[1.]Marius LOLEA, [2.]Levente LORINCZ, [3.]Valentin BESCHIU, [4.]Adrian CHEREGI, [5.]Cristian SANDRO

OPPORTUNITIES TO EXPLOITATION AND INTEGRATION OF RENEWABLE ENERGY SOURCES IN THE ENERGY SYSTEM STRUCTURE OF BIHOR COUNTY, ROMANIA

[1-5]University of Oradea, ROMANIA

Abstract: The paper analyses the possibilities of integration of the existing Renewable Energy Sources – RES – in the Bihor County into the regional energy system. In this scope, the potential of the RES, the RES-based energy objectives achieved to date are assessed and proposals are made to create new objectives for the coupling with the energy system on the two directions of conversion: electrical and thermal. The paper presents at the beginning the general framework of valorisation of RES with the justification of their valorisation and the necessity of integration in the Romanian energy system. Next, the identification of the RES and the existing objectives in Bihor County will follow. At the end of the paper, conclusions are drawn as a result of the study. The main idea of the paper is to present and analyse the opportunities for energy recovery of existing RES at regional level by identifying the possibilities for connection to the system through electrical networks and their components and sources of financing of new projects in the field.

Keywords: Renewable energy sources, Power System (PWS), energy conversion

1. INTRODUCTION

In the last years, all developed countries of the world admit that they are faced with major challenges of primordial importance, namely: the increase in energy consumption, due to the increase of the population on the globe and, on the other hand, the increase of its needs in relation to the stage current economic and social development, which translates into increasing the exploitation of resources; global warming, as a direct and often uncontrolled consequence of excessive exploitation of natural resources. These challenges are closely interdependent and must be addressed in the light of this close link. The need for energy is dictated primarily by the need for economic growth in highly developed countries. At the same time, this energy need faces the rehabilitation of the exhaustion of classical energy sources - coal, crude oil, natural gas - and the unequal distribution of these sources from a geographic point of view. These issues have led to a permanent increase in the price of these energy sources, and these, in turn, to certain economic imbalances, which can ultimately lead to blockages of economic development in the current form. Considering these particularly important but pressing issues (exhaustion of existing stocks in the near future), mankind is focused on developing new directions for capitalizing on renewable energy resources. These resources are transformed into usable energy sources such as hydro, wind, solar, geothermal and biomass [1].The implementation of an energy strategy for capitalizing on the potential of Renewable Energy Sources (RES) is part of the medium and long term of energy development of Romania and provides the appropriate framework for adopting decisions on energy alternatives. Romania's contribution to the achievement of electricity and heat from RES must be met by each region of the country. In this purpose, we analyse the opportunities offered by the territory and the administrative and economic conditions of Bihor County.

2. WEB PLATFORMS AND ONLINE SOFTWARE APPLICATION FOR EVALUATE THE POTENTIAL OF RES. CASE STUDY OF BIHOR COUNTY SIMULATION

Assessing a region's energy potential is the first way to make the decision to achieve an energy project. There are several possibilities to assess the potential of RES. Of course, the safest method is experimental research with various techniques and measuring devices. However, the high duration, field conditions or cost difficulties make practical methods not to be preferred by many researchers. Thus appear, the additional sources of information such as articles or scientific reports or specialist books in which different authors publish their research results by compiling RES distribution maps. Software applications on various dedicated digital platforms, available online and managed by government agencies or RES-related companies, provide a quick and easy way to identify the existence or potential of the various renewable resources. Some data taken from these digital online applications is statistically processed, analysed, and presented in a personal form by the authors.

Table 1. The Annual potential of RES in Romania [5][6]

Renewable energy sources(RES)	Energy annual potential	Energy economic equivalent (thousands toe)	Applications
Thermal solar energy	60 x 10^6 GJ	1.433,00	Heat
Photovoltaic solar energy	1.200 GWh	103,20	Electricity
Wind energy	23.000 GWh	1.978,00	Electricity
Hydro power	40.000 GWh	3444,00	Electricity
From which under 10 MW	6.000 GWh	516,00	Electricity
Biomass	318 x 10^6 GJ	7.597,00	Heat
Geothermal energy	7 x 10^6 GJ	167,00	Heat

