Renewable Energy Sources
for Safe Future
2021-1-SK01-KA220-ADU-000026274

Renewable Energy Toolkit

The project has been funded with the support from the European Commission.
This publication reflects only the views of the authors and the Commission cannot be held responsible for any use of the information contained therein.

This book contains five chapters: the first four focusing on the renewable energy policies in the countries of the project partners and the last one presents the source code for the Lego application.

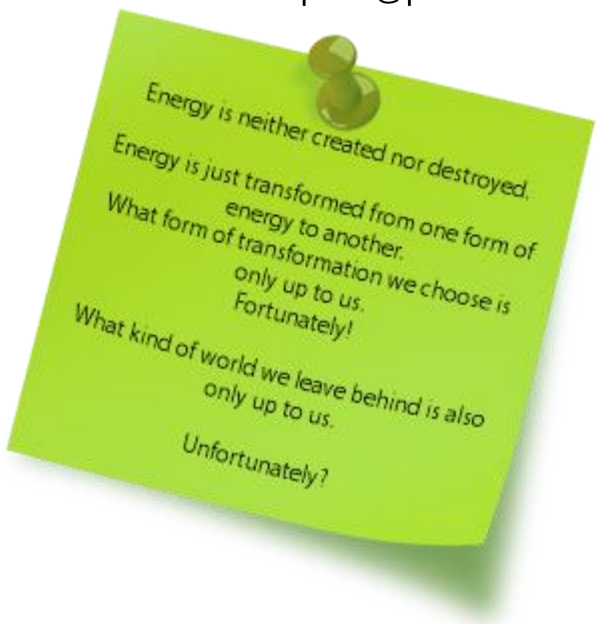
Chapter 1

Renewable Energy Sources in Slovakia

Potential, use, policies

Use of renewable energy sources in Slovakia
STEFANI n.o., SLOVAKIA
https://www.youtube.com/watch?v=Kfmh_H3gnYw

Under the professional supervision of:
Prof. Ing. Peter Tauš, PhD.
e-mail: peter@petertaus.com



The Abstract
The current situation in Europe and in the world underscores the need to maximize the use of local renewable and alternative energy sources. This will ensure increased diversification of energy sources and increase the energy security of the state and its citizens. The State and the responsible institutions must be supporters of the development of the use of these resources, if not economic instruments, by simplifying the legislative procedures for their implementation. In this paper we highlight the possibilities of increasing the use of RES in the area of heating and cooling of buildings.

Content

1. Introduction

Renewable and alternative energy sources (RES and AES) are no longer an optional alternative to traditional energy sources, but they are becoming a necessity for each country's energy mix. However, necessity does not always mean open access and support to the state in the implementation of RES technologies in various sectors of industry, the municipal sphere, services, administration, etc. Thus, the share of RES in the country's overall energy mix mainly reflects the commitment of policymakers and policies in this area, especially if there is an enormous interest from consumers in the use of RES. The efforts and interest of politicians in developing renewable and alternative energy sources in the country can also be deduced from state-present studies and analyses aimed at predicting the share of RES in the country's energy mix. The paper focuses on comparing the estimated potential of RES in Slovakia defined by the state and international expert organizations, including the design of technological possibilities for its use.

2. Policies, concepts and action plans of the Slovak Republic in the field of RES

The most important act concerning renewable energy sources in Slovakia is Act No. 309/2009 Coll. on the Promotion of Renewable Energy Sources and High Efficiency Cogeneration. [1]

2.1. Potential of RES in Slovakia

If you are interested in information on the use of RES in a given country, it is natural to look for this in the office under which energy belongs. In Slovakia, it is the Ministry of Economic (MESR). The following documents relating to RES can be found on the official website under the box "Concepts and Action Plans" (situation as at 14.9.2022, [7]):

- The concept of the use of RES (2003); [2]
- A strategy for increased use of RES (2007); [3]
- Forecast for the 2020 target (2009); [4]
- The National Energy Action Plan of RES (2010); [5]
- Analysis of the RES support system and proposal for its review (2011); [6]

It is clear from the above that the responsible authority did not publish under the RES agenda an update of existing documents or a new document on the potential and possibilities of increasing the use of RES for almost 11 years. However, it should be noted that renewable energy sources are addressed in the document *"Integrated National Energy and Climate Plan 2021-2030"* published in 2019 under Energy field. [8]
According to the above documents, analyses of available RES potential in Slovakia show significant disproportions in terms of overall potential, as shown in Figure 1. The picture also includes an estimate of the use of RES in the Slovak Republic in 2030, as set out in the Integrated National Energy and Climate Plan.

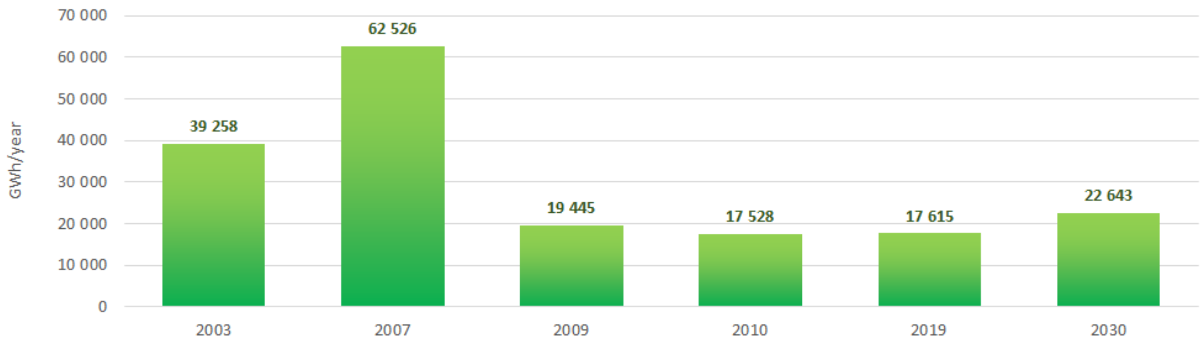


Figure 1 Evolution of estimating the potential of RES according to the MES (Source: own processing)

As can be seen from the graph, Slovakia had the most optimistic estimate of the use of RES in 2007, since 2009 the estimates have been more or less balanced. This may be due to considering the implementation of RES research and development results and increasing the expertise of experts in the field. This would be the case in the case of developments since 2009, and we also consider this estimate to be significantly undersized in relation to the possibilities of the Slovak Republic.

However, if we take a closer look at these estimates, it is clear that other factors, such as considering available and expected technologies, had to enter into the analyses and predictions. The detailed distribution of estimates of potentials of different types of RES and AES is shown in Figure 2.

