificarea metrologică a contoarelor în anul 2022 și logistica asigurării ei - distanțele de transportare a contoarelor, specifice fiecărui scenariu.

Comparativ cu situația din anul 2022:

- Scenariul I denotă că distanța totală parcursă anual de automobile ar crește cu 50578 km (de la 67676 km până la 118254 km), iar costul combustibilului s-ar majora cu circa 77%;

- Scenariul II indică că distanța totală parcursă anual de automobile ar crește cu 20250 km (de la 67676 km până la 87926 km), iar costul combustibilului s-ar majora doar cu circa 1%, datorită amplasării geografice uniforme a laboratoarelor în aria de prestări servicii de verificare metrologică.

Compararea Scenariilor I și II demonstrează că în Scenariul II cheltuielile de logistică, reflectate prin consumul de combustibil, se reduc cu circa 25% în raport cel din Scenariul I pe fonul distanței totale parcurse anual de automobile în scădere de la 118254 km (Scenariul I) până la 87926 km (Scenariul II).

Scenariile elaborate prevăd reducerea costurilor resurselor umane și de întreținere a încăperilor destinate prestării serviciilor examinate. De rând cu aceasta, distanța parcursă de asemeni influențează consumul resurselor umane implicate și uzura transportului. Totodată este necesar de specificat, că cu cât mai mică este distanța de transportare cu atât sunt mai mici riscurile de deteriorate a contoarelor verificate în timpul transportării, ținând cont de calitatea proastă a drumurilor raionale din Republica Moldova.

2) Asigurarea sarcinii nominale a instalațiilor etalon din laboratoare metrologice.

În conformitate cu [10], pentru un ciclu de verificare metrologică a contoarelor de tip G1,6÷G6, pe standul unei instalații etalon „Tempo” pot fi montate concomitent până la 10 unități, G10 – 3 unități, iar G10÷G25 - câte 1 unitate.

Astfel, ținând cont că ciclu de verificare durează în mediu 2 ore, inclusiv procesul de montare și demontare a contoarelor pe stand, pe parcursul unei zile de muncă pot fi verificate metrologic circa 40 contoare de tip G1,6÷G6. Prin urmare, o instalație are capacitatea de verificare de circa 10120 contoare pe an, reieșind din balanța anuală a timpului de muncă de 253 de zile. În același timp statistica anilor 2018 – 2022 demonstrează varierea numărului de verificări anuale până la ±10% în raport cu media anuală.

În fig.2 sunt prezentate în formă grafică scenariile de verificare metrologică, în particular: numărul de contoare verificate de facto în anul 2022 (Scenariu 0), Scenariile analitice I și II.

Graficele din fig.2 demonstrează că:

- scenariu II reprezintă varianta tehnică, economică și geografică echilibrată de reorganizare a laboratoarelor metrologice;

- laboratoarele metrologice din Vulcănești, Cimişlia, Florești și Drochia urmează a fi lichidate pe motivul sarcinii sub 40%, iar cel din Ceadâr Lunga – din cauza amplasării geografice nefavorabile;

- sarcinile laboratoarelor din Edineți, Bălți, Orhei și Comrat urmează a fi suplinite cu capacitățile de verificare ale laboratoarelor metrologice lichidate și cu resursele de verificarea din zonele acestora, tabelul 3.

