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MID-TERM REPORT OF THE HUC PILOT ACTION IN LENDAVA (SI)

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TITLE AND LOCATION of the PILOT action: Lendava

REPORTING STAGE (tick on the proper option)

☒ Mid-term

☐ Final

☐ Transnational evaluation

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Content

1. SUMMARY

Even though the Covid-19 pandemic also affects the progress of the pilot in Lendava, as physical meetings with the stakeholders were not possible for some times and some works have been delayed, the midterm report can still be very positive as a lot has already been achieved. The construction phase of the new pipeline connection started in January 2021 and was completed with the installation of the new PCM based latent storage in February 2021.

The implementation of a PCM based latent storage is necessary, because there are currently too high emission loads, there is no emergency boiler and in general the lifetime of the system, energy efficiency and the use of renewable energy sources should be increased. The expected energy savings are calculated with 5,5% in total, 100 % of fossil fuel reduction and 23 tonnes of CO_2 reduction. As described in the following chapters, there is a great potential to implement the planned system in other HUCs. The pilot in Lendava in question can and should therefore serve as an innovative best-practice example over the next few years and as a model for simplified technical and, above all, economic implementation in protected historic monuments and landscapes and lead to a significant increase in the proportion of renewable energy sources in historic urban centres.

Nevertheless, it is challenging to provide a low carbon energy supply in cities in a style of energy storages. Especially in historical urban centres it is very difficult to achieve these results, because interventions in this specific area meet strict architectural protection constraints, involve higher implementation costs and often come in conflict with town planning policies. Therefore, one of the main objectives of the Store4HUC project is also to improve and enrich energy and spatial planning strategies targeting historical city centres by focusing on integration of energy storage systems to enhance the public institutional and utility capabilities.

Moreover, the involvement of all relevant institutions and organizations from the beginning was and is very important for the success of the pilot implementation. These took place at the so-called deployment desk meetings, where all stakeholders come together every few months, as well as at some other informal meetings in between whenever necessary. With this instrument, it was also ensured that all relevant players were reached to share the knowledge and transfer it to other external audiences that are not part of the inner circle.

2. INTRODUCTION

This document describes the reporting activities of the pilot actions foreseen in the Store4HUC project.

It describes the monitoring activities that the involved PPs will conduct on the pilot implementation and the indicators (KPIs) to be monitored at different stages:

- Intermediate stage (Mid-term report) – March 2021
- Final stage (Final report) – September 2021
- Transnational evaluation stage – November 2021

It also provides (chapter 3) a summary of the aspects to be included at the feasibility study and pre-investment stages, as a memorial for the responsible of pilot actions.

The document in particular has two specific objectives:

- Report on the investment process foreseen for each pilot.
- Monitor other aspects related to the positive impacts and successfulness of pilots, such as:
    - Results of application of operational and monitoring tools.
    - Adaptations of energy and urban policy frames that are needed.
    - Mapping and adaptation of HUC regulations for the authorization of building integration.
    - Energy storage promotion and replication activities.
    - Follow up - recommendations, improvements.
    - Evaluation of the sustainability of the pilot and risk reduction measures.

3. ASPECTS AND KPIs TO BE MONITORED AT DIFFERENT STAGES

Aspects and Urban KPIs	Chapter in the template	Feasibility study	Pre - investment stage	Mid-term report	Final report	Transnat. evaluation
Technical specifications and performance requirements of the identified storage system		X	X			
Strengths, Weaknesses, Opportunities, Threats (SWOT Analysis)		X				
Initial situation: energy consumption, CO_2 emissions and energy costs			X			
Procurement procedure	4.1		X	X	X	
Installation and integration process	4.2		X	X	X	
Impact of the investment on energy and overall costs	4.3		X	X	X	
Energy management	4.4		X	X	X	
Energy and urban policy frames	4.5	X		X	X	X
Stakeholders’ involvement	4.6	X		X	X	X
Transferability of the pilot action	4.7	X		X	X	X
Impact of the pilot action	4.8	x		X	X	X
KPI_1 - External energy needs of the pilot system	4.9.1		X		X	X
KPI_2 - External energy costs of the pilot system	4.9.2		X		X	X
KPI_3 - Average yearly CO_2 abatement	4.9.3		X		X	X
KPI_4 - Autarky rate	4.9.4		X		X	X
KPI_5 - Use of energy from RES	4.9.5		X		X	X
KPI_6 -Security of energy supply	4.9.6		X		X	X
KPI_7 - Power peak	4.9.7		X		X	X
KPI_8 - Profitability	4.9.8		X		X	X
KPI_9 - Stimulation of local economy	4.9.9		X		X	X
KPI_{10} - Other pilot specific KPIs	4.9.10		X		X	X

4. PROGRESS REPORT OF THE PILOT ACTION

According to what is described in the former chapters, in the sub-chapters below the progress of the pilot implementation is discussed. For the PCM based storage which is installed in the Public Library of Lendava in Pomurje Region, the actual level of development of the investment, according to the activities planned in the application and the timeline of the entire process for each of the following steps are shown for the public procurement, the realization of the storage and auxiliary components, the operation and monitoring of the storage. Additionally, the energy and urban policy frames, the stakeholders' involvement, the transferability of the pilot action and the impact of the pilot actions are discussed.

4.1. Procurement procedure

Type of tendering procedure

In Slovenia, relevant procurement procedures are depending on who is investing and on the contract value according to the Slovenian Public Procurement Act - ZJN-3 (Official Gazette of the Republic of Slovenia no. 91/15 and 14/18). Direct purchase is allowed for supplies and services contracts valued below EUR 20.000 and work contracts below EUR 40.000. All contracts above these thresholds must be posted on the Slovenian Public Procurement portal. For so-called 'low-value' contracts i.e. supplies and services between EUR 20.000 and EUR 40.000 and public work contracts between EUR 40.000 and EUR 80.000 in value, simplified procedures may be applied. Contracts above the 'low-value' limits must be procured using standard procedures, i.e. open, restricted, and negotiating procedures with or without publicised terms of the contract, and competitive dialogue. Due to the coronavirus pandemic in 2020 there were new rules and the EUR 40.000 limit was increased for 100% to EUR 80.000. In this case in Lendava pilot (under EUR 80.000) there was no obligation to post the project on the Slovenian Public Procurement portal. The procurer made with a help of an expert an inventory of materials / services on the basis of price verification (references, web analytics) and collected 3 bids / offers.

Eligibility criteria and timetable for the procurer

The bidder should submit a completed bid list and cost estimate based on the prepared list of projects/materials/services and send to the procurer.

In **Napaka! Vira sklicevanja ni bilo mogoče najti.** the work plan is shown. It includes management aspects, the realisation of construction work and the implementation of the storage. In addition, dissemination activities are foreseen after the completion of the work.

Table 1: *Timetable of pilot in Lendava*

No .	Pilot Work packages / Date	Feb 2020	Mar 2020	Apr 2020	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Mar 2021
1 Project Management															
1.1	Start of the project														
1.2	Project coordination														
1.3	Preparation of project documentation														
1.4	End of the project (formal)														
2 Project implementation / Construction works															
2.1	Public pocurement process														
2.2	Construction works - Pipeline														
2.3	Work on DH substation / storage														
3 Monitoring															
3.1	Instalation and testing of monitoring equipment														
3.2	Ongoing monitoring														
4 Dissemination															
4.1	Articles in local/national media														
4.2	Implementation of workshop with interested stakeholders														
4.3	Ongoing dissemination activities														

Procedure and award criteria and scores

The selection criteria in case of Lendava pilot based on the current Slovenian Public Procurement Act (pandemic exceptions included and taken into account) is 100% the price.

The implemented progress of the PP process and resulting problems/delays

On the basis of the prepared investment specifications and the feasibility study, the starting points for the preparation of the public procurement for the infrastructure part of the project was prepared and the bids have been gathered. The procurement process has been carried out in first weeks of August 2020. The procurer made with a help of an expert an inventory of materials / services on the basis of price verification (references, web analytics) and collected 3 bids / offers. The bidder had to submit a completed bid list and cost estimate based on the prepared list of projects/materials/services and send to the procurer. The construction company has been chosen in the second half of August 2020 and started to gather the material on the market. Based on the prepared documents the investment includes in the first part the purchase of 2x 65m of pre-insulated pipes (suitable for temp. up to 95°C, STANDARD or PLUS insulation, CALPLEX – DUO H, DN40+40, 50+50/182) and the connection of the public building to the existing geothermal district heating system with all connecting materials. The second part of the investment includes the purchase and the installation of 2 PCM latent storages (paraffin based – phase change material, 2x 1000l, 17,6 kWh/15°K) with all necessary electrical and mechanical parts for energy transmission and measurement.

In the process several obstacles were encountered. The most important fact was to find a suitable expert for geothermal district heating in connection with PCM storages and in parallel to find a suitable product on the market, which can lead to the expected results. This resulted in a delay of the execution of the public procurement.

In the *Investment specification for the integration of an energy storage in HUC of Lendava* (deliverable D.T2.1.5) in September 2020 after the public procurement process we predicted to install 4x 500l PCM storages, but due to the pandemic situation in parallel with small and limited dimensions of the Lendava Library basement/storage tank final locations, the contractor had serious problems to find and deliver a suitable storages (problems with the storage hight and width in connection with all electrical and mechanical parts). The final decision was to change to the solution of 2x 1.000l PCM storages (same volume).

