The Potential of Introducing Heat Pumps (HP) and Thermal Energy Storage for the Crucea Commune, Constanta, Romania Systems in Order to Enable the Decarbonization in Romania

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Abstract

This case study aims to analyse the market potential of heat pumps and thermal energy storage in Romania at the level of a small commune, Crucea from Constanța. It was carried out on the basis of interviews with the main decision-makers of the commune. During the study, documents regarding the thermal energy and electricity consumption of the main public buildings in Crucea have been analysed and field visits have also taken place. Documents such as the existing energy certificates of the buildings and their RLVs were also studied. It presents the structure of the thermal energy consumption of public buildings and analyses the data on the consumption and costs of thermal energy in order to reduce electricity consumption and the carbon footprint. The study proposes technical solutions based on integrated systems with heat pumps and thermal energy storage, customized for each public building analysed.

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

1. Introduction

This paper will firstly present a short description of the Crucea Commune of Constanta, considering the number of population and annual temperatures. It will continue with a description of the heating-cooling and the hot water supply systems of the commune. It will analyse of the current energy consumption of buildings in the Crucea commune from the perspective of the new energy standards of the European Union. Afterwards, it will give solutions to solve specific problems regarding the installation of heat pumps (hp) in Romania and give proposals regarding the installation of new integrated technologies based on heat pumps in public buildings in Crucea commune.

Crucea is a commune in Constanța County (3,482 inhabitants), Dobrogea, Romania, consisting of the villages of Băltăgeşti (513 inhabitants), Crişan (395 inhabitants), Crucea (residence with 1204 inhabitants), Gălbiori (336 inhabitants), Stupina (773 inhabitants) and Şiriu (261 inhabitants). (INS, 2021).

Regarding the climate conditions, the territory of Crucea Commune is characterized by a temperate-continental climate. The average annual temperature varies between 10.8 degrees °C, for the areas of the villages Băltăgeşti and Gălbiori and 11.4 degrees°C for the area of the village

Crucea. The absolute maximum temperature was 41 degrees C and the absolute minimum was minus 24 degrees °C.

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 Crucea Commune, 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 Crucea Commune, (3) the documents relating to the thermal energy and electricity consumption of the main public buildings in the Crucea Commune. 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.

Baseline analysis - the process of identifying, collecting and evaluating data about existing energy resources, energy suppliers and producers of the Crucea Commune, as well as about the structure of consumption. In the first part of the paper was considered the development of a framework structure regarding the diagnostic analysis from an energetic point of view, establishing and identifying the data categories, the required information and the main data providers. In the second part of the paper, due to the large temperature differences from one season to another in the area of Crucea Commune, the proposals regarding the installation of new integrated technologies that allow the reduction of greenhouse gas emissions are based on air-water or soil-water heat pumps, proposals presented further. To determine the value of the heat pump, the regression line is made using the least squares method.

3. Findings

Crucea Town Hall is responsible for ensuring the thermal energy supply of all public buildings under its authority. This supply will be provided in different forms, as follows: with the help of gas propane, electricity and wood. Each public building has its own specific amenities and means for consumption measurement. Electricity consumption for thermal heating is measured monthly by the thermal energy supplier, ENEL Energie SA. One of the gas suppliers required for heating thermal company is GASPECO L&d S.A., and here gas consumption is estimated quarterly when paying bills, there being no monthly gas consumption measurement system. For the purchase of wood for thermal heating, no information on consumption and related costs were received, but this is the smallest source of the total consumption.

3.1. The heating-cooling and the hot water supply system in Crucea commune

The heating-cooling and the hot water supply system in the Cruce Commune is decentralized, this being independent at the level of each representative building for the local public administration. The main public buildings in CRUCEA Commune and their heating sources are highlighted in the table no. 1.

