The Potential of Introducing Heat Pumps (HP) and Thermal Eenergy Storage for the Tulcea Municipality, Romania Systems in Order to Enable the Decarbonization in Romania

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Abstract

This case study aims to analyze the market potential of heat pumps and thermal energy storage in Romania. It was done at the level of a medium-sized city, the Tulcea Municipality. It was carried out on the basis of interviews with the main stakeholders of the city, such as the deputy mayor, the employees of the urban planning department, the director and the employees of Energoterm, the heating company. Documents were analyzed regarding the thermal energy and electricity consumption of the main public buildings, their existing energy certificates and their RLVs were also studied together with field visits. The study presents the structure of thermal energy consumption of public buildings in the municipality, analyze the possibilities of reducing heating and cooling costs and greenhouse gas emissions of public buildings and proposes some technical solutions based on integrated systems with customized heat pumps for each analyzed public building.

Key words: heat pumps, thermal energy, decarbonization, cost and electricity reduction, public buildings
J.E.L. classification: O33, Q42

1. Introduction

This case study was done at the level of a medium-sized city, the Tulcea Municipality in Tulcea County, where there is interest in the implementation of such technologies. This study was carried out on the basis of interviews with the main decision-makers of the municipality. Besides the interviews with the main stakeholders, the analyze of the most relevant documents regarding the thermal energy and electricity consumption of the main public buildings, there were also on-site visits taken, which followed the photography of these buildings in order to verify the existence of their insulation and to identify the spaces where the thermal and electric heating systems of the buildings are installed. Moreover, documents such as the existing energy certificates of the buildings and their RLVs were also studied. The study presents the structure of thermal energy consumption of public buildings in the municipality and analyzes data on thermal energy consumption and the costs from the perspective of the new energy standards of the European Union in order to reduce carbon footprint and energy consumption.

The study presents Romania`s specific overall problems regarding the installation of heat pumps and comes with proposals regarding the installation of new integrated technologies based on heat pumps in the public buildings from Tulcea Municipality.

Tulcea is the city of residence of Tulcea County. The resident population in Tulcea Municipality on December 1, 2021 is 65,624 people according to the first definitive results of the Population and Housing Census published by the Tulcea County Statistics Directorate (INS Tulcea, 2023a).

The centralized heat supply system in Tulcea Municipality serves approximately 6686 users (88-90% natural persons, 10-12% legal and public persons; and of the surfaces 78% for natural persons, 22% legal and public persons; according to the interview in May 2023 with the director of S.C. ENERGOTERM S.A). In 2012 it served about 42,000 people (approx. 63% of the total population of Tulcea Municipality, Tulcea City Hall, 2013).

At the end of 2021, there were 33,721 existing homes in Tulcea Municipality, with a living area of 1,322,144 m^2, meaning with an average area per home of 39.2 m^2. It should be noted that in 2021, 59 homes were completed (INS Tulcea, 2023b).

The climate in Tulcea Municipality is temperate-continental, with arctic air from the north during the winter. The temperature registers in Tulcea some of the highest extremes in Romania. Thus, the maximum temperature recorded was 40.3 °C, and the minimum was -26.8 °C in 1942. Regarding the average annual temperature in Tulcea, it is one of the highest in the country, having a value of 10.8 °C. On the other hand, average annual precipitation is low, recording only 350–500 mm/year.

2. Theoretical background and research methodology

The present case study is developed based on the following data sources: (1) the case study regarding the potential of introducing heat pumps and thermal energy storage systems for the Tulcea Municipality, an integral activity of this project (activity A4, 2023), (2) the interviews conducted by the members of the project team with different interested parties (stakeholders) from the Tulcea Municipality, (3) the documents relating to the thermal energy and electricity consumption of the main public buildings in the Tulcea. Also, to carry out the study on-site visits were carried out, in order to determine the specifics of each individual building and to be able to identify the best solutions for implementing systems based on heat pumps. The research is substantiated with the help of studies and documents presented in the bibliography.