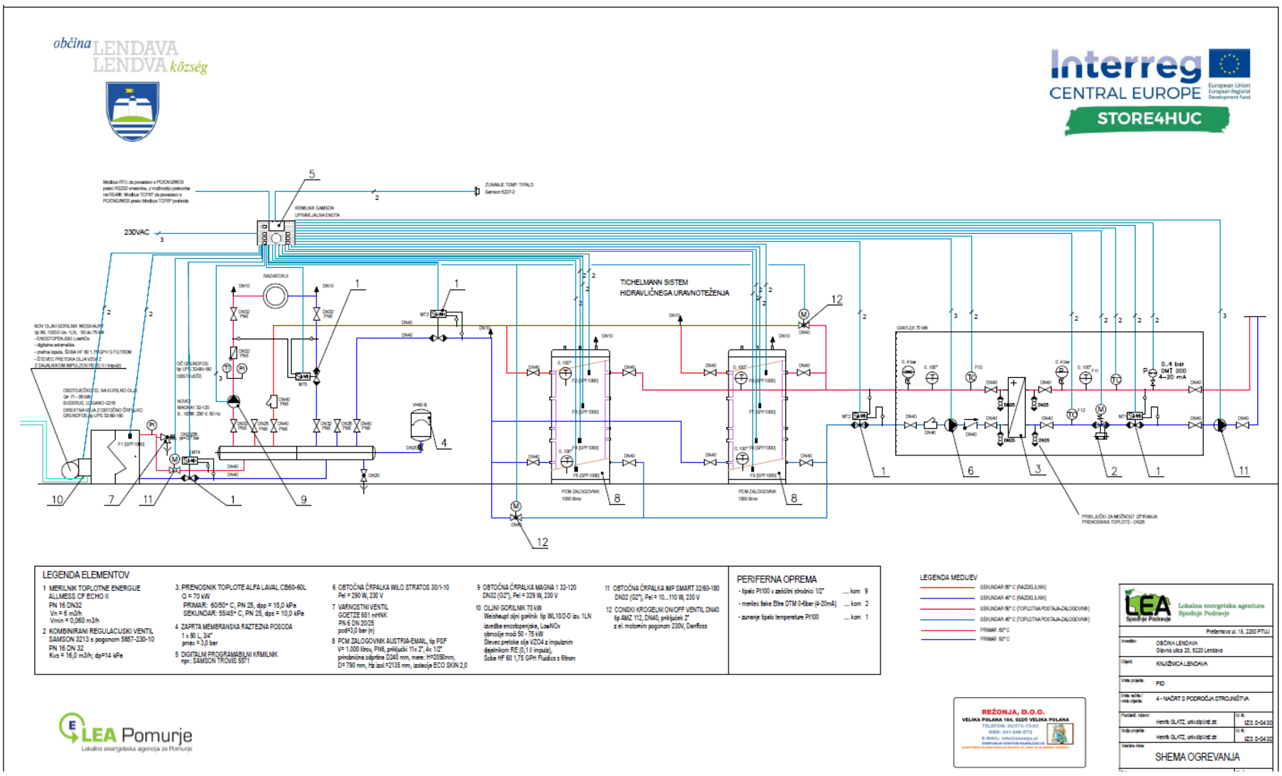

Figure 1: *Scheme of installed 2x 1000l PCM storages in accordance with the newly implemented control and EMS system*

4.2. Installation and integration process

The main aim of the pilot project is the replacement of the existing Oil-Fired Boiler in Lendava Library (public building) with a renewable energy source. The building will be connected to the existing geothermal district heating network to increase the share of renewables for heating in public sector.

Lendava Library will be the last connection in the geothermal district heating network and the supply is not stable - the supply medium temperature will/cannot be constant. This was the main reason, why the owner did not change the fossil fuel in this building yet - the storage selection in the pilot is crucial, to change into RES. The properly selected storage will in this case ensure the stable supply for end users.

An innovative solution of energy storing system will be installed in the basement of Lendava Library to increase the level of energy efficiency in public buildings (related to the higher efficiency of the heating system). Paraffin cells are modern and innovative buffer storages that have been developed to efficiently store heat and cold generated from small irregular energy sources such as solar energy, heat pumps etc. Thermal energy storage technologies and geothermal district heating systems have the potential to play a significant role in the transition towards 100% renewable energy systems through increasing system flexibility and overall efficiency and thus reduce CO_2 emissions and increase domestic energy security and additionally reduce the costs of heating. The advantage of paraffin used storages compared to regular water storages: requires less space, which is very important in case of Lendava Library.

The building of Lendava Public Library is located in the Oskar Laubhaimer's neo-baroque villa built in 1906. The building was restored several times. In 1996, the roof was restored. The renovation included the replacement of the roof structure, the replacement of the roofing and the installation of 15 cm thick thermal insulation. The next major renovation was made in 2005, when the basement was completely renovated. The windows are wooden, boxed versions. The building is a cultural heritage and is under the protection of monuments. This means that investments/renovation on the building are limited or under control. The Library employs 10 people, the average daily number of Library visitors is around 45.

Figure 2: *Lendava Library - Oskar Laubhaimer's neo-baroque villa built in 1906*

In the building the storage will be installed in the basement of the building where currently the heating oil tanks are stored. The PCM storage tanks will be connected to the existing geothermal district heating network to increase the share of renewables in public sector. Lendava Library will be the last connection in the geothermal district heating network.

Due to the Covid-19 pandemic the construction work and all planned stakeholder engagement meetings had to stop for some weeks in the last quarter of 2020. This situation resulted in the building phase starting in January 2021. Before the construction work the most important fact was also to find a suitable expert for geothermal district heating in connection with PCM storages and in parallel to find a suitable product on the market, which will lead to the expected results. However, the construction work has been carried out from last 2 weeks in January till mid-February 2021 in two phases:

1. Connection of the building to the existing geothermal district network;
2. Installation of the PCM storage tank and all electrical and mechanical components for energy transmission and measurement.

Last work done of phase 1 and phase 2 is shown in Figure 3 and Figure 4. In more details and based on the prepared documents the investment includes in the first part the purchase of 2x 65m of pre-insulated pipes (suitable for temp. up to 95°C, STANDARD or PLUS insulation, CALPLEX – DUO H, DN40+40, 50+50/182) and the connection of the public building to the existing geothermal district heating system with all connecting materials. The second part of the investment includes the purchase and the installation of 2 PCM latent storage tanks (2x 1.000l; 130kg) filled with paraffin-based phase change material (2.160 pieces of Ø42 x 310mm sticks; 50°C) with all necessary electrical and mechanical parts for energy transmission and measurement.

Figure 3: *Construction work - pipelaying and connection of the building to the geothermal network*

Figure 4: *Installation of the storage tank with PCM material and all electrical and mechanical components for energy transmission and measurement*

With the additional installation of an energy management tool we will be able to monitor all features that will prove the effectiveness of the pilot installations. The monitoring and testing phase started in first half of March in 2021.

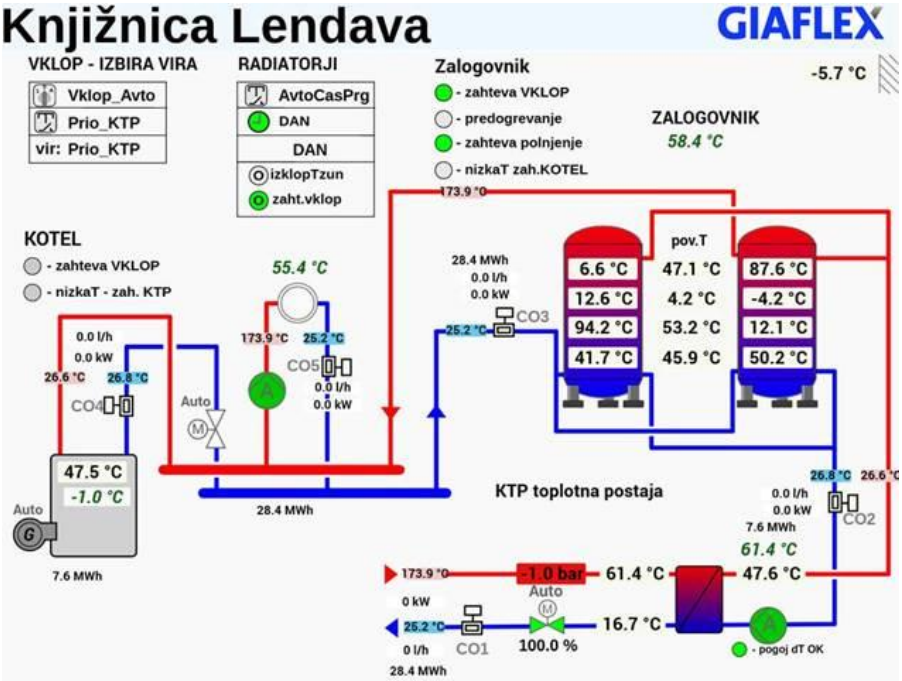

Figure 5: *Installed central control system for pilot system in Lendava*

4.3. Impact of the investment on energy and overall costs

Due to the above-mentioned challenges, however, there is a need to catch up in terms of energy efficiency and the use of renewable energy sources, especially in these districts with its listed buildings concerning historic monument and landscape protection. The project in question can and should therefore serve as an innovative best-practice example over the next few years and as a model for simplified technical and, above all, economic implementation in protected historic monuments and landscapes.

