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Final Report:

Energy Efficiency Concept for the City of Trebinje

Mapping of Local Energy Sources

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Date of the Report: 3rd Aug. 2020	Contract Number: 2018.06
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The REPIC Platform is a mandate issued by the:
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1. Summary

In 2010 the government of the City of Trebinje in Bosnia & Herzegovina signed an agreement to increase energy efficiency by 20%, to increase the share of renewable energy by 20% and to reduce the CO2 emissions by 20 % until 2020. The city government has recognized that they will reach their goals faster and with better results if they cooperate with external experts. The biggest local need is to reach scalable and transferable energy efficiency solutions and to learn how to approach energy efficiency projects systematically.

In 2018, the City of Trebinje initiated the project “Energy efficiency for the City of Trebinje” that serves as a beacon project and which makes use of the know-how embedded in currently ongoing activities in the international frame work (Switzerland, Norway, Germany etc.).

In the project, a heterogeneous Swiss and international team has introduced a comprehensive approach for energy efficiency projects on city and district level. The procedure combines a systematic approach that is scalable, flexible and adaptable to different needs and conditions. Various technologies, local requirements and needs are integrated.

The overall objective of the project, a summary of best practices and a project approach and design that can be multiplied later for Trebinje as well as neighboring cities or countries has been achieved. Three objectives have been pursued to address the following topics:

For the first objective, improvement of **energy efficiency**, a detailed concept has been elaborated which includes (1) a detailed mapping of energy consumption, (2) a verification of simulation models using recorded data and collected information and (3) detailed energy efficiency concepts which align to change requests of the City of Trebinje. Three target buildings have been assessed and potential renewable resources for the City of Trebinje have been analysed.

Due to financial, technological and political factors, the installations and measurements according to the energy efficiency concepts have not been implemented. A key outcome of the project are estimates of energy efficiency gains, the required setup and technological alternatives needed for deciding on a smart city strategy.

The second objective, **ensuring know-how transfer** for local staff from municipalities, authorities, local NGOs and local company that are active in the building and energy sector, has been partially achieved. Although the planned tasks were changed and the project was terminated, the studies carried out for different energy efficiency concepts aggregate specific technological know-how and form an instrument for the City of Trebinje for their decision making. All prepared concepts are ready for implementation in Trebinje. The following energy efficiency concepts were developed: (1) Zero energy building including solar cells and heat pumps using geothermal energy, (2) HVAC systems for building, (3) Solar farm and (4) Wind farm.

The last objective, **scalable project outcomes and an increased awareness of energy efficiency issues for relevant stakeholders** has been addressed by initiating outreach actions. Potential actions for the transition to renewable energy and higher energy efficiency have been presented in a roadmap. Further steps, in particular the foundation of an Association Tribunus for promoting energy efficiency projects and for enlarging know-how of energy efficiency have been conceptualized.

In summary, reviewing the outcomes of the project and the managerial aspects, the following conclusions can be drawn and lessons learned highlighted:

The scope of the project, i.e. the energy concept has been adjusted to meet change requests. As a result, different technological solutions have been elaborated which will help the City of Trebinje chose and implement energy solutions.

The time plan for developing and implementing an energy efficiency project was appropriate. However, the time needed for responding to change requests led to a prolongation of the project.

The resources in terms of funding and infrastructure were appropriate. However, additional requirements such as architectural protection regulations and technological challenges with the heat pump were not covered with the project funding.

The project benefitted from excellent collaboration with project partners: the City of Trebinje, local delegates, local experts, expert network, the Swiss Embassy and REPIC. They were fully engaged and motivated to solve problems which arose during the project.

A major lesson learned is that the context should not be underestimated. In this project, the appropriate timing of the project suffered from the political (election), environmental (heavy storm damage) and economic context (Covid-19 impact on economy and society).

2. Glossary

EERA	European Energy Research Alliance
HVAC	Heating, ventilation and air-conditioning system
NGO	Non-governmental organization
PCM	Phase change material in e.g. solar thermal applications
PV	Solar electrical
PVT	Solar hybrid
SUPHER	Sustainable polyenergy generation and harvesting conference
Tribunus	Founding Association to promote fundraising and to promote smart city Trebinje to other cities
VRF	Variable refrigerant flow

3. Starting Point

In 2010 the government of the City of Trebinje in Bosnia & Herzegovina signed an agreement to increase in energy efficiency by 20%, to increase the share of renewable energy by 20% and to reduce the CO_2 emissions by 20 % until 2020. Until now they have conducted smaller projects that have led to small improvements. The city government has recognized that they will reach their goals faster and with better results if they cooperate with external experts. They have learned that Switzerland is one of the leading countries in the sector of Cleantech and energy efficiency and therefore they have reached out to Swiss companies and institutions to discuss a potential cooperation. Based on the initial discussions, the City of Trebinje has initiated this “energy efficiency project”. This project in Trebinje is in line with the goals of the “Energy strategy of Republic of Srpska up to 2030” (see Reference Banja, 2012).

The target area for the project are three buildings of Trebinje City Administration (see Figure 1). The buildings have been built during Austro-Hungarian rule. Taking into account the age of the facility, construction techniques and material used, the need for increasing energy efficiency is obvious. Heating is mostly realized by use of high-storage heaters (one per office). Only a few offices use air conditioners, small electric portable radiators and quartz heaters for heating.

Figure 1: Location of the three municipality buildings

The three buildings have specific requirements regarding energy efficiency (see Figure 2).