Located in the north - west of Romania, Bihor County is included in a territory with rich RES. This county owns all important categories of RES that are distributed unevenly within its territory. In order to appreciate the classification of these sources at national level, Table 1 presents the energy potential of RES for Romania [4] [5] [6]. Depending on the RES category, Bihor County has a larger or smaller share in the national energy balance.
In Romania, according to [5] there are five solar energy potential zones (zones I - V), differentiated by the average annual flows of incident solar energy, and more than half of the country's surface benefit from an average annual energy flow of 1275 kWh / m^2. Bihor County can be characterized in terms of the distribution of solar radiation, as fallow: the county has a wider region in the western part of the entire north-south alignment, which is included in the solar radiation zone II. In the middle region, also extended from north to south, there is the radiation zone III; In the south-eastern part of the county, in the area of the Apuseni Mountains, the IV and V solar zones are predominantly low (1200-1250 for zone IV and below 1200 kWh / m^2 / year for zone V). The hydro-energetic potential of our country is estimated that the theoretical potential of precipitation is about 230 TWh / year, the theoretical drainage potential of about 90 TWh / year, and the linear theoretical potential of the water courses is 70 TWh / year [5]. Bihor County lies in the Crişuri hydrological reservoir with an area of 13085 km2 and a theoretical energy potential of 2.5 TWh per year [5]. Most MHP located in Bihor County are owned and managed by the state-owned company Hidroelectrica SA. Only few low-power hydro-power plants are in the patrimony of private companies. The wind potential of the county is in a medium area characterized by wind speed ranging between 4-10 m / s distributed according to the measuring point. Instead, the geothermal potential of the county is the highest in the country, the western side of the country having the most important deposits of thermal water. Until 1973 in Bihor County, 23 drillings were carried out and then put into operation. Productive geothermal probes can be found in the following localities: Oradea, Baile Felix, Baile 1 Mai, Beius, Săcuieni, Livada de Bihor, Marghita, Madaras, Ciumeghiu, Cichid etc. The temperature at the production wells head fluctuates between 45 and 105 °C.

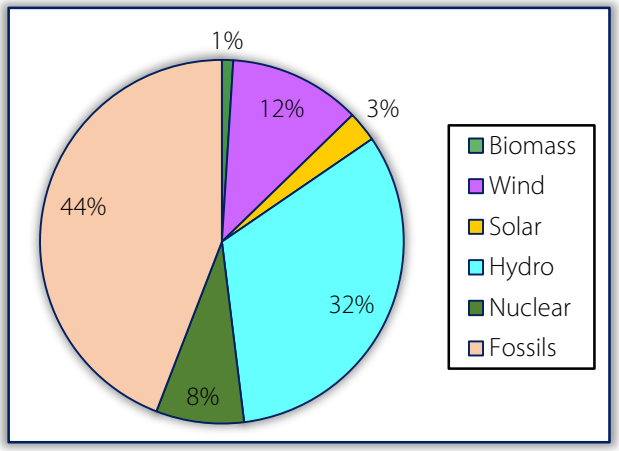


Figure1. Daily national structure of Electricity production based on RES[12]

