MANAGEMENT OF IMPLEMENTING A PILOT PROJECT AT UPB-FACULTY OF POWER ENGINEERING: "HYBRID GEOTHERMAL-SOLAR SYSTEM DEVELOPED TO SUPPLY THE ENERGY DEMANDS OF A BUILDING AND INTEGRATION WITH UPB DISTRICT HEATING NETWORK"

MANAGEMENTUL IMPLEMENTĂRII UNUI PROIECT PILOT LA UPB - FACULTATEA DE ENERGETICĂ: "SISTEM HIBRID GEOTERMAL-SOLAR DEZVOLTAT PENTRU ASIGURAREA CERERII DE ENERGIE A UNEI CLĂDIRI ȘI INTEGRAREA ÎN SISTEMUL CENTRALIZAT DE ALIMENTARE CU CALDURĂ"

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Abstract: *Within the framework of this article the management system of WEDISTRICT – DEMO Romania is presented. The key performance indicators of energy, economics, environmental impact or social type are explained and analysed throughout the entire project.*

The general objective of the European project is to demonstrate the possibility of switching off from fossil fuels usage for centralized generation of thermal energy, by optimally integrating different types of renewable energy sources in the existing systems of different European countries.

Throughout the project, 10 technologies will be developed, which will be integrated in 4 demonstrators. One of the demonstrators will be developed and integrated and University POLITEHNICA Bucharest.

Keywords: renewable resources, solar-geothermal, thermal energy, district heating network, prosumer.

Rezumat: *In cadrul acestui articol este prezentat sistemul de management al proiectului WEDISTRICT- DEMO Romania, precum si rolul principalilor*

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indicatori de performanta de natura energetica, economica, de impact asupra mediului, precum si de impact social, determinati si analizati pe intreaga perioada de implementare a proiectului.

Obiectivul general al proiectului european este de a demonstra posibilitatea inlocuirii combustibililor fosili pentru producerea centralizată a căldurii și frigului, prin integrarea optimă a diferitelor surse regenerabile de energie în sistemele existente, în diferite țări din Europa.

În cadrul proiectului se vor dezvolta 10 tehnologii care vor fi implementate în 4 demonstratoare. Unul din demonstratoare va fi dezvoltat și implementat la Universitatea POLITEHNICA din București.

Cuvinte cheie: surse regenerabile, solar-geotermal, energie termică, sistem centralizat de alimentare cu căldură, prosumer.

1. Introduction

WEDISTRICT project is born with the objective of demonstrating 100% fossil free heating and cooling solutions by optimally integrating multiple sources of renewable energies and excess heat in new and existing district heating and cooling (DHC) systems. For this, integration of 9 upgraded renewable solutions for DHC generation into 4 real DHC sites in Spain, Romania, Poland and Sweden will be performed within the project. All of this, in a holistic context, smartly managed by information and communication technologies (ICT) integration, sustainable business models and engagement of citizens [1].

The overall objective of WEDISTRICT is to demonstrate DHC as an integrated solution that exploits the combination of renewable energy sources (RES), thermal storage and waste heat recycling technologies to satisfy 100% of the heating and cooling energy demand in new DHC and up to 60-100% in retrofitted DHC. For this purpose, the focus of WEDISTRICT is large-scale replication of best practice: better valorization of local resources, like renewable and waste heat by making DHC networks more efficient in relation to the use of new resources. In parallel, systems will evolve to provide even more flexible solutions by the integration of innovative molten-salts based thermal storage, the interaction with other energy networks (electricity and gas) and the involvement of end-users (operators and consumers) through ICT-based control and decision making.

The main target is the research and development of a technological solution for generation of thermal and electrical energy using renewable sources. Based on the technical-economic analysis of the proposed solutions (equipment, functional schemes and performance indicators) the optimal technological solution will be chosen. Analysis of the solution integration in the energy network of University POLITEHNICA of Bucharest (UPB) campus will also be conducted. The new hybrid installation will contain geothermal system (geothermal heat exchanger and geothermal heat pumps), photovoltaic (PV) panels and a set of integration systems such as heat exchangers, thermal energy storage. Furthermore, solar hybrid panels (PV/T) will be installed in the building for satisfying domestic hot water (DHW) requirements. The overall system will face the prosumer concept acting as heat provider to the existing district heating network at Bucharest demo-site, since the overproduction of heat will be injected to the University's network. Finally, the electrical integration with an existing microgrid will be performed, using the electricity generated by the PV panels array. The PV array will be sized to satisfy at least the electrical consumption of the geothermal heat pumps on a yearly basis. A local energy storage based on batteries will provide a certain resilience of the system in case of electricity blackout. The university's power grid will be also used as "storage" for the electricity generated by the PV array [1].