No.	Front View	Short Description
1		Business facility and administrative building located in Vuka Karadžića no. 2. It was built in 1911 and renovated in 2006 has a total office area of about 1417 m^2. Current annual electricity consumption of 172'850 kWh (2017), which includes air conditioning and heating
2		The building is located Vuka Karadžića no. 1. It was built in 1934 and extended in 1963. It has a total area of about 656 m^2. Current annual electricity consumption of 126'870 kWh, including air conditioning and heating.
3		Building No. 3 is located in Nemanjina no. 2. The building was built in 1912 and has an office area of 1'386 m^2. An annual electricity consumption of 58'026 kWh, including air conditioning and heating. Today only a few employees work within this building, only a few offices are used on a regular basis. This explains the lower energy consumption compared to building No. 1 and No. 2.

Figure 2: Three municipality buildings

The City Administration has carried out several small-scale activities regarding increase of energy efficiency within the municipality. These include improving the public lighting and upgrading the heating system of the kindergartens and raise of public awareness about the importance of establishing an efficient system of energy management at the local level. However, so far no specific measures have been taken to improve the energy efficiency of the three buildings.

The biggest local need is to reach scalable and transferable energy efficiency solutions and to learn how to approach energy efficiency projects systematically. The local authority and companies do not have experience with the assessment and monitoring of their energy consumption and infrastructure. In addition, they want to learn how to develop a self-sufficient energy supply, storage and distribution based on renewable energy.

4. Objectives

The City of Trebinje is asking for a summary of best practices and a project approach and design that serves as a beacon project and can be multiplied later for Trebinje as well as neighboring cities or countries. The following three objectives have been addressed:

Objective 1: Energy Efficiency

A first project objective was to support the city administration of Trebinje to reach and exceed their political goals for 2020 to increase the overall energy efficiency in the city of Trebinje by 20% and to increase the share of renewable energy by 20%. In addition, the CO_2 emissions shall be reduced by 20 %.

Objective 2: Training / Know-How Transfer

A second project objective was to ensure know-how transfer for local staff from municipalities, authorities, local NGOs and local companies that are active in the building and energy sector.

Objective 3: Multiplication / Awareness

A third project objective was to make project outcomes scalable and to increase the awareness of energy efficiency issues for relevant stakeholders.

5. Project Review

5.1 Project Implementation

The project makes use of the know-how embedded in currently ongoing activities in the international frame work (Switzerland, Norway, Germany etc.), amongst others for example the newly founded EERA Joint Program for Energy Systems Integration, within which members of EscherTec AG have a coordinating role.

The project is geared towards integrating solutions focusing on the overall improvement of the energy efficiency based on Swiss technology and know-how. Our approach for the energy assessment and concept will allow Trebinje to implement a smart energy management and several zero-energy areas.

In our project we will work with a heterogeneous Swiss and international team that introduces a comprehensive approach for energy efficiency projects on city and district level. The procedure combines a systematic approach that is also scalable, flexible adaptable to different needs and conditions. We will include various technologies, local requirements and needs. E.g., existing and additional measurements will be used for developing tailored energy concepts.

In addition, we focus on active know-how transfer and training of local staff, experts and NGOs. We involve different local players (City Government, local NGO, local businesses, etc.) in the project and train them according to their role.

Project partners and their competencies and responsibilities are listed in Table 1:

Table 1: Project organisation

Organisation	Competence	Responsibility
Trebinje Municipality, Republic of Srpska	Administrative Topics regarding the City of Trebinje	• Project beneficiary • Project management • Collecting ad providing information on the area and infrastructure • Decision making
Center for Development of Herzegovina, Trebinje, Republic of Srpska	Political Advisor Communication	• Communication • Advisor for communication, multiplication and training of the Trebinje project • Networking with other municipalities and additional NGOs
EscherTec AG; Zürich, Switzerland	Energy systems integration & optimisation in an international environment	• Analysis of the current energy system • Evaluation of potential to integrate locally available renewable energy sources • Concept development of the energy system and the transition process • "Energiestadt" Consultant • Technical Advisor • Project Management
LANS wGh d.o.o, Serbia	Local Project Management & Implementation	• General contractor • Project Management
Egarch Architects, USA	Architecture, sustainable urbane planning	• Advisor on sustainable urban planning
Drift Consulting GmbH, Baden, Switzerland	Facilitator for Innovation Strategies	• Facilitator for Innovation Strategies / Design Thinking Methodology
Lucerne University of Applied Sciences and Arts, Switzerland	Modelling and simulation	• Dynamic simulation

The project is divided into three milestones (see Figure 3). For each milestone, tasks have been defined and carried out.

			2018							2019					
MS	**No.**	**Tasks**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**
Evaluation of potential renewable energy sources															
M1	**Project setup**														
	1	Kick Off meeting													
	2	Meetings with Local NGO, local experts and companies													
	Preliminary analysis														
	3	Site visit and assessment of target buildings													
	4	Mapping of local energy sources													
	Intermediate report					**M1**									
Design and concept															
M2	5	Detailed energy measurement & data collection													
	6	Data evaluation & analysis													
		Design and development of energy concept													
	Intermediate report										**M2**				
Implementation and know-how transfer															
M3	**Implementation of energy efficiency concept**														
	7	Purchase & installation of PV solar panels for 3 selected buildings													
	8	Training & know-how transfer													
	9	Multiplication & awareness													
	Final report: Energy concept, road map und implemenation														**M3**

Figure 3: Original project plan for milestones 1 to 3

Each task is described in the following section.

Milestone 1: Evaluation of potential renewable energy sources

All tasks performed in milestone 1 are listed below:

Task 1: Kick-Off Meeting

During the Kick-Off Meeting with the municipality of Trebinje, we agreed about the overall concept and objectives of our Energy Efficiency project.

