FINAL REPORT OF THE HUC PILOT ACTION IN BRACAK (CRO)

D.T2.2.5

Version
03/ 2022

TITLE AND LOCATION of the PILOT action: Energy management of the Bracak Manor with PV and batteries integrated with existing energy systems, Bracak (CRO)

REPORTING STAGE (tick on the proper option)

☐ Mid-term

☒ Final

☐ Transnational evaluation

Title	Final report of the HUC pilot action in Bracak (CRO)
Deliverable	D.T2.2.5
Authors	Matija Hrupački, Martina Krizmanić Pećnik, Miljenko Jagarčec, Velimir Šegon
Contributors	
Status	V1
Reviewed by	
Submission	

Content

1. SUMMARY

Bračak Manor was reconstructed and restored in 2017 in accordance with best practices in renewing heritage on the principle of energy efficiency and today is used as central place for organisations, companies and institutions interested in the renewable energy as well as small and medium companies (SME) from other sectors. It also serves as business incubator for young companies with favourable lease of business office spaces. The manor is a protected cultural and heritage monument listed in Register of Cultural Goods of the Republic of Croatia, and it is owned by the Krapina-Zagorje County.

The aim of the Bračak pilot project is the implementation of a central battery (bank) system, installation of a photovoltaic system, and integration of it to an advanced Energy management system (EMS). Bračak Manor is already equipped with wood pellets boiler for heating, micro-CHP for hot water and power production, air-water heat pump system for cooling and heating in transitional periods, wall insulation on the inside and energy efficient windows and doors, efficient lighting system, HVAC system, central EMS for monitoring of heating, cooling and energy consumption, rainwater harvesting for irrigation of green areas and wastewater treatment as well as electric vehicle charging station. The already existing systems will be combined with the new ones through an advanced energy management ICT system that will be built on top of the already existing central monitoring system as decision support for the system operators instructing how to run the micro-CHP and wood pellets boiler on one-day ahead scale, in the presence of the newly introduced photovoltaic and battery system. The introduced energy management system will inherit the preview project - 3Smart[1] (UNIZGFER, PP9).

This Final report (D.T2.2.5) reflects the progress on the Bračak pilot installation, launching of the tender procedure for installation on the site and outlines preliminary energy management steps. It describes the progress of the pilot action, the procurement procedure for installing the pilot, the execution of works and construction supervision, the installation and integration process, the impact of the investment on energy and overall costs and the integration of battery system and photovoltaic system into energy management system. Also, it describes the Energy and urban policy frames as well as the Stakeholder's involvement, the transferability of the pilot action and the impact of the pilot action. The last chapters of this Final report describe key performance indicators to evaluate the impacts of the pilot actions on different aspects and benefits foreseen by the implementation of energy storages in HUCs.

Due to the need of obtaining a building permit for the installation of the photovoltaic system, whose proceedings lasted more than two months, the start of execution of works was slightly delayed. Also, due to the COVID 19 pandemic, the manufacturer of the designed battery system could not deliver the equipment in due time, so the deadline for the execution of works was extended.

Construction officially started on 28.10.2020, while the commissioning was done on November 2, 2020. Construction works were completed on 30.06.2021. Due to the need of obtaining a building permit for the installation of the photovoltaic system, whose proceedings lasted more than two months, the start of execution of works was slightly delayed. The works on the construction of the solar power plant have been completed, the solar power plant is in operation. The works were not performed within the deadline as defined in Annex II of the contract because no technical inspection was held, that is the conditions of the Contract were for the issued permit to be considered a successful completion of the works. On that occasion, the contractor received an extension until 30.09.2021. After eliminating all deficiencies, the Administrative Department for Physical Planning, Construction and Environmental Protection, Zabok issued on 23.11.2011. decision (Use permit, CLASS: UP / I-361-05 / 21-01 / 000097, REGISTRATION NUMBER: 2140 / 01-08-5-21-0011 dated 26.10.2021) which became final.

[1] http://www.interreg-danube.eu/approved-projects/3smart

The battery storage and photovoltaic system as low carbon energy source will provide a good showcase to the local authorities which can benefit in terms of improved energy efficiency and increased use of renewable energy sources and lower energy costs. Bračak pilot project should serve as an innovative good-practice example over the next years and as a model for simplified technical and economic implementation in cultural heritage and may lead as lighthouse pilot to a significant increase in the proportion of renewable energy sources in historic urban centres in Krapina-Zagorje county. The long-term goal is to show innovative materials and technology in reconstruction as a demonstrative example for other similar examples of cultural heritage and show that despite of strict conservation requirements a project of this type is possible.

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) –February 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 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:
  - First results of the application of operational and monitoring tools.
  - Adaptations of energy and urban policy frames that are needed for the realisation.
  - Mapping and adaptation of HUC regulations for the authorisation of building integration.
  - Energy storage promotion and replication activities.
  - Follow up - recommendations for 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 has been described in the former chapters, the subchapters below show the course of implementation of the Croatian pilot project. For the installation of the central battery (bank) system, the installation of a photovoltaic system, and integration and connection of it to the advanced Energy management system the investment is presented according to the activities planned in the application form. This chapter describes procurement procedure, installation and integration processes, impact of the investment on energy & overall costs, and the energy management upgrade. 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

This chapter describes the public procurement procedure that is carried out as a part of the implementation of the Pilot Project. The procurement is carried out in accordance with the Public Procurement Act (OG 120/2016) of the Republic of Croatia, internal acts of the Agency and in accordance with the Interreg CENTRAL EUROPE Program Rules, and consists of:

- Procurement for the Installation Project for the construction of a free-standing canopy with a photovoltaic power plant and battery system with integration in the central monitoring system
- Procurement for Execution of works (photovoltaic power plant + battery system + central monitoring system)
- Procurement for the Construction Supervision.

The power plant construction procurement procedures are described below:

Procurement for the Installation Project for the construction of a free-standing canopy with a photovoltaic power plant and battery system with integration in the central monitoring system

Procurement for the Installation Project for constructing a free-standing canopy with a photovoltaic power plant and battery system with integration in the central monitoring system has begun with market research. Market research was conducted following the Interreg CENTRAL EUROPE Program Rules. As part of the market research, based on the terms of reference, a request for bids was sent to five different design offices and 5 were collected. After the market research was conducted, inquiries for offers were again sent to 5 design offices, and after the evaluation, a contract was signed with the most favorable bidder - Elektrik d.o.o. Since the Law on Protection and Preservation of Cultural Heritage in Croatia prohibits any action that could directly or indirectly change the properties, shape, meaning, and appearance of cultural property and it is obligatory to protect and preserve cultural goods in their pristine and original condition, and to pass on cultural goods to future generations the installation of a photovoltaic system on the roof of a building is impossible. For that reason, it was necessary to look for other solutions to accommodate a photovoltaic system. For the execution of the pilot project Bračak, the Conservation department suggested and accepted the construction of a canopy in the parking lot next to the manor on the same cadastral plot. To achieve that, it was necessary to obtain a building permit and meet special conditions for construction. All special conditions for construction and building permits are obtained and the designers designed the pilot project according to these instructions. Also, a fire protection study was made. Due to the procedure of obtaining a building permit, and meeting special construction conditions, the entire design process took a little longer.