3. Findings

3.1. The heating-cooling and hot water supply system in Tulcea Municipality, Tulcea County, Romania

The analysis of the existing situation in Tulcea Municipality in terms of energy was based on a process that identified, collected and evaluated data on the existing energy resources, energy suppliers and producers of Tulcea Municipality, as well as on the structure of energy consumption. At this stage, the development of a framework structure regarding the diagnostic analysis from the energy point of view, the establishment and identification of data categories, the necessary information and the main data providers was considered.

Currently, the structure of thermal energy consumers in Tulcea Municipality consists of:

a) the population, which lives in residential buildings (condominium) or individual homes;

b) socio-cultural institutions, economic agents and units assimilated to them.

They are being supplied from the city's centralized heating system served by S.C. Energoterm S.A., which is the local operator of the centralized thermal energy system.

The population that lives in condominium type dwellings (blocks) or in individual dwellings (houses) is added to the consumers connected to the centralized heating system, and who, following the disconnection from the centralized heating system of the city, opted for alternative sources of heating (individual central heating units powered by natural gas or electricity).

The centralized heating system of Tulcea Municipality was put into operation in 1982, consisting of: two C.A.F. hot water boilers, each with a capacity of 100Gcal/h and 39 thermal points.

The thermal points went through successive transformations, especially of a heritage nature, thus, 23 thermal points were taken over by R.A.C.E.T., and 14 thermal points were transformed into district heating systems in 1995, being taken over by the MONTENAY company (later becoming S.C. Dalkia S.A. and S.C. Veolia S.R.L. Romania). The latter ended up in the administration of the S.C. Energoterm S.A. company, in 2015, being taken over together with the

distribution networks for the respective districts. Thus, since 2015, a C.A.F. hot water boiler no. 1 of 50 Gcal/h (fueled with natural gas) has been operating within the Energoterm SA centralized heating system, as well as transport networks, intermediate pressure raising station, 10 thermal points, 75 thermal modules and distribution networks, 20 district heating systems, of which 19 operate with natural gas and a heating system works with CLU, 4 apartment buildings thermal energy systems that serve the ANL buildings on Izvorului Street., one heating system that serves the multifunctional Hall and a heating system that serves the Swimming Pool (Tulcea Strategy, 2021).

The primary heating network transports hot water over a length of 11.6 km, through steel pipes with diameters between 150mm-800mm, mounted partly above ground and partly underground, in concrete channels. The distribution network related to thermal points has a route length of 27.6 km and consists of classically insulated pipes, laid underground in protective channels.

3.2. Analysis of the current energy consumption of buildings in Tulcea Municipality from the perspective of the new energy standards of the European Union

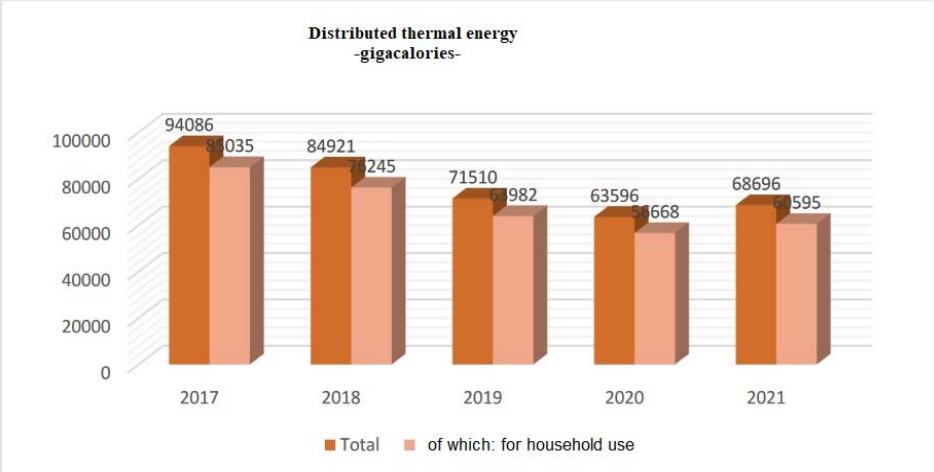
The Tulcea Municipality is one of the two cities of Tulcea County where a centralized heating system was planned. The values of the thermal energy distributed in the last years (until 2021) are recorded in Table 1. Regarding domestic consumers, a significant decrease in the consumption recorded in 2020 (56.668 Gcalories) is observed compared to previous years (see Table 1, Figure 2). This was due to the continuous increase in the rate of disconnections from the centralized system.