To calculate and monitor the impact on energy and costs, we decided additionally to install a central control system for this pilot. The testing and monitoring works are already running. Concerning the impact of the investment, it is enabled the collection, aggregation and filtering of the energy data and other information that are provided by a wide range of equipment (such as installed meters) and sources mainly responsible for energy transmission and consumption. The information gathered is afterwards exported to a central service system. The CAPEX is given in Table 2. The maintenance costs OPEX cannot be calculated yet as it is depending on robust monitoring data.

Table 2: *Estimated costs of the planned measures*

Cost position	Costs [€]
1 New pipeline (construction and assembly work)	20.000,00
2 District heating substation with storage system	47.000,00
3 Peripheral regulation equipment	10.000,00
4 Electrical installation	5.000,00
5 Construction costs for boiler room preparation	8.000,00
6 Planning and tendering	10.000,00
Total incl. VAT	**100.000,00**

In terms of energy, the PCM based storages (in our case paraffin cells) are innovative buffer storages that have been developed to efficiently store heat and cold generated from small irregular energy sources such as solar energy, heat pumps etc. Thermal energy storage technologies and geothermal district heating systems have the potential to play a significant role in the transition towards 100% renewable energy systems through increasing system flexibility and overall efficiency and thus reduce CO_2 emissions, increase domestic energy security and additionally reduce the costs of heating. There are several advantages of latent paraffin-based storages against the "usual" thermal heat storages: Require less space - smaller dimensions; Less temperature loss; Less reactivity with the environment and less likelihood of leakage as it changes phases; Better heat transfer performances=higher efficiency=lower heating costs.

The aim of our monitoring and testing phase is to prove (or disprove) the above-mentioned positive characteristics with numbers.

4.4. Energy management

In Lendava Petrol Geoterm d.o.o. built a district heating system with geothermal energy (geothermal energetic source) on the basis of Mining Act (Official Gazette of the Republic of Slovenia no. 56/99 and 46/04). After the construction of the entire district heating system with geothermal energy system, this is the first system of its kind in Slovenia.

The principle of operation of the district heating system is as follows: thermal water is pumped from aquifer with the production well, heat is transferred through heat exchangers to consumers and then cooled water is injected back into the aquifer.

The entire area of district heating with geothermal energy with all consumers, production and (re)injection well is shown in Figure 6.

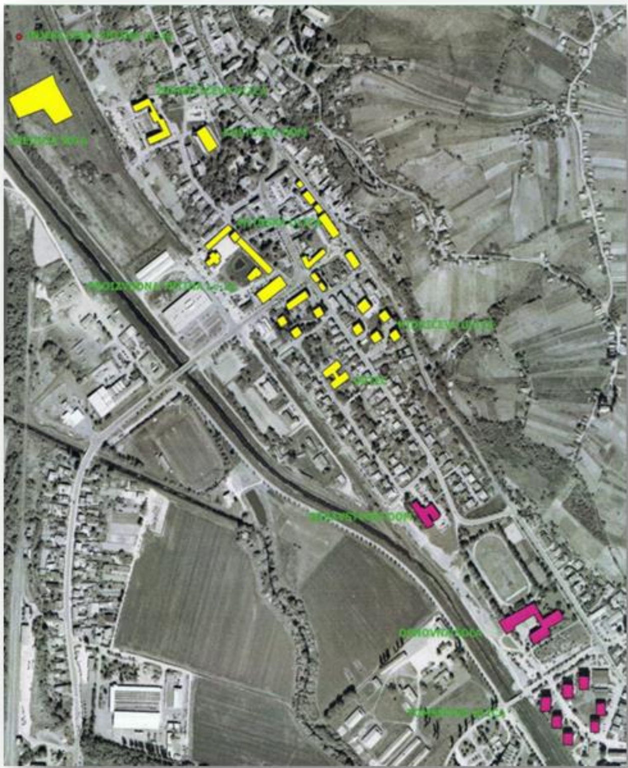

Figure 6: *Area of district heating with geothermal energy with all consumers, production and (re)injection well (in yellow – public buildings heated by geothermal energy; in purple – public buildings heated by fossil fuel)*

Facilities, connected to the district heating system, are built in different time periods and are poorly isolated. Annual specific heat varies between 28 and 170 kWh/m². For the rational use of heat, most of the facilities should be renovated.

In some existing facilities, hot-water boilers on standard fuels are installed. They are used as reserve for operation at extremely low temperature and in the events of the district heating system failures.

The total installed heat power of the district heating system is 6.65 MW with total heating area of 65,000 m². Consumers connected to the district heating system are residential (residential blocks), business (shops and business facilities) and educational (school and gym). All consumers have built-in calorimeters to measure heat supplied by the heat distributor.

Annually the heat consumption of all consumers comes approximately at 5.000 MWh, which means about 1.500 tons of CO_2 less greenhouse gas emissions, than in the case if the heat would be provided by incineration of 600.000 litres of extra light heating oil.

The characteristic of the Lendava district heating system is gathered in Table 3.

Table 3: *Basic information of Lendava district heating system*

District heating system (DH)	Yes operating
Flow temperature (in case of DH)	66ºC
Total installed power (of heat power plant)	7 MW
Estimations of total installed power in individual systems	6.65 MW
Type of heat production	thermal water, gas boiler, heat pump
Energy source	Geothermal energy
Annually sold heat to households	18,000 GJ
Annually sold heat to industry	/
Share of heat loss in the DH	7 %
Total flat (heated) area surface	260,539 m^2
Flat (heated) area surface on DH	65,000 m^2
Flat (heated) area surface out of DH	195,539 m^2
Share of Flat (heated) area surface on DH (m^2)	25 %
Share of Flat (heated) area surface out of DH	75 %
Estimated specific heat load per square meter (in average)	3.333 W/m^2

Destrict Heating Existing Facilities

The first phase of district heating in Lendava, with exploitation of geothermal energy, started with a well and boiler room for the needs of hotel Elizabeta and business facilities in Mlinska Street in Lendava. In boiler room the heat exchanger with power of 435 kW is operating with temperature difference around 10 °C and a regime 50/40 °C.

In the second phase, the well was rehabilitated and a pumping-transport water system was made with partially implemented hot water system to the Secondary school, the block in Župančičeva Street and the Cultural home. Gas boiler room with power of 2.6 MW was completed and an additional heat exchanger for covering peaks and reserve was installed.

In the system was used the existing heating system of Mlinska Street, the regulation and connection of residential blocks in Square Ljudske pravice and Krajnčeva Street in Lendava was made. At the same time, the heating of the Secondary school in Lendava was made.

Residential settlements - residential blocks (Kranjčeva TLP, Župančičeva and Tomšičeva) with a total power of 4.54 MW, connected on district heating system, are older and inappropriately isolated. Temperature heating regime is 60/40 °C.

Residential settlement Kranjčeva includes residential blocks and business facilities (Administrative office, companies ...).

Residential settlement Župančičeva was built in 1980. Heating is conducted through heat exchanger from boiler room. In the building pipeline for thermal water and return of the DN 150 were made. The distribution station is set in basement entrance 1 and had installed distribution board with connection, automatic and pumps for each entrance in the building.

Residential settlement Tomšičeva Street was built in 1978 with poor isolation. In existing boiler room two hot-water boilers were installed. The newer boiler has a heat power of 700 kW and older boiler has heat power of 1,500 kW. Heating with geothermal energy was performed.

The Secondary school was built in 2004 and is quite well isolated. The installed heat power is 480 kW. The heat exchanger is used for heating and as a reserve they use hot-water gas boiler Buderus. The system is designed in a way that the thermal water is heated by a system which, if necessary, is warmed up by a hot-water gas boiler.

The Cultural home is a newer building, already designed for low temperature regime of 50/40 °C. For heating, a Buderus hot-water boiler with heat power 270 kW is used. After the connection to the thermal water system, the boiler is needed for warming up the system at extremely low temperatures and for reserve.

The Elementary school was built in 1968. In 2004 windows were partially changed and in 2008 the renovation of whole building furniture and isolation of building was carried out. The heating of the building is made from hot water system, which leads to Tomšičeva Street. In boiler room were installed two hot-water boilers with power of 2 x 580 kW and for preparation of hot sanitary water a hot-water boiler with power 28 kW. All boilers use heating oil.

A Health Centre was built in 1975. Building is quite well isolated, if we look a year of construction. Connection on heating system is carried out from hot water system, which leads to Tomšičeva Street.

The building of Lendava Library will be the last connection in the geothermal district heating network and the supply is not stable - the temperatures will/cannot be constant. This was the main reason, why the fossil fuel usage in this building hasn't been abandoned yet - the storage selection in the pilot is crucial, to change into RES. The properly selected storage will in this case ensure the stable supply for end-users.

Description of building energy parameters

The geothermal district heating network will be connected through the PCM storage tanks to the Lendava Library and will be the last connection in the geothermal district heating network. Lendava Library is one of the biggest public buildings in Lendava and is still heated by fossil fuel – residual fuel oil.