Procurement for Execution of works (PV system + battery system + central monitoring system)

The Procurement for Execution of works (PV + battery system + central monitoring system) has begun with market research. Market research was conducted in accordance with the Interreg CENTRAL EUROPE Program ules. As a part of the market research, based on the Installation project a request for bids was sent to 5 different companies and 4 bids were collected. After the market research was conducted, on September 24 inquiries for offers were again sent to 5 different companies, and the deadline for submission of bids was October 9, 2020. As a part of the public procurement, each bidder had to prove his ability to perform professional activities, technical and professional ability, submit a guarantee for the proper performance of the contract, fill in the tender form and attach other documents in accordance with the procurement rules. After the evaluation, a Turnkey Contract was signed with the most favorable bidder - Solaris Pons d.o.o. within the simple procurement procedure with a lowest total price of 324.401,70 HRK including VAT (EUR 43.543,85 according to the middle exchange rate of EUR 1 = HRK 7.45). The execution of works officially began on November 2, 2020. During November, all preparatory and earthworks for the construction of the canopy were carried out. and the canopy was built during December and January.

On January 27, 2021, the contractor requested an extension of the deadline due to the unfavourable epidemiological - Covid 19 situation in Europe, which makes it difficult to deliver the equipment and materials necessary to complete the pilot project. The reason is that manufacturers work with reduced capacities and under special conditions, and due to the specifics of the project, and thus the designed equipment, it is available only directly from the manufacturer, and is delivered exclusively on order, not via the warehouse. This argument was accepted by the construction supervision, and the deadline for the execution of works has been extended to April 30, 2021.

The second extension of the deadline (until 30.06.2021) was requested due to the unfavorable epidemiological situation in Europe and around the world, and the delivery of equipment and materials necessary for the completion of works on the installation of microinverters at the photovoltaic power plant was difficult. The works on the construction of the solar power plant have been completed, the solar power plant is in operation. The works were not performed within the deadline as defined in Annex II of the contract because no technical inspection was held, that is the conditions of the Contract were for the issued permit to be considered a successful completion of the works. On that occasion, the contractor received an extension until 30.09.2021.

Procurement for the Construction Supervision

Procurement for the Construction supervision was carried out by the simple procurement procedure in accordance with the Public Procurement Act (OG 120/2016) of the Republic of Croatia, internal acts of the Agency and in accordance with the Interreg CENTRAL EUROPE Program Rules. Construction supervision was carried out in accordance with the Croatian Construction Act (OG 153/3, 20/17, 39/19, 125/19), and Law on Works and Activities of Physical Planning and Construction (OG 78/15, 118/18, 110/19). As a part of the construction supervision, the following have been contracted: Professional supervision, Design supervision and Coordinator of safety at work. For each of them, inquiries for offers were sent to 3 different companies, and contracts have been concluded with the most favourable bidder. The total cost of construction supervision is 19.687,50 HRK (EUR 2.642,61 according to the middle exchange rate of EUR 1 = HRK 7.45).

4.2. Installation and integration process

The aim of the pilot project is the implementation of a central battery (bank) system, installation of a photovoltaic system, and integration of it to advanced Energy management system. Bračak Manor is already equipped with a wood pellets boiler for heating, micro-CHP for hot water and power production, air-water heat pump system for cooling and heating in transitional periods, wall insulation on the inside and energy efficient windows and doors, efficient lighting system, HVAC system, a central Building Management System for monitoring of heating, cooling and energy consumption, rainwater harvesting for irrigation of the green areas and wastewater treatment as well as electric vehicle charging station. The already existing systems are combined with the new ones through an advanced energy management ICT system that is built on top of the already existing central monitoring system as a coordination service that optimally exploits all different available assets. The energy management system serves as decision support so the operators can decide one day ahead how to engage micro-CHP and the wood pellet boiler in the presence of newly installed photovoltaic and battery system (UNIZGFER, PP9).

Photovoltaic system and the battery system are connected to the billing metering point of the Bračak manor where all produced energy is primarily used for own consumption and the surplus is stored in the battery system. If the production of electricity exceed the needs of Bračak Manor and the capacity of the battery system, then the surplus is delivered to the grid. The distribution system operator, as one of the stakeholders, was informed from the beginning about the implementation of the pilot project and its task was to issue the prior electricity approval required for the connection to the distribution network.

After the public procurement for the execution of works, a Turnkey Contract was signed with the company Solaris pons d.o.o. and the official introduction to the work was held on November 2, 2020. During November, all preparatory and earthworks for the construction of the canopy were carried out, and a steel structure was delivered to the construction site and the construction of the canopy began and a steel structure was delivered to the construction site and the construction of the canopy began (see Figure 1, and Figure 2).

Figure 1: Preparatory works
Source: REGEA 2020

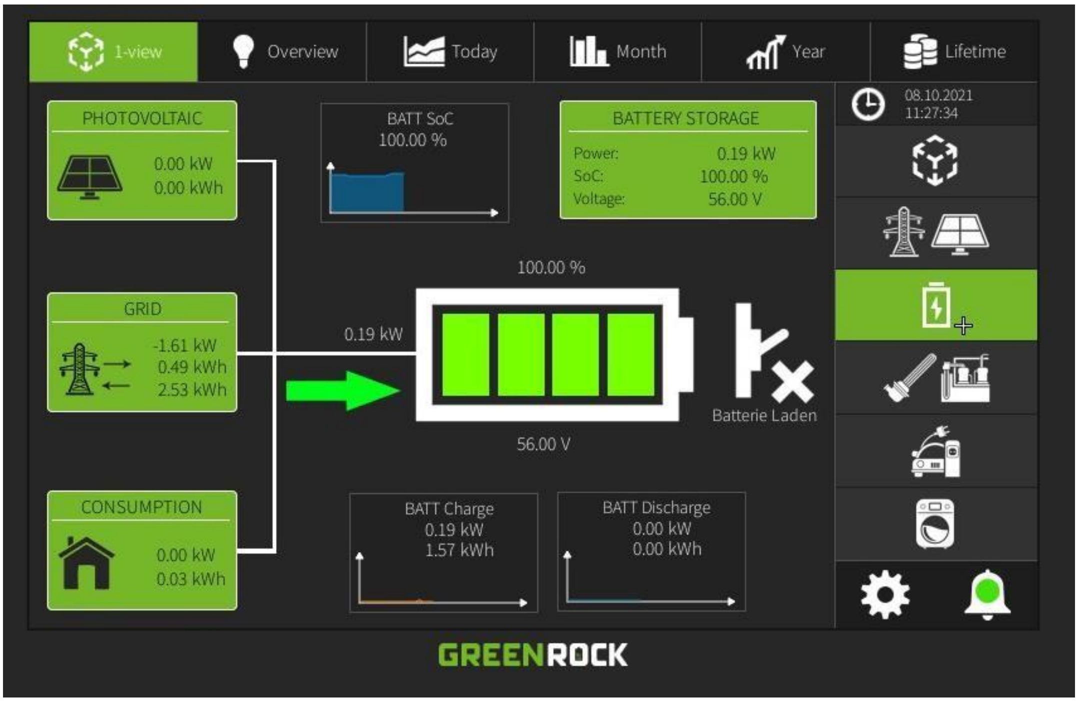
Figure 2: Canopy construction
Source: REGEA 2021.