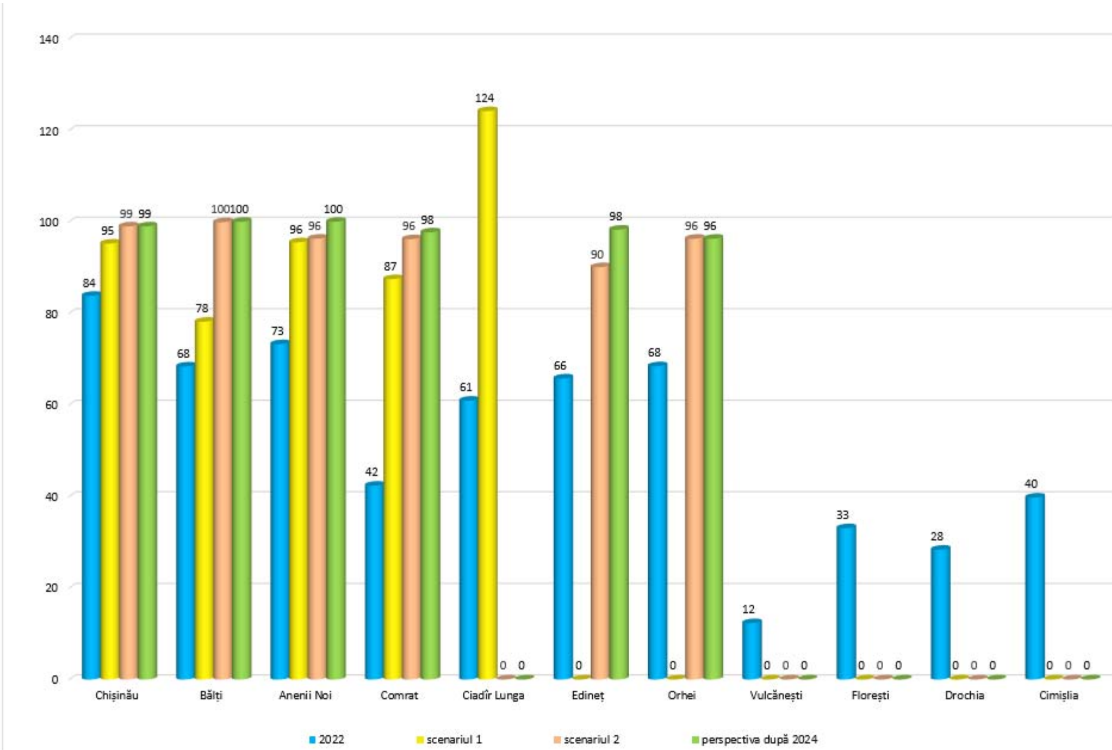

Fig.2. Sarcinile anuale de verificare metrologică a contoarelor de facto înregistrată în laboratoarele metrologice în anul 2022 (Scenariu 0), Scenariile analitice I și II și perspectiva după anul 2024, în %.

În tabelul 4 este prezentată informația privind cheltuielile legate de întreținerea laboratoarelor metrologice ale OSD și costul mediu de verificare a unui contor de facto și estimativ conform Scenariilor I și II.

Tabelul 4. Informația privind cheltuielile legate de întreținerea laboratoarelor metrologice ale OSD și costul mediu de verificare a unui contor de facto și estimativ conform Scenariilor I și II.

	Efectiv 2022	Prognozat 2023	Estimat după Scenariul I	Estimat după Scenariul II
Cheltuieli de întreținere a încăperilor și personalului, mii lei	6364,9	10758,1	9577,84	9615,9
Costul mediu de verificare a 1 contor, lei	63,28	108,37	85,45	85,21

Costul mediu de verificare a unui contor demonstrează că Scenariul II este preferențial în raport cu Scenariile 0 și I. Reieșind din aspectele menționate și indicii din tabelele 3 și 4, verificarea metrologică rațională a contoarelor urmează a fi centralizată în 6 laboratoare metrologice regionale (Scenariul II).

Laboratoarele respective vor fi completate cu instalații de verificare din celelalte 5 laboratoare, care vor fi lichidate după reorganizare (Florești, Drochia, Cimișlia, Ceadâr Lunga, Vulcănești), tabelul 5.

Tabelul 5.

Repartizarea instalațiilor și a capacităților lor de verificare în laboratoare metrologice.