During our meeting we introduced and discussed the following topics: Swiss Platform REPIC, European Energy Award, building assessment according to Gebäudestandard 2015 and an alternative approach for building assessment that is more suitable for the target buildings, “Energiebuchhaltung für Gemeinden, EnerCoach”). In addition, we agreed to sign a separate contract that regulates the funding and cooperation between the City of Trebinje and EscherTec AG.

Task 2: Meetings with local NGO, local experts and companies

Multiplication and know-how transfer are an important part of the overall Energy Efficiency project. During our meeting with local NGOs e. g. Centre for Development of Herzegovina, Trebinje, Republic of Srpska, and Agency for the Development of Small and Medium Enterprises of Trebinje and the NGO “Home” we introduced and discussed the following topics: Energy Efficiency Project for Trebinje, Swiss Platform REPIC and European Energy Award.

The local NGOs were interested to cooperate with us and agreed to support us regarding the following activities:

- Preparing Training Session for Know-how Transfer
- Multiplication of the project in form of round tables or various stakeholders.
- Public Relation activities.

We were also in contact with the NGO Centre for Ecology and Energy, Tuzla, Bosnia-Herzegovina, and planned to share the know-how and projects results with them during our project.

The Municipality of Trebinje and local experts provided all required and relevant information to assess and map potential locally available renewable energy sources in the surrounding area in Trebinje. The local power supplier company Elektrohercegovina AD confirmed the installation of smart meters in all three buildings.

Task 3: Site visit and assessment of target buildings

The Urban Planning Department provided relevant building information as drawings and information about the building condition and use.

We reviewed all relevant information of the three target buildings and confirmed that an assessment of the infrastructure according to ”Gebäudestandard 2015, Energiestadt” is not applicable and therefore we assessed the relevant elements of the building condition in a modified format. The building assessment was replaced with an alternative assessment questionnaire. The questionnaire covers the collection of

basic building data, features of construction and thermal insulation, glazing such as roof and window, type of system such as heating and cooling, lighting system and energy costs.

During the Site Visits in June 2018 we visited all three buildings in the center of Trebinje. Based on the collected building information, the target buildings have been assessed:

Building No. 1 is in good condition, the last renovation took place in 2006. The building has the highest rate of employees per square meter and is intensively used (about 5m^2/person). Building No. 1 is the main building of the city administration and has the highest yearly energy consumption. This building has a high potential for further energy measures.

Building No. 2 is in less good condition due to a lack of maintenance. The building part that has been added around 1963 shows poor building quality. The roof and openings (doors and windows) of both building sections are in bad condition. In 2010 the interior of the "Permit Service Center" has been renovated. The building is less intensively used than building No. 1 (about 10m^2/person). Compared to building No 1, the energy consumption per workplace (respectively per employee) is relatively high.

Building No. 3 is in poor condition due to a lack of maintenance and has not been renovated in the last 110 years. Therefore, it is not used intensively as an office building. Only a few employees (about 28m^2/person) use this building as their working place. Compared to building No. 1 and No. 2, the energy consumption is relatively low. Currently this building is mainly used as an archive and storage place.

Task 4: Mapping of local energy sources

In November 2018 we travelled to Trebinje for further site visits and a status meeting

During the status meeting with the municipality of Trebinje, we discussed the intermediate results and suggested our concepts and solutions.

According to the mapping of local energy sources, the region of Trebinje has a high potential to increase the use of renewable energy sources. For the generation of electricity solar energy, wind turbines and small hydropower plant can be envisaged. Heating and cooling can be covered with shallow geothermal energy as well as solar thermal energy. One of the main biomass sources in Trebinje are vineyards. Therefore, biomass might be an additional source of energy, via e. g. anaerobic digestion or gasification to generate bio-gas/syngas as base to generate electricity and/or heat.

Milestone 2: Design and concept

All tasks performed in milestone 2 are listed below:

Task 5: Detailed energy measurement & data collection

To be able to collect detailed and accurate data of the energy consumption of the target buildings we replaced all electricity meters in building no1, 2 and 3 with smart ones.

The new smart meters started their operation on 30th June 2018. The municipality of Trebinje provided data of the energy consumption of 2017 monthly. This data is used for comparison and plausibility checks with current data.

In addition, for the qualitative assessment of infrastructure, an infrared camera was used to get thermal images from the outside walls and the roof for the identification of spots of energy loss.

The setup of data collection was as follows:

- Photos / videos of target buildings taken with drone
- Smart meter readings (every 15 minutes for the duration of one year)
- Infrared photos takings (every week for the duration of one year)
- Weather reports (3 times a day for the duration of one year)

Task 6: Data evaluation & analysis; design and development of energy concept

Based on the collected data, all data was checked against plausibility. This formed a clean base to develop a set of possible technical concepts and strategies for a net zero-energy area (see Appendix 9.1). A transition roadmap including a centralized energy service center for monitoring and optimized operation was worked out.

The roadmap consisted of the following elements:

- Combining existing energy infrastructure with new and advanced technologies.
- Making use of locally available renewable energy sources such as solar thermal, geothermal, heat pumps and, if viable, wind.
- Connecting energy exchange between different buildings and end-users.
- Integrating local consumers and producers of – currently - “waste” energy from e.g. cooling systems.
- Evaluating the current electricity consumption.
- Defining local storage and buffer capabilities of the existing system.

Milestone 3: Implementation and know-how transfer

For milestone 3 various change requests have been implemented; tasks 7, 8 and 9 have been replaced with tasks 7.1 to 7.10 to meet the new requirements (see Figure 4).