Table no. 1: The main public buildings in CRUCEA Commune with the heating sources highlighted

TAU name (territorial administrativ unit)_	Public building	Amenities	Heating/cooling source
CRUCEA VILLAGE	1.Town Hall 2.Elementary school and high school 3.Kindergarten 4.Community Centre 5.Gym 6.Tourist Centre/ Integrated Medical-social Community Centre	1.Insulated; with air conditioners 2.It will be renovated C10 (COMPONENT C10 – LOCAL FUND FROM THE NATIONAL REDRESSION AND RESILIENCE PLAN) and will benefit from energy rehabilitation and alternative sources; has air conditioners. 3.Insulated	1.Gas 2.Gas and Power (air conditioner) 3. Power 4. Power 5.The changing rooms have an electric supply (4 rooms), and the hall had a gas-based ventilation system, which is no longer functional.
BĂLTĂGEȘTI	1.Kindergarten 2.Community Centre		1. Power 2. Power
CRIȘAN	1.Kindergarten	1.Insulated	1. Power
GĂLBIORI	1.Kindergarten 2.Community Centre		1.Gas 2. Wood
STUPINA	1.Kindergarten + School 2.Community Centre 3.Senior Centre	3. Insulated	1.Power 2.Wood 3.They went from wood to gas (evidence of consumption)
ȘIRIU	1.Community Centre		1.Wood

Source: Interview with the Mayor of Crucea Commune on 22.02.2023

A central heating system is used to heat the Town Hall of the Crucea Commune during the cold months powered by propane (table no. 2), while the space cooling during the peak summer period is ensured with electric air conditioners.

In 2015 three Max Optimus central heating systems of 31 kW that run on propane have been installed for heating the Town Hall.

At the Crucea community centre and at the Crucea kindergarten, 24 kW Romstal central heating systems are installed, respectively PROTHERM (see table no. 2).

Table no. 2: The heating systems of the main public buildings in Crucea Commune

Building	Type of heating	Brand	Heating system power
1 Crucea Town Hall (3 pc)	GPL propane	MAX OPTIMUS	31 KW
2. Crucea Community Centre	ELECTRIC	ROMSTAL	24 KW
3 Crucea kindergarten	ELECTRIC	PROTHERM	24 KW

Source: Processing of official data of the Crucea Town Hall

The air conditioners, numbering 11 (Town Hall), 2 (Community Centre), 2 (Kindergarten) and having an output of 2.78 kW (Town Hall), were installed in 2021 (Crucea Community Centre), in 2015 (Town Hall) and in 2017 (Crucea Kindergarten).

The other representative public buildings of the Crucea Commune benefit from different types of wall-mounted central heating systems with an output between 24 and 35kW that use different types of power: electricity, propane, coke or wood (see table no. 3).

Table no. 3 Types of central heating systems in public buildings from Crucea Commune

Building	Type of power (fuel)	Brand	The heating system output	Age (year of installation)
Gălbiori Community Centre	COKE (solid)	DEMRAD SOLITECH PLUS	23 KW	2015
Șiriu Community Centre	COKE (solid)	FERROLI DP. 35	35 KW	
Crucea Community Centre	ELECTRIC	ROMSTAL	24 KW	
Stupina Community Centre	COKE (solid)	VIADRUS	24 KW	
Băltăgești Community Centre	ELECTRIC	ROMSTAL	24 KW	
Crucea kindergarten	ELECTRIC	PROTHERMRY	24 KW	
Băltăgești kindergarten	ELECTRIC	PROTHERMRY	28 KW	2018
Crișan kindergarten	ELECTRIC BOILER	FERROLI	6 KW	2020
Stupina Senior Centre (3 pc)	PROPANE GAS	CT. MOTAN MKDENS	35 KW	
Tourist Centre	WOOD (solid)	VIADRUS	25 KW	
Town Hall (3 pc)	PROPANE GAS	MAX OPTIMUS	31 KW	

Source: Processing of official data of the Crucea Town Hall

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

The annual energy consumption of the Crucea Town Hall building is highlighted in table no. 4. It is delimited in energy consumption for heating and domestic hot water (propane-based) and for air conditioning and lighting (including that for the operation of the propane-based central heating system).