The colour of the canopy was determined by the conservation office. The selected colour is RAL 9017. The roof surface (Figure 3) of the canopy is used to install photovoltaic modules. The canopy has a rectangular roof surface measuring 9,44 x 6,39 meters and a total of 36 photovoltaic monocrystalline modules with a capacity of 300Wp each is installed on it. All technical details of the photovoltaic modules are listed on page 58 of the electrical installation project. It is installed 4 rows with 9 modules, which ensure that the entire roof surface is covered with photovoltaic modules. This means that the peak power of the photovoltaic system is 36 X 300Wp = 10,8 kWp. Each photovoltaic module has an associated micro inverter to reduce losses from possible shading during the day.

Figure 3: Installed photovoltaic modules
Source: REGEA 2021.

The storage (battery system) is placed in the premises of the Bračak Manor, in the basement next to the stairs. Three-phase battery system has a capacity of 8,0 kWh, together with inverters / chargers and battery management equipment. All technical details of the battery system are listed on page 65 of the installation project. Some of them are: Max. active power battery 88,5%; Max. active power charging/discharging: 96%; Discharge depth: 100%; Communication: Web interface via Ethernet, external communication via Modbus TCP; Maximum output current: 11.0 A; Nominal output current 9,1A.

Figure 4: The storage (battery system) is placed in the premises of the Bracak Manor, in the basement next to the stairs
Source: REGEA 2021.



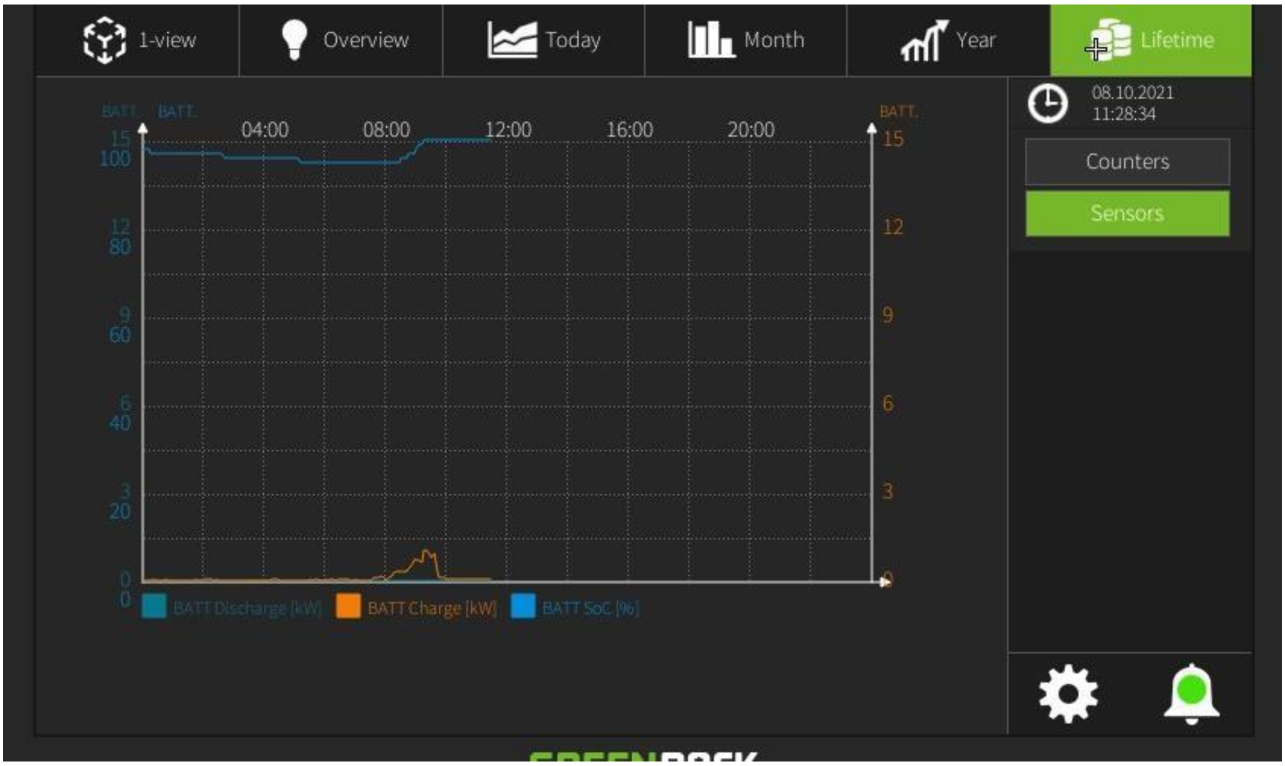


Figure 5: Building management system

Source: REGEA 2021.

Below is given the schedule of all activities through the implementation of the project.

Table 1: Timetable pilot Bračak

Activity/Phase	12/19	1/20	2/20	3/20	4/20	5/20	6/20	7/20	8/20	9/20	10/20	11/20	12/20	1/21	2/21	3/21	4/21	5/21	6/21
Main project Design																			
Building permit																			
PP & Exec. of works																			
Installation's supervision																			
Connection to the grid																			
Final testing																			
Verification of performance																			
Training																			

All investments costs are described below in the table 2.

Table 2. Investment Costs - After the public procurement

Costs categories	Costs [€]*)
Installation project	9.765,10
Execution of works	43.543,85
Construction supervision	2.642,61
Total costs (including VAT)	55.951,56

* according to the middle exchange rate 1 EUR = 7,45 HRK

4.3. Impact of the investment on energy and overall costs

Concerning the impact of the investment, at the time of writing this report, the pilot project is just finished the execution phase so the exact impact of the investment on energy and overall costs will be known after the few months of operation. At this stage, for the calculation we use numbers from Installation Project for the construction of a free-standing canopy with a photovoltaic power plant and battery system with integration in the central monitoring system.
Below is an overview of monitoring data from August to September 2021:

- the total energy demand of Bračak Manor,
  August = 2109 kWh
  September = 1981 kWh
- the total PV-production
  August = 1356 kWh
  September = 1065 kWh
- the share of PV-production which is used by Bračak Manor
  August = 90%
  September = 85%
- respectively the share of PV-production which is feed-in into the public grid
  August = 10%
  September = 15%
- peak power of the PV-system = 10,8 kWp
- orientation: southeast
- inclination: 15°C
- useful capacity of the storage (kWh): 8,0

The calculation of savings was made based on a comparison of electricity bills in the year before and after the installation of a photovoltaic power plant (compared, for example, 10/2020 with 10/2021, etc.). Currently, the productivity of photovoltaics is very low and will be so until April/May2022, when the time with better insolation starts again. Actual savings will be visible only after a year of using the system because we are currently in the wrong (winter) part of the year in which there is no production. Without the input of energy from the photovoltaic system, the battery system itself also has no effect on consumption (there is no point in putting energy from the mains into the battery). The point of the storage management system (battery) is that in the summer months in the day mode the part of the energy that is produced and is not currently consumed (in the morning) is stored and consumed in the night mode. In this way, the transfer of surplus energy to HEP's network is avoided because it does not make financial sense (HEP pays much less for purchased energy than it charges for energy from the network - the ratio is approximately 26 lipa- 0,035EUR to 1 HRK – 0,13 EUR per kWh).