Table 4: *Energy consumption of main public buildings in Lendava municipality*

Public building	Heated area	Heating method	Heating source	Heat consumption	Specific heat energy consumption	Electric energy consumption
	m²	/	/	kWh	kWh/m²	kWh
Primary school Lendava I	7503	thermal substation	geothermal energy	477.964	64	132.680
Primary school Lendava II	828	individual boiler	heating oil	128.125	155	20.970
Primary school Lendava – Petišovci	259	individual boiler	heating oil	70.623	273	3.542
Primary school Genterovci	1.905	individual boiler	LPG	316.000	166	24.302
Kindergarten Lendava	981	central heat. station	geothermal energy	143.000	146	49.400
Public Library Lendava	596	Individual boiler	heating oil	84.351	142	32.653
Theater - concert hall	2.082	thermal substation	geothermal energy	319.002	153	93.693
Castle - Lendava Museum	320	individual boiler	natural gas	61.313	192	13.758
Lendava Health Center	2.075	individual boiler	heating oil	348.750	168	123.000
City hall Lendava	767	individual boiler	natural gas	88.630	116	54.271

The current average annual heat consumption is 84.351 kWh on a heated area of 596 m². Figure 7 shows the existing inefficient old heating oil boiler and the heating oil storage tank. Together with the electric consumption (32.653 kWh), the library has an annual energy consumption of 196 kWh per square meter. Lendava Library produces annually 23,5 tons of CO_2 related to space heating. The connection to the existing geothermal network would reduce this amount to zero.

Existing boiler plant description

Figure 7: *Existing inefficient old heating oil boiler*

The heating temperature in the building is regulated by an outdoor temperature sensor. In the rooms are radiators, which are not equipped with thermostatic valves.

Table 5: *Key characteristics of the existing boiler plant*

Boiler plant		
Cast-iron boiler	BUDERUS	
Type	Logano G215	
Power	71 - 85	[kW]
Dimensions	1027/920/695	mm
Net weight	317	kg
The amount of water in the boiler	85	l
The amount of flue gases	101,4	l
Flue gas temperature	160-180	°C
Maximum flow temperature	110	°C
Maximum working pressure	4	bar
Burner type	Gulliver RG2	
Used heating oil (2017/18)	8.452	l

The secondary source of heating In Lendava Library is the electric power for the operation of two Mitsubishi MX2 air conditioners (power of 10,5 kW). Heating with the secondary source may be considered during a transitional period when the rooms are heated by the specified air conditioners. The estimated electricity consumption for heating during the transition period is 25.000 kWh, but will not be included in the following calculations related to savings/costs/consumption.

New heating station requirements

To achieve optimal heating results, it is necessary to install the optimal size of the heating station with first-class control and regulation equipment. Compact modern heating stations have low heat losses and high energy transfer efficiency with extremely small temperature drops in the transfer from the primary high-pressure part to the secondary heating system. The planned heating station is of the indirect type of compact design with a secondary circuit for heating the building for the temperature regime:

- primary 60˚C / 50˚C
- secondary 55˚C / 45˚C at Tout = - 16˚C

The heating station is designed as a compact heating station, mounted on a steel frame and with all electrical connections. The elements and pipe connections are insulated as much as possible. It consists of a primary and a secondary part. It will be connected to the hot water network (2C) Lendava and implemented in accordance with the technical conditions for connection to the distribution network.

Regarding the *system operating instructions* for the **district heating system** in the geographical area of the Municipality of Lendava the following regulation have to be considered to define the temperature diagram for the hot water (2C) system for buildings: Official Gazette of the Republic of Slovenia no. 3/2018 (12 January 2018). From the diagram in Figure 8 we can see that the maximum flow temperature of the system is 65˚C and at outside temperature of -10˚C this temperature drops to 60˚C and less.

At outside temperature of 5˚C, the distributor provides 50˚C temperature. As the tolerance is ± 3˚C, a temperature of 47˚C can be expected.

Regarding the data above and due to the additional temperature drop of 2-5˚C, we can expect a maximum of 45˚C on the secondary side.

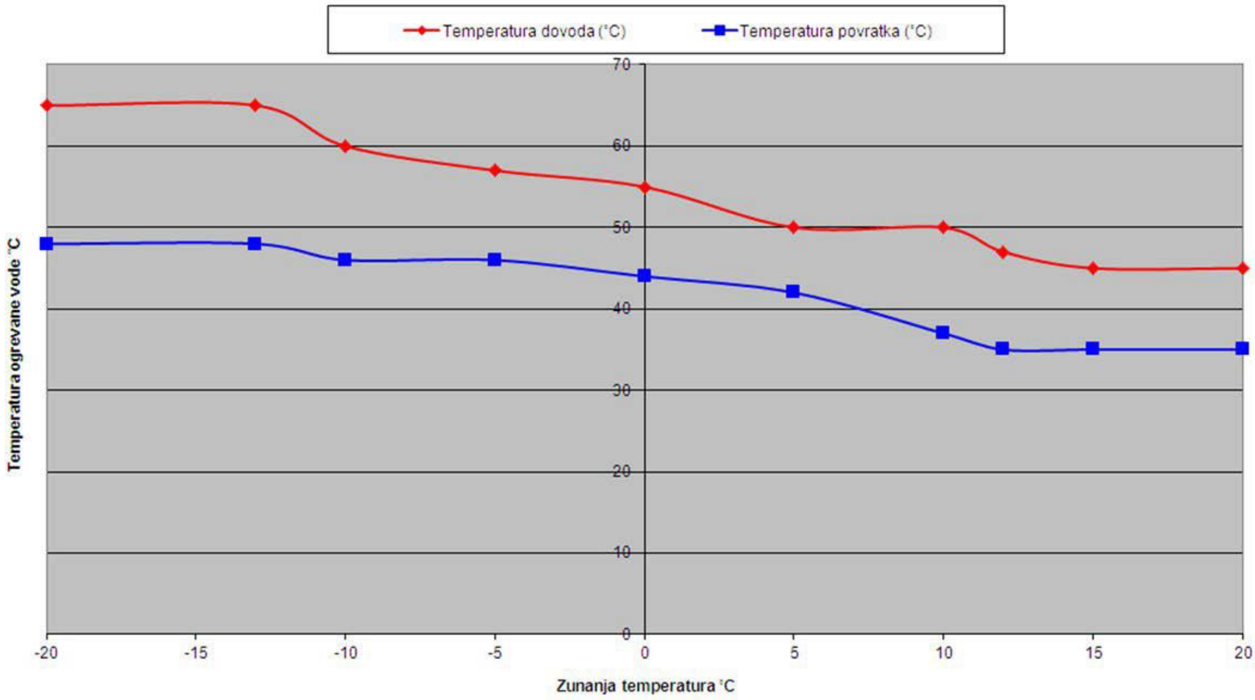

Figure 8: *Temperature diagram of hot water (2C) district heating system 2*

(in red the inlet temperature and in blue the outlet temperature)

Footnotes:

- The permissible deviation of the heated water temperature at each consumption point is ± 3°C;
- The flow temperature depends on the day/night mode, on the outside temperatures and on the return temperatures. The “day mode” is valid from 5.30 am till 9 pm and the “night mode” from 9 pm till 5.30 am;
- If the return temperature is higher than the reference temperature, the flow temperature is reduced by the same value;
- The flow temperature in the ”night mode” depends on the outdoor temperature and is equal to (± 3°C) the return temperature in “day mode”;
- Heating stations must be manufactured in accordance with the requirements of the district heating network operator.

Selected storage tank and PCM

In case of Lendava library, we are limited by the operating temperature of the district heating, which is low, and with the required indirect connection to the heating system, the flow temperature will be further reduced by 5°C, if we take into account the losses of pipelines. In energy terms, the PCM storage tank used is already a proven technology in some countries in the EU. This solution of course cannot be regarded as the most cost-effective solution compared with other storage technologies (for example: water buffer tanks), but due to the additional problems with lack of space in the Lendava Library (e.g. the problem of low basement height) and due to the several positive effects of paraffin based latent storages, this is the appropriate solution.

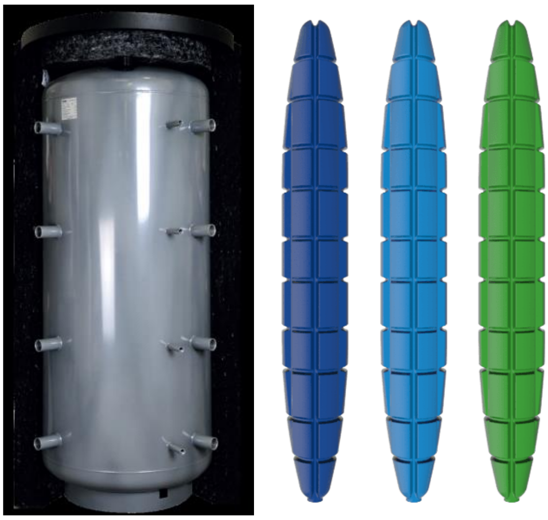

Figure 9: *Catalog picture of newly installed storage tanks and PCM*

Latent paraffin storage tanks consist of a classic heating water storage tank filled with balls that have a paraffin filler (PCM). At a temperature withdrawal of 45/30°C, energy can be absorbed during the day, distributed overnight and in the morning.

Unlike a conventional storage tank, a hybrid storage tank has correspondingly high dynamics of energy store and discharge. It also gives a constant outlet temperature in the discharge over a longer period of time. The stored heat energy can be taken away with a time delay at a certain temperature that does not fall. It is possible to additionally install electric heaters or heat exchangers from a roof solar system.