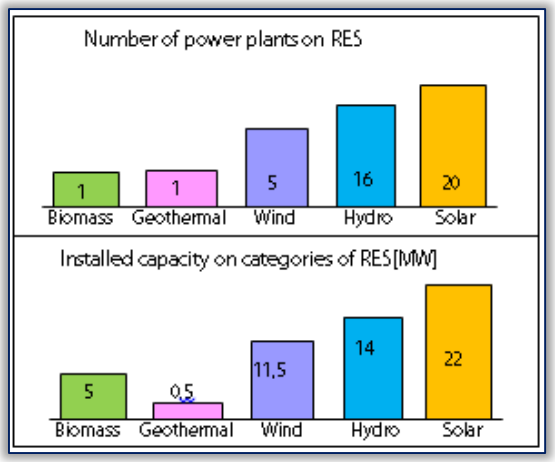
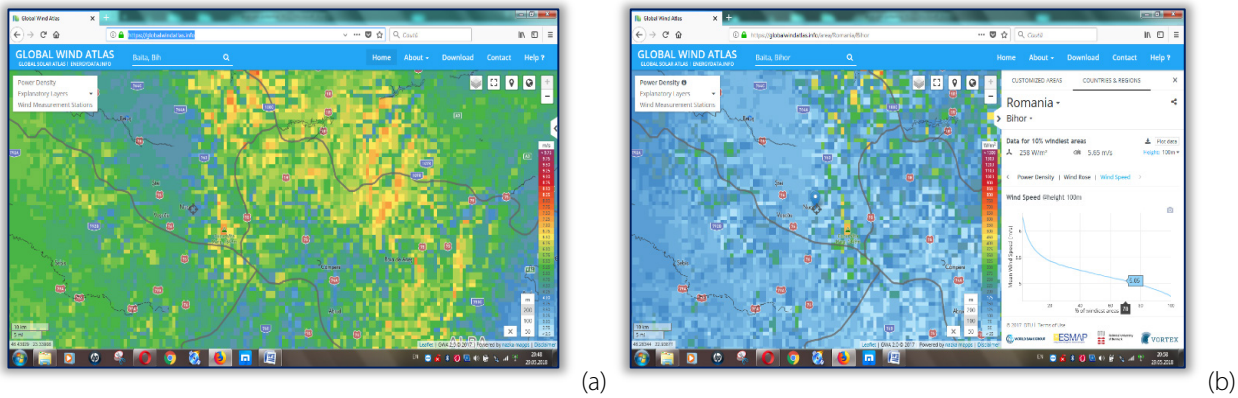


Figure 2. Structure of power capacities based on RES from Bihor County[11]

From the point of view of the energy potential of biomass, Romania's territory was divided into eight regions. Bihor County corresponds to the regions of the Western Plain and the Apuseni Mountains and has estimated a biomass potential of between 60,906 and 65,415 TJ, consisting of several sources: forest biomass, agricultural biomass, biogas and urban waste [5]. The Web platform of the Power System and Electricity Transmission Operator in Romania - Translectrica SA, offers the possibility to view through function „System Status", the daily production and consumption of electricity by categories of resources at various time intervals. Thus, Figure 1 presents the state of the Romanian energy system for the day 07.07.2017 adapted from [12]. For selected date

of report are registered a total electricity production of 7013 MW (100 %). Then, Figure 2 presents a statistic made by the authors of the paper using the platform [11], with regard to RES-based capacities in Bihor County, at the level of year 2017. Exclusive dedicated digital RES platforms available through the included applications may have multiple user options allowing for potential point analysis by selecting geographic coordinates of interest. For example, the "Global Wind Atlas" platform [8] provides information on wind power density, wind speed measuring stations emplacement, wind rose and wind speed values for selected locations.

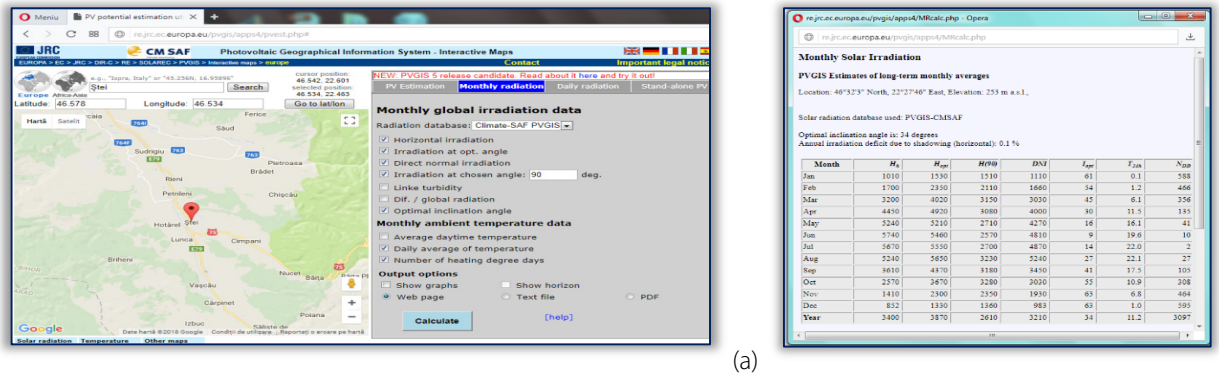
From Figure 3 we can deduce how to work with the platform presented. From the existing menu you can choose the wind speed display for a measurement location at 50, 100 and 200 m height. In the figure is selected a region, overlaid over the territory of Bihor County, indicating Baita village geographical coordinates for which the wind speeds are indicated by colour code. To the right of the window there is the possibility of graphically displaying other wind parameters. Variant (a) in figure 3 expresses the wind speed for the height of 200 m and the variant (b) for the height of 100 m. The power density displayed in Figure 3 - b is 258 W/m^2 and speed is 5,65 m/s for 10 % windiest areas(around selected point on the map).