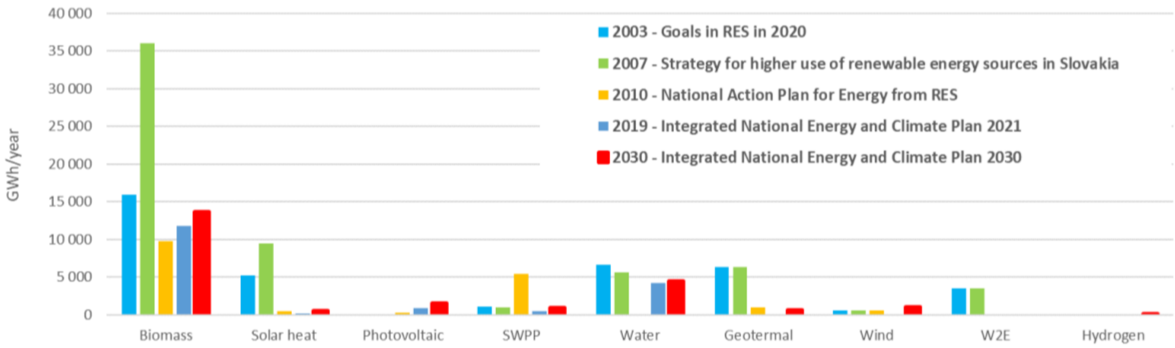


Figure 2 Evolution of estimating the potential of each RES species according to the MES (Source: own processing)

Based on a detailed comparison, it is clear that in 2007 Slovakia preferred mainly biomass, solar collectors, geothermal and hydropower, as well as energy recovery of waste. On the contrary, it was not considered at all with photovoltaics (FV), wind energy and hydrogen.

In 2010, in addition to biomass, energy from small hydroelectric power plants is already at the forefront, other types of RES are considered as from obligation, energy from waste and hydrogen is not considered at all.

The year 2019 also brought about the Integrated National Energy and Climate Plan 2021-2030, which more — less notes the current state of use of RES and despite the experience of the world and the surrounding states, practically does not count on the potential of RES, except for biomass and hydropower. It is striking that Slovakia still weighs or hinders (based on data from available documents) the development of photovoltaics, wind turbines, the use of energy from waste, as well as the use of hydrogen.

Why this is the case, it is only possible to argue. Whether on the basis of the ratio of current demand for RES in Slovakia and the actual development of installations, or on the basis of expert discussions in the relevant fora. The fact that the real potential of using RES in Slovakia may be and is higher is evidenced, among other things, by the analysis of the International Agency for RES (IRENA) entitled "Prospects of RES for the Energy Interconnection of Central and South-Eastern Europe". [12]The positive result of the study is that RES could cost-effectively cover more than one third of the energy demand in the region under consideration by 2030. The analysis was carried out in two scenarios:

- **Reference Case —** continuation of current trends and implementation of planned policies
- **ReMaP** — accelerated RES use scenario, additional realistic potential of renewable energy sources by sector, technology and resource.

Interestingly, the more pessimistic Reference Case scenario assumes "only" implementation of existing and thus valid policies and trends, which in the prediction means for Slovakia an estimate of a lower potential of about 1 000 GWh per year compared to the plans of the MHSR. It follows from the above that both institutions seem to have different sources of data, which is another problem in Slovakia not only in the field of energy. Free data on energy consumption is virtually non-existent.

On the other hand, taking into account the country's expertly estimated real potential, we could use renewable and alternative energy sources by up to 5,000 GWh more than the estimates of the MESR! As shown Figure 3, is the amount of energy corresponding to the heat consumption of all households in Slovakia!

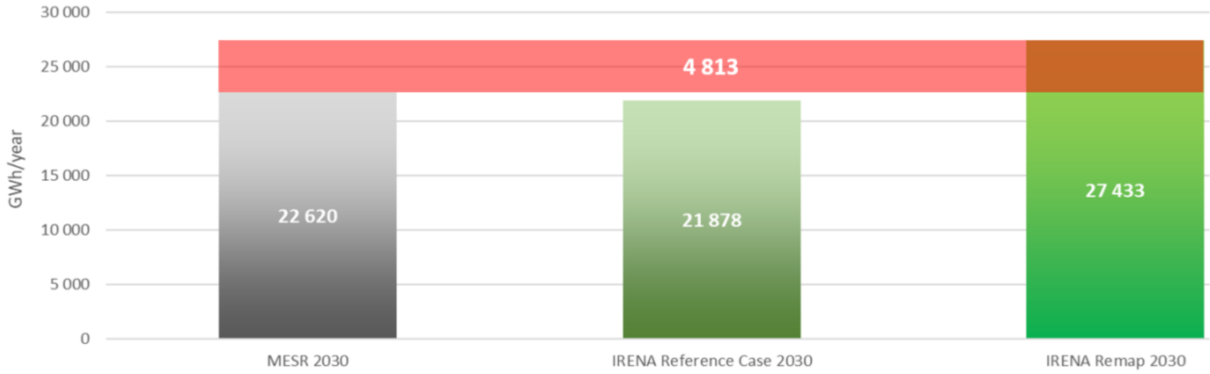


Figure 3 Comparison of usable RES potential estimates for Slovakia (source: own processing)

Renewable and alternative energy sources can in principle be used for direct production of heat or electricity. From the point of view of heating, the optimal solution is technology directly converting a renewable source to heat. However, despite the inconvenience of many experts and laypersons, technologies converting RES into electricity are also justified in heating systems, which is subsequently a source of heat production. In the following we will approximate the potential of individual types of RES in Slovakia, compare the estimation of Slovak experts with foreigners and we will try to indicate the possibilities of using these resources with an accent on heating systems. When comparing the potential, we rely on estimates of the usability of individual RES sources in 2030 as shown in the Figure 4.