Table 6: *Characteristic values of the new storage tank*

PCM latent storage tank with paraffin wax beads	
Volume (water + PCM)	1000 lit.
Height	1693 mm
Diameter	749 mm
Number of PCM sticks per 100l	130
Number of PCM sticks (in total)	1300
Weight (storage tank - empty)	180 kg
Weight (water quantity)	636 kg
Weight (PCM material)	436,8 kg
Capacity (PCM - ATS50 HeatStixx)	27,91 kWh
Capacity (water)	11,07 kWh
Capacity (water + PCM)	38,98 kWh
Factor	2,2
Temp. of crystallization	45°C on request
Volume (equivalent storage)	2200 lit.

4.5. Energy and urban policy frames

The storage is installed in the Public Library of Lendava in Pomurje Region. Geographical position of Lendava is in the eastern part of Slovenia near Slovenian-Hungarian and Slovenian-Croatian border. The unique position of the town at the foothills of picturesque vineyards originates from its rich historical role and a profuse cultural image, contributed by inhabitants with diverse ethnic definition. In Lendava members of different nationalities live closely together; Slovenes, Hungarians, Croats and other nationalities. Based on the city's cultural tradition there is a multicultural centre which defines the city and also the municipality. The unique position is defining Lendava in its culture, languages and the way of thinking and living. Based on the city's cultural tradition, rich history, multicultural aspect Lendava is a typical example, where United Europe project easily finds its place.

The Lendava Library is located in the centrum of the town near the Evangelical Church and the Lendava Town Hall, where the municipal administration is located.

Figure 10: *The location of Public Library in Lendava*

HUCs are in Slovenia subject to the building and spatial planning laws of the local community and the Slovenian Preservation of Cultural Heritage Act.

Today the Institute for the Protection of Cultural Heritage of Slovenia (*Zavod za varstvo kulturne dediščine Republike Slovenije*[1]) brings together art historians, archaeologists, architects, ethnologists, historians, landscape architects, sculptors, painters and many other experts, who work in the Institute's Cultural Heritage Service with the seven regional offices located across Slovenia and in its Conservation Centre with its Restoration and the Preventive Archaeology Centres. In 1999 the new Law on Cultural Heritage Protection clearly defined the administrative and professional functions of protection, especially in binding the rights and obligations of heritage owners to a legal document. In 2008 the Preservation of Cultural Heritage Act was adopted, which includes movable as well as non-movable and intangible cultural heritage, defining the tasks to be performed by public services concerning the preservation of cultural heritage and its executants.[2]

In 2016, The Ministry of Culture in cooperation with the Ministry of Infrastructure published the *Guidelines for energy renovation of cultural heritage buildings*[3]:

"…CONNECTION TO DISTRICT HEATING

In places where a district heating system is established for heating, it is necessary to connect to such a system. The district heating system is the most environmentally acceptable method of heating. District heating is a method of heating in which heat is transferred from a larger source to consumers via a pipe network. Easy connection to the system, lower energy costs, environmental friendliness and additional benefits when connected are just some of the benefits of district heating. …"

[1] https://www.zvkds.si/sl

[2] https://www.culture.si/en/Heritage_preservation_and_restoration_in_Slovenia

[3] http://www.energetika-portal.si/fileadmin/dokumenti/podrocja/energetika/javne_stavbe/smernice_kd_23.2.2017.pdf

<u>Necessary documents for implementation of the pilot:</u>

(1) It is necessary to obtain project conditions and opinions from different experts/institutions (municipal administration, public utility service provider for drinking water supply, public utility company for sewer services, IT provider, telephony operator, electricity operator, services related to the protection of cultural heritage, housing service companies, DHS operator, etc.)

(2) It is necessary to prepare the Project for the implementation document (PZI)

(3) An official building permit is NOT required for this type of construction work!

In accordance with the Slovenian Decree on the Classification of Facilities[4] (*Official Gazette of the Republic of Slovenia, no. 37/18, according to Annex 2)* the installation of a thermal substation is classified as an intervention "Maintenance of facilities" for a number of works: installation of devices and installations in, on and next to the facility. This includes also: the installation of new appliances and related installations for heating, cooling, ventilation, domestic hot water and lighting, including the use of renewable energy sources.

<u>A building permit is not required for this type of construction work.</u> It is necessary to obtain project conditions and opinions on the PZI (project for the implementation).

Based on the *Register of Slovene Cultural Heritage*[5], which is under the jurisdiction of Ministry of Culture, the Lendava Library is classified as Profane Building. In 2018, based on the Local Self-Government Act[6] (Official Gazette of the Republic of Slovenia, no. 94/07, 76/08, 79/09, 51/10 and 84/17) and the Cultural Heritage Protection Act – ZVKD-1[7] (Official Gazette of the Republic of Slovenia, no. 16/08), the Municipality of Lendava has adopted an *Ordinance on the proclamation of cultural monuments of local importance in the area of the Municipality of Lendava*[8].

The *Ordinance on the proclamation of cultural monuments of local importance in the area of the Municipality of Lendava* prescribes the protection regime description for the building Lendava Library:

- ✓ *protection of cultural, architectural, artistic and ambient values in their entirety, their originality and integrity, and protection of all views of the monument;*
- ✓ *any use and all interventions in the monument must be subject to the preservation and protection of monumental properties;*
- ✓ *professional maintenance and restoration of all intact elements of architecture according to the principle of preserving the original floor plan, dimensions, position, appearance, materials, paintings and decoration;*
- ✓ *enabling the presentation of the whole and individual protected elements and accessibility to the public to the extent that it does not endanger the protection of the monument and does not interfere with the activities taking place in it;*

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[4] https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina/2018-01-1900#
[5] https://gisportal.gov.si/portal/apps/webappviewer/index.html?id=df5b0c8a300145fda417eda6b0c2b52b
[6] https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina/82670
[7] https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina?urlid=19997&stevilka=287
[8] https://gis.gov.si/MK_eVRDpredpis/p1904_1.pdf

✓ *it is forbidden to place infrastructure and advertisements on and next to the monument.*

In terms of energy supply the Lendava district heating system is managed by the company PETROL d.d. The following are the general and technical conditions for the construction of the Lendava district heating extension.

Terms and conditions:

1. The connection can be made at the location Kranjčeva 6, which is owned by the residents and managed by the Stanovanjsko podjetje Lendava ("Lendava Housing Company") - it is necessary to obtain their consent;
2. The reserve location for connection is the common consumption point of the boiler room at Kranjčeva 8;
3. It is necessary to follow the *System Operating Instructions* for the heat distribution system in the geographical area of the Municipality of Lendava (Official Gazette of the Republic of Slovenia No. 3/2018) and all instructions given by the representative of Petrol d.d. in the field regarding the construction of the heating station and connection to the heating pipeline;
4. Drawing of existing pipelines must be ordered before the start of construction;
5. Before filling the connecting pipeline and before connecting the heating station to the district heating system, it is necessary to inform the representative of Petrol d.d.;
6. In the project for implementation, it is necessary to show the installation of the indirect heating station and the connection to the internal installation in accordance with the System operating instructions.

Figure 11: *Construction work – connection of the new pipeline to the primary network*

Technical conditions:

1. Separate heating system via indirect heating station for the heating (System Operating Instructions) for the heat distribution system in the geographical area of the Municipality of Lendava (Official Gazette of the RS No. 3/2018), which applies to the common consumption point Kranjčeva 8;
2. Separate preparation of hot sanitary water through an indirect heating station is not feasible;
3. Intended installation of an indirect heating station;
4. Internet access and enabled remote control and monitoring of the secondary heating system;
5. Enabled remote monitoring of heat consumption.

4.6. Stakeholders‘ involvement

Pomurje as a region and in this particular Lendava municipality has at its disposal a wide range of energy options already at the level of energy sources: from natural gas, various types of biofuels (wood, straw, oil, bio-gas), geothermal energy and industrial waste. The potentials of geothermal energy in the municipality of Lendava are well-drained. Geothermal energy is sufficient in the municipality of Lendava, more than it is now exploited. Thermal water is extracted from five wells. It is used in two areas: spa tourism and heating of buildings.

Only three geothermal district heating (DH) plants were considered in Slovenia in Dec. 2015 (in Lendava, Murska Sobota and Benedikt).

Final consumption of district heat in Slovenia amounted to 7,166.3 TJ in 2015. Geothermal energy used for district heating at four localities in Slovenia amounted to 21.85 TJ/yr (6.07 GWh/yr) in 2015. It stems from this that district heating systems in Slovenia cover 0.3 % of their energy needs from geothermal energy. If transformations (8,685.5 TJ) are instead taken into account, then the district heating systems cover 0.25% of their energy needs from geothermal energy.

In the Municipality of Lendava the installation of a paraffin-based latent heat storage is planned in the local library building. Moreover, the library should be connected to the geothermal grid. The pilot of a paraffin-based latent storage in connection with a geothermal district heating system is a highly innovative investment in Slovenia because no similar installation has yet been built anywhere else in Slovenia. Therefore, the installation can be a very good best practice example for the region.

In the action of the development of the pilot in Lendava three internal stakeholders and eight external ones are identified. The internal stakeholders (employees of the municipality, Mayor of the municipality and employees of Development agency Sinergija) are already involved in the project and will be informed via personal meetings, emails or telephone calls. External stakeholders are for example owners of district heating networks, representatives of the municipalities and cities in Slovenia, representatives for cultural heritage protection or local energy agencies. The communication channels will be similar as for the internal ones.

The following table shows the roles of stakeholders in cooperation and they approach, method and tools for integration into the project (communication channels included).