Projected annual production of the power plant is 11.340,00 kWh. In combination with the battery system, all the energy produced is used for the needs of the Bračak castle. In previous years, the building consumed an average of 24,312.67 kWh of electricity, and now this consumption will be reduced by 11,340.00 kWh or 46.4%. This electricity savings will also generate savings on electricity bills for HRK 23,739,21 per year.

4.4. Energy management

Already existing systems in the building are combined with the newly installed photovoltaic (PV) system and battery energy storage system (BESS) through an advanced and smart energy management ICT system. The existing central monitoring system is upgraded, which includes the integration of battery storage system and photovoltaic system with all associated equipment needed for a safe and efficient management and monitoring of newly installed systems through the central monitoring system. The system has been reconfigured to enable coordination services that optimally exploit different available assets. With this system, it is possible to monitor all data such as the:

- current electricity production,
- battery charge,
- current energy consumption and
- all other data from the HVAC system and
- the various sensors in the building to maximise energy efficiency.

Also, the Energy management system inherit the 3Smart project concept[1] which enable smart management of production, consumption, and energy storage through decision support to building operators. With the EMS integration the photovoltaic and battery system have the ability to display all important operating parameters, such as folows:

- current production of PV,
- battery charging current and battery charging time,
- current consumption, etc.

With these data it is possible to adjust energy flows and to control load management and/or peak shaving. Everything is connected in a way that already existing systems is combined with the new ones through an advanced energy management ICT system. A new photovoltaic and battery management system has been built on top of the already existing central monitoring system. Such a connection allow us to have real time data on the operation of all systems (new ones, and existing) and to optimally exploit different available assets. Based on the data collected it is possible to coordinate the energy systems and to predict and manage costs.

Everything has been done with the help of project partners from University of Zagreb, Faculty of Electrical Engineering and Computing where we inherit the developments from the Interreg Danube 3Smart project[1] in terms of modular energy management of buildings that is coordinated with the electricity grid management. The new system enables monitoring the consumption and production of energy (electricity and heat) of the building trough visualisation on the central monitoring system. Table 3 shows the variables/data points that will be tracked and recorded in the system upgrade.

Table 3: Data points for integration into the central monitoring system

Title	Description	Refresh period	Signal direction
U_bat	Total battery system voltage	15 min	Read (R)
I_bat	Total battery charging / discharging current	15 min	Read (R)
SoC	Estimated state of charge of the battery system (SoC)	15 min	Read (R)
Bat_status	Battery system state of use	COV (15 min)	Read (R)
P_bat,ch	Current electrical power of battery charging	15 min	Read (R)
P_bat,ch*	Preferred electrical power charging	15 min	Write (W)
P_bat,dch	Current electrical discharge power of batteries	15 min	Read (R)
P_bat,dch*	Preferred electrical power discharge battery	15 min	Write (W)
P_pv	Current electrical power of PV system	15 min	Read (R)
PV_status	Solar fraction of the PV system	COV (15 min)	Read (R)

Source: REGEA 2020

4.5. Energy and urban policy frames

The Europe strategy aims to ensure that EU becomes a smart, sustainable, and inclusive economy. Cities host 68% of EU population, generate around 80% of the EU's GDP, and are also responsible for 70% of energy consumption and 75% of CO_2 emissions. They therefore play a key role in achieving the targets. Historic buildings and areas are often excluded from technological and sustainable development due to the strict and complex legislative and planning framework. Additionally, their exclusion from the European Directive (2002/91/EC), national policies and obligations towards energy efficiency and renewable energy, often holds them back from any dynamic development and technological innovation. Still some regional strategies support such actions. In Croatia, different cities have developed or are developing Smart city strategies, and these support the innovative approaches to energy management if proven economically viable. Store4HUC aims to overcome barriers to the adoption of energy efficient technologies and RES, influence policy makers by providing the recommendations and to promote innovation in storage facilities and related energy management in HUC.

By joining the European Union, Croatia has committed itself to increasing energy efficiency to achieve the goal of saving 20% of primary energy consumption at EU level by 2020. The EU's climate and energy policy for the period from 2020 to 2030 has set new ambitious targets for increasing energy savings of at least 27%, bearing in mind the 30% energy savings target at the EU level. The European Union has also set a long-term goal of reducing CO_2 emissions from the construction sector by 80-95% by 2050. To achieve this basic objective, it is necessary to ensure the implementation of energy efficiency measures at all levels: national, regional and local. The Bračak pilot project will be in line with all legislative frameworks of the Republic of Croatia such as:

- Croatian Energy Efficiency Act (OG 127/2014, 116/18)[2];
- Croatian Construction Act (OG 153/13, 20/17, 39/19)[3];
- Croatian Law on the Protection and Preservation of Cultural Property (OG 69/99, 151/03, 157/03, 100/04, 87/09, 88/10, 61/11, 25/12, 136/12, 157/13, 152/14, 98/15, 44/17, 90/18)[4];
- Croatian Energy Development Strategy[5];
- Proposal of the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia[6];
- National Public Sector Building Renovation Program 2016-2020[7];
- Fourth National Energy Efficiency Action Plan for the period from 2017 to 2019[8];

---

[2]Croatian Energy Efficiency Act https://www.zakon.hr/z/747/Zakon-o-energetskoj-u%C4%8Dinkovitosti [December 2019]

[3]Croatian Construction Act https://www.zakon.hr/z/690/Zakon-o-gradnji [December 2019]

[4]Croatian Law on the Protection and Preservation of Cultural Property https://www.zakon.hr/z/340/Zakon-o-za%C5%A1titi-i-o%C4%8Duvanju-kulturnih-dobara [December 2019]]

[5]Croatian Energy Development Strategy http://oie.mingo.hr/UserDocsImages/zakonski%20i%20drugi%20propisi/a)energetika%20opcenito/strategija%20energetskog%20razvoja%20rh/NN%20130_2009.pdf

[6]Proposal of the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia https://ec.europa.eu/energy/sites/ener/files/HR-Art4BuildingStrategy_en.pdf

[7]National Public Sector Building Renovation Program 2016-2020, available at: https://narodne-novine.nn.hr/clanci/sluzbeni/2017_03_22_508.html [December 2017]

[8]Fourth National Energy Efficiency Action Plan for The Period From 2017 to 2019 https://ec.europa.eu/energy/sites/ener/files/hr_neeap_2017_en.pdf

- Proposal of the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia[9].