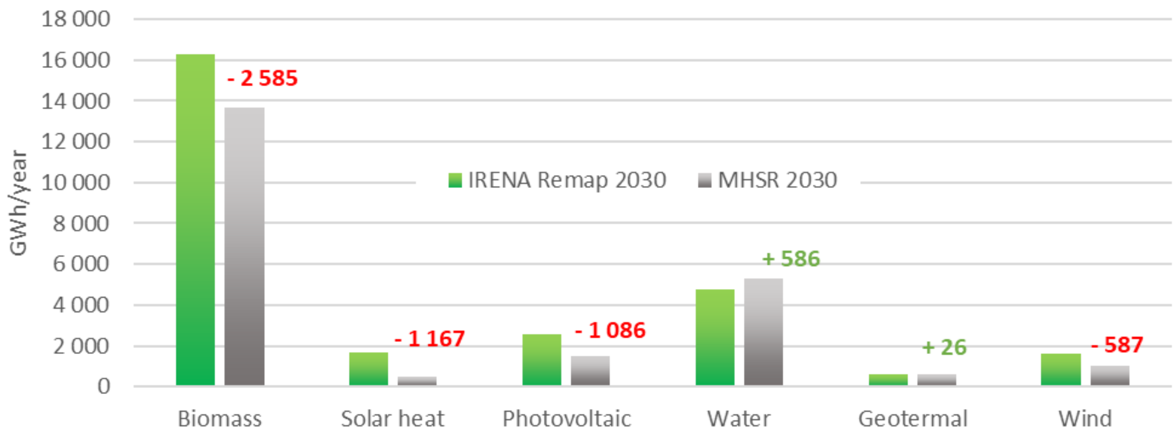


Figure 4 Prediction of the usable potential of RES by MESR and IRENA

It follows from the above that the responsible authorities of the Slovak Republic foresee lower RES energy production in almost all types of sources except hydropower and, to a minimum, geothermal. For hydropower plants, the MHSR estimates that production will be increased not only from small hydropower plants, but also from large hydropower plants (approximately 400 GWh per year), which is debatable in the current situation.

However, Slovenian legislation has one priority. It was the first EU country to implement into Slovak legislation the following concepts within the framework of Act No. 309/2009:

- the prosumer
- a small source
- local source
- production exclusively for own consumption

Prosumer is an English new word that was created from the words **Pro**ducer and Con**sumer**. It is therefore an entity that produces and consumes electricity at the same time. It should be one of the guiding principles of the future European energy industry - to produce electricity closest to its consumption.

Small source - is any production of electricity from RES up to 10 kW.

Local source – is a device that is used to produce electricity from renewable energy sources, primarily to cover own consumption at the point of consumption.

Production exclusively for own consumption - it is a state of "non-business" in the energy industry, which (with few exceptions) is not covered by the energy law.

3. Use of RES in Slovakia

Data on the real use of RES in Slovakia can be drawn from the following sources:

- the documents referred to in section 2.1, and only the document *"Integrated National Energy and Climate Plan 2021-2030" can be*considered for topicality.
- Statistical Office of the Slovak Republic
- Data from outputs of different national and questionnaire surveys projects on the use of RES
- energy and RES websites and portals

However, neither of those sources is sufficiently precise to explicitly determine the level of use of a specific renewable resource in the area concerned. In Slovakia, we can talk about practically two areas — heat production and electricity production. The production and distribution of cold in Slovakia is mainly carried out by refrigeration plants for electricity, not by direct production of cold from renewable sources.

Government data, namely the Integrated National Energy and Climate Plan, show that the share of RES in gross final consumption of energy in recent years is as follows:

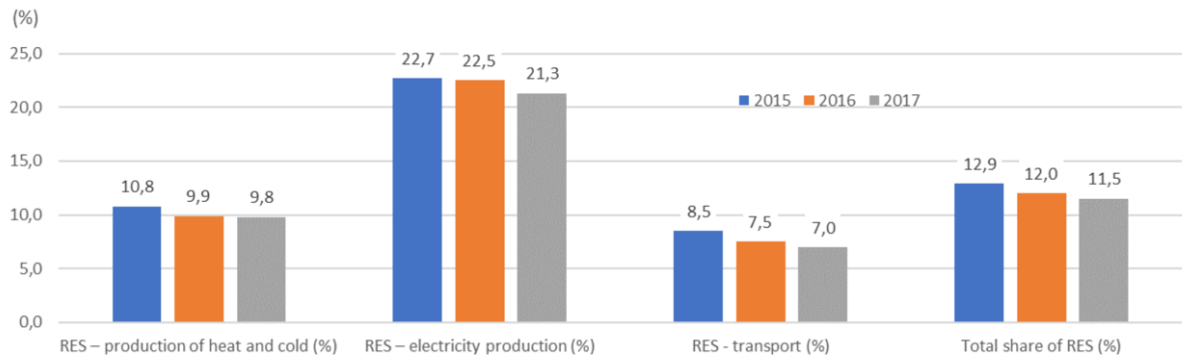


Figure 5 Development of the use of RES in Slovakia in individual areas [8]

The apparent decrease in the share of RES in Slovakia's total energy consumption is due to an increase in energy consumption. This is contrary to the plans of the Slovak Republic and the EU, but this fact is indisputable. This is why the implementation of RES in all areas needs to be stepped up so that the development of RES achieves a higher year-on-year increase than the increase in energy consumption. Of course, the ideal scenario is to reduce overall energy consumption year-on-year.

The current energy mix of Slovakia is shown in the following picture. RES covered almost 13.5 % of the total energy demand in 2021. [9]

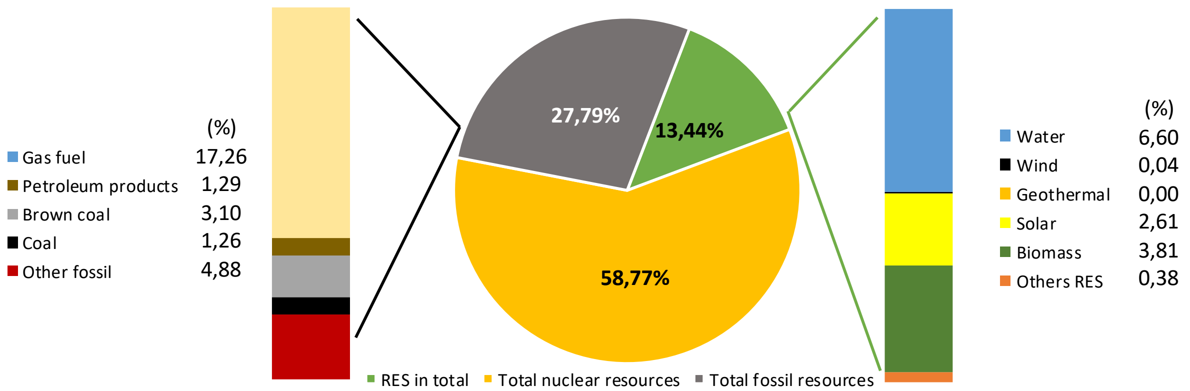


Figure 6 Energy mix in Slovakia in 2021 (own processing by [9])

Based on data from the Statistical Office of the Slovak Republic, it is possible to indicate RES shares in individual sectors. In the analysis, the so-called gross inland energy consumption is considered. The figure below shows the share of RES in heat production in Slovakia.