Table no. 4 Annual energy consumption of the main public buildings in Crucea Commune

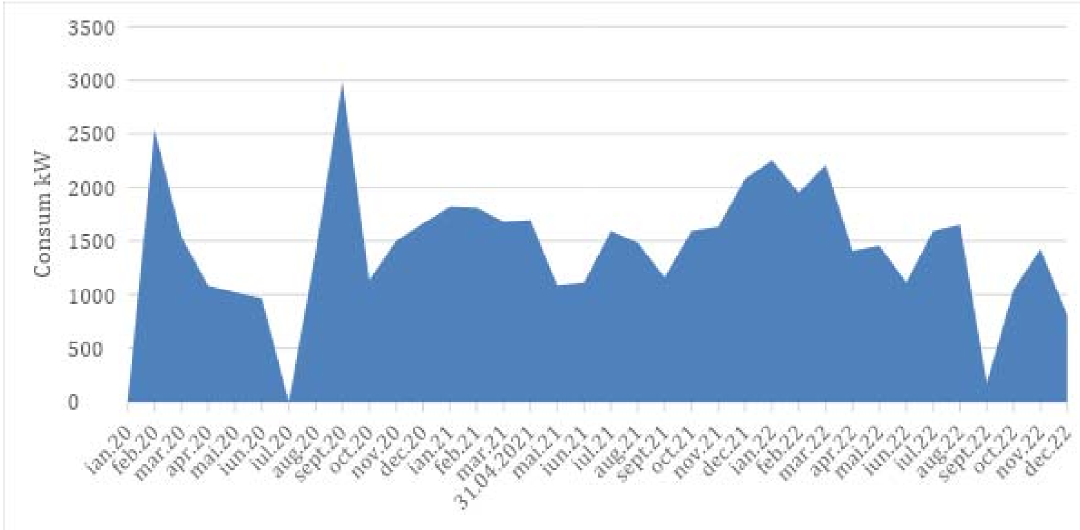
Type of energy carrier	Representative buildings	Year of consumption	Energy used [MWh/an]	Measuring report-surface [m^2]	Reference energy indicator [kWh/(m^2 and year)]	Expenditure/ year expressed in Ron	Remarks
Thermal energy for heating and domestic hot water (Propane gas)	1 Crucea Town Hall	2020	4200 Liters (L)	294	14,28 L/m^2 (98,532 kWh/m^2*year)	17.295,5	GPL propane (1L= 6,9kWh)
		2021	9000 L	294	30,61l/m2 (211,2159 kWh/m^2*an)	39.674,6	GPL propane
		2022	6000 L	294	20,41 L/m2 (138 kWh/m^2*an)	29.797,6	GPL propane
Electricity for lighting and air conditioning and for the functioning of the gas-based heating system	1 Crucea Town Hall	2020	15.833	294	53,85		consumption on 10 months
		2021	11.914,54	294	50,52		consumption on 12 months
		2022	17.097	294	58,15		consumption on 12 months

Source: Processing of official data of the Crucea Town Hall

The building of Crucea Town Hall has recorded in the last three years an almost constant consumption for lighting and the use of air conditioners of 58kWh/m^2*year (see table no. 4).

Regarding energy consumption for heating and domestic hot water, it fluctuated significantly from a minimum of 98.532 kWh/m^2*year in 2020 to a maximum of 211.2159 kWh/m^2*year in 2021 and at an intermediate value of 211.2159 kWh/m^2*year in 2022.

Chart no. 1 Histogram for the monthly energy consumption of the Crucea Town Hall (2020-2022)



Source: Processing of official data of the Crucea Town Hall

Given the fact that the Town Hall of the Crucea Commune has been thermally insulated from the outside, the recorded thermal energy consumption is high, being far from the new European consumption standards for buildings. The fluctuating values of thermal energy consumption at the Crucea Town Hall headquarters can be explained by the limitations of the COVID19 pandemic, unheated/uninhabited space, different temperatures in the same month, but in different years or poor use of doors and windows.

Thus, the measures that will be taken to reduce the energy consumption and reduce the carbon footprint of this building will have to consider both the replacement of the thermal agent and the possibilities of improving the insulation of the building and even the efficient management of the thermal agent through the appropriate use of doors and windows during the cold months, but also of proper ventilation during the hot summer months.