Energy storages, and photovoltaic systems as well as the smart building management systems are important for the development of a sustainable energy system in HUCs and these systems play an important role in Energy transition. The biggest obstacle to the improvement and greater use of renewable energy sources and energy storages in buildings under cultural heritage is the insufficiently adapted legal framework to new technologies. Croatian Law on the Protection and Preservation of Cultural Property prohibits any action that could directly or indirectly change the properties, like the shape, the meaning, and the appearance of cultural property and it is obligatory to protect and preserve cultural goods in their pristine and original condition, and to pass on cultural goods to future generations. Therefore, the installation of a photovoltaic system on the roof of a building is impossible and for that reason, it was necessary to look for other solutions to accommodate a photovoltaic system. Given the technologies available today, the legal framework needs to be adapted to simplify the procedures for installing energy storages and photovoltaic systems on historical urban sites. In Croatia, this would enable further integral renovation of buildings that are under cultural heritage, which would be adapted to modern requirements and needs. Historical urban sites would thus be modernised and would stop lagging in time. In this way, historical urban sites would become more comfortable to live in, and their market value would increase.

4.6. Stakeholders‘ involvement

Krapina Zagorje County, as REGEA-s founder and associate partner and key stakeholder is actively committed to increase energy efficiency and use of renewable energy sources. Every year, the County develops the Annual Energy Efficiency Plan in accordance with the Energy Efficiency Act, which represents the national plan for an efficient use of energy. The Annual Energy Efficiency Plan is aligned with existing national and regional energy efficiency improvement documents such as the:

- ● Energy Development Strategy of the Republic of Croatia,
- ● National Energy Efficiency Program,
- ● Energy Performance Action Plan of Krapina-Zagorje County.

The plan contains analysis of the objectives, implementation deadlines, measures to improve energy efficiency in accordance with the Energy Strategy and other strategic documents of the Croatian Government, calculation of planned energy savings, methods for monitoring the execution of the plan and methods for financing

The plan also includes a separate measure for energy renewal and revitalisation of cultural heritage in the Krapina-Zagorje County. Bračak Manor as a pilot project within the Store4HUC project is a protected cultural and heritage monument listed in Register of Cultural Goods of the Republic of Croatia. Because of that, the Cultural heritage protection office needs to approve the planned investments within the project after the planning phase is finished.

Based on the development strategies and action plans, it is evident that the County continuously thinks and works on activities to increase energy efficiency in all segments of society and to encourage local community to use RES for their own energy production.

Bračak pilot project seven stakeholders have been identified, and the following tables show how selected stakeholders are involved in the implementation of the project. The identified stakeholders have been clustered in groups with similar activities. The tables (Table 4 to Table 10) will be used as living documents for presenting the deployment desks in WPT1, which means they will be updated during the project time. As far as they are already known, the planned activities are outlined in the following tables.

[9] Proposal of the Long-Term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia https://ec.europa.eu/energy/sites/ener/files/HR-Art4BuildingStrategy_en.pdf

Table 4: Stakeholder 1: Pilot site users (employees of REGEA (PP8) on the pilot site)

Actions	
1.	provide preferences, requests and define problems within the current system

Table 5: Stakeholder 2: local pilot experts from REGEA (PP8)

Actions	
1.	lead the piloting process, from the concepting, drafting, and publishing the public procurement, over watching pilot set-up by subcontractors, providing all needed local information and performing local simple support actions during the energy management system commissioning, monitoring of performance and communication with the tool developer, local dissemination to potential users of the solutions from Store4HUC in municipalities, cities and counties covered
2.	decide how the pilot should be technically organized in terms of energy management, performing final verification of the performed installations, commissioning of the real-time energy management tools, over watching their on-line operation
3.	evaluate self-sustainability of different pilot options in the pilot preparatory phase
4	providing other consulting services based on experience from investments in historical urban centers
5.	sharing knowledge of the pilot to make it relevant also for other sites

Table 6: Stakeholder 3: energy management tool developers – UNIZGFER (PP9) representatives

Actions	
1.	technical organization in terms of energy management; regularly
2	agreeing with REGEA on the final tool outlook for the site and performing necessary adaptation and extensions to the energy management tool developed in Stroe4HUC (relied on 3Smart[1]) to exhibit best possible effects on the pilot site; off-line analysis of the achievable performance
3.	checking with REGEA the installations progress and perform final verification
4.	commissioning of the energy management tools for decision support to operators, and watching their operation and usage

Table 7: Stakeholder 4: Owner of Bračak Manor (Krapina-Zagorje County) representatives

Actions

1.	check the pilot actions from the legal side
2.	sharing knowledge of the pilot to make it relevant also for other sites

Table 8: Stakeholder 5: local authorities in reach of REGEA, cities and municipalities representatives from the Krapina-Zagorje County area

Actions	
1.	check the pilot actions from the legal side
2.	sharing knowledge of the pilot to make it relevant also for other sites

Table 9: Stakeholder 6: cultural heritage preservation authorities County area

Actions	
1.	advise on feasible ways of the pilot investment planning
2.	approve the planned investments within the project after the planning phase is finished
3.	providing other consulting services based on experience from investments in historical urban centers
4.	check the pilot actions from the legal side

Table 10: Stakeholder 7: Croatian Association of historical towns

Actions	
1.	contribute to the promotion of Croatian cultural and historical heritage and of feasible ways how to improve their energy performance
2.	work on the public awareness about the importance of Croatian cultural heritage and history especially in the light of need for their up to date keeping with appropriate energy-efficiency measures

Table 11: Stakeholder 8: Distribution system operator for electricity (HEP DSO)

Actions	
1.	advises on how to connect the battery system and the solar power plant to the electricity distribution network
2.	check the pilot actions from the legal side

- REGEA (PP8) is a regional energy agency, and their employees and experts will gain extra knowledge, and experience in implementation of renewable energy systems and storages in historical urban areas.
- UNIZGFER (PP9) will learn how to implement photovoltaic systems and storages on objects under cultural heritage protection and will gain experience in setting up of the energy management tool for the case of high level of already existing presence of energy efficiency measures.
- Krapina-Zagorje County representatives will be educated about the benefits of energy efficiency and the use of renewable energy sources and storages on buildings under cultural heritage protection. The pilot will provide a good showcase to the local authorities, which will also benefit in the sense of improved energy efficiency and increased usage of renewable energy sources and lower costs for energy.
- Cities and municipalities will be educated about the benefits of energy efficiency and the use of renewable energy sources and storages on buildings under cultural heritage protection, and also what careful planning with the tools for energy management and operation of on-line energy management bring to the efficiency of the investment itself (optimal sizing, optimal on-line operation; what difference the storages bring especially if smartly controlled).
- Cultural heritage preservation authorities will be educated how to enable further development of projects dedicated to renewable energy sources on the other cultural heritage buildings and will gain knowledge about possible technologies in renovation and reconstruction of such buildings.
- Croatian Association of historical towns will be educated how to enable the further development of projects dedicated to renewable energy sources on the other cultural heritage buildings and will gain knowledge about possible technologies in renovation and reconstruction of such buildings.
- Distribution system operator (HEP DSO) will gain additional experience and knowledge on renewable energy sources and the integration of a solar power plant with a battery system on other cultural heritage buildings in Croatia.