(a) (b)

Figure 3. Using the platform [8] to identify the potential of wind energy

Platform [8], also allows viewing of the location and power of wind farms developed by the year selected by the user. A platform that strictly manages energy projects based by wind energy is that of the Global Wind Energy Council [15]. From this platform it is deduced that at the level of 2016 in Romania, the capacities installed in wind power plants reached 3, 028 MW and worldwide 486.7 GW were installed. The platform allows comparisons between countries and conducting analyses on the dynamics of wind power plants. The wind energy electricity market is presented on continents and countries on the Wind Power platform of Wind Market Energy Intelligence. In this platform you can view the locations, the number of wind turbines, the installed power in kW and the wind turbine manufacturer for the country selected by the user. An example will be given below in figure 4, on the evaluation of the solar potential of the city of Ştei and on the selection mode of the solar radiation parameters for a photovoltaic plant application. The application is based on the use of the platform PVGIS - SOLAREC from web-site administered by The European Commission through Research Institute for the production and transport of electricity - Joint European Research Center [7]. On the left side of figure 4(a), are presented the menu functions and on the right (b), the parameters for option "Monthly Solar Irradiation".



(a) (b)

Figure 4. Using the platform [7] to identify the potential of solar energy

The simulations made for the cities of Bihor County with the PVGIS online platform led to the following results: Oradea – 1370 kWh/m^2/year, Salonta – 1360 kWh/m^2/year, Beiuş - 1260 kWh/m^2/year, Marghita – 1290 kWh/m^2/year, Valea lui Mihai – 1410 kWh/m^2/year, Aleşd - 1210 kWh/m^2/year, Nucet – 1160 kWh/m^2/year, Săcuieni – 1380 kWh/m^2/year.

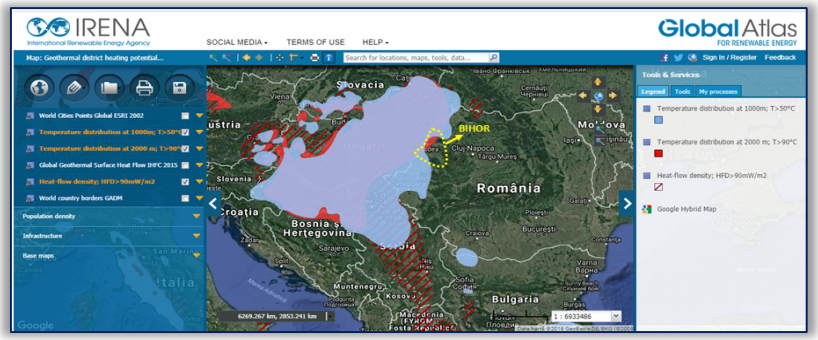


Figure 5. Using the platform [14] to identify the potential of geothermal energy

To highlight geothermal resources, was used the International Renewable Energy Agency platform which is shown in Figure 5. The geothermal energy options are to display temperature distribution zones at various depths. Both the temperature values and the resulting depth can be selected. For the case in Figure 5, three options are highlighted in the legend on the right side of the window: temperature greater than 50°C at a depth of 1000m, distribution of areas with temperatures greater than 90°C for a depth of 2000m, or density of the thermal flow on the selected surface. It is noticed that Bihor County overlaps as a territory in the western part, especially with the area of high potential of geothermal energy. Many of the RES can be measured more easily. In biomass, there are only observations of territorial distribution involving several aspects of the potential assessment. It is hard to appreciate, for example, the annual occurrence of grassy energy crops that will then be continuously introduced into the maps. The World Energy Council web platform [10] presents for Romania the biomass production capacity of 1.3 GW for year 2016. A platform which provides information on several categories of RES is that of the Global Energy Network Institute - GENI [9].

3. PROJECTS BASED ON RES IN BIHORCOUNTY

There are realized, at the time moment of carrying out the researches for the elaboration of the paper, several projects based on RES, made at the level of the Bihor County. Table 2 presents a situation regarding the allocation of capacities in RES-based plants in Bihor County for the period 2009÷2016 [12].