Table no. 1 Thermal energy distributed in Tulcea County

Indicators	Years				
	2017	2018	2019	2020	2021
➢ localities where thermal energy is distributed - no.	2	2	2	2	2
of which					
• municipalities and cities	1	1	1	1	1
➢ Distributed thermal energy -gigacalories	94086	84921	71510	63596	68696
of which					
➢ For household use - tousends m^3	85035	76245	63982	56668	60595

Source: Tulcea INS, 2022

Figure no. 1 Thermal energy distributed in Tulcea County



Source: Tulcea INS, 2022

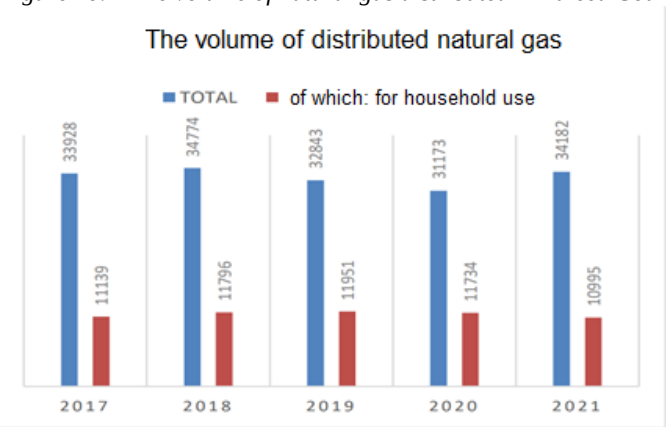
Regarding the evolution of natural gas consumption in recent years (until 2021) is presented in Table 2 and Figure 2.

Table no. 2 Natural gas consumption in Tulcea County

Indicators	Years				
	2017	2018	2019	2020	2021
➢ Localities where natural gas is distributed (at the end of the year) - no.	4	4	4	4	4
of which					
• municipalities and cities	3	3	3	3	3
➢ simple length of distribution pipes (at the end of the year) - no.	170,7	176,3	165,5	172,6	174,4
➢ Distributed natural has - tousends m^3	33928	34774	32843	31173	334182
of which					
• For household use - tousends m^3	11139	11796	11951	11734	10995

Source: Tulcea INS, 2022

Figure no. 2 The volume of natural gas distributed in Tulcea County



Source: Tulcea INS, 2022

It is noted that with regard to domestic consumers the consumption of natural gas did not show significant fluctuations.

The project team's analysis focused on energy consumption in 24 buildings of public institutions in Tulcea Municipality (see Table 3).

From the collected data, a very diversified profile of public buildings can be observed from the perspective of energy supply. Thus, depending on the building, the energy used for heating is provided with: electricity, natural gas, thermal energy or liquid fuel (diesel).

The energy consumption of the 24 analyzed buildings is presented in Table 3.