			2018							2019												2020							
MS	No.	Tasks	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Implementation and know-how transfer																													
M3		Implementation of energy efficiency concept																											
	7	Purchase & installation of PV solar panels for 3 selected buildings																											
	7.1	Protection of Cultural of Trebinje informs us that solar panels are not allowed in the centre of Trebinje									C1																		
	7.2	Heavy storm in Trebinje -> Trebinje asks to postpone second planned invoice											C2																
	7.3	Work out new concept: heat pump and roof isolation for building no. 1, work out solar farm, develop Association Tribunus																											
	7.4	Plan study tour in Switzerland, work out study program with partner companies																											
	7.5	Municipality informs us that they will build new building close to building 1: request for heat pump to heat both buildings; additional request: feasibility study for a 2.5 MWp solar farm near Trebinje; study tour cancelled, Association founding postponed															C3												
	7.6	Work out new heat pump concept, solar farm investor brief: costs for drilling too high -> try with Swiss embassy and REPIC to reimburse VAT to lower costs																											
	7.7	Change in contract: new concept proposal: Heating, ventilation and air conditioning (HVAC) for building no. 1																							C4				
	7.8	Work out new HVAC concept																											
	7.9	Letter from Trebinje regarding COVID-19: tourist season down -> budget down by 87% -> terminate project																										C5	
	7.10	Project terminated																											
	8	Training & know-how transfer																											
	9	Multiplication & awareness																											
		Final report: Energy concept, road map und implementation																											M3

Task cancelled
Change request/Info from Trebinje
Carried out work by EscherTec
Project delay

Figure 4: Changed project plan for milestone 3

Task 7 (cancelled): Purchase & installation of PV solar panels for 3 selected buildings

The planned installation of solar panels for the 3 selected buildings was cancelled (see Task 7.1). In this task we would have supported local authorities during the preparation, selection of suppliers and implementation and assessment phase.

Task 7.1 (change request): C1 - February 2019

In February 2019, we received a recommendation from the Institute for the Protection of Cultural, Historical and Natural Heritage of the Republic of Srpska that it is not advisable to install solar panels on the roofs of the city administration facilities. This is especially true for the main building no. 1. This information was followed by our explanation that the solar panels will be made in colour that dominates the roofs in the part of Trebinje where the main building of the City Administration is located, and that these solar panels will not disturb this recognizable image of Trebinje. Experts from

the aforementioned institution pointed out that the City Administration must be an example of good practice in managing cultural and historical heritage such as this building and, as they pointed out, if we install these panels on the roof of the mentioned building, we will lose the legitimacy to regulate this area when it comes to other possible tasks of urban planning and protection of urban heritage in Trebinje.

Task 7.2 (change request): C2 - April, 2019

In April 2019, the municipality of Trebinje informed us, that due to a heavy storm, the city is facing numerous challenges to function normally and that planned city budget funds will not be collected on the basis of electricity generation because the HPP (hydro power plant) is out of operation. Although the city did not change the attitude to continue and fully implement the project, they asked to postpone the second invoice payment.

Task 7.3 (added): Work out new concept: heat pump and roof isolation for building no. 1, work out solar farm, develop Association Tribunus

In line with the recommendation from Trebinje, we adjusted the previous design concept and prepared an alternative solution:

- A heat pump for the building no. 1 by using geothermal energy. The city of Trebinje is ready to provide land / site for carrying out geological explorations, while the preparation of the necessary project documentation and the execution of works will be financed from the project funds
- Roof insulation for building no. 1
- A feasibility study for a solar farm near Trebinje: The installed power would be specified during its design, this project would be carried out in three phases:
    - The first phase would include the provision of land for the construction of this facility and the necessary permits, the development of a design and implementation project, and construction works of all the necessary facilities of the solar field.
    - In the second phase, the installation of photovoltaic panels within the amount of funds provided by investors would be initiated.
    - The third stage involves the installation of photovoltaic panels in order to achieve the aforementioned installed power.

In addition, we suggested to found an Association called Tribunus in order to ensure the awareness and continuation of smart city initiatives (see Appendix 9.2).

Task 7.4 (added): Plan study tour in Switzerland, work out study program with partner companies

In order to promote energy efficiency concepts, we planned and worked out a 3 days study tour for the delegates of the Department of Spatial planning City of Trebinje, for the Deputy City Mayor and the Trebinje City support team. The study tour would cover visits to a self-sustained building, a smart street light company in the Zurich area and a novel PV plant in an alpine region.

Task 7.5 (change request): C3 - July, 2019

In July 2019, we were informed that the municipality planned a new building near the building no. 1 for which we were invited to prepare a concept which estimates of the size of the heat pump by using geothermal energy to feed both buildings.

Task 7.6 (added): Work out new heat pump concept, solar farm investor brief

A new heat pump and geothermal probes drilling concept was developed for building no. 1 and the new building. Since the required drilling for the geothermal probes would exceed the budget, a new technical and financial solution was suggested. In addition, EscherTec, REPIC, the representatives on behalf of the City of Trebinje, the representatives of the non-governmental sector and the Embassy of Switzerland held several meetings to find a solution for reimbursement of VAT. In November, 2019 the Swiss Embassy informed us that we cannot reimburse the VAT.

Also in Task 7.6, the investor brief for a 2.5MWp solar farm near Trebinje was worked out. The previously developed concept for an association with smart city goals was postponed.

Task 7.7 (change request): C4 - April, 2020

In April 2020, we were informed by the City of Trebinje that a decision was made to switch to a different solution that would fit the budget: The new system should be a HVAC (heating, ventilation, and air conditioning) system. As a consequence, the original contract was adjusted and confirmed by REPIC.

Task 7.8 (added): Work out new HVAC concept

In the light of the difficult financing, we proposed a revised technical solution.