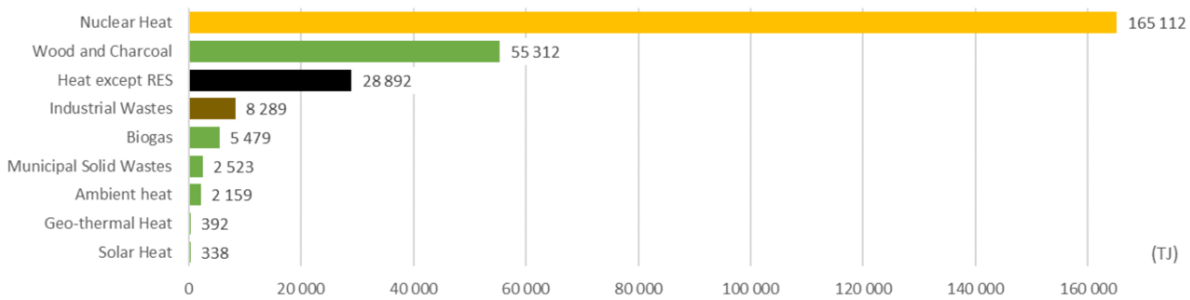


Figure 7 Share of individual energy sources in heat production in the Slovak Republic [10]

It follows from the above that the share of RES (including heat produced from municipal solid Waste and Industrial Wastes) in total heat production is approximately 28 %. Data on the share of RES in electricity production in the Slovak Republic are processed from the same source.

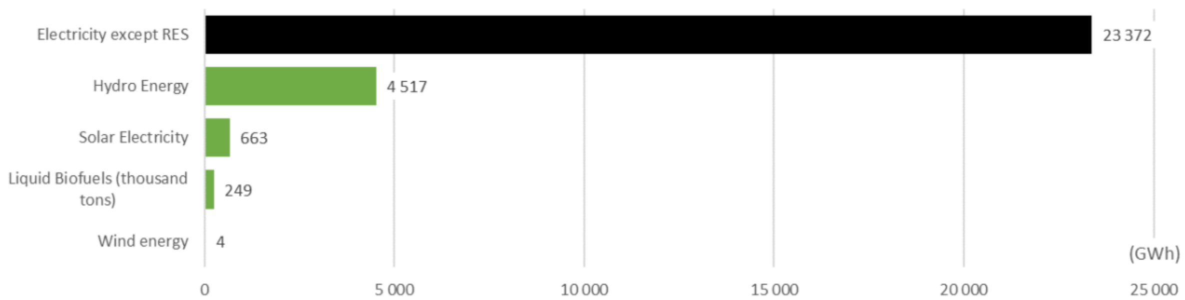


Figure 8 Share of individual energy sources in electricity production in the Slovak Republic [10]

In the area of electricity generation, the share of RES is therefore ca. 19 %.

A sub-indicator of the use of RES in Slovakia may be the interest of the population. A project called "Green Households" has been ongoing in Slovakia since 2015, which allows owners of single-family houses to receive a subsidy for technology using RES. In the last two years it is also possible to receive a subsidy for apartment buildings. Unfortunately, technology statistics that have been installed from users' own sources are not available in Slovakia. However, it can be considered to follow the trend of installations supported by the program Green Households.

3.1. Biomass

Biomass is mainly used for heat production in most EU countries, as shown in Figure 9. Of this, the largest share is the heating of residential and family houses.

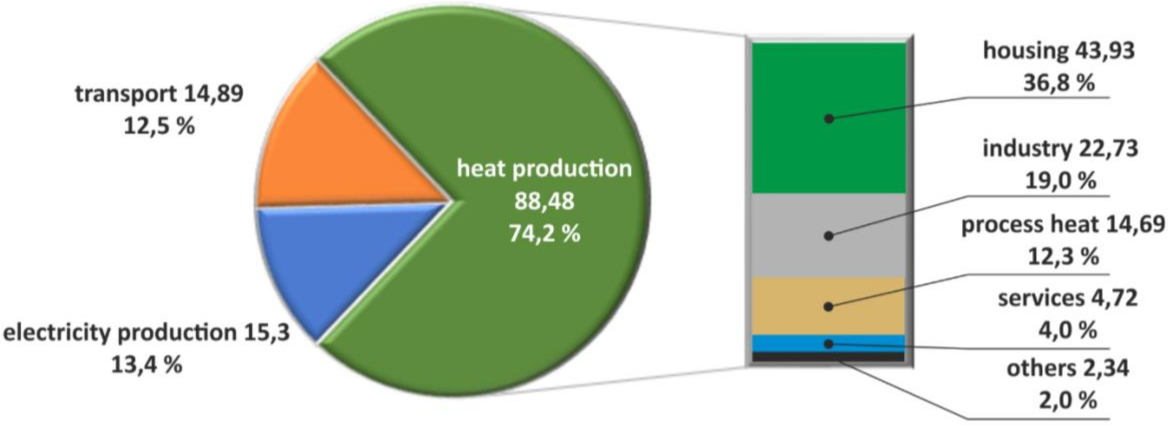


Figure 9 Use of biomass for heat production in the EU (kt_{oe}) [11]

Slovakia is a balanced partner to other countries in this regard, thanks to the sufficient renewable potential of wood biomass. According to Figure 4, the potential for energy use of biomass is more than 16 TWh per year, compared to the estimates of the MHSR, which expect to produce energy from biomass by more than 2.5 TWh. [12]

Apart from the difference in prediction, the use of biomass must follow the sustainability rule, which means that all sectors of the economy that use renewable biological resources from land and sea as well as bio-waste for the production of food, feed, biomaterials and energy must be involved in the energy use process. The current product-specific use of biomass needs to be transformed into a shared way that eliminates the energy and material losses of the entire process of using biomass in the circular economy.

It is equally important that biomass is used primarily locally, minimising distribution flows, which, on the contrary, maximises the efficiency of its use, including the use of local human resources, local sources of other renewable energy, etc. *A Strategy for a Sustainable Bioeconomy* has been adopted within the EU since 2012, which defines three basic pillars for building this relatively new field [13]:

- Development of new technologies and processes in the field of bioeconomy.
- Strengthening markets and competitiveness in the bioeconomy sectors.
- Promoting closer cooperation between policy makers and stakeholders.