Table 2. Capacity of power plants based on RES from Bihor County

RES	Power of TCA[MW]	Power of CC [MW]	Total Power[MW]	Power with PIS at issuers [MW]	Power with PIS at NED[MW]
Biogas	0,000	1,754	1,754	0,498	0,498
Biomass	0,000	8,480	8,480	0,500	0,000
Wind	0,000	21,500	21,500	11,500	15,000
Photovoltaic	0,316	94,539	94,955	70,903	66,881
Geothermal	0,000	0,050	0,050	0,050	0,050
Hydro	0,215	11,949	12,164	12,020	12,678
Total	0,531	138,272	138,803	95,471	95,107

In Table 2 the following abbreviations are adopted: TCA = Technical Connection Approval; CC = Connection Contract; PIS = Putting into Service; NED = National Energy Dispatcher. Based on the analysis of Table 2, the results of a statistical processing on the share of some RES categories in the Bihor County's energy balance are presented in Figure 6. The Most installations based on RES in the Bihor County are solar photovoltaic power plants – SPP. Their distribution for the territory analysed in [3] is shown in Figure 7.

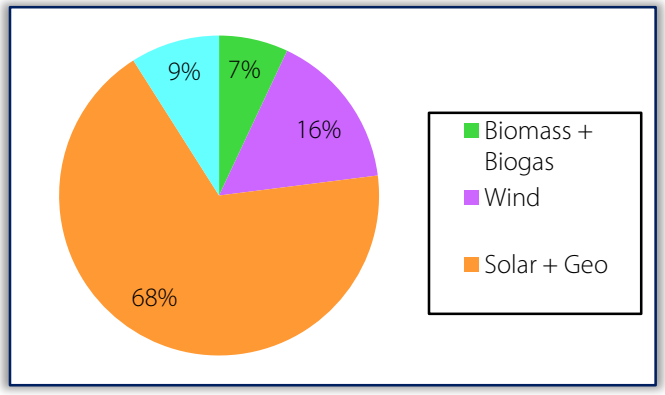


Figure 6. Percentage of RES in energy balance of Bihor County

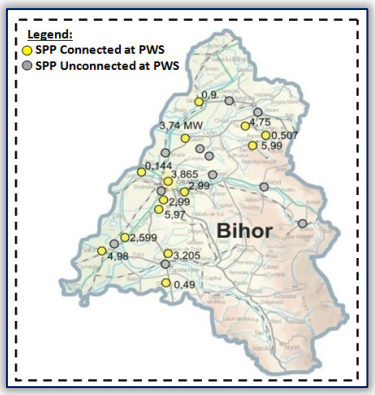


Figure 7. Distribution of SPP[3]

Getting heating energy and hot water is a bigger problem than obtaining electricity. The centralized systems of existing county towns have suffered major degradations and in some cases were dismantled. The population has begun to obtain thermal energy on the basis of small apartment or block plants running on natural gas or electricity. Localized locations based on solar collectors are installed more in family houses. A large part of the county's population gets heat from wood biomass-burning plants.

An important resource of Bihor County is geothermal water. There are many drillings on the territory of the county, but the basic use is recreation and balneology. Only two large projects for obtaining heating energy have been achieved. These are projects from Oradea and Beiuş. There are 12 drilling wells in Oradea, of which 11 for production and one for reinjection. The wells produce about 15% of the city's thermal energy demand, the main beneficiaries being the Municipal Hospital, State University, two hotels and a few thousand apartments from blocks of flats. The production of the wells is about 70 million m^3, which transmits 100,000 Gcal / year. City of Beiuş is the only in the country where the thermal energy supply provided by a centralized system based on geothermal water extracted from two production wells with water temperatures reaching 84°C. The heat produced reaches 25000 Gcal / year.

4. POSIBILILIES TO INTEGRATE THE RES POWER PLANTS IN ENERGY SYSTEM OF BIHOR COUNTY

The analysis of the expansion of an energy system, notably through the power and thermal power plants to be implemented, is made preliminarily on the basis of several criteria. These include the availability of energy resources, energy consumers and energy capacities for transport and distribution of electricity and heat. For take the final decision on implementation, is necessary the acceptance to the majority of people involved and the capacity of the financing of the projects.