Given the existing split systems in building no. 1, the heating, ventilation, and air conditioning (HVAC) system is appropriate if the need to remove numerous external blocks from the facades and to replace the existing equipment is expressed.

With the HVAC system, the architectural requirements to keep the facades clean and free from any mechanical equipment or equipment can be met.

One technology of the HVAC system is the variable refrigerant flow (VRF). VRF technology, compared to split systems, enables more precise control and more economical operation.

If the existing split systems are classic on / off type, the savings can be up to 30%.

The optimal solution for heating, cooling and ventilation of the building no. 1 is within the compromise zone of the following requirements:

- Maximum energy savings
- Architectural-urban requirements
- Choice of mechanical equipment such that construction and craft work related to the installation of such equipment are minimized
- Choice of machinery that has the highest possible efficiency in operation (the ratio of the obtained energy and the energy consumed as much as possible)

According to the above criteria, the following solution is proposed:

- Discard existing furnace.
- Check existing split systems functionally, dismantle and retain all correct ones for secondary use on ancillary facilities.
- Install a new VRF system (one or two outer blocks on the north façade)
- Pay maximum attention to ventilation systems, which means:
    - Provide special ventilation systems based on heat recovery (80% recuperator efficiency) with integrated Freon circuit to heat-cool air with adequate capacity.
    - The system includes Freon heaters-air coolers based on VRF system with direct evaporators, individually controlled, connected to the operation of the recuperator.

Task 7.9 (change request): C5 - July, 2020

In July 2020, we were informed by the municipality, that Herzegovina is affected by the COVID-19 virus; the tourist season is completely destroyed and the City of Trebinje budget inflow is only 13% compared to the same period last year. For that reason, the City of Trebinje proposed that the existing agreement should be terminated. However, if in future, the situation would improve, the City of Trebinje would resume cooperation.

Task 8 (cancelled): Training & know-how transfer

Training would have been provided for local staff from municipalities, authorities, local NGOs and local company that are active in the building and energy sector.

The local authorities and companies would have benefitted when cooperating during the implementation phase. They would have learnt the advantages of our systematic approach, design and implementation phase and the results. Local companies would have increased their know-how and benefit from a competitive advantage.

Task 9 (cancelled): Multiplication & awareness

Multiplication of the project approach would have been carried out in form of round tables for various stakeholders. Awareness of energy efficiency would have been increased with Public Relation activities (media, social media, exhibitions, smart phone app, and public display information system in the nearby park to show energy savings to visitors).

5.2 Achievements of Objectives and Results

The overall objective of the project, a summary of best practices and a project approach and design that serves as a beacon project and can be multiplied later for Trebinje as well as neighboring cities or countries has been achieved.

As for **objective 1, energy efficiency**, following tasks have been developed and carried out:

- Detailed mapping of energy consumption
- Simulation models verified using recorded data and collected information
- Detailed energy efficiency concepts aligned to change requests of the City of Trebinje.

Due to financial, technological and political factors, the installations and measurements according to the energy efficiency concepts have not yet been put into practice. A key outcome of the project are estimates of energy efficiency gains, the required setup and technological alternatives needed for deciding on a smart city strategy.

All tasks performed in milestone 1 and milestone 2 contribute to the achievement of objective 1. Potential renewable resources for the City of Trebinje have been analysed; an overview can be found in the Appendix 9.3. The assessment of buildings with the changed questionnaire forms a good basis to extract information on the status of the targeted buildings.

Objective 2, ensuring know-how transfer for local staff from municipalities, authorities, local NGOs and local company that are active in the building and energy sector, has been addressed in milestone 3. Although the planned tasks for milestone 3 were changed and the project was terminated, the studies carried out for different energy efficiency concepts form an instrument for the City of Trebinje for their decision making. All prepared concepts are ready for implementation in Trebinje. The following energy efficiency concepts were developed:

- Zero energy building including solar cells and heat pumps using geothermal energy
- HVAC systems for building
- Solar farm (see Appendix 9.4)
- Wind farm

Objective 3, scalable project outcomes and an increased awareness of energy efficiency issues for relevant stakeholders have been initiated. Potential actions for the transition to renewable energy and higher energy efficiency have been derived from analyses and presented in a roadmap. Further steps, in particular the foundation of an Association Tribunus for promoting energy efficiency projects and for enlarging know-how of energy efficiency have been conceptualized in milestone 3.

5.3 Multiplication / Replication Preparation

With signing the contract for energy efficiency project of Trebinje, EscherTec AG and the Mayor of Trebinje undertook first steps in disseminating the project's framework: The signing of the contract was announced, several local TV, radio and online as well as print media attended the press conference and published articles, radio interviews and TV reports (see Appendix 9.5).

In milestone 3, further steps for multiplication and replication have been suggested, in particular the founding of the Association Tribunus.

Furthermore, the example of Trebinje has been presented in the SUPHER conference in Savona (September 2019)

5.4 Impact / Sustainability

The energy efficiency concepts generated in the framework of the project provides an accurate data base which will guide future decision-making on renewable energy strategy. Furthermore, the potential of distinct energy efficiency solutions and their interdependencies have been shown by assessing and mapping the existing infrastructure and designing scalable and modular energy solutions. This constitutes a noticeable higher knowledge level on energy efficiency for the stakeholders involved in the project.