At the same time, five objectives of the strategy are defined:

- ensure food and nutrition security;

- sustainable management of natural resources;
- reduce dependency on non-renewable, unsustainable resources;
- reduce and adapt to climate change;
- strengthen European competitiveness and create jobs;

Slovakia published the Scenarios for a Sustainable Bioeconomy in 2015 and in the same year was established an association of legal entities called Bioeconomy Cluster BEC, which aims, among other things, to cooperate with practice while linking practice with science and research. [14] However, the promotion and popularization of the cluster in the field of energy does not seem to be sufficient, since even today many biomass energy processes are oriented towards the production of only one commodity, mostly electricity, while the simultaneous product of heat is frustrated or discharged into the air without benefit. Heat makes up at least 50 % of the energy generated in all thermal power plants. It is essential to ensure that the maximum energy potential, including heat, is exploited from biomass. Where this is not technically possible, it is preferable to focus on biofuel production and distribute it to the point of consumption with maximum efficiency. It is also necessary to ensure that second and third generation biofuels and waste biomass are used for energy production.
In a situation where the whole of Europe is facing a shortage of natural gas, it is appropriate to consider replacing it with biogas in industrial plants that technologically allow it to do so directly (heating, cement, metallurgical processes, magnesia, etc.) or after treatment of biogas and technologies as an enabling fuel.
Solid biomass has huge potential for heating single-family houses, but again under sustainability conditions, i.e. using only waste or firewood to the extent that the site can absorb. The use of dendromass for heat production is concentrated in the following sectors:

- heat production for the residential-municipal sector,
- production of heat from dendromass in the wood processing industries;
- production of heat from dendromass in energy and other industries.

Wood fuel was the biggest competitor to natural gas even in times before the extreme increase in electricity and natural gas prices started. In 2015, fuel wood consumption in Slovakia was 2.5 million tonnes per year. [17]

Tab. 1 Fuel wood consumption in Slovakia in 2018

Region	**Annual consumption of fuel dendromass (thousand t)**			
	Individual heating	**Central Heat Supply**	**Energy and other industry**	**Sum**
BA	20	35	0	55
TT	43	11	0	54
TN	123	144	0	267
NI	56	136	55	247
ZA	181	224	25	431
BB	231	301	167	699
PO	197	169	47	413
KE	126	111	58	295
Sum	**977**	**1 131**	**352**	**2 460**

The graphic shows that the highest consumption of firewood is in the regions with the largest area of afforestation. These are the counties of Banská Bystrica, Žilina and Prešov.

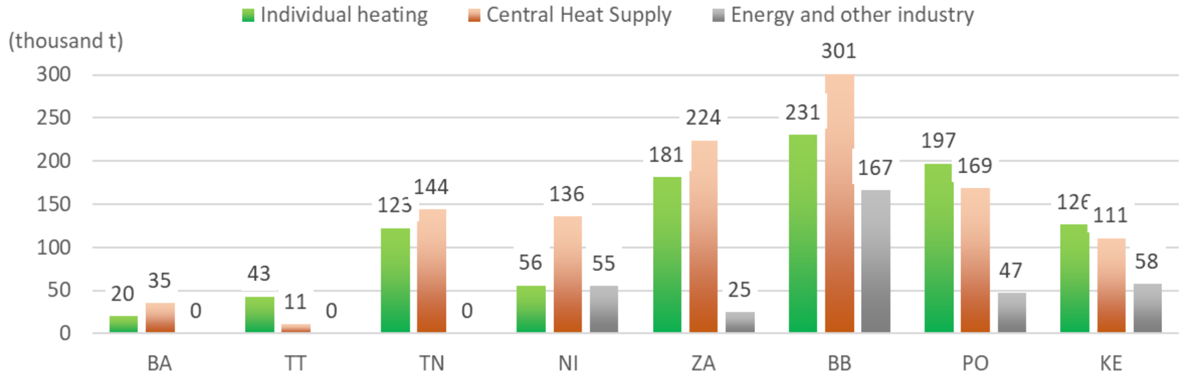


Figure 10 Fuel wood consumption in Slovakia in 2018

The current situation of the trend of using wood for heating is only accelerating. Fuel wood consumption reached almost 3 million tonnes per year in 2018. [16] Despite the sufficient potential of wood mass, it is also necessary to conserve this resource. Education of the population in the field of good heating practices and the use of the right technologies will also contribute to reducing the consumption of wood for heating houses. Using efficient gasification boiler technology, it is possible not only to reduce emissions of particulate matter into the surrounding area by almost 90 %, but above all to save up to 30 % of firewood.

Therefore, in the area of the use of biomass for heating, the most important activity for Slovakia to increase heating efficiency and reduce the consumption of wood fuel is education of the population, providing advice and subsidies for efficient technologies.

3.2. Solar collectors

From the point of view of the direct transformation of solar energy into heat, it is possible to consider, in particular, solar collectors of liquid and air. Air is mainly used in agriculture and industry in the world, in Slovakia almost at all. In our conditions, solar liquid collectors can be used primarily for hot water and low-temperature heating systems as well as to support heating in favourable weather conditions. For full-fledged heating it is possible to use these systems only with the support of seasonal heat accumulation, in which case it is more appropriate to consider large systems in industry or central heat supply.

In Slovakia, however, it can be stated that solar collectors are used for the preparation of hot water in single-family, multi-family and residential buildings and buildings providing accommodation and recreation services, they are increasingly beginning to appear in schools and administrative units. Interest in solar collectors in Slovakia increased sharply after the introduction of the Green Households project, as shown in the graph in Figure 11.

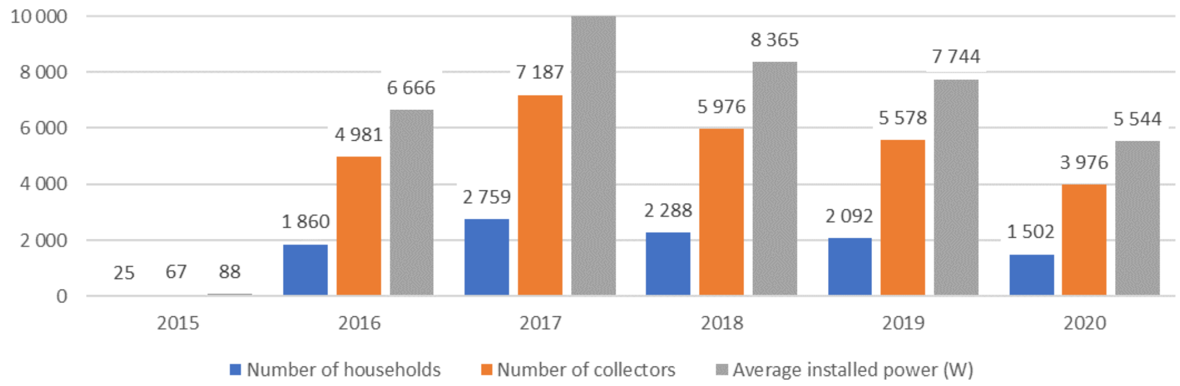


Figure 11 Evolution of the use of solar collectors supported by the program Green Households

The installed capacity of collectors installed within the project ranged for single-family houses from 1.09 to 10 kW, the average output was 3.6 kW. In multi-apartment buildings, systems with a power from 9 to 23 kW were installed. This also shows the use of solar collectors mainly for the preparation of hot water. In view of the potential of using solar collectors, it is possible to consider the share of solar energy for hot water production at a level from 60 to 100 %, in the case of their use and for the support of heating it is possible to reduce primary energy consumption by about 35 % in the conditions of the Slovak Republic and without additional use of excess heat, for example in the pool.