Table no. 3 Centralizer of electricity, natural gas, thermal energy, liquid fuel gasoline consumption for the years 2020, 2021, 2022 and their total costs

Nr Crt	Objective	Electricity (KW)			Natural gas (mc)			Thermal energy (Gcal)			Liquid fuel gasoline (l)		
		2020	2021	2022	2020	2021	2022	2020	2021	2022	2020	2021	2022
1.	SC Agropiete SA	354.506	403.833	313.759									
2.	Kindergarten with Extended Hours no. 19	12.659	20.824	17.904							10990	15600	12450
3.	Kindergarten with Extended Hours no. 3	24.100	30.847	34.611	12.995	16.796	17.222						
4.	Kindergarten with Extended Hours no. 17	9.250	21.564	12.432				105,7	124,4	70,57			
5.	Kindergarten with Extended Hours no. 18	7.415	8.691	10.385				186,7	150,5	128,1			
6.	G. Georgescu Arts High School	44.648	49.550	32.249	13.915	24.170	188.277	125,8	145,9	204,1			
7.	G. Moisil Theoretical High School	65.892	88.199	96.307	81.848	128.825	126.683						
8.	Ion Creanga Theoretical High School	42.897	60.360	88.785									
9.	Elementary School No.12	15.005	22.913	10.859									
10.	Alexandru Ciucurencu Elementary School	24.770	46.437	33.796	234.196	417.751	370.104						
11.	Sf. Ioan Casian Orthodox Theological Seminary	40.610	39.073	38.198	19.994	27.223	25.274						
12.	Anghel Saligny Theoretical High School	83.312,7	52.641,5	78.288,2	90.767,54	120.993,0	122.420						
13.	Danube Delta Economical College	93.766	106.714	150.371	1.237	1.323	1.560						
14.	Spiru Haret Dobrogean College	50.886,49	47.769,77	58.866,27	44.722,17	30.903,72	45.611,71						
15.	Brad Segal Technological College	95.855	97.671	88.237	800.230,2	801.741,8	726.173,1						
16.	Henri Coandă Technological High School	71.646	87.416	102.211	664.312,1	899.646,8	790.233,3						
17.	C. Gavenea Elementary School	30.836	32.184	90.648				299	203	176			
18.	Elena Doamna Elementary School	13.128	20.442	6.687,6	20.147	23.244	28.549						
19.	Nifon Balasescu Elementary School	40.901	42.017	52.965	28.354	34.333	253.766,2						
20.	Ion Mincu Technological High School		14.335	9.384		248.103	245.920,8						
	Grigore Antipa Elementary School		27.539	24.613		188.847,7	160.180						
21.	I. L. Caragiale Elementary School		20.428										
22.	Danubius Professional School	18.837	34.057	21.515							9.456	8.487	10.850
23.	Agricol N.Corlateanu Technological High School	89.948	112.074	117.172	960.390	1.114.044	990.744						

24.	SC Energoterm SA	4.129.099	4.214.916	3.252.447	11.688.718	11.803.122	8.632.344						
Total Quantity		5.359.967,21	5.702.496,08	4.762.690,14	14.661.827,40	15.881.067,30	12.725.063,60	717,48	623,70	578,75	20.446	24.087	23.300
Total Value (thousands Ron)		2.943	3.508,4	5.007	16.843	23.726	33.481	417	362,	582,1			

Source: Tulcea City Hall Data, 2023

The continuation of the phenomenon of disconnections will further increase the price of heat because, according to the calculation of costs, production decreases while the fixed component in the structure of total costs remains the same, thus the price increases.

The reduction of this phenomenon and possibly the return of disconnected consumers to the centralized system, will not be possible without offering a feasible alternative solution to the consumers of Tulcea Municipality, and this solution will only be able to increase the efficiency of the centralized heating system, and implicitly lowering the set price of Gcalories.

Based on the energy consumption data analyzed for the years 2020, 2021 and 2022 at the main public buildings in Municipality Tulcea and the specific features of each building, its surface area, degree of insulation, climatic conditions in Tulcea Municipality in Study A6 Tulcea, measures are proposed to implement integrated systems based on heat pumps. They will allow the significant reduction of greenhouse gas emissions, according to the new EU targets and the strategy implemented through the European Green Deal.