Table 7: *List of stakeholders in Slovenia*

Group	*Stakeholder anonymous*	*Role of stakeholder*	*Approach, method and tools for integration into to project of the stakeholders, communication channels*
internal	*Employees of Municipality of Lendava*	*Pilot funder, implementer*	*Personal meetings, emails, telephone calls.*
	Mayor of the Municipality of Lendava	*Decision-maker, it politically supports the pilot*	*Personal meetings, emails, telephone calls.*
	Employees of Development agency Sinergija	*technical and administrative support in pilot*	*Personal meetings, emails, telephone calls*
external	*Petrol - Geoterm*	*Business company Petrol Geotherm is the owner of the district heating network with geothermal energy, it is also distributor and supplier of the electricity and geothermal energy. Their role in the deployment desk will be the practical and technical point of view on investment and after the investment, network maintenance.*	*Personal meetings, emails, telephone calls, stakeholder meetings.*
	Geological Survey of Slovenia	*The Geological Survey of Slovenia provides information about geological setting and natural resources of Pomurje region and they will participate in the development of the pilot investment with their knowledge and data. They are experts in the field of geothermal energy.*	*Personal meetings, emails, telephone calls, stakeholder meetings.*
	Association of Municipalities and Towns of Slovenia	*Association of Municipalities and towns of Slovenia is the biggest representative association of municipalities established in 1992. Association has 175 member municipalities (212 of them) and they will expand and promote project aim and pilot investments across the association network*	*Personal meetings, emails, telephone calls, stakeholder meetings.*
	Institute for the Protection of Cultural Heritage of Slovenia	*The institute for the Protection of Cultural Heritage of Slovenia is a public institute that carries out professional and administrative tasks with regard to the*	*Personal meetings, emails, telephone calls, stakeholder meetings.*

		preservation of immovable and corresponding movable property and intangible cultural heritage. Institute will be responsible for frames of pilot investment based on the rules for monument protection.	
	Pomurje technology Park	*Pomurje technology Park is supporting institution for the promotion of entrepreneurship and innovation. They are supporting the new products, services and technologies. Their role will be in part of development of the innovative investment.*	*Personal meetings, emails, telephone calls, stakeholder meetings.*
	Local energy agency Pomurje (LEA Pomurje)	*The mission of Local Energy agency is promotion and fostering of continuous improvement of energy efficiency and accelerated introduction of use of renewable energy sources in Pomurje Region. LEA Pomurje is an expert in the field of RES & RUE (rational use of energy) project implementation.*	*Personal meetings, emails, telephone calls, stakeholder meetings.*
	Ekopark d.o.o.	*Business company Ekopark d.o.o. is in charge for the commercial public service. Their role in the deployment desk will be the practical point of view on investment and after the investment, network maintenance.*	*Personal meetings, emails, telephone calls, stakeholder meetings.*
	Institute for Tourism and Development Lendava	*Institute for Tourism and Development Lendava is part of a partnership for implementation of the general development priorities in Pomurje region. They are responsible for infrastructure. Their role in deployment desk is to expand and promote project aim and pilot investments in Pomurje region.*	*Personal meetings, emails, telephone calls, stakeholder meetings.*

Public participation in spatial planning and environmental protection processes in Slovenia is regulated by:

- ✓ Convention on access to information, public participation in decision-making and access to justice in environmental matters
- ✓ Spatial Planning Act and
- ✓ Environmental Protection Act

This is a legal national frame, but within the EU projects there are no formal/official rules how to involve stakeholders. This is sometimes a current decision, depending also on the current conditions and needs. Informally it is set that the stakeholder involvement is crucial and should be always considered when planning.

4.7. Transferability of the pilot action

The investment in a pilot energy storage system in Lendava will be the first in the region and at national level. The storage, which will be installed in the cultural and historic protected building of Public library of Lendava, will represent a decentralized system of thermal energy advancement in the system with paraffin – latent storages. Municipality of Lendava is one of two Slovenian municipalities that has geothermal district heating. In parallel the municipality also works on energy efficiency, where there are restrictions on cultural and historical protected structures. Pilot paraffin-based latent storages in connection with geothermal district heating system in Lendava is an innovative investment at the national level, such installation has not yet been built anywhere in Slovenia. Investment can serve as an example of good practice in the project area; example of innovative solution of storing renewable energy in an effective way and can be easily transferred to other municipalities/regions/countries.

4.8. Impact of the pilot action

It is challenging to provide a low carbon energy supply in cities in a style of energy storages. Especially in historical urban centres it is very difficult to achieve these results, because interventions in this specific area meet strict architectural protection constraints, involve higher implementation costs and often come in conflict with town planning policies. Therefore, the main objective of the Store4HUC project is to improve and enrich energy and spatial planning strategies targeting historical city centres by focusing on integration of energy storage systems to enhance the public institutional and utility capabilities.

The degree of energy self-sufficiency achieved with the implementation of these measures varies in the different pilots depending on the local climatic conditions, type of technology, previous energy consumption, etc. Each demonstration site is combining locally available renewable energy sources with storage units. Even though the used technologies are proven and well established, the way they are combined is innovative and will produce new knowledge. This has been advertised and disseminated via two conferences by presenting the Store4HUC poster on the SSPCR conference in Bolzano on 10-12-19 as well as oral and poster presenting of Store4HUC on the CEBC 2020 conference in Graz on 24-01-20 (dissemination material distributed at events).

Mutual learning sessions of Store4HUC provided benefit to the participating audiences among the consortium via project meetings and to stakeholders via deployment desk meetings. In Lendava the implementation measures have started. Due to the Corona virus the construction work and all planned stakeholder engagement meetings are postponed. However, energy experts to the project of Lendava pilot connected, got valuable and transferable experience in the field of this “new” technology in connection with low temperature geothermal energy. Local authorities are involved in the procurement and communication processes as harbingers providing the necessary permits of the site and for future other projects. Pilot-related socio-economic aspects are investigated during and after the construction work.

As a result of the connection to RES and newly implemented storage in accordance with the newly implemented control and EMS system, the following positive effects can be achieved:

- ✓ Increasing the energy efficiency of the system by changing the heating system from energy in-efficient (old Oil-Fired boiler) to efficient (DHS) → min. primary energy savings → CO2 saving through lower final energy consumption
- ✓ Lower pollutant emissions by changing from fossil to renewable energy source (carbon dioxide - CO_2, carbon monoxide - CO, dust and other greenhouse gas emissions as NOx and CxHy)
- ✓ Exploitation of local renewable energy – geothermal energy
- ✓ Extension of maintenance intervals → lower maintenance costs (no maintenance on heating system and low maintenance cost on storage)

Table 8: *Calculated fuel and pollutant savings*

Parameters	before	after	difference
energy savings			
Fuel energy used	kWh	kWh	%
	84.351[9]	79.711	- 5,5
savings of fossil fuels			
Fossil fuel used	kWh	kWh	%
	84.351	0	- 100
reduction of pollution			
	kg/a		
CO_2-equivalent emissions[10]	26.148,81		
CO_2-standard emission factor	23.533,92		
SO_2	36,44		
CO	13,66		
NO_x	12,15		
Dust	1,53		
CxHy	1,82		

9 https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi9pdeTuYbqAhUyRxUIHbs3CPwQFjAAegQIAxAB&url=https%3A%2F%2Fwww.lendava.si%2Fsites%2Fdefault%2Ffiles%2Flek_koncno_porocilo.pdf&usg=AOvVaw1SPl54_yz9LG42fO5rTkKr

10 https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjrwtreu4bqAhVMQMAKHUJPCWgQFjADegQIBRAB&url=http%3A%2F%2Fwww.covenantofmayors.eu%2FIMG%2Fpdf%2Ftechnical_annex_en.pdf&usg=AOvVaw292jg4vxVp9v9b5BH6WRZj

The benefits of the regions will be presented in the deliverable D.T2.3.1 Transnational evaluation by fellow specialists of research. All four pilots in Cuneo, Lendava, Weiz and Bračak are performed. The surveys of Lendava and Weiz will follow. All interview results are connected to the WPT2 - Systematic procedures for implementation of energy storages in HUC to better understand favourable conditions for the implementation of the demonstration measures. The transnational cooperation within Store4HUC allows to get higher visibility at regional, national and European level.

4.9. KPIs (Key Performance Indicators)

This paragraph reports on the KPIs identified to evaluate the impacts of the pilot actions on different aspects and benefits foreseen by the implementation of energy storages in HUCs. As already stated in chapter 3, the KPIs are classified in 2 different categories:

- **Pilot specific KPIs**, specifically aimed to measure the performance and evaluate the results of the storage investment and the direct benefits of its application, coupled with a suitable control algorithm for their energy management. Each PP must identify its pilot-specific KPIs, depending on the features of its pilot investment
- **Urban KPIs**, identified to measure or evaluate the benefits of the pilot action at urban level or other intermediate levels (for example: municipal properties). All PPs are required to monitor these common urban KPIs.

In order to understand the meaning of the implemented indicators, a short introduction to the definition of the parameters referred to energy consumption is necessary.