After the decision to build an energy project on RES based on the identification of the potential of a region, in the initial plan of the energy management should be establish as accurate as possible the place of the project. This will ensure the good functioning of new installations and the optimal management of resources. So, other criteria regarding the establishment of the location point, are [2]:

- Concrete conditions in the field (land morphology, obstacles, land nature);
- The proximity of human settlements;
- Natural reservations, historical, tourist, archaeological sites;
- Special landmarks: forbidden areas, civil / military airport, special telecommunication installations;
- Existence and status of access paths;
- The conditions of land use: legal regime, concession / purchase;
- Possibility to connectivity at utilities;
- The existence of an important consumer in the area;
- Potential investors in the area;
- Potential auto producers in the area;
- The possibility of a public / private partnership;
- Technical and economic performance indicators favourable to the investment approach at the selected site (resulting from a feasibility study).

Exist various funding opportunities for RES-based county projects that we have identified:

- European Program "Horizon 2020";
- Cross-border Development Program INTERREG Romania - Hungary RO- HU.
- National Program for Rural Development(NPRD) 2014-2020;
- Operational Program for Great Infrastructure(OPGI) 2014-2020,
- Operational Program for Competitively 2014-2020;
- Operational Regional Program(ORP) 2014-2020;

A model for the expansion of the regional PWS will be presented by capitalizing renewable sources in an area located in the south of Bihor County. The analysed area includes 4 cities and 12 communes. Both the existing energy objectives and new ones proposed by the authors are included in the power grid, based on potential analysis and existing opportunities. The opportunities are considered both the demand for capacities by consumers and the components of the existing or potential electrical grids. Following this model, several such regions can be formed at the county level with the extension of the interconnected PWS so as to ensure a reservation of power, the continuity in the consumers' supply, the elasticity of the interconnection schemes and the insularisation of the energy system. Within the PWS Bihor are currently constructed the following electrical grid structures: 1 interconnection station of 400/110 kV , PL on 110 kV there are 593,95 km length, PL on MV there are 3553,79 km length, distribution substations on 110 / MV are 26 units and transformation posts

are 2170 pieces. The location and delimitation of the considered area is shown in figure 8. The components of the high and medium voltage electrical grid and the location of the RES-based energy objectives are shown in the figure. In Figure 8, the meaning of the terms in the legend is as follows: PL – Power lines, PS – Power Substations. Figure 9 shows the locations of the existing electric and thermal power plants and those proposed to be achieved.