The case study aims to analyze the possibilities of reducing heating and cooling costs and greenhouse gas emissions in Romania by implementing integrated technologies based on heat pumps and thermal energy storage systems in Tulcea Municipality.

3.3. Romania`s specific overall problems regarding the installation of heat pumps

Romania has a series of specific overall problems regarding the installation of heat pumps, which we list below:

1. *High initial costs*: One of the main problems faced by building owners is the initial cost of purchasing and installing heat pumps. Although they are considered a long-term investment, the initial investment can be quite high for many homeowners.
2. *Lack of information and awareness*: A large part of the population does not have enough knowledge about heat pump technology and its advantages. Many people are still educated in the idea that traditional fossil fuel heating systems are the most affordable and efficient solution.
3. *Incompatibility with existing systems*: Installing heat pumps in older buildings can be difficult due to incompatibility with existing heating systems. This may require additional infrastructure investment to facilitate heat pump implementation.
4. *The need for clear rules and financial incentives*: To encourage the switch to greener and energy efficient technologies, the government and local authorities should provide financial incentives and create clear support policies for the installation of heat pumps.
5. *Deficiencies in the training and certification of specialists*: To ensure a correct and efficient installation of heat pumps, it is necessary for the technicians to be well trained and certified. Sometimes the lack of qualified specialists can be a problem.
6. *Infrastructure issues*: In certain regions, access to electricity or geothermal power grids may be limited, making it difficult to implement heat pumps in these areas.
7. *Heating with wood as a cheaper alternative*: Many Romanians still prefer heating with wood, as it can be considered a cheaper option compared to heat pumps or other ecological systems. This can be a barrier to the adoption of heat pumps.

Overall, in order to surpass these problems and promote the use of heat pumps, an integrated approach is needed, involving educational efforts, financial incentives, professional training and supporting government policies oriented towards greener and energy efficient technologies. (Activity 6, 2023)

3.4. Proposals regarding the installation of new integrated technologies based on heat pumps in the public buildings from Tulcea Municipality, Tulcea city

From an administrative point of view, Tulcea City Hall is responsible for ensuring the supply of thermal energy to all public buildings, (the central heating system being served by the operator S.C. Energoterm S.A.) which have been analyzed from the perspective of energy consumption, the degree of insulation and energy management.

From the collected data, a very diversified profile of public buildings can be observed from the perspective of energy supply. Thus, depending on the building, the energy used for heating is provided with: electricity, natural gas, thermal energy or liquid fuel (gasoline).

The project team analyzed every important public building in Tulcea Municipality and made a series of proposals for integrated systems based on heat pumps which are centralized in Table 5.

These proposals were formulated for each public building that proved to have a high technical-economic potential for the implementation of a technical solution based on heat pumps.

To determine the value of the heat pump, the regression line was made using the least squares method.

Table no. 4 Determining the average power of the heat pump using linear regression

Surface (m2)	Power (Kw)	Power average (Kw)
200	3-5	4
400	6-12	9
600	10-18	14
800	15-25	20
1000	20-30	25
1400	25-40	32,5
1800	30-50	40
2200	40-60	50
2500	50-80	65
3000	70-100	85
3500	80-120	100
4000	100-150	125
4500	120-180	150
5000	150-200	175

Source: Activity 6, 2023

Based on the information provided in table no.4 we have used SPSS 20 for the regression line and we got the following results:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-11,801	4,188		-2,818	,016	-20,927	-2,675
	Suprafata	,034	,002	,988	21,991	,000	,031	,038

a. Dependent Variable: Puterea

Where: -11.801 is the intercept or constant b.

The unstandardized regression coefficient is 0.034 which means that for every one unit increase in the Surface variable, the Power variable increases by 0.034. It is the slope of the right.

The standardized regression coefficient is 0.988, it is close to the regression coefficient.