Potential impact for the Trebinje area

For the development of energy concepts for the Trebinje area, a roadmap has been elaborated (see Table 2) to reach the City of Trebinje's targets for 2020 through the strategies "Renewable Energy" and "Efficiency":

- increase in energy efficiency by 20%
- increase the share of renewable energy by 20%
- reduce the CO_2-eq emissions by 20 %

Table 2: Potential goal attainment of technology actions for the Trebinje area

Technology actions	**Efficiency Increase %**	**Renewable Increase %**	**CO_2 Reduce %**
Retrofit residential buildings pre 1992-95	20%		2.5%
Large solar farm		17%	11%
Wind turbines		19%	14%
Anaerobic digestion or gasification		6%	3%*

*CO_2-eq

Whereas for the action «Retrofit residential buildings pre 1992-95» an assumed efficiency improvement of the wood stoves of 20% and roof insulation will reduce the CO_2 by about 2.5%, installation of a large solar farm (10MW) will almost reach the share of renewable increase by 17%, for the wind turbine (10MW) this value is 19%. The CO_2 reduction for the solar farm is 11% and for the wind turbine it will be 14%. Adding anaerobic digestion or gasification, the renewable share can be increased by another 6% with an equivalent reduction in CO_2 by 3%.

Potential impact for building no 1

For the target building, no. 1, a roadmap consisting of two technology actions has been developed which are suitable for reaching the City of Trebinje's targets for 2020 through the strategies "Renewable Energy" and "Efficiency".

Table 3: Potential goal attainment of technology actions for the building no. 1

Technology actions	**Efficiency Increase %**	**CO_2-eq Reduce %**
Roof insulation only	20%	20%
Heat pump instead of electrical heater		73%

If the main city building is only refurbished by insulating the roof, a CO_2-eq reduction of 20% can be expected (see Table 3). Replacing the electrical heaters with a heat pump will reduce the CO_2-eq by about 73%. Combining both technology actions will reduce the CO_2-eq by 93% (see Figure 5).

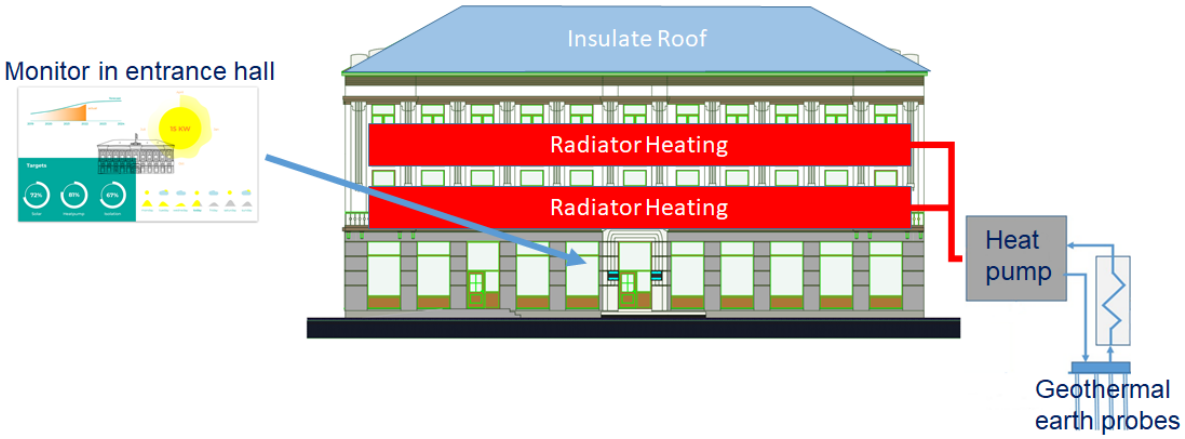

Figure 5: Combined technology actions for building no. 1.

6. Outlook / Further Actions

6.1 Multiplication / Replication

Due to the termination of the project, planned steps for multiplication and know-how transfer have not been carried out. Assuming that project activities are resumed in the future, possible next steps consist in sharing the knowledge gained in this project, deciding on technology actions, implementing the chosen technology actions and measuring the impact on energy efficiency.

6.2 Impact / Sustainability

Effects on sustainability will depend on the chosen and implemented energy solutions.

7. Lessons Learned / Conclusions

For successful energy efficiency projects five factors are key:

(1) Scope, technological solution

(2) Time

(3) Resources

(4) Collaboration

(5) Context

The scope of the project, i.e. the energy concept has been adjusted to meet change requests. As a result, different technological solutions have been elaborated which will help the City of Trebinje chose and implement energy solutions.

The time plan for developing and implementing an energy efficiency project was appropriate. However, the time needed for responding to change requests led to a prolongation of the project.

The resources in terms of funding and infrastructure were appropriate. However, additional requirements such as architectural protection regulations and technological challenges with the heat pump were not covered with the project funding.

The project benefitted from excellent collaboration with our project partners: the City of Trebinje, local delegates, local experts, expert network, the Swiss Embassy and REPIC. They were fully engaged and motivated to solve problems which arose during the project.

A major lesson learned is that the context should not be underestimated. In this project, the appropriate timing of the project suffered from the political (election), environmental (heavy storm damage) and economic context (Covid-19 impact on economy and society).

8. References

Banja Luka, *Energy Strategy of Republic of Srpska up to 2030*, February 2012

Escher Patrick, *Optimisation and integration: An approach for smart city energy solutions*, SUPHER (Sustainable polyenergy generation and harvesting) conference, Savona (Italy), September 2019

9. Annex

9.1 Data plausibility checks

Before any study is carried out, it is important to check all values against plausibility. This will form a clean base for further studies and trustworthy results.