In the following indicators these parameters have been defined:

- $E_{c,i}$: i-th thermal/electrical energy consumption of the pilot system, supplied by external source for one year [kWh]
- $E_{c,tot} = \sum E_{c,i}$: total thermal/electrical energy consumption of the pilot system, supplied by external sources for one year [kWh]
- $E_{self\text{-}RES,i}$: i-th consumed energy from self-production of local RES system in a year [kWh]
- $E_{self\text{-}RES} = \sum E_{self\text{-}RES,i}$: total consumed energy from self-production of local RES systems in a year [kWh]
- $E_{TOT} = E_{c,tot} + E_{self\text{-}RES}$: total thermal/electrical energy consumption of the pilot system for one year [kWh]

Moreover, to evaluate these indicators and compare the calculated values during the reporting period, a fixed set of conditions is defined in order to adjust the calculated values from their actual conditions to the common fixed set of conditions.

The adjustment terms are defined from identifiable physical facts about the energy governing characteristics of equipment/system. Two types of adjustments are possible:

- Routine Adjustments – for any energy-governing factors, expected to change routinely during the period of calculation of the indicator, such as weather conditions, annual lift runs, hours of utilisation of the system.
- Non-Routine Adjustment - for those energy-governing factors which are not usually expected to change, such as the facility size, the heated volume or the use of the system.

Table 9: *Complete list of KPIs*

Indicator	Category	Description	Measurement Unit
KPI_1: External energy needs of the pilot system	Pilot specific KPI	Energy consumption supplied by external sources	[kWh]
KPI_2: External energy cost of the pilot system	Pilot specific KPI	Cost of the energy supplied by external sources	[€]
KPI_3: Average yearly CO_2 abatement	Pilot specific / Urban KPI	CO_2 emissions	[t CO_2]
KPI_4: Autarky rate	Pilot specific / Urban KPI	Energy self-sufficiency	[%]
KPI_5: Use of energy from RES	Pilot specific / Urban KPI	RES self-consumed energy, associated to storage	[kWh]
KPI_6: Security of energy supply	Pilot specific KPI	Hours without service interruptions/discomforts	[-]
KPI_7: Power peak	Pilot specific KPI	Average power peak	[kW]
KPI_8: Profitability	Pilot specific KPI	Net Present Value / Investment	[-]
KPI_9: Stimulation of the local economy	Urban KPI	New jobs created calculated through estimation of investment and replicability potential	[-]

4.9.1. KPI1: External energy needs of the pilot system

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Energy consumption supplied by external sources
Input parameters & Calculation	Calculation method: 1. Total thermal/electrical energy consumption of the pilot system, supplied by external sources for one year $\mathbf{E_{c,tot}}$ [kWh] 2. Calculation of Key Performance Indicator: $\mathbf{KPI_1 = E_{c,tot}}$
Measurement Unit	[kWh]
References	Efficiency Valuation Organization, *International Performance Measurement and Verification Protocol*, 2017

Status quo:

$\mathbf{KPI_1 = E_{c,tot}}$ = 84.350,9 [kWh]

Background and assumptions:

- Average consumed extra light heating oil by old boiler in last years by *Local Energy Concept of Municipality of Lendava*: 8.452 [l]
- Lower heating value (LHV): 9,98 [kWh/l]
- Electrical energy consumption not considered, as electrical energy is only used as auxiliary energy for circulating pumps, for instance, and amounts to only a very small proportion of the total energy consumption.

Target (prediction):

$\mathbf{KPI_1 = E_{c,tot}}$ = 80.133,3 [kWh]

Background and assumptions:

- Predicted savings (related to more energy efficient heating system) with planned measures: 5,0 [%]

4.9.2. KPI2: External energy cost of the pilot system

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Cost of the energy supplied by external sources
Input parameters & Calculation	Calculation method: 1. External thermal/electrical energy cost[1] $\mathbf{C_E}$ [€], as function of yearly energy profile of each external energy source 2. Thermal/electrical energy consumption profile of the pilot system, supplied by external sources for one year $\mathbf{E_{c,tot}}$ [kWh] 3. External thermal/electrical cost of peak power taken from external sources $\mathbf{C_P}$ [€], which also includes the contracted power delivery with the external source 4. Sequence of peak powers absorbed from the external sources on yearly basis $\mathbf{P_{peak}}$ [kW] 5. Calculation of Key Performance Indicator: $\mathbf{KPI_2 = \Sigma\,[C_E(E_{c,i}) + C_P(P_{peak})]}$
Measurement Unit	[€]
References	-

[1] This cost must include all expenses related to energy purchasing, energy distribution and transportation, energy meter management, system charges and taxes.

Status quo:

$\mathbf{KPI_2 = \Sigma\,[C_E(E_{c,i}) + C_P(P_{peak})]}$ = 8.460,45 [€]

Background and assumptions:

- Extra light heating oil is the primary energy source for the local heating network. Therefore, there is no peak load boiler or similar → $\mathbf{C_P}$ and $\mathbf{P_{peak}}$ are zero.
- Average consumed extra light heating oil by old boiler in last years by *Local Energy Concept of Municipality of Lendava*: 8.452 [l]

- Extra light heating oil price[11] in business year 2019: 1,001 [€/l] or 0,0828 [€/kWh]
  - Average price; includes delivery and all taxes (excise duty, environmental tax, RES and RUE tax, etc.)

Target (prediction):

$KPI_2 = \Sigma [C_E(E_{c,i}) + C_P(P_{peak})]$ = 5.272,93 [€]

Background and assumptions:

- Also, in future there is no peak load boiler or similar planned → **C_P** and **P_{peak}** are zero.
- Predicted price from geothermal district heating system[12] without tax (22%): 22,85264 [€/MWh$_{(VC\text{ - variable cost})}$] and 3.517,12707 [€/MW/month$_{(FC\text{ - fixed cost})}$]
  - Represents the heat energy price for the business year 2020 and according to the district heating system operator the price will stay constant for the next few years.
  - The standard VAT (Value Added Tax) rate in Slovenia is 22 % and 9,5 % reduced rate – latter applies to goods and services specially defined by the VAT Act.
  - The estimated thermal power for heating of 600 m^2 is 72 kW at 120 W/m^2.

[11] https://www.statista.com/statistics/597582/heating-oil-price-slovenia/

[12] https://www.petrol.si/binaries/content/assets/www/2018/pages/za-dom/energenti/daljinsko-ogrevanje/lendava/tarifna-skupina.pdf

4.9.3. KPI_3: Yearly CO2 emissions

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	Yes
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	CO_2 emissions
Input parameters & Calculation	Calculation method: 1. Total thermal/electrical energy consumption of the pilot system, supplied by external sources for one year $\mathbf{E_{c,tot}}$ [kWh] 2. CO_2 emission factor to be applied to the energy source **EF** [t CO_2/kWh], e.g IPCC emission factors 3. Calculation of Key Performance Indicator: $\mathbf{KPI_3 = E_{c,tot} \times EF}$
Measurement Unit	[t CO_2]
References	Covenant of Mayor: http://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf

Status quo:

$\mathbf{KPI_3 = E_{c,tot} \times EF}$ = 84.350,9 kWh × 0,000279 t CO_2/kWh = 23,53 [t CO_2]

Background and assumptions:

- **EF** for Residental Fuel Oil = 0,279 [t CO_2/MWh]
- $\mathbf{E_{c,tot}}$ = 84,3509 [MWh]

Target (prediction):

$\mathbf{KPI_3 = E_{c,tot} \times EF}$ = 80.133,3 kWh × 0 t CO_2/kWh = 0 [t CO_2]

Background and assumptions:

- **EF** for Geothermal = 0 [t CO_2/MWh]

- $\mathbf{E_{c,tot}}$ = 80,1333 [MWh]

4.9.4. KPI4: Autarky rate

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	Yes
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Energy self-sufficiency
Input parameters & Calculation	Calculation method: 1. Consumed energy from self-production of local RES system in a year $\mathbf{E_{self\text{-}RES}}$ [kWh] 2. Total thermal/electrical energy consumption of the pilot system for one year $\mathbf{E_{TOT}}$ [kWh] 3. Calculation of Key Performance Indicator: $$\mathbf{KPI_4 = [E_{self\text{-}RES}/\ E_{TOT}] \times 100\ \%}$$
Measurement Unit	[%]
References	Deliverable D.T3.2.4 “Validation report and establishment of the autarky rate tool & the checklist”

Status quo:

$\mathbf{KPI_4 = [E_{self\text{-}RES}/E_{TOT}] \times 100\ \% = 0\ [\%]}$

Background and assumptions:

- There is no self-production of a local RES system for the heating plant → $E_{self\text{-}RES}$ is zero. The only (external) energy source is the geothermal energy, provided 100% by the district heating system operator → $E_{TOT} = E_{c,tot}$.

Target (prediction):

$\mathbf{KPI_4 = [E_{self\text{-}RES}/E_{TOT}] \times 100\ \% = 0\ [\%]}$

Background and assumptions:

- Also, in future there is no self-production of a local RES system planned.

4.9.5. KPI5: Use of energy from RES

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	Yes
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Consumed energy from self-production of local RES systems in a year
Input parameters & Calculation	Calculation method: 1. Consumed energy produced by local RES systems in a year $E_{\text{self-RES}}$ [kWh] 2. Calculation of Key Performance Indicator: $KPI_5 = E_{\text{self-RES}}$
Measurement Unit	[kWh]
References	-

Status quo:

$KPI_5 = E_{\text{self-RES}} = 0$ **[kWh]**

Background and assumptions:

- See KPI_4.

Target (prediction):

$KPI_5 = E_{\text{self-RES}} = 0$ **[kWh]**

Background and assumptions:

- See KPI_4.