3.3. Geothermal energy

In the area of heating, Slovakia has huge potential in geothermal energy, which it uses to a reprehensibly negligible extent. The constant struggle of individual departments and ministries consisting of exaggerated nature conservation, excessive bureaucracy and inconsistent legislation concretizing the procedures and methods of the possible use of geotherm ranks Slovakia at the tail of countries using this huge potential of predictable and stable heat source. The potential of geothermal energy in Slovakia is sufficiently mapped and documented. For illustrative reasons, we present the temperature of the environment at a depth of 1 000 to 5 000 m according to the Atlas of Geothermal Energy, which was created and managed by the State Geological Institute of Dionýz Štúr.

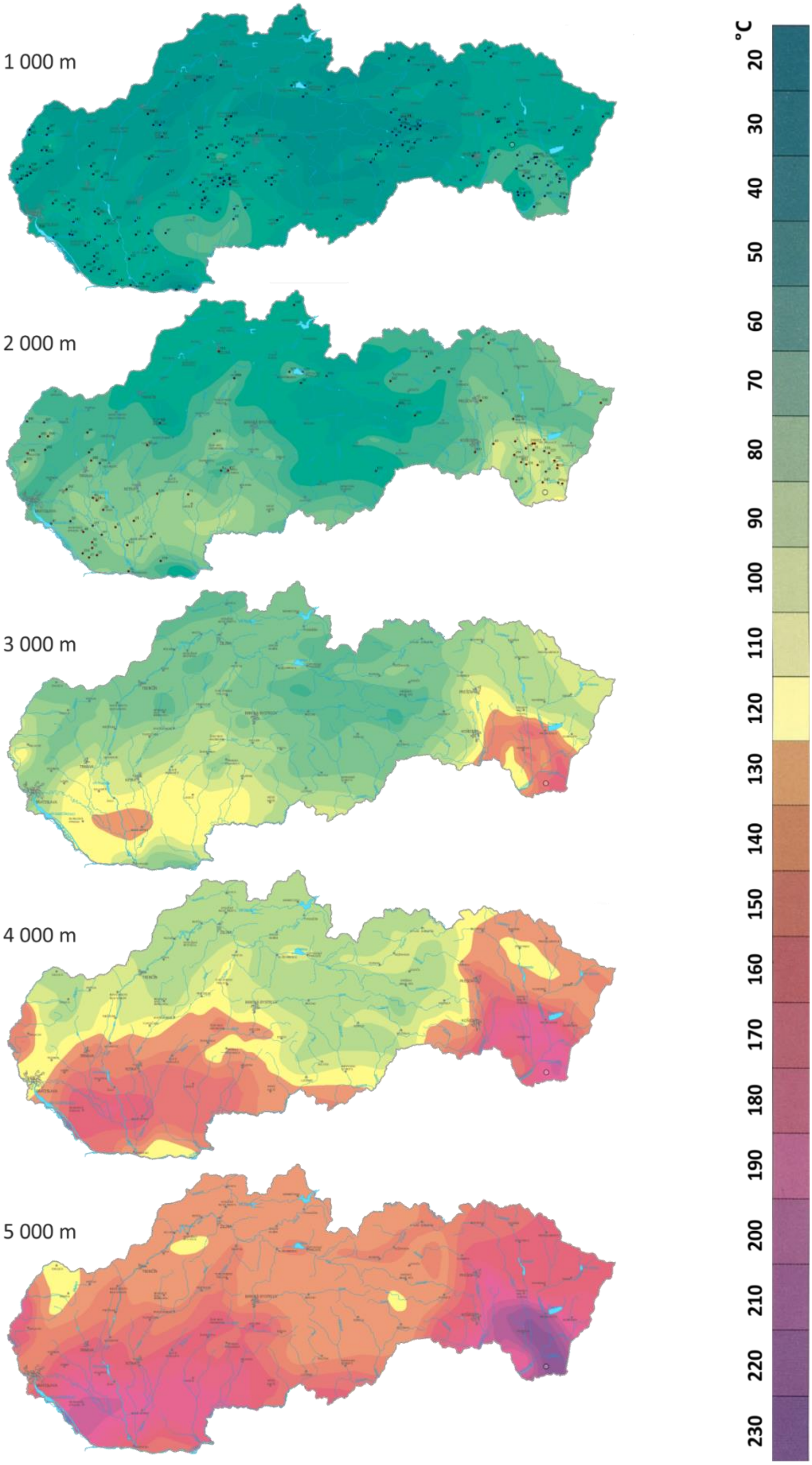


Figure 12 The temperature of the environment at a depth of 1 000 to 5 000 m in Slovakia [21]

3.4. Heat pumps

An increasingly desirable source of heat for heating and preparation of the TV becomes a heat pump. While in 2005 almost ½ million heat pumps were sold in Europe and 1.15 million were sold in Europe by the Federation of European Associations for Heating, Ventilation and Air Conditioning (REHVA), 1.62 million were already sold in 2020 and almost 15 million units were in storage. The most commonly installed type is the air-to-water heat pump. From a technological point of view, today's heat pumps can cover a wide range of temperatures. They can operate at outdoor temperature levels up to -25 °C and increasingly provide a temperature output above 65 °C in an efficient manner. This allows them to be deployed in a much larger range of buildings than 10 years ago. Hybrid systems and cascading connection allow the use of heat pumps not only in residential and office buildings, but also for heating and cooling of industrial buildings. Here even today it is no problem to see heat pumps with a total output of 50 MW or more with temperatures up to 200 °C. [26]
This is supported by data from the program Green Households, according to which in Slovakia the air-to-water heat pump is an absolutely dominant type and the number of installations supported by the program is at the level of 2 000 TČ per year.