For each building, a questionnaire was filled out by the city of Trebinje. The questionnaire collected data on energy features such as:

- basic building data
- data on the organization/operation
- features of construction and thermal insulation
- glazing overview
- system of heating/cooling etc.
- specific consumption
- lighting system
- energy costs

The plausibility check for the building no. 1 reveals that all installed devices (e.g. heaters, split air-conditioners etc.) capacity (typically oversized design) will give an electricity consumption of about 169 MWh. This fits well with the average electricity consumption for the years 2015-2017. An interesting fact is the profiling of different systems (heating about 57%, cooling about 18% and computers about 17%) compared to the total used energy (see Figure 6):

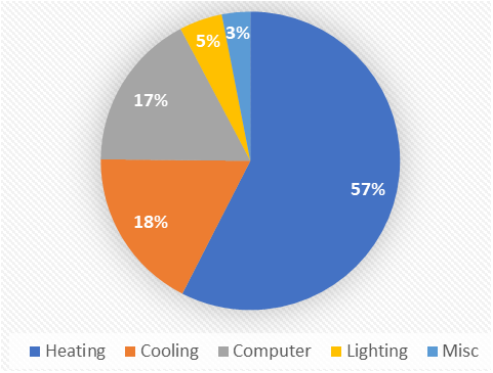

Figure 6: Building no 1 profile electricity usage

Smart meter readings of the building no. 1 are checked against the monthly standard meter readings from the previous years. Since the smart meter readings are every 15 minutes, the readings are summed up every hour, further to every day and finally for every month. A comparison of monthly values is shown in Figure 7. Note, that the striped bars are incomplete smart meter readings. In general, the monthly smart meter readings match well with the monthly standard meter readings.

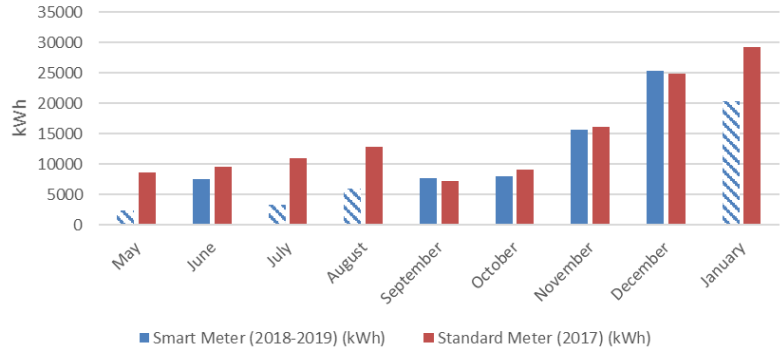

Figure 7: Electricity usage building no. 1 smart meter against standard meter reading

9.2 Founding Association Tribunus

The main goal of the association is the transformation of Trebinje city and neighboring cities into smart cities according to the Cohen wheel (see Figure 8).

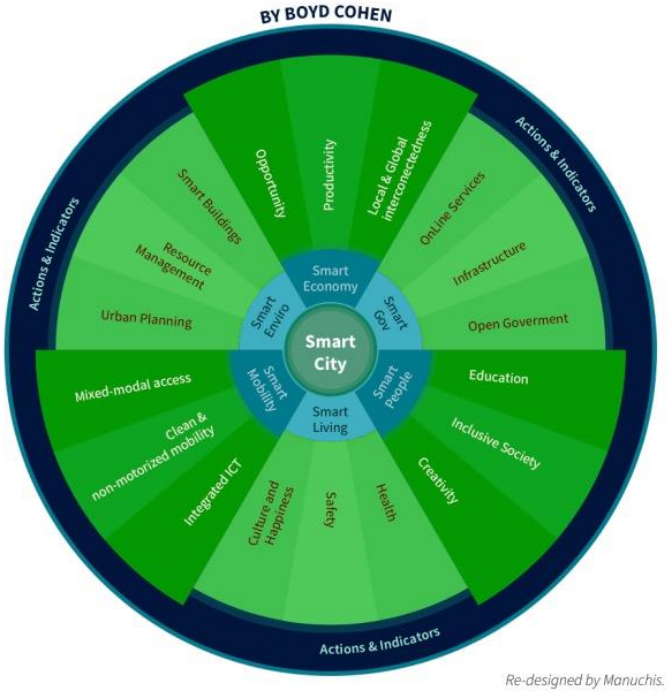

Figure 8: Smart city wheel by Boyd Cohen

The committee of the Association would consist of members from the City of Trebinje, delegates from EscherTec and members of nearby Universities. Their main function would be:

- Promoting Tribunus for fundraising (financing)
- Promoting smart city Trebinje to other cities (marketing)
- Applying for smart city calls/projects (education, e.g. with universities)

9.3 Analysis of energy sources available in Trebinje

The region of Trebinje has a high potential to increase the use of renewable energy sources (see Table 4) which today already represents a high percentage of the total energy use. For the generation of electricity solar energy (various technologies), wind turbines and small hydropower plant can be envisaged. Heating and cooling can be covered with shallow geothermal energy as well as solar thermal energy. One of the main biomass sources in the area of Trebinje are vineyards. Therefore, biomass might be an additional source of energy, e. g. generating fuel via anaerobic digestion or gasification which can be used in a CHP also as backup energy for fluctuating renewables (solar and wind).