Table no. 5 Proposals regarding the type and power (P) of heat pumps (HP) that can be installed in public buildings in Tulcea Municipality

Building	HP Type	P average HP (KW)	Surface Objective m^2	No. photovoltaic panels
SC Agropiete SA	Air-water with provision of domestic hot water	12	150	18
Kindergarten with Extended Hours no. 19	Air-water with provision of domestic hot water	68	800	100
Kindergarten with Extended Hours no. 3	Air-water with provision of domestic hot water	87	1.028	128
Kindergarten with Extended Hours no. 17	Air-water with provision of domestic hot water	66	740	98
Kindergarten with Extended Hours no. 18	Air-water with provision of domestic hot water	60	710	89
G. Georgescu Arts High School	Air-water with provision of domestic hot water	170	2000	251
G. Moisil Theoretical High School	Air-water with provision of domestic hot water	420	2.759	622
Ion Creangă Theoretical High School	Air-water with provision of domestic hot water	200	2500	296
Spiru Haret Dobrogean College	Air-water with provision of domestic hot water	200	2500	296
Henri Coandă Technological High School	Air-water with provision of domestic hot water	350	4.125	518
Constantin Gavenea Elementary School	Air-water with provision of domestic hot water	365	4.270	540
I.L.Caragiale Elementary School	Air-water with provision of domestic hot water	168	1978	249
Danubius Professional School	Air-water with provision of domestic hot water	200	2363	296

Source: Activity A6, 2023

Based on the analyzed energy consumption data for both heating and cooling for the years 2020, 2021 and 2022 at the main public buildings in Tulcea Municipality (Activity A4, 2023) and the specific features of each building, its surface area, degree of insulation, climatic conditions, the powers proposed for the heat pumps from Table 6 emerged. It can be seen that they are of low power and vary from the lowest power of 12 kW recommended for SC Agropiete SA, which has an area of 150 m^2, at powers up to 420kW, recommended for G. Moisil Theoretical High School/Elementary School No. 12.

If, in the case of determining the power of the heat pump, in addition to the surface of the public building, the climatic factors specific to Tulcea Municipality with the associated temperatures and the level of insulation of the buildings were considered, in terms of sizing the number of photovoltaic panels, the calculation considers both the conditions of climate, as well as the efficiency of the panels. In the last column of Table 5, the number of photovoltaic panels needed to be installed at each of the public buildings, for which solutions were proposed to implement an integrated system with heat pumps, were estimated by calculation. The photovoltaic panels

considered are those with standard dimensions. The standard size of a monocrystalline or polycrystalline photovoltaic panel is 1-meter wide x 1.6 meters long. The panels considered are monocrystalline (monocrystalline silicon) and produce an average of 235W. They are known for their high efficiency and good performance in low light conditions. The advantages are: high yield, good efficiency in limited spaces, durability. The number of panels is the average number required to fully cover the electricity consumed by the heat pump.

We specify the fact that the calculation model used did not consider the daily and seasonal fluctuations of solar radiation in the area, which instead will be highlighted in the Detailed Technical Project that will be made for each public building in Tulcea Municipality, where the implementation of an integrated system based on heat pumps is intended.

4. Conclusions

Following the analysis of the consumption and the geographical position of Tulcea Municipality, one of the options to improve the efficiency of the energy system correlated with the reduction of CO_2 emissions consists in the use of heat pumps together with photovoltaic panels and/or wind energy.

These recommendations came after the field visit report, where water sources were identified in the event of the installation of water-water type pumps, the identification of roofs that could be used for the installation of photovoltaic panels, as well as the fields in the vicinity of the municipality.

The proposals of the expert team are based on the implementation of integrated systems of heat pumps of different sizes (depending on the specificity of each public building) associated with photovoltaic panels and intelligent control systems corresponding to the proposed dimensioning.

For the implementation of the solutions associated with these proposals based on integrated systems with heat pumps, it is necessary to develop Detailed Technical Projects for each separate building, for which the implementation of an integrated system based on heat pumps is intended.

5. Acknowledgement

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