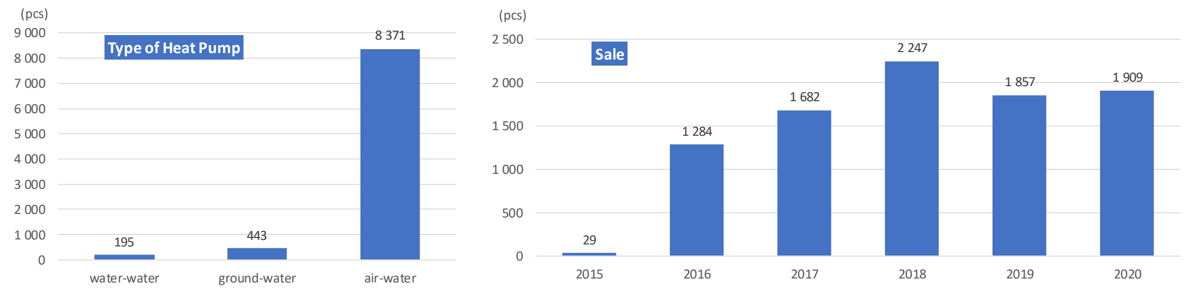


Figure 13 Evolution of the use of heat pumps supported by the Green Household Programme

A particularly promising area is heat pumps for multi-apartment buildings using sewage energy as a heat source, i.e. waste energy. In Figure 14 is possible to see the resulting electricity consumption to drive such a pump in a particular apartment building in Košice.

Figure 14 Evolution of purchased energy consumption for the preparation of TV in an apartment building

Currently, the disadvantage of heat pumps is uncertain and rising electricity price. However, the renewable energy sector offers an economically advantageous and technically accessible solution. Electricity from renewable sources can be obtained directly in three ways — photovoltaic systems, hydropower plants and wind turbines, and this ranking also represents the availability for those interested in their use.

3.5. Photovoltaics

According to data sources (Commercial Register on the Internet, Business Register of the Czech Republic, Register of Accounts, websites of individual companies), which are processed on www.energie-portal.sk, a total of 375 large photovoltaic ground power plants with a total installed capacity of 438 MWp were installed and operated in Slovakia in 2015. [22]
From the point of view of PV facilities installed on single-family houses and multi-apartment buildings, it is possible to use statistical data from the program Green Houses. According to the available data, the development of the use of PV equipment is as follows.

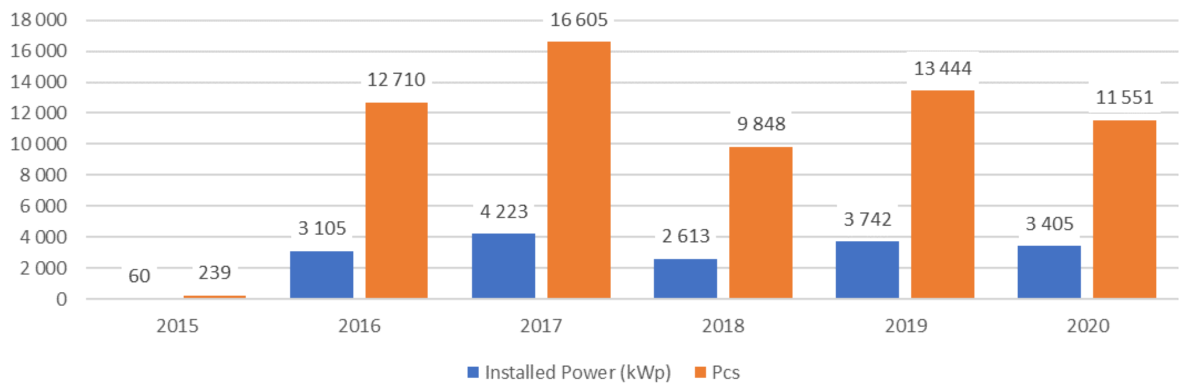


Figure 15 Installation of PV devices in households in Slovakia

PV systems seem to be the most appropriate solution in terms of technology and the available potential and interest of society. Their use is possible either with a battery of electricity or with a seasonal heat storage in conjunction with an electric boiler or heat pump. In both cases, however, there is a need for project training In order to maximise the coverage of the energy demand in winter and when using a sufficient storage facility, there is a problem with excess electricity generated in the summer months.

3.6. Wind energy

The use of wind generators is disadvantageous for small sources such as heat pumps in terms of prediction but also in terms of available potential. If we consider using wind turbines at a height of 50 m above the ground, the energy potential of most of the area is at the level of 20-200 W.m^{-2}, respectively wind speed reaches values up to 7 m.s^{-1}. Standard small wind turbines require a nominal speed of 11 m.s^{-1}.

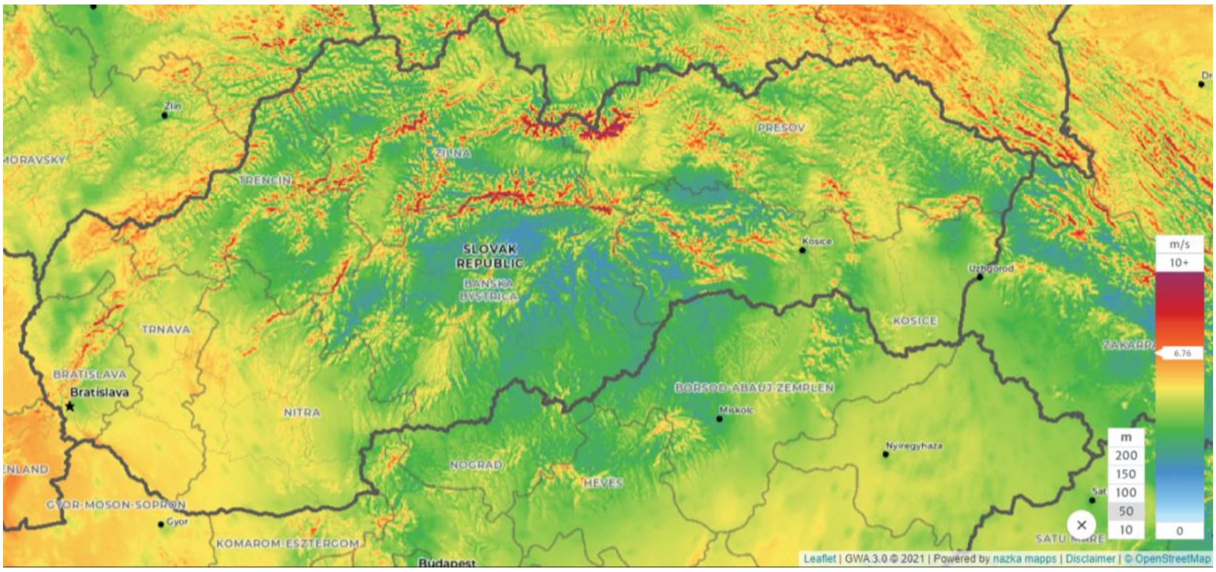


Figure 16 Wind speed in Slovakia at an altitude of 50 m above ground [24]

For classical wind power plants and wind farms I have sufficient potential in Slovakia, as shown in the figure below. Generators with installed power from 2 to 6 MW require a starting speed of 6 m.s^{-1}. This speed can be achieved in a large area of Slovakia.