The Renewable Energy Sources Laboratory will be used as the case study for a new heat supply based on renewable energy. The Target Building (TB) is dedicated to teaching and research activities.

Objectives of UPB Bucharest demo-site by implementing the proposed system:

- generate three forms of energy (electricity, heat and cold) based on a hybrid renewable energy source (geothermal and solar), in which the electricity produced will cover at least the electrical consumption of the thermal energy generation unit (on a yearly basis);
- fully cover the heating and cooling demand for the target building using thermal energy produced from 100% renewable energy sources;
- reintegration of the Target Building into the UPB heat distribution network to inject the overproduction of heat;
- develop a modular concept that will ease the process of replication and scaling.

The pilot project implemented at UPB represents one of the 4 demonstrators proposed to be developed within European WEDISTRICT project. The remaining 3 demonstrators will be developed in Sweden, Spain and Poland. Each demonstrator is different due to:

- climatic conditions of the location
- national or local existing infrastructure

All the proposed solutions for each demonstrator have the same basis which practically is the main objective of the WEDISTRICT project. In Figure 1 the structure of the 4 demonstrators developed within the project is presented.

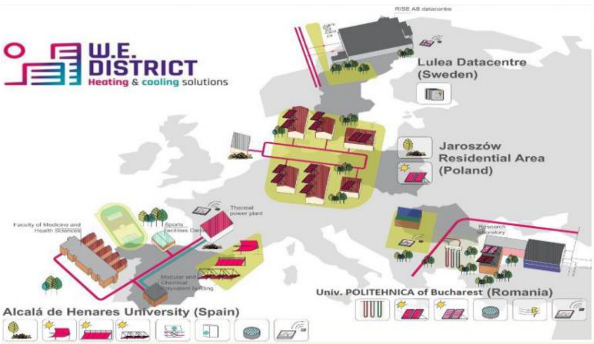

Figure 1. Structure of the 4 demonstrators [2].

2. Conceptual development of project management within UPB - Faculty of Power Engineering

The starting point and the key to success in the implementation of an investment project is the development of a coherent management plan. The management plan has to be developed in well structured distinctive modules which are, at the same time, interconnected and has to take into account the 3 types of resources:

- materials
- financial
- human

This harmonization has to be realized throughout all three phases of the implementation of the project, taking into account the time axes, from year 0 (start point of the project):

- pre-Investment phase (evaluation of existing situation, opportunity of the solution and feasibility study)
- Investment phase (equipment acquisition, installation of proposed system and commissioning)
- monitoring phase of the new system throughout the exploitation period [2].

In Figure 2, the main phases of the project are presented with respect to the time axis throughout the project.

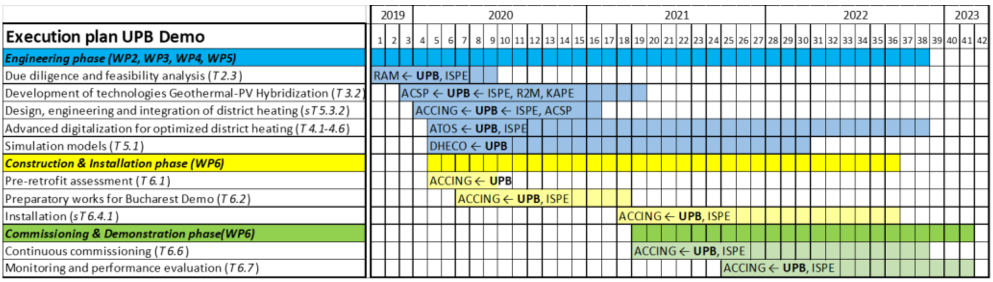

Figure 2. Implementation plan of the project.

As it can be seen from Figure 2, UPB's activities are conducted in collaboration with project partners such as: RAM(Ramboll), ISPE (Institutul de Studii si Proiectarii Energetice) ACCING (Acciona Engineering), R2M (R2M solutions), KAPE, ACSP, ATOS, DHECO (DH eco Energias).

Within the management implementation of the project, the followings were considered:

- Determination of the reference system boundaries on which the energy audit is related (see Figure 3 and Figure 4).

- The system boundaries considered during energy audit, of the analyzed system will represent the frame for key performance indicators definition. Those indicators will be monitored during the entire project development.
- Performing feasibility study which had as a starting point the defined system along with the energy audit results.