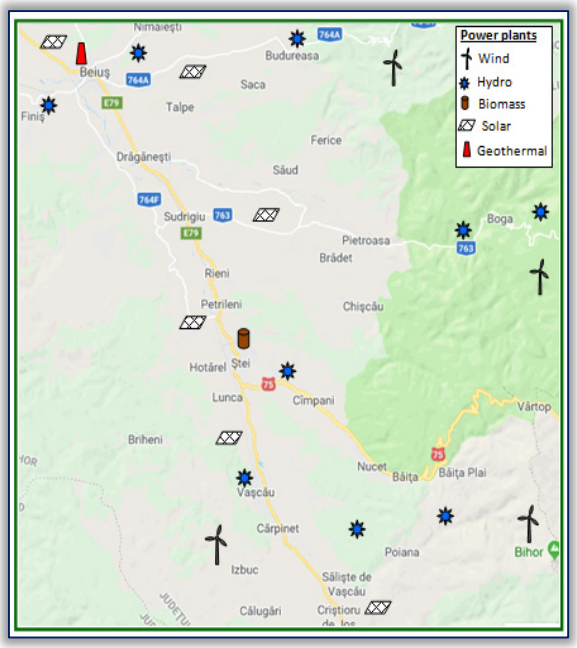


Figure 8. Location of the analzyed area

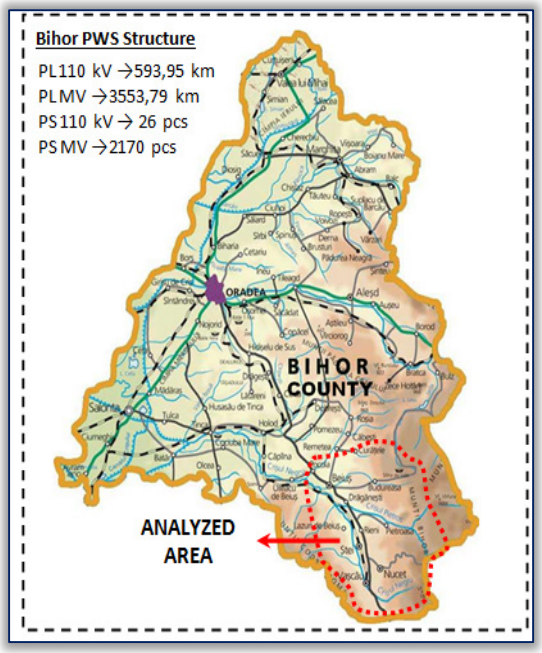


Figure 9. Map of local RES Power Plants

The existing energy capacities at the level of the analysed area are as follows: on the low power hydraulic side, two MHP on river Crişul Pietros, in the upper part of it, a MHP on Budureasa Valley and a MHP on Nimăeşti Valley, in the vicinity of localities with the same name; two power plants based on geothermal energy, with heat exchangers and hot water distribution points located in city of Beius; a wind farm located on the peak Curcubăta Mare(or Bihorul Peak), at 1849 m altitude, in Apuseni Mountains, on the territory of Avram Iancu commune in Alba County, but with power discarge in PS Băiţa what belong to PWS Bihor.

In addition, they have building permits two MHP located in the upper part of the Crişul Negru River near Poiana and Carpinet settlements and a photovoltaic solar power plant located in the vicinity of Lunca. Figure 10 shows an image of the wind turbines on the Bihorul Peak and in figure 11 the external image of the MHP Nimăeşti building is presented.

Figure 10. Wind farm Bihorul

Figure 11. Micro –hydro Plant Nimăeşti

In the perimeter under consideration there are also five power substations by 110 / MV located in the localities of Vaşcău, Nucet, Băiţa, Sudrigiu and Beiuş. Four of these are state-owned, managed by company Electrica SA, and one of this is private property owned by company Transilvania General Impex and located on the Scandic Distillieries industrial platform in Sudrigiu. These stations are interconnected through the OPL on 110 kV voltage level as shown in Figure 12 by the proposed regional PWS extension scheme proposed by the authors. The micro-hydropower plants (MHP) built on Crişul Pietros operate in cascade and have the powers installed as follows: Boga 2 x 630 kW and Piatra Bulz, 2 x 1200 kW, in asynchronous generators. MHP Nimăeşti has an installed

capacity of 1.17 MW in two generators by 0,585 MW each. MHP Budureasa has a total installed power of 0,731MW (0,3 + 0,431 MW). The installed capacity of the WF Bihorul is 11,5 MW in five wind turbines manufactured by Vestas Denmark with unit power of 2,3 MW operating at a voltage of 0.69 kV. Electricity evacuation is done by underground cable at the medium voltage level. The MHC Poiana 1 capacity is 0,53 MW and the capacity of MHP Poiana 2 is 0,237 MW. The approved capacity from Lunca photovoltaic plant is 4.1 MW [11]. On the basis of the analysed criteria, the energetic capacities proposed by the authors for the extension of the regional energy system with the related justifications which, in some cases of necessity, will be realized as follows: doubling the interconnection line between Băiţa and PS Vascău or creating a new double circuit line between PS Băiţa and PS Ştei, to ensure the reservation and elasticity of the evacuation scheme for manoeuvres; solar power plants(SPP) at Bunteşti, Pocola and Criştior; a biomass cogeneration plant (BCP) at Ştei or Nucet; micro-hydropower plants at Seghişte, Finiş and Şuştiu; wind farms (WF) at Padiş, Stâna de Vale and Izbuc; a geothermal plant (GP) at Beiuş. The loads assigned to each power station are shown as such in Figure 12 in blue colour.