To discuss the potential and execution of the Bračak pilot project at the pilot site of the Bračak Manor (Energy Centre Bračak) 2 Deployment desk meetings took place (see Deliverable D.T1.1.3). The main objectives of the Deployment desk meetings have been to gather opinions of all relevant stakeholders, present the pilot planning to them, receive their initial feedback, and agree on the next steps related to pilot investment as well as their involvement. The meeting was attended by representatives of the Krapina-Zagorje County, Ministry of Culture - Conservation Office in Krapina, Croatian electricity distribution system operator (HEP-ODS), Ministry of Construction and Physical Planning, Zagorje Development Agency (ZARA), Croatian Association of Historic Towns (HUPG) and representatives of project partners University of Zagreb Faculty of Electrical Engineering and Computing (UNIZGFER, PP9) and North-West Croatia Regional Energy Agency (REGEA, PP8). The meetings were organized as an open discussion where the planned interventions on Bračak Manor were first explained from the investment point of view (REGEA) as well as the energy management and IT point of view (UNIZGFER). After that we discussed about the pilot site Bračak implementation with focus on technical, conservation and economic barriers linked to this pilot action in Croatia. Since the communication was interactive, all the requirements for the construction and execution of the pilot project were agreed together between the stakeholders. Respecting all proposals and suggestions of stakeholders after the meeting, the terms of reference for the installation project were prepared.

4.7. Transferability of the pilot action

Today the Bračak Manor is used as central place for organizations, companies and institutions interested in the renewable energy as well as small and medium companies (SME) from other sectors. Bračak Manor was reconstructed and restored in 2017 in accordance with best practices in renewing heritage on the principle of energy efficiency. It also serves as business incubator for young companies with favourable lease of business office spaces. Bračak Manor is already equipped with wood pellets boiler for heating, micro-CHP for hot water and power production, air-water heat pump system for cooling and heating in transitional periods, wall insulation on the inside and energy efficient windows and doors, efficient lighting system, HVAC system, central BMS for monitoring of heating, cooling and energy consumption, rainwater harvesting for irrigation of green areas and wastewater treatment as well as electric vehicle charging station.

The aim of the Bračak pilot project is the implementation of a central battery (bank) system, installation of a photovoltaic system, and integration of it to advanced Energy management system. The already existing systems are combined with the new ones through an advanced energy management ICT system that is built on top of the already existing central monitoring system as a coordination service that optimally exploits all different available assets. The introduced energy management system inherits the preview project - 3Smart[1] (UNIZGFER, PP9), in a form of decision support for the site operators. The battery storage and photovoltaic system as low carbon energy source provides a good showcase to the local authorities which benefit in terms of improved energy efficiency and increased use of renewable energy sources and lower energy costs. Bračak pilot project will serve as an innovative good-practice example over the next years and as a model for simplified technical and economic implementation in historical urban sites and will lead to a significant increase in the proportion of renewable energy sources in historic urban centres. The long-term goal is to show innovative materials and technologies in reconstruction as a demonstrative example to other similar historical urban sites and to show that despite of the strict conservation requirements the project of this type can be realised.

At the Deployment desk meetings outputs and knowledge has already been transferred to stakeholders, who represent decision-makers at all levels in the implementation of renewable energy sources in historical urban sites in the Krapina-Zagorje county. Most stakeholders also participate in the process of issuing permits for the installation of storage systems and photovoltaic systems in the county, and this is the first of such projects in this part of Croatia. Given that this is the first pilot in this part of Croatia, stakeholders intend to gain the necessary experience and knowledge. This will allow all processes to be shorter in the future when implementing similar projects. As Krapina-Zagorje County is rich in cultural heritage that needs to be restored and put into operation, this pilot project can pave the way for the restoration of such cultural and historical sites.

4.8. Impact of the pilot action

It is challenging to provide a low carbon energy supply in cities in combination with energy storages. Especially, in historical urban centres it is very difficult to perform interventions in this specific area meeting strict architectural protection constraints, facing higher implementation costs, and often coming 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.

Bračak Manor has already been known as a place and an example of how to renovate a building under cultural heritage according to the highest standards of energy efficiency with the use of renewable energy. With the implementation of this pilot project, Barack Manor (Energy Centre Bračak) will be even more positioned on the map of excellence in energy efficiency. Energy management of the versatile energy systems in the Bračak Manor including heating, cooling, energy production and storage will allow to investigate what are the economically and ecologically most favourable technology mixes on historical sites. Target groups will thus benefit from future renovations of historical urban sites because they will have the best example of which technology is most cost-effective. Also, stakeholders representing decision makers at all levels in the implementation of renewable energy sources in historical urban sites in the Krapina-Zagorje county will gain additional experience and knowledge that will allow all processes to be shorter in the future when implementing similar projects.
Mutual learning sessions of Store4HUC provided benefit to the participating audiences among the consortium via project meetings and stakeholders via deployment desk meetings. In Bračak the implementation measures have already started and are nearly finished.
The benefits of the regions will be presented in the deliverable D.T2.3.1 Transnational evaluation by fellow specialists of research. All four surveys for the pilots in Bračak, Cuneo, Lendava and Weiz are already performed. 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.

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 to adjust the calculated values from their actual conditions to the commonly agreed 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 and 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 12. List of used KPIs in Bracak

Indicator	Category	Description	Measurement Unit
KPI_1: External energy needs of the pilot system	Pilot specific KPI	Energy consumption supplied by external sources	126.879,67 kWh
KPI_2: External energy cost of the pilot system	Pilot specific KPI	Cost of the energy supplied by external sources	9.295,27 €
KPI_3: Average yearly CO_2 abatement	Pilot specific / Urban KPI	CO_2 emissions	14,59 t CO_2
KPI_4: Autarky rate	Pilot specific / Urban KPI	Energy self-sufficiency	8,2%
KPI_5: Use of energy from RES	Pilot specific / Urban KPI	RES self-consumed energy, associated to storage	11,340kWh
KPI_6: Security of energy supply	Pilot specific KPI	Hours without service interruptions/discomforts	99,92%
KPI_7: Power peak	Pilot specific KPI	Average power peak	10,64 kW
KPI_8: Profitability	Pilot specific KPI	Net Present Value / Investment	0,78
KPI_9: Stimulation of the local economy	Urban KPI	New jobs created calculated through estimation of investment and replicability potential	0,283