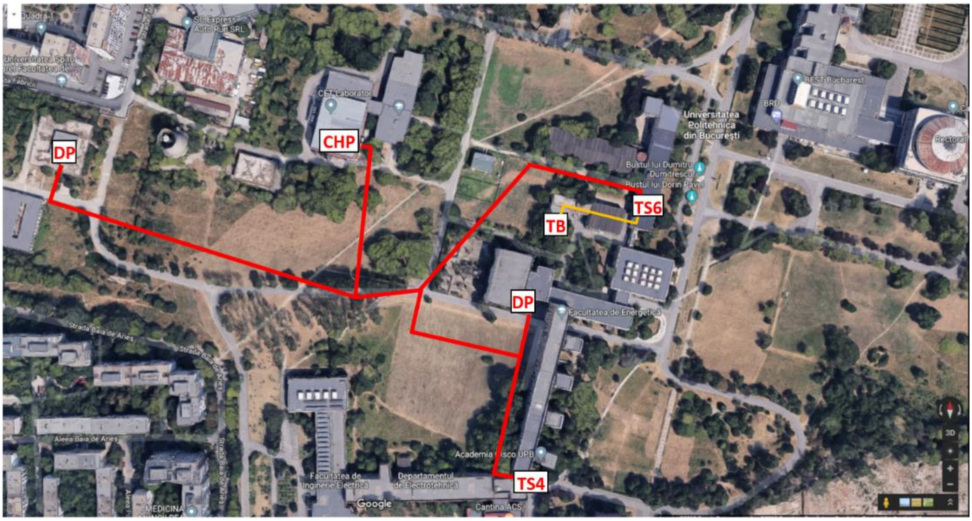

Figure 3. Layout of the primary circuit of branch B1 from the UPB heating network (CHP – Combined Heat & Power Plant; TB – Target Building; TS – Thermal Substation; DP – Distribution Point; red line – primary circuit; yellow line – secondary circuit).

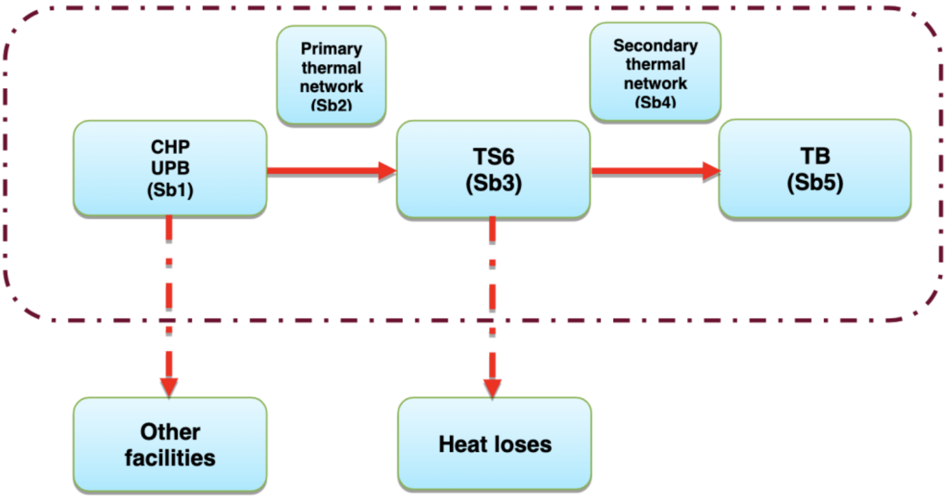

Figure 3. System Boundaries.

The reference system boundaries are established taking into consideration the position of the target building within the general configuration of the UPB district heating system [3].

The actual energy audit will be carried out for the component systems that directly influence the present and future supply (after the implementation of the new solution). In this sense, the reference system boundary on which the energy audit is considered is composed of 5 subsystems (Sb), as following:

- Combined heat and power (CHP) UPB (Sb1)
- Primary Thermal Network -branch B1 from CHP to thermal substation (TS6) (Sb2)
- Thermal substation TS6 (Sb3)
- Secondary Thermal Network (connection from TS6-TB) (Sb4)
- Target Building (Sb5)

The thermo-energy audit will be developed on each component of the centralized heat supply system of the UPB, Sb1-Sb5 (previously mentioned)

The energy audits will then be integrated within the analyzed system [4][5].

The objectives of the energy audit of the Target building and UPB DH were:

- Evaluation of the current energy situation of the Target Building, as well as of the district heating system of UPB (UPB DH), specifically of the segment defined in Figure 4 of System Boundaries.
- Establishing a plan of measures to increase the energy efficiency of the building and of the system.
- The opportunity to implement a new solution for supplying thermal energy to the Target Building, based on renewable energy sources.