Table 4: Summary of evaluated possible renewable energy sources

Technology	Pre-request	Pros	Cons
Solar electrical (PV)	Electrical energy storage for peak shaving	Well proven technology	Highly seasonal and daytime dependent and fluctuating.
Solar thermal	Thermal energy storage for peak demand shaving; thermal heating system (ventilation or water based)	Well proven and mature technology; partly replacing electricity for heating (tap water and room heating) if the weather allows; energy can be stored easily (H_2O or PCM)	Tap water heating only has a small share in energy consumption. Highly seasonal dependent and fluctuating Installation of thermal system necessary
Solar hybrid (PVT)	Thermal and electrical energy storage for peak shaving; thermal heating system (ventilation or water based)	Combining electricity and heat in one component; increased efficiency of PV	Relatively new; Seasonal dependence and fluctuating; Installation of thermal system necessary
Wind	Preferably wind turbine on a nearby hills; energy storage and grid connection	Well proven and mature technology, less seasonal influenced compared to solar;	Longer distance electrical connection necessary or using the existing grid; Fluctuating energy source
Geothermal	Centralized heating and cooling e.g. via water-based system or central ventilation system	Well proven and mature technology. Four to five-time lower amount of bought energy; can be combined with PV, PVT, make use of low temperature waste heat. Seasonal independent.	Installation of water based thermal system necessary; not covering electricity.
Biomass	Collection of preferable 2nd generation biomass	Proven technology, reducing the emissions of greenhouse gas emission resulting from storage and disposal of biowaste; dispatchable energy source; re-use of waste after biofuel production possible.	Collection and transport biomass required;
Hydro	Comparatively large infrastructure required (damn, piping, etc.).	Can be a dispatchable resource in connection with damns; fast start up and control also of large units => well suited for balancing and use as a flexible energy source.	High investment necessary; possible environmental and societal impact which needs to be evaluated in depth.

9.4 Concept solar farm in the region of Trebinje

For the solar farm concept in the region of Trebinje, a simulation was carried out. The simulation tool allows for hourly dynamic simulation and the study was carried out for a solar farm plant range up to 15 MW (see Figure 9).

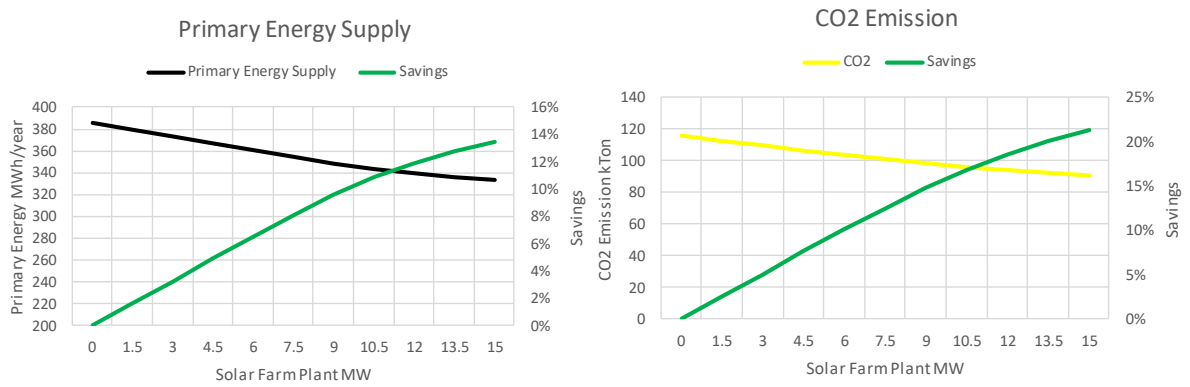

Figure 9: Different solar farm plant sizes showing effect on primary energy supply and CO2 emission

With a 10MW peak solar farm plant, the annual emission of CO_2 could be reduced by 17%. The primary energy use would be reduced by 11%. Since the Trebinje area cannot use all produced energy, a solar farm plant size bigger than 9MW would generate excess energy (see Figure 10).

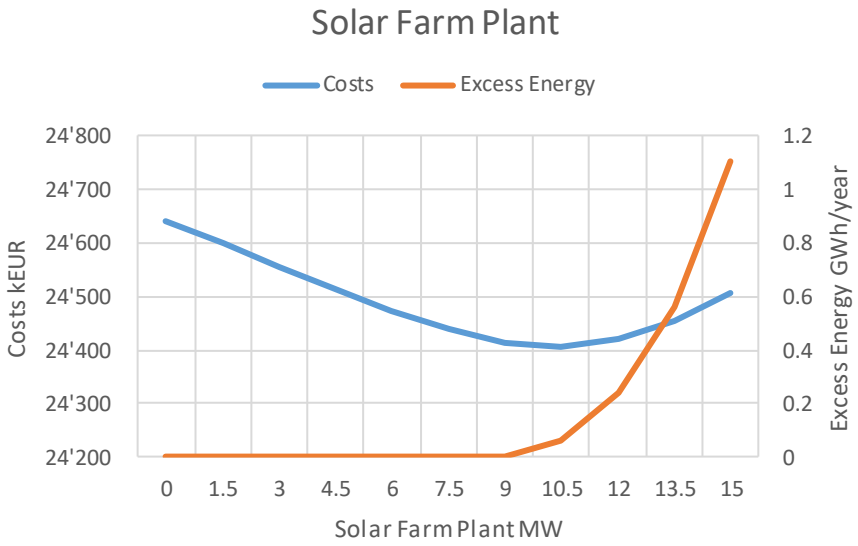

Figure 10: Different solar farm plant sizes showing effect on annual energy system costs and excess energy

The annual energy system costs would have an optimum around a plant size of 10MW.

9.5 Examples of media reports

- http://www.herceg.tv/drustvo/10725/trebinje-svajcarska-i-vlada-rs-finansiraju-projekat-energetske-efikasnosti-gradske-uprave
- https://www.glassrpske.com/novosti/vijesti_dana/Svajcarska-i-Vlada-Srpske-finansiraju-projekat-energetske-efikasnosti-trebinjske-Gradske-uprave/lat/257077.html
- http://www.trebinje059.com/059/svajcarska-finansira-projekat-energetske-efikasnosti-objekta-gradske-uprave-u-trebinju/
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