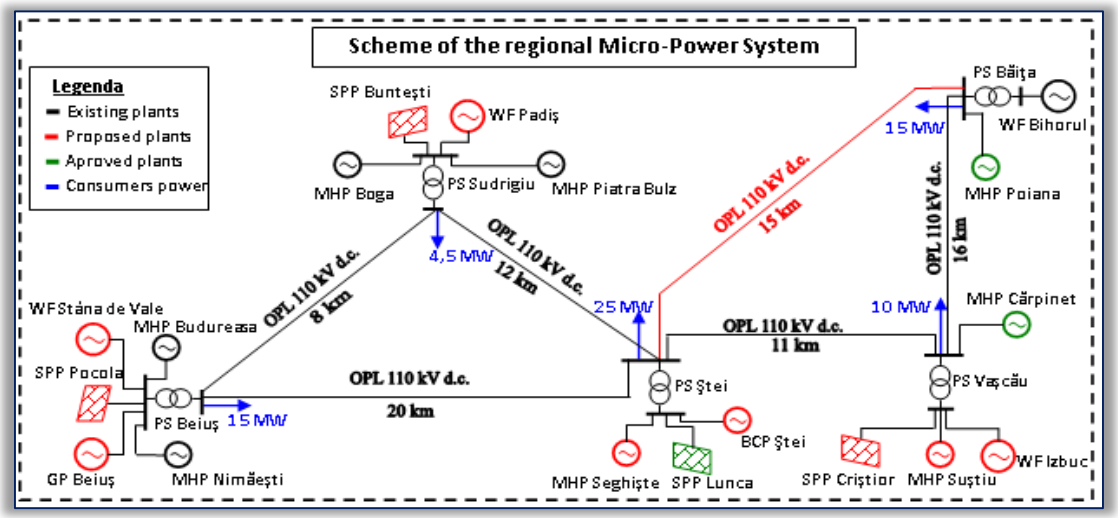


Figure 12. Regional PWS scheme

Cogeneration Power Plant (both thermal and electric energy), as is the case with the one proposed for the city of Ştei, operating on biomass, is primarily necessary to produce heat and hot water from a centralized system. The city is a centre of a wood – producing area that supplies waste and especially firewood for private homes. If the inhabitants were to abandon individual low-power plants, they could benefit by a centralized heating system, that is more refined and efficient, which and which would thus provide for increased biomass resources. Another biomass plant for centrally heated buildings could, due to conditions, be built in the vicinity of Nucet City, where there is currently no functional or efficient district heating system.

5. DISSCUSSION

The major difference between RES and classical power plants is given by the impact on the environment. Another difference is the price of the energy produced, plus the green certificates received for the energy obtained from the RES called "Green Energy" and the carbon emission certificates for the fossil fuel power plants. The second applies to the principle that the polluter pays.

The green certificate is a document that is given for a certain amount of electricity in MW obtained on the basis of RES and which is sold on a separate market from the electricity market. It is possible to analyse the increase in the price of electricity produced on the basis of RES through the contribution of the price obtained on green certificates. For producers this thing leads to additional profit. Following the market for green certificates on the web platform presented in [13], we can see the following: for a transaction day (15.02.2018) a green certificate was valued at 134,3021 RON; on the inside daily market, the electricity obtained from the RES is traded on the same day from Romanian Day-Ahead Market platform [13], for example with a maximum of 222,38 RON / MWh; this means a price increase of 60,39% resulting value of 356,3641 RON/ MWh, which is a very beneficial thing for the RES electricity producer.

6. CONCLUSIONS

At the level of Bihor County there is a wide variety of renewable energy sources that can be utilized and integrated through power and thermal power plants in the regional energy system. The sources of funding for energy infrastructure and energy efficiency are opportunities that recommend the implementation of RES-based energy objectives. The administrative structures of the state have not yet elaborated an energy strategy

for the development of the Bihor County's regional energy system, including the renewable energy resources. This thing is imperative and must be done with the co-operation of specialists with recognized results in the field of RES utilization. Correlations must also be made between a future energy strategy at the county level with the city's energy strategies and the division of the county into interconnected subsystems through electric and thermal grids, leading to the continuous supply of energy to consumers, limiting the damage and optimal resource management. The electric stations in or near the cities can take over and distribute, due to the installed transformation capacity, the quantity of electricity produced by the RES-based power plants in Bihor County. Thermal or cogeneration power plants based on RES can be major district heating providers for city buildings that concentrate large populations or big industrial enterprises.

It is possible to establish similarly the case presented in the paper, by analyzing the distribution and the potential of RES other areas in Bihor County for which there are opportunities for realization of energy projects and what type of projects by primary resource categories can be implemented.

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