3. The purpose of the key performance indicators (KPI) throughout the implementation of the project

KPIs are a key element for assessing the project evolution and success. This is particularly truth for complex systems, which involves different technological innovation in a single ensemble, as it is case for WEDISTRICT pilots, and more generally for different renewable energy technologies integration in district energy systems.

For the establishment of the correct key performance indicators for the Bucharest demo-site the followings were considered:

- Type of performance to be expressed (energy, economics, environmental impact and social impact).
- System boundaries (see Figure 4).
- Phase in which the KPI is analyzed [6].

Taking into account the elements expressed previously, for the case of Bucharest demo-site the following KPIs were defined:

A. Key performance indicators KPIs (Technology) – for each technology (HP, PV, PVT, TES tank)

The KPIs (Tech) will be calculated:

- as part of the feasibility study (for proposed schemes, based on them, the optimal scheme is selected),
- after implementation and will be monitored during the period of operation.

B. Key performance indicators KPIs (System) – for the technological configuration

The KPIs will be calculated:

- as part of the feasibility study (for proposed schemes, based on them, the optimal scheme is selected),
- after implementation and will be monitored during the period of operation.

C. Key performance indicators KPIs (Building) – for Target Building

The KPI's (Building) will be calculated:

- during the audit (initial assessment)
- as part of the feasibility study (for proposed schemes, based on them, the optimal scheme is selected),
- after implementation and will be monitored during the period of exploitation.

D. Key performance indicators KPIs (DH) – for the district heating system of UPB

The KPI's (DH) will be calculated:

- during the audit (initial assessment)
- as part of the feasibility study (for proposed schemes, based on them, the optimal scheme is selected),
- after implementation and will be monitored during the period of operation.

For exemplification, in the following paragraph, some of the energetic KPIs are defined and determined during the pre-assessment phase [4][5].

Specific heating energy demand:

$$\boldsymbol{q_h} = \frac{\boldsymbol{Q_h}}{\boldsymbol{A \cdot Year}} \left[\frac{\mathbf{kWh}}{\mathbf{m^2}\ \boldsymbol{year}}\right] \tag{1}$$

where, $\boldsymbol{Q_h}$ $[\boldsymbol{kWh}]$ represents the yearly thermal energy for heating required by the building and $\boldsymbol{A}$ $[\boldsymbol{m^2}]$ represents the area of the building.

Specific cooling energy demand:

$$\boldsymbol{q_c} = \frac{\boldsymbol{Q_c}}{\boldsymbol{A \cdot Year}} \left[\frac{\mathbf{kWh}}{\mathbf{m^2}\ \boldsymbol{year}}\right] \tag{2}$$

where, $\boldsymbol{Q_c}$ $[\boldsymbol{kWh}]$ represents the yearly thermal energy for cooling required by the building.

Specific DHW energy demand:

$$q_{DHW} = \frac{Q_{DHW}}{A \cdot Year} \left[\frac{\mathrm{kWh}}{\mathrm{m}^2\ year}\right] \tag{3}$$

where $Q_{DHW}[kWh]$ represents the yearly thermal energy required for domestic hot water by the building.

Specific total thermal energy demand:

$$q_{total} = \frac{Q_{total}}{A \cdot Year} = q_h + q_c + q_{DHW} \left[\frac{\mathrm{kWh}}{\mathrm{m}^2\ year}\right] \tag{4}$$

Specific total primary energy equivalent:

$$E_{total,echiv} = \frac{q_h}{\eta_{heating}} + \left(\frac{q_c}{COP_{Cooling}} + \frac{q_{DHW}}{\eta_{DHW}}\right) \cdot a_{conv} \left[\frac{\mathrm{kWh}}{\mathrm{m}^2\ year}\right] \tag{5}$$

Where $\eta_{heating}$ [%] represents the efficiency of the transformation of the primary energy (natural gas) into heat, $COP_{Cooling}[-]$ represents the efficiency of the cooling system, $\eta_{DHW}[\%]$ is the efficiency of the domestic hot water production system and $a_{conv}[-]$ is the conversion factor of final energy into primary energy [7].

Specific total CO_2 equivalent:

$$CO_{2\,total} = \frac{E_{CO_2\,total}}{A \cdot Year} \left[\frac{\mathrm{kg}}{\mathrm{m}^2\ year}\right] \tag{6}$$

Where $E_{CO_2\,total}\left[\frac{kg}{year}\right]$represents the total emissions of CO_2 related to the total primary energy consumed to satisfy the thermal demand of the building. It is calculated by using “Ordinul 2641/2017” [7].