3.3. Solutions to solve specific problems regarding the installation of heat pumps (HP) in Romania

The main solutions identified to facilitate the implementation of integrated systems with heat pumps in Romania are presented below.

1. Education and awareness: The government and non-governmental organizations should implement information campaigns to educate the population about the benefits and advantages of using heat pumps. These campaigns should emphasize energy savings, carbon emission reduction and positive effects on the environment.
2. Financial incentives: The government could provide various forms of financial incentives for the installation of heat pumps, such as subsidies or tax reductions. This would reduce the initial costs for owners and they would consider this option more attractive.
3. Favorable regulations and policies: Adopting clear and environment-friendly policies and regulations to promote heat pumps would facilitate the transition to this technology. For example, the government could implement energy efficiency requirements for buildings or introduce restrictions on the use of fossil fuels.
4. Specialist training programme: Investing in specialist training and certification in the field of heat pump installation and maintenance would ensure correct and quality installations, increasing owners' confidence in this technology.
5. Infrastructure development: Local authorities could invest in developing the necessary infrastructure to support the installation of heat pumps, such as electricity or geothermal energy networks in suitable regions.
6. Public-private partnerships: Collaboration between the public and private sectors could facilitate access to finance and expertise, helping to promote heat pumps and their wider implementation.

7. Developing more affordable and innovative technologies: Governments and industry should continue to invest in research and development to bring more affordable and innovative heat pump solutions to the market.

By adopting a complete set of solutions and coordinated measures, Romania can overcome the specific problems regarding the installation of heat pumps, benefiting from all the advantages of these ecological and energy efficient technologies. (Activity A6, 2023)

3.4. Proposals regarding the installation of new integrated technologies based on heat pumps in public buildings in Crucea Commune, Constanța County

From an administrative point of view, Crucea Town Hall is responsible for ensuring the supply of thermal energy to all public buildings in the commune. Therefore, this has been analyzed from the perspective of energy consumption, degree of insulation and energy management.

From the collected data a diversified profile of these buildings can be observed from the perspective of an energy management. The energy supply to buildings for heating and cooling is carried out on a regular basis decentralized. Thus, although each public building has its own heating and cooling facilities and its own means of measuring energy consumption, heating sources are different. Gas supply for heating is provided by GASPECO L&d S.A., but gas consumption is invoiced mainly by quarterly estimation, as there is no monthly gas consumption measurement system. For example, the Town Hall headquarters in Crucea Commune is heated with the help of a heating system that works with propane (Activity A4, 2023)

Three of the main community centres in Crucea Commune are heated with the help of thermal energy systems between 23 and 35kW, powered by coke (solid), namely the Gălbiori community centre (23kW), the Șiriu community centre (35kW) and the Stupina community centre (24kW).

There are also wood-heated buildings (e.g. Tourist Centre), but in this case the supply is not rhythmic and highlighting the real associated costs is more difficult.

A more accurate record of energy consumption is recorded in the consumption of electricity for thermal heating which is monitored by ENEL Energie SA, but accumulated with other electricity consumption. For example, 24kW thermal energy systems are installed at the Crucea Community Centre and the Crucea Kindergarten.

The same situation also occurs with the cooling of the spaces during the peak summer period, which is provided with electric air conditioners, therefore recording electricity consumption. The air conditioners, numbering 11 (Town Hall), 2 (Community Centre), 2 (Kindergarten), have a power of 2.78 kW (Town Hall) and have been installed in 2021 (Crucea Community Centre), in 2015 (Town Hall) and in 2017 (Crucea Kindergarten).

The project team analyzed every important public building in Crucea Commune and made a series of proposals for integrated systems based on heat pumps which are centralized in Table no. 6.

These proposals were formulated for each public building that proved to have a 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. 5: 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.5 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.