Laboratorul OSD	2022	Scenariul I			Scenariul II			Perspectiva după 2024		
	Numărul total de instalații	Necesarul total de instalații p/u verificarea contoarelor	Necesarul de instalații p/u verificarea contoarelor casnice	Necesarul de instalații p/u verificarea contoarelor non casnice	Necesarul total de instalații p/u verificarea contoarelor	Necesarul de instalații p/u verificarea contoarelor casnice	Necesarul de instalații p/u verificarea contoarelor non casnice	Necesarul total de instalații p/u verificarea contoarelor	Necesarul de instalații p/u verificarea contoarelor casnice	Necesarul de instalații p/u verificarea contoarelor non-casnice
Chișinău	7	8	6	2	7	5,5	1,5	7	6,6	0,4
Bălți	2	5	3	2	3	1,7	1,3	3	2,1	0,9
Anenii Noi	2	3	2	1	2	1	1	2	1,2	0,8
Comrat	1	1	1	0	3	2,2	0,8	3	2,6	0,4
Ciadâr Lunga	1	2	1	1	0	0	0	0	0	0
Edineț	1	0	0	0	2	1	1	2	1,1	0,9
Orhei	1	0	0	0	2	1	1	2	1,2	0,8
Vulcănești	1	0	0	0	0	0	0	0	0	0
Florești	1	0	0	0	0	0	0	0	0	0
Drochia	1	0	0	0	0	0	0	0	0	0
Cimișlia	1	0	0	0	0	0	0	0	0	0
Total	19	19	13	6	19	12,4	6,6	19	14,8	4,2

Totodată, luând în considerație că parcul de contoare exploatate la consumatori casnici constituie 776 mii, în următorii ani cantitatea de contoare verificate anual va atinge media de 155 mii/an. Acest fapt va determina OSD să utilizeze zilnic instalațiile de verificare la capacitatea nominală.

Aspectele menționate s-au luat în calcul în Scenariul II, care prevede configurarea geografiei amplasării laboratoarelor reieșind din asigurarea capacității anuale nominale a unei instalații de verificare în următorii ani.

Utilizarea resurselor umane a laboratoarelor în cadrul reorganizării va fie supusă optimizării reieșind din ciclurile non stop de montare/demontare pe/de pe stand a contoarelor, în particular: în perioada în care derulează procesul de verificare metrologică pe standul contoarelor G1,6÷G6 (1,5 ore), operatorul urmează să monteze contoare pe al doilea stand pentru verificarea metrologică a contoarelor G10÷G25. Deci, personalul laboratoarelor pentru verificarea centralizată a contoarelor va continua activitatea, iar cei din laboratoarele lichidate vor fi angajați în sectoarele de exploatare ale OSD.

Reorganizarea va permite organizarea procesului de verificare cu următoarele performanțe:

- demontarea/montarea contoarelor la consumatori într-o singură vizită cu verificarea lor continuă, toate instalațiile din laboratoare metrologice funcționând la capacitatea nominală;
- diminuarea cheltuielilor de întreținere a încăperilor și personalului din 11 laboratoare la nivelul cheltuielilor a 6 laboratoare metrologice;
- reducerea cheltuielilor de deplasare a verificatorilor din 11 în 6 laboratoare metrologice ale OSD.

În plus, activitatea laboratoarelor metrologice reorganizate poate fi sporită în continuare prin externalizarea lor legală conform [11] în bază de concurs către o persoană juridică desemnată cu dreptul de emitere a buletinelor de verificare metrologică și de aplicare a marcajelor metrologice conform [8]. Aceasta va permite optimizarea cheltuielilor legate de procesul de verificare periodică a contoarelor G1,6÷G25 prin fixarea în contract a numărului și a termenului strict de prezentare a contoarelor în laboratoarele metrologice de către OSD, cât și prin comasarea funcțiilor verificatorilor cu funcțiile operatorilor instalațiilor etalon conform metodei de verificare, utilizate în laboratoarele metrologice ale Institutului Național de Standardizare a Republicii Moldova (în continuare - Moldova Standard). Totodată, în cadru concursului de externalizare va fi posibil de stabilit un preț unic per contor verificat pentru toți OSD, care va reflecta obiectiv principiu „cost/calitate”.

Concluzii

Studiul bibliografic și calculele tehnico - economice efectuate în scopul sporirii calității măsurărilor volumelor de gaze naturale cu contoare G1,6÷G25 și utilizării capacităților nominale ale laboratoarelor metrologice din cadru OSD, demonstrează că:

1. cinci laboratoare metrologice ale trei OSD actualmente activează cu o eficiență scăzută în raport cu capacitatea tehnică prevăzută de uzina producătoare, în particular Vulcănești – 12% (SRL „Gagauz-gaz”), Drochia - 28%, Florești – 33% (SRL „Florești-gaz”) și Cimișlia – 40% SRL („Cimișlia-gaz”).