Table 1 provides the energetic KPI’s for the target building with the current thermal installations (before WEDISTRICT retrofitting scenario).

Table 1. **KPI’s of Target Building**

KPI	U.M	Value
Specific heating energy demand	[kWh/m^2 year]	240.1
Specific cooling energy demand	[kWh/m^2 year]	24.97
Specific DHW energy demand	[kWh/m^2 year]	1.17
Specific total thermal energy demand	[kWh/m^2 year]	266.24
Specific total primary energy equivalent	[kWh/m^2 year]	292.25(1)
Specific total CO2 equivalent	[kg/m^2 year]	59.92(2)

All the calculations were performed with the surface of Target Building of 532 m^2
(1) The calculation was performed considering the conversion factor from final energy to primary energy of 1.17, according to national order “Ordinul 2641/2017”.

(2) The calculation was performed considering the conversion factor from primary energy to CO2 production of 0.205, according to national order "Ordinul 2641/2017".

The WEDISTRICT new thermal supply unit that will be installed, implies production of thermal energy based on renewable energy sources and the thermal connection between UPB DH and Target Building will be re-designed. Therefore, it is necessary to define the renewable energy ratio for both Target Building and UPB DH.

The renewable energy ratio (RER), or share of renewables, is the fraction of renewable primary energy used by network compared to total primary energy consumed in order to fulfil the heating and cooling demand [8].

Considering the system boundaries presented in Figure 4, the equation for RER is explained below.

$$RER = \frac{E_{Pren}}{E_{Ptot}} \cdot 100\ [\%] \tag{7}$$

where

- $\boldsymbol{E_{Pren}}[kWh/year]$**:** Renewable primary energy used by UPB DH/Target Building.
- $\boldsymbol{E_{Ptot}}[kWh/year]$: Total primary energy used by UPB DH/Target Building.

In the current case, both KPI are equal to zero since the there is no renewable primary energy used by either of subsystems.

$$RER_{UPB\ DH} = \frac{E_{Pren}}{E_{Ptot}} \cdot 100 = 0\ [\%] \tag{8}$$

$$RER_{TB} = \frac{E_{Pren}}{E_{Ptot}} \cdot 100 = 0\ [\%] \tag{9}$$

The energy evaluation of the current situation of the other subsystems was carried out in order to establish the necessary measures to be applied for the reintegration of the Target Building in the DH system of UPB, with the new heat supply solution of the building.

4. Conclusions

In the context of the establishment and functioning of the internal energy market and from the perspective of the need to protect and conserve the environment, the ***EU's energy policy aims*** mainly at:

- promoting energy efficiency and energy saving;
- development of renewable energy sources;
- depletion of greenhouse gas emissions (GHG) [9].

The Romanian energy strategy 2019-2030, with 2050 perspective is a programmatic care document that defines the vision, that establishes the fundamental objectives of the process of creating an energy sector and indicates the national, the EU and the global landmarks that influence and determine policies and decisions in the field energy. The strategic energy vision is to create a sustainable energy sector [9].

It is obvious that the implementation of the WEDISTRICT project is in accordance with most of the objectives of the strategy. In this sense it is mentioned:

- Efficient heating of buildings;
- Ensuring access to electricity and heat for all consumers;
- Energy efficiency, the main priority of the new reform package;
- Promoting energy from renewable sources.

Within the framework of this article, the management of implementing a pilot project which started in October 2019 was addressed. Until the moment of this writing, the pre-Investment phase was conducted in which the energy audit and feasibility study led to the opportunity of implementing the proposed solution. The optimal technical and economical solution along with monitoring the energy performance of the system was assessed and will be further assessed using the key performance indicators. Along with the KPIs presented in this article, economical and social KPIs were also considered [10].

The energy audit of the Target Building led to the opportunity of implementation of a new solution for the thermal energy supply of the building, which ensures heating, cooling and domestic hot water. It integrates technologies based on renewable sources, namely: ground-to-water heat pump, PVT or PT, photovoltaic panels (to ensure the supply of electricity of the thermal supply unit).

The proposed solution also involves the development of a new heat, cold and DHW distribution system of the building.

The energy capacities of the proposed solution will ensure:

- the interior comfort in the building spaces
- the safety and flexibility of the supply thermal energy unit
- the delivery in the DH system of UPB of a share of heat energy produced from renewable sources (dependable on the operating regime)

The decision of the final form of the hybrid geothermal-solar system was taken based on dynamic simulations that were conducted and, on the results, obtained from the feasibility study along with the key performance indicators. Further, the system will be monitored using the key performance indicators.

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