4.9.6. KPI6: Security of energy supply

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Percentage of time without interruptions/discomforts in terms of operation of local energy consumption system without service interruptions/discomforts
Input parameters & Calculation	Calculation method: 1. Number of hours without interruptions/discomforts on yearly basis $N_{no\_interrupt}$ [h] 2. Total number of hours of local energy consumption systems operation on yearly basis N_{tot} [h] 3. Calculation of Key Performance Indicator: $KPI_6 = N_{no\_interrupt} / N_{tot} \times 100\ \%$
Measurement Unit	[%]
References	-

<u>Status quo:</u>

$$KPI_6 = N_{no\_interrupt} / N_{tot} \times 100\ \% = 99{,}00\ [\%]$$

Background and assumptions:

- N_{tot} = 8.760 [h]
  - The heating plant is operated the whole year.
- $N_{no\_interrupt}$ = 8.672,4 [h]
  - The $N_{no\_interrupt}$ was derived from the experiences of the users. It was assumed that there were 87,6 [h] with interruptions, related to regular maintenance works.

<u>Target (prediction):</u>

$$KPI_6 = N_{no\_interrupt} / N_{tot} \times 100\ \% = 100\ [\%]$$

Background and assumptions:

- Based on the planned measures and the implementation of the storage, it is assumed that no interruptions/discomforts or under-temperatures of the network will occur in the future.

4.9.7. KPI7: Peak power

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Average yearly peak power delivered from external energy sources
Input parameters & Calculation	Calculation method: 1. Array of monthly peak powers delivered from external energy sources $P_{peak,month}$ [kW], where *month* goes from January to December [$P_{peak,January}$, $P_{peak,February}$, ... , $P_{peak,December}$] 2. Calculation of Key Performance Indicator: $$KPI_7 = \frac{1}{12} * \sum_{month=January}^{December} P_{peak,month}$$
Measurement Unit	[kW]
References	-

Status quo:

Q = 71- 85 kW (Boiler LOGANO G215 BUDERUS)

Q = 70 kW (New heat station GIAFLEX)

KPI_7 = 22,25 [kW] (Calculation of Key Performance Indicator)

Background and assumptions:

	Average	[kW]	Peak	[kW]
$P_{peak,January}$	45	[kW]	64	[kW]
$P_{peak,February}$	33	[kW]	47	[kW]
$P_{peak,March}$	23	[kW]	32	[kW]
$P_{peak,April}$	12	[kW]	17	[kW]
$P_{peak,May}$	3	[kW]	4	[kW]
$P_{peak,June}$	0	[kW]	0	[kW]
$P_{peak,July}$	0	[kW]	0	[kW]
$P_{peak,Augus}$	0	[kW]	0	[kW]

$P_{peak,September}$	4	[kW]	6	[kW]
$P_{peak,October}$	11	[kW]	16	[kW]
$P_{peak,November}$	21	[kW]	30	[kW]
$P_{peak,December}$	36	[kW]	51	[kW]

- $P_{peak,month}$ for each month are derived from software RETScreen, Canada, data for one year[13]. (Location data: Murska Sobota).

<u>**Target (prediction):**</u>

Q = 47 kW (maximum heat output of the new GIAFLEX indirect heat station when installing PCM storage tanks)

KPI_7 = 16,5 [kW] (Calculation of Key Performance Indicator)

Background and assumptions:

- In the future, only a heat station with the support of heat accumulators will operate.
- However, the existing boiler will only serve as a backup in the event of a district heating failure.
- From the results of the predicted condition, we can see that the installation of heat accumulators will reduce the peak load from 64 kW to 47 kW.
- The above calculations are made on the assumption that the entire building has a heating area of 600 m². In the case of heating ½ the building (library only), all values written below are halved.

Assuming the max power of the boiler in operation leads to following $P_{peak,month}$:

	Average	[kW]	Peak	[kW]
$P_{peak,January}$	45	[kW]	47	[kW]
$P_{peak,February}$	33	[kW]	34	[kW]
$P_{peak,March}$	23	[kW]	24	[kW]
$P_{peak,April}$	12	[kW]	13	[kW]
$P_{peak,May}$	3	[kW]	3	[kW]
$P_{peak,June}$	0	[kW]	0	[kW]
$P_{peak,July}$	0	[kW]	0	[kW]
$P_{peak,Augus}$	0	[kW]	0	[kW]
$P_{peak,September}$	4	[kW]	5	[kW]
$P_{peak,October}$	11	[kW]	12	[kW]

[13] Source: https://www.nrcan.gc.ca/maps-tools-publications/tools/data-analysis-software-modelling/retscreen/7465

$P_{peak,November}$	21	[kW]	22	[kW]
$P_{peak,December}$	36	[kW]	38	[kW]

4.9.8. KPI8: Profitability

Applicability for objects of assessment

Pilot specific KPI	Yes
Urban KPI	No
Thermal energy storage	Yes
Electric energy storage	Yes
RES system	Yes

Description	Net Present Value / Investment
Input parameters & Calculation	Calculation method: 1. Calculation of Net Present Value: $NPV = -I_0 + \sum_{t=0}^{t} [\frac{R_t}{(1+i)^t}]$ NPV = Net Present Value [€] I_0 = investment [€] R_t = Net cash inflow-outflows during a single period t [€] t = numbers of time periods i = discount rate or return that could be earned in an alternative investment 2. Calculation of Key Performance: **KPI_8 = NPV / I_0**
Measurement Unit	[-]
References	-

Status quo:

Not applicable.

Target (prediction):

KPI8 = NPV / I0 = 1.49 [-]

Background and assumptions:

- I0 = 96.356,99 [€]
  - Estimated costs of planned measures on the basis of the offers obtained from vendors.
- Rt = 3.825,04 [€]

    - Difference between net cash outflow (cost for energy before investment) and net cash outflow (cost for energy after investment)
    - assumed to be constant over the entire period
- t = 15 [a]
    - the number of time periods is assumed to be 15 years according to the technical life of the pilot (defined in KPI9)
- i = 0 [%]
    - internal rate
- NPV = 144.169,94 € [€]
    - Net Present Value after t time periods

4.9.9. KPI9: Stimulation of the local economy

Applicability for objects of assessment

Pilot specific KPI	-
Urban KPI	X
Thermal energy storage	X
Electric energy storage	X
Only energy storage integrated by RES system	X

Description	New jobs created calculated through valuation of investment and its maintenance and operational costs
Input parameters & Calculation	Calculation method: 1. Total cumulated expense of the storage installed, calculated as the Investment (*CAPEX* [€]) + associated Operation & Maintenance costs ($OPEX$ [€], evaluated on the system technical life: 20 years for electric pilot and 15 years for thermal pilot) 2. Constant K [€], equal to 200.000 €, that represents an empirical factor calculated as the ratio between a generic Company turnover and the number of company employees 3. *r*, equal to the number of the same storage solutions potentially installed in the district/region, considering a mid-term perspective of 5 years after the end of the pilot project. At the pre-investment stage consider this parameter equal to 1 4. Calculation of Key Perfomance Indicator: **$KPI_9 = (CAPEX+OPEX) * r / K$**
Measurement Unit	-
References	-

Status quo:

Not applicable.

Target (prediction):

$KPI_9 = (CAPEX+OPEX) * r / K = 0,48$ [-]

Background and assumptions:

- *CAPEX* = 96.356,99 [€]
    - Estimated costs of planned measures on the basis of the offers obtained from vendors
- *OPEX = 0 [€]*
    - In case of our pilot the Operation and Maintenance costs are not calculated, because it is about reducing the cost of energy supplied from external distributer

5. CONCLUSIONS

As with all construction measures at sites listed as monumental and landscape protected, the greatest challenge for the pilot in Lendava was to harmonise the additional regulations and requirements of monument and landscape protection with the objectives of the implementation. Additionally, due to the Covid-19 pandemic situation the construction work and all planned stakeholder engagement meetings had to stop for some weeks in the last quarter of 2020. This situation resulted in the building phase starting in January 2021. Before the construction work the most important fact was also to find a suitable expert for geothermal district heating in connection with PCM storages and in parallel to find a suitable product on the market, which will lead to the expected results. However, the construction work has been carried out from last 2 weeks in January till mid-February 2021 in two phases:

1. Connection of the building to the existing geothermal district network;
2. Installation of the PCM storage tank and all electrical and mechanical components for energy transmission, measurement and control.

In the meantime, deployment desk meetings (individual and group) were held with stakeholders, creating a working network on the topics related to the pilot (geothermal energy, district heating, EMS tool, local renewable energy, innovative storage solutions, local/national policy on monumental and landscape protected, etc.). These meetings proved to be very useful in laying the foundations for future collaboration involving different actors, from institutions to private companies operating in the energy sector, creating an even wider network thanks to the cross-fertilization events that have been and will be held during the project.

During the project preparation phase, public procurement process and construction phase, partnerships were established between Local Energy Agency Pomurje, Municipality of Lendava, regional Development Agency Sinergija, distributer Petrol – Geotherm, national Geological Survey of Slovenia, Institute for the Protection of Cultural Heritage of Slovenia and the Pomurje technology Park), which will hopefully be continued successfully in future projects and cooperation. Despite the delays due to the pandemic situation, there were no major problems during the construction phase, the monitoring and testing phase of the system has started already in the heating season and will be completed in the beginning of the next heating season when also the designed EMS tool will be applied to provide decision support for one-day ahead system operation.