4.9.1. KPI: 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 yearly energy consumption of the pilot system, supplied by external sources for one year $E_{c,tot}$ [kWh] 2. Calculation of Key Performance Indicator: $E_{c,tot\ (Electricity)}$ $E_{c,tot(Thermal)} = E_{c,tot\ (Pellets)} + E_{c,tot\ (Natural\ gas)}$ ***Ec,tot (Electricity) = 24.312,67 kWh** **Ec,tot(Thermal) = 113.907,00 kWh** **Ec,tot (Pellets) = 72.864,00 kWh** **Ec,tot (Natural gas) = 41.043,00 kWh** **Ec,tot(PV production) = 11.340,00 kWh** $KPI_1 = E_{c,tot}$ $KPI_1 = E_{c,tot\ (Electricity)} + E_{c,tot(Thermal)} - E_{c\_tot(PV\ production)}$ $KPI_1 = 24.312,67\ kWh + 72.864,00\ kWh + 41.043,00\ kWh - 11.340,00$ $KPI_1 = 126.879,67\ kWh/year$ ***Average yearly electricity consumption (2017-2021) for metering point 205018516**
Measurement Unit	[kWh]
References	Efficiency Valuation Organization, *International Performance Measurement and Verification Protocol*, 2017

Status quo:

The average annual electricity consumption at the billing metering point OMM 205018516, where the installation of a battery energy storage system and the installation of a photovoltaic system for energy production is installed, is 24,312.67 kWh per year. Thermal energy is divided into pellet energy - 72,884.00 kWh per year and natural gas energy - 41,043.00 kWh per year, so that the total annual thermal energy consumption is 113,907.99 kWh.

Target (prediction)

It is estimated that energy consumption will be reduced in the coming years due to the installation of a photovoltaic system and a battery energy storage system and an improved central monitoring control system. We estimate that the total energy consumption in the future due to the implemented measures will amount to 107,811.00 kWh / year or 22% less.

4.9.2. KPI: 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 and 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: $\mathbf{C_E(E_{c,i})_{(pelltts)}}$ = 31.410,00 HRK $\mathbf{C_E(E_{c,i})_{(natural\ gas)}}$ = 11.390,65 HRK *$\mathbf{C_E(E_{c,i})_{(electricity)}}$ = 26.449,16 HRK *$\mathbf{C_E(E_{c,i})_{(PV)}}$ = $KPI_2 = \sum [C_E(E_{c,i}) + C_P(P_{peak})] - CE_E(Ec,i)_{(PV)}$ $KPI_2 = \sum [C_E(E_{c,i}) + C_P(P_{peak})] + C_E(E_{c,i})_{(pelltts)} + C_E(E_{c,i})_{(natural\ gas)} - C_E(E_{c,i})_{(PV)}$ KPI_2= 26.449,16 HRK + 31.410,00 HRK + 11.390,65 HRK - KPI_2= 69.249,81 HRK / 7,45 **KPI_2= 9.295,27 €** **Savings = (11.340 kWh * 0,14 EUR)** ***Average cost of the electrical energy supplied by external sources (2017-2019) for the metering point 205018516**
Measurement Unit	

	[€] (tax included)
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:
The average annual cost for electricity at the billing metering point OMM 205018516 where it is planned to install a battery system for energy storage and installation of a photovoltaic system for energy production is 26,449.16 HRK per year with VAT (3,550.22 EUR according to the middle exchange rate 1 EUR = 7,45 HRK). The average annual cost for thermal energy is HRK 42,800.65 (EUR 5,745.05 according to the mi ddle exchange rate of EUR 1 = HRK 7.45), of which HRK 31,410.00 is spent on pellets and HRK 11,390.65 on natural gas.

Target (prediction)
With the installation of a battery system and the installation of a photovoltaic power plant is expected to reduce the annual cost of electricity. It is also expected that the consumption of pellets decreases due to the improved central monitoring system and a more frequent usage of micro-CHP when it is economically beneficial, as the application of Module 2 of the energy management tool has shown. It is estimated that in the future the average annual cost for energy will amount to HRK 52,859.76 (EUR 7095.27 according to the middle exchange rate of EUR 1 = HRK 7.45)

4.9.3. KPI: Yearly CO_2 emission

Applicability for objects of assessment

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

Description	Yearly CO2 emissions
Input parameters & Calculation	Calculation method: 1. Total thermal and 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: $E_{c,tot\ (pellets)}$ = 72,864 MWh; EFpellets = 34.4 [kg CO2/MWh] $E_{c,tot\ (natural\ gas)}$ = 41,043 MWh; EF natural gas =220,20 [kg CO2/MWh] *$E_{c,tot\ (electricity)}$ =24,312 MWh; EF electricity = 234,81 [kg CO2/MWh] *$E_{c,tot\ (PV\ production)}$ =11,340 MWh; $$\mathbf{KPI_3 = E_{c,tot} \times EF}$$

	$KPI_3 = (E_{c,tot,\ electricity} - E_{c,tot,\ PV\_production}) \times EF_{electricity} + E_{c,tot,\ pellets} \times EF_{pellets} + E_{c,tot,\ natural\ gas} \times EF_{natural\ gas}$ $KPI_3 = (24{,}312 - 11{,}340) \times 234{,}81 + 41{,}043 \times 220{,}20 + 72{,}864 \times 34{,}4$ $KPI_3 = 5.708{,}71\ kg\ CO_2 + 9.037{,}67\ kg\ CO_2 + 2.506{,}52\ kg\ CO_2$ **$KPI_3 = 14.519{,}15\ kg\ CO_2$** **$KPI_3 = 14{,}59\ t\ CO_2$** ***Average CO_2 emissions (2017-2019) for metering point 205018516**
Measurement Unit	[t CO_2]
References	Covenant of Mayor: http://www.eumayors.eu/IMG/pdf/technical_annex_en.pdf https://mgipu.gov.hr/UserDocsImages/dokumenti/EnergetskaUcinkovitost/meteorologki_podaci/FAKTORI_primarne_energije.pdf

Status quo:
According to the average annual consumption of electricity and heat, the average CO_2 emission is 17.25 t CO2 per year.

Target (prediction)
With the installation of a photovoltaic system and battery storage system annual CO2 emissions are reduced. After the implementation of the pilot project, by the calculation, it is estimated that the annual emissions will be 15,26 t CO_2.

4.9.4. KPI: 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 $E_{self\text{-}RES}$ [kWh] 2. Total thermal and electrical energy consumption of the pilot system for one-year E_{TOT} [kWh] 3. Calculation of Key Performance Indicator: **$KPI_4 = [E_{self\text{-}RES} / E_{TOT}] \times 100\ \%$** **$KPI_4 = [E_{self\text{-}RES} / (E_{TOT(pellets)^*} + E_{TOT(electricity)} + E_{TOT(natural\ gas)})] \times 100\ \%$**

	KPI_4 = [11,340 / (72.864,00 +24.312,67 + 41.043,00)] × 100 % KPI_4 = [11,340 /138.219,67] × 100 % **KPI_4 = 8,2 %**
Measurement Unit	[%]
References	Deliverable D.T3.2.4 “Validation report and establishment of the autarky rate tool & the checklist”

Status quo:
There is no self-production of a local RES system in the total energy consumption → KPI_4 is zero.

Target (prediction)
The installation of a photovoltaic system will enable the production of electricity from its own local renewable energy source. Total self-production after the pilot execution is 8,71%.