Based on data related to energy consumption for both heating and cooling, data analyzed for the years 2020, 2021 and 2022 for all public buildings in Crucea Commune (Activity A4, 2023) and as a result of considering the particularities specific to each building, of its surface, the degree of insulation, the climatic conditions, the proposed powers for the heat pumps have emerged from Table no. 6.

Table no. 6 Proposals regarding the type and power (P) of heat pumps (HP) that can be installed in the public buildings of Crucea Commune

Building	HP type	P average of HP (kW)	Surface Objective (m^2)	No. photovoltaic panels
Gălbiori Community Centre	Air-water or Soil-water, with provision of domestic hot water	15	178	23
Gălbiori School	Air-water or Soil-water, with provision of domestic hot water	7	79	11
Șiriu Community Centre	Air-water or Soil-water, with provision of domestic hot water	20	237	30
Șiriu School	Air-water or Soil-water, with provision of domestic hot water	32	376	48
Cămin Cultural Crucea	Air-water or Soil-water, with provision of domestic hot water	15,5	180	23
Stupina Community Centre	Air-water or Soil-water, with provision of domestic hot water	15,5	180	23
Stupina School	Air-water or Soil-water, with provision of domestic hot water	16	181	24
Băltăgești Community Centre	Air-water or Soil-water, with provision of domestic hot water	15,5	180	23
Crucea	Air-water or Soil-water, with provision	25,5	300	38

Community Centre	of domestic hot water			
Băltăgești Kindergarten	Air-water or Soil-water, with provision of domestic hot water	25,5	300	38
Crișan Kindergarten	Air-water or Soil-water, with provision of domestic hot water	25,5	300	38
Crișan School	Air-water or Soil-water, with provision of domestic hot water	13,5	158	20
Stupina Senior Centre	Air-water or Soil-water, with provision of domestic hot water	25,5	300	38
Tourist Centre	Air-water or Soil-water, with provision of domestic hot water	8,5	98	13
Town Hall	Air-water, Soil-water or Hybrids, with provision of domestic hot water as well	25,5	300	38
School and high school	Air-water, Soil-water or Hybrids, with provision of domestic hot water as well	51	600	76
Boarding school	Air-water, Soil-water or Hybrids, with provision of domestic hot water as well	26	351	39
Health Centre	Air-water, Soil-water or Hybrids, with provision of domestic hot water as well	8,5	98	13
Gym	Air-water, Soil-water or Hybrids, with provision of domestic hot water as well	25,5	300	38

Source: Activity A6, 2023

It can be seen that the proposed heat pumps are of low power and vary from the lowest power of 7 kW recommended for the School of Gălbiori village, which has a developed surface of only 79m^2, with an output ranging from 25.5kW (most buildings analyzed) to 51kW in the event that a heating system will provide thermal energy for both the school and the high school in Crișan village.

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 Crucea Commune with the associated temperatures and the insulation level of the building 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 no. 6, the number of photovoltaic cells needed to be installed on each of the public buildings for which implementation solutions of an integrated system with heat pumps were proposed, was 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, which will be made for each public building in the Crucea Commune where the implementation of an integrated system based on heat pumps.

4. Conclusions

Following the analysis of the consumption and the geographical position of the Crucea Commune, one of the options to improve the efficiency of the energy system correlated with the reduction of CO2 emissions consists in the use of heat pumps together with photovoltaic panels and/or wind energy. At the same time, Crucea Commune should hire or appoint a person in charge of energy consumption and increase its capacity to collect data on monthly consumption and at the level of each public building. These recommendations also come after the field visit report, where water sources were identified in the event of the installation of water-air 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 commune, where there are already working wind turbines.

The study presents the results of the analysis regarding the possibilities of reducing heating and cooling costs and greenhouse gas emissions from public buildings in Crucea Commune, Constanța County. 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 desired.

5. Acknowledgement

This study was conducted within the framework of the project "The potential for starting and developing a business for integrated technology based on heat pumps, thermal energy storage, and smart control systems in order to enable the decarbonization in Romania", financed by EEA and Norway grants 2014-2021, Fund for Bilateral Relations, and implemented by the Bucharest University of Economic Studies, Romania, contract no. 132477/2022.

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