2. activitatea laboratoarelor metrologice, inclusiv utilizarea resurselor umane și a capacităților existente de verificare din 11 laboratoare necesită a fi reorganizată în 6 laboratoare potrivit Scenariului II.

2.1 Numărul rațional de laboratoare pentru desfășurare procesului de verificare metrologică a fost determinat cu evidența tuturor cheltuielilor, inclusiv celor de logistică și constituie 85,21 lei/contor în raport cu varianta existentă (11 laboratoare) – 108,37 lei/contor și scenariu I (5 laboratoare) – 85,45 lei/contor.

2.2 restanțele de Grafic pentru verificarea metrologică periodică a contoarelor înregistrată anual actualmente la nivel de 14%÷22% va fi redusă la nivelul numărului de instalații de utilizare a gazelor naturale inactive, fapt care va minimiza funcționarea contoarelor menționate în plaja măsurărilor incerte și cu erori peste cele normate, și care în consecință va reduce pierderile de gaze naturale în rețelele de distribuție ale OSD;

3. sporirea în continuare a eficienții și calității procesului de verificare metrologică a contoarelor G1,6÷G25 prin externalizarea lui legală conform [11], către o persoană juridică desemnată potrivit [8], contractarea numărului și a termenului strict de prezentare a contoarelor în laboratoarele metrologice, cât și prin comasarea funcțiilor verificatorilor cu funcțiile operatorilor instalațiilor etalon conform metodei de verificare aplicate de Moldova Standard. Totodată, în rezultatul concursului de externalizare se va stabili pentru toți OSD un preț unic pentru verificarea unui contor, care va reflecta obiectiv principiu „cost/calitate”.

Bibliografie

1. Planul de măsuri de reducere a pierderilor de gaze naturale și a consumurilor lor tehnologice ale întreprinderilor de distribuție afiliate SA ”Moldovagaz” pentru perioada 2021-2025, aprobat prin Hotărârea Consiliului de Observatori din 28.09.2021.
2. Хворов Г.Ф. Об оценке потерь природного газа в газотранспортной системе. Сборник научных трудов «Проблемы развития, реконструкции и эксплуатации газотранспортных систем», ВНИИГАЗ, Москва, 2003г., стр. 125-136.
3. SM SR EN 1359:2018 ” Contoare de gaz. Contoare de gaz cu membrană”. Hotărârea Institutului de Standardizare din Moldova nr. 15 din 13.03.2018.
4. ГОСТ Р 50696-94 «Плиты газовые бытовые. Общие технические условия». Стандарт РФ.
5. https://www.c-o-k.ru/articles/metrologicheskaya-stabil-nost-membrannyh-schetchikov-gaza
6. https://kkconstanta.com/files/misc/razbalans.pdf.
7. Hotărârea ANRE nr. 938 din 16 decembrie 2022 privind modificarea Metodologiei de calculare, aprobare și aplicare a tarifelor reglementate pentru serviciul de distribuție a gazelor naturale, aprobată prin Hotărârea Consiliului de administrație al ANRE nr. 443/2020. Publicat:
19-10-2018 în Monitorul Oficial Nr. 398-399 art. 1044.
8. Legea metrologiei nr.19 din 4 martie 2016 (art. 17 Desemnarea persoanelor juridice în domeniul metrologiei legale). Publicat: 15-04-2016 în Monitorul Oficial Nr. 100-105 art. 190.
9. Hotărârea Guvernului nr. 1042 /2016 cu privire la aprobarea Listei oficiale a mijloacelor de măsurare şi a măsurărilor supuse controlului metrologic legal. Publicat: 16-09-2016 în Monitorul Oficial Nr. 306-313 art. 1130.
10. Паспорт компьютеризированной установки для определения и контроля метрологических характеристик бытовых газовых счетчиков «Темпо-3». ИВФ «Темпо», Ивано-Франковск, Украина, 2011г.
11. Hotărârea ANRE nr. 233/2017 din 27.06.2017 cu Lista serviciilor și a lucrărilor ce pot fi externalizare de către titularii de licențe din sectorul gazelor naturale). https://anre.md/public/assets/admin/vendor/ckeditor/plugins/fileman/Uploads/Hot_ANRE_233_din_27.06.2017.pdf