4.9.5. KPI: 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_{RES} [kWh] 2. Calculation of Key Performance Indicator: **$KPI_5 = E_{RES}$** **KPI_5 = 11,340 kWh**
Measurement Unit	[kWh]
References	-

Status quo:
With photovoltaic power plant and battery system consumed energy from self-production of local RES systems in a year is 11.320 kWh by the main installation project.

Target (prediction):
By installing a photovoltaic system for electricity production, we will be able to consume energy from our own production. It is estimated that the use of energy from local renewable energy sources will increase due to the installation of a photovoltaic system on 12.036,17 kWh per year.

4.9.6. KPI: 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: $KPI_6 = N_{no\_interrupt} / N_{tot} \times 100\ \%$ $KPI_6 = 8759{,}32 / 8760\ h \times 100\ \%$ $KPI_6 = 99{,}992\ \%$
Measurement Unit	[%]
References	-

Status quo:
In 2019, the power outage was 41 minutes. The power outage occurred to regular maintenance of the power distribution system.

Target (prediction)
Security of electricity supply is at the same level as before. The pellet boiler and the micro cogeneration unit have regular annual services, but the duration of the service is not counted as a supply interruption

because there are several heat sources in the building and the services are usually done when there is no need for heat. In the coming period, it is estimated that the security of energy supply will continue to be higher than 99%.

4.9.7. KPI: Power peak

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 $\mathbf{P_{peak,month}}$ [kW], where *month* goes from January to December [$P_{peak,January}$, $P_{peak,February}$, … , $P_{peak,December}$] 2. Calculation of Key Performance Indicator: $P_{peak\ max\ (2019)}$ = 20kW $P_{peak\ max\ (2018)}$ = 20kW $P_{peak\ max\ (2017)}$ = 22kW $P_{peak\ max\ (2020)}$ = 20kW $P_{peak\ max\ (2021\ prediction)}$ = 8,5 kW $$KPI_7 = \frac{1}{12} * \sum_{month=January}^{December} P_{peak,month}$$ KPI_7= *See energy consumption analysis KPI_7= 10,64 kW
Measurement Unit	[kW]
References	Consumption 2019

Status quo

The peak power of the billing metering point was analyzed in electricity consumption as a part of D.T2.1.3 - Investment specification of the integration of an energy storage in Bračak. The average monthly peak power is 10,64 kW.

Target (prediction)

By installing a battery system that can control the charging and discharging power, it is expected that the engaged peak power will be reduced. The battery system will serve as a kind of compensator for the engaged peak power. It is estimated that the average annual power engaged will decrease to 8,5 kW in the coming years.

4.9.8. KPI: 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** **KPI_8 = 0,78** t = 25 years
Measurement Unit	[-]
References	-

The net present value of the project is 0.78. A positive net present value indicates that the projected earnings generated by the pilot project exceeds the costs, so investment will be profitable.

4.9.9. KPI: 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	Valuation of investment as well as maintenance and operational costs
Input parameters & Calculation	Calculation method: 1. Total cumulated expense, calculated as the Investment (*CAPEX* [€]) + associated Operation & Maintenance costs ($OPEX$ [€]) of the storages installed, starting from T_0 (moment of reference) 2. Constant K [€], equal to 200.000EUR, that represents an empirical factor calculated as the ratio between a generic Company turnover and the number of company's 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 Performance Indicator: **KPI_9 = (CAPEX+OPEX) *r / K** **KPI_9 = (55.951,56 + 650) / 200 000** **KPI_9 = 0,283**

5. CONCLUSIONS

Despite the Covid-19 pandemic and the unexpected lockdowns in Europe and thus in Croatia, the execution of works on the Croatian pilot project is progressing with some delays. As stated in the application form, the risk associated with the investment was the potentially infeasible installation of a photovoltaic system at the Manor. After starting preparations of the implementation of the pilot project and organizing initial meetings with all relevant stakeholders, the conclusion was that in Croatia, as well as in the Krapina-Zagorje County, significant constraints are related to the energy storage, the energy management system, and the installation of the photovoltaic system at locations that are under cultural heritage protection. Corresponding conditions are prescribed by the Ministry of Culture and Conservation Departments. The constraints are defined by the Law on Protection and Preservation of Cultural Heritage. The law prescribes the prevention of any action that could directly or indirectly change the properties, form, meaning and appearance of a cultural property. It is also obligatory to protect and preserve cultural goods in their pristine and original design, and to pass on cultural goods to future generations. Since the Law on Protection and Preservation of Cultural Heritage prohibits any action that could directly or indirectly change the properties, shape, meaning and appearance of a cultural property, the installation of a photovoltaic system on the roof of a building was impossible to be realized. Therefore, it was necessary to look for other solutions. As a result, a lot of time has been spent for preparing an alternative pilot option and has involved more REGEA staff (PP8) in the planning to find the right solution. We held several internal and external coordination meetings where we discussed potential solutions. Finally, the conservators have agreed on constructing a canopy in the parking lot next to the castle on the same cadastral plot. For building a canopy and for installing a photovoltaic power plant on it, it was necessary to meet special construction conditions and to obtain for a building permit. In addition, it has been necessary to prepare a fire protection study to meet all the requirements of the Fire Protection Act, performed by the REGEA staff.

The public procurement for the execution of works was carried out and the Turnkey Contract for the execution of works was signed, and the agreed price of the works was 55.951,56 including VAT. The main reason that the total investment is less than the planned 90.000 EUR is that the investment costs for PV installations have decreased considerably within the last two years. At the time of the writing of the project application the estimation was done based on for the time being available data regarding the investment, however since then the situation has considerably changed, which has been proved by the amounts obtained through the public procurement. We further came to this conclusion during the preparatory phase of the investment where we reviewed the existing building management system and servers and existing electrical installations and found that we can use some of the existing equipment and this reduced the total cost. The review of existing installations and equipment was also time consuming, and it was necessary to involve REGEA staff experts and engineers. This planning has reduced investment costs, but the ultimate functionality described in the application form will be fully met. The purpose of the photovoltaic system is to produce electricity for the site own needs with the possibility of handing over the surplus to the grid. Combined with a battery system, surplus will first charge the battery and thus increase system efficiency. The expected annual electricity production of the photovoltaic system is 11 MWh. According to the contract, the works on the installation of the photovoltaic system and of the battery system, as well as the works on the integration into the energy management system has been completed during December 2021. The Administrative Department for Physical Planning, Construction and Environmental Protection, Zabok issued on 23.11.2011. decision (Use permit, CLASS: UP / I-361-05 / 21-01 / 000097, REGISTRATION NUMBER: 2140 / 01-08-5-21-0011 dated 26.10.2021) which became final for the photovoltaic system.

The system testing phase began as soon as the complete system was put into operation. The module from the energy management tool for decision support on using the micro-CHP and wood pellets boiler in the optimal way in the new conditions with installed battery and the photovoltaic system has been integrated. Employees of REGEA will be trained to monitor the system operation such that they can maintain the system in optimal operation and present it as a showcase to different regional, national, and international stakeholders. The Manor is already used as a demonstration centre for good practices in energy renovation of historical sites and will continue to act in that way even after the project end in a reinforced way.