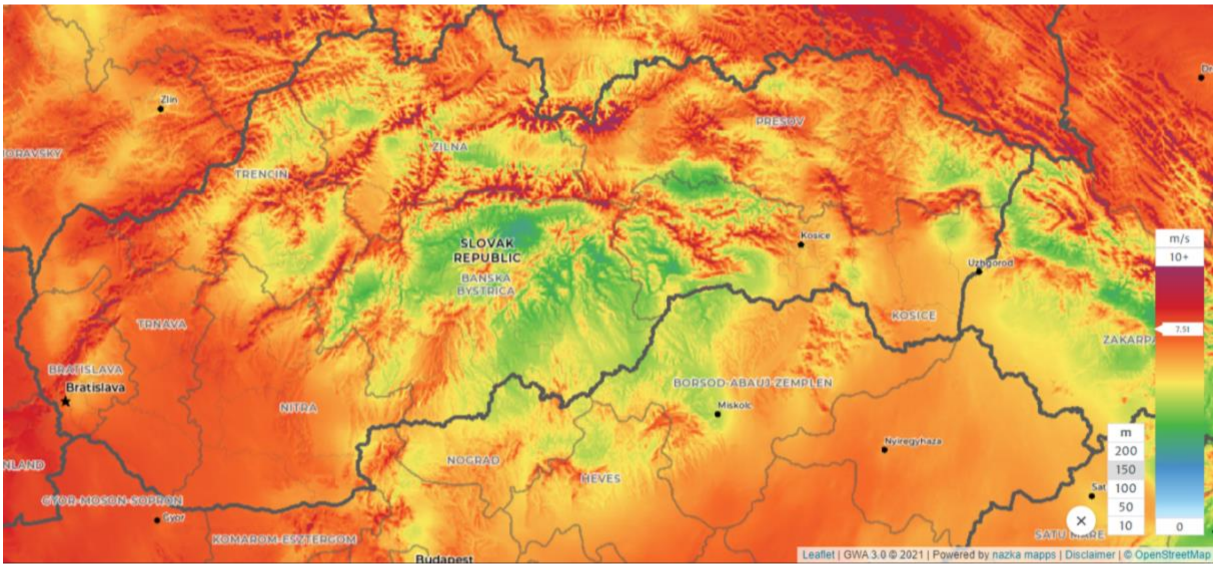


Figure 17 Wind speed in Slovakia at an altitude of 150 m above ground [24]

3.7. Hydropower

Hydroelectric power plants in Slovakia account for up to 40 % of the total installed capacity of power plants. The power of hydroelectric power plants is 1 653 MW. However, the share of hydropower in total electricity production is 11 %. The location of large hydropower plants in Slovakia is shown in the following picture. [18]
In terms of continued use of hydropower, it is necessary to focus on power plants without the need to build hate. Large and small hydropower plants cause changes in the water regime. This is the reason for stopping permitting the construction of new large and small hydropower plants in Slovakia. The total potential of hydropower in Slovakia is used at about 50 %.

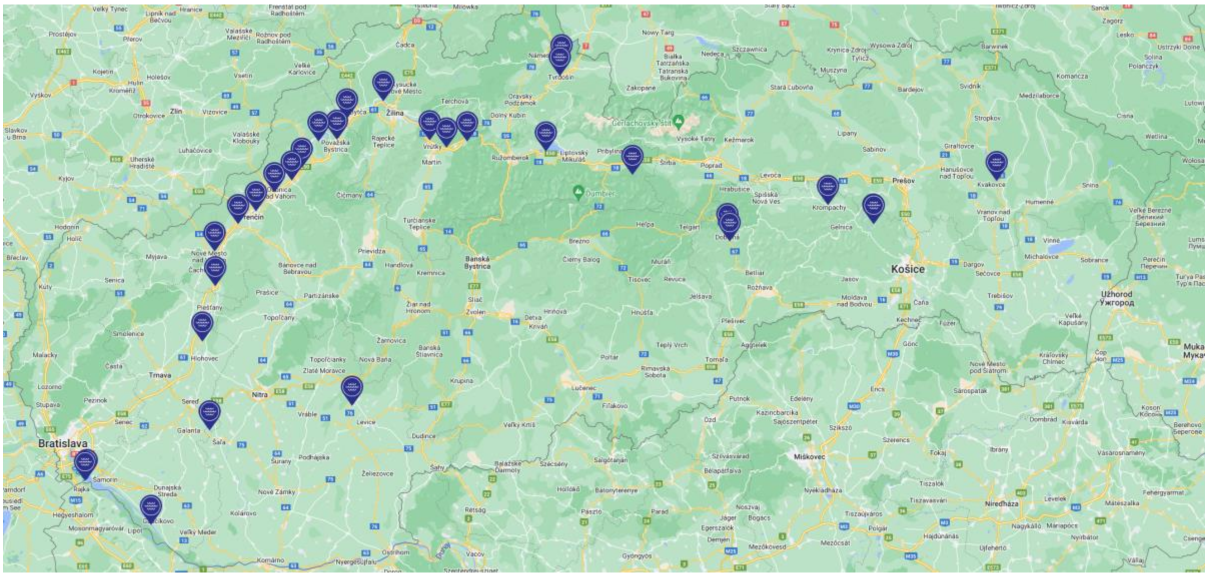


Figure 18 Large hydropower plants in Slovakia [18]

In 2015, according to data from the Regulatory Office for Network Industries in Slovakia, a total of 234 hydropower plants belonging to so-called regulated entities with a total installed capacity of almost 700 MW were in operation. Of which 21 large hydropower plants with a capacity of 630 MW, the rest are small hydropower plants. This number does not include the largest Gabčíkovo hydropower plants (720 MW), the Čierny Váh pumping plant (735 MW)(Liptovská Mara (198 MW), Mikšová (93.6 MW), Nosice (67.5 MW) and Ružín (60 MW). [19]
The production of electricity by water mini, micro and pico power plants is an interesting solution for the support of heat pumps as well as other electrical appliances. The reason is uniform production practically throughout the year 24 hours a day, which eliminates the need for electricity accumulation. Based on our research, for example, on the section 11-60 river km of the Slaná river is the energy potential of such installations at the level of 9 MW, technical 7.3 MW and currently economically usable at the level of about 4.8 MW. For illustrative purposes, we present a graph of the usability of specific types of water turbines on a given section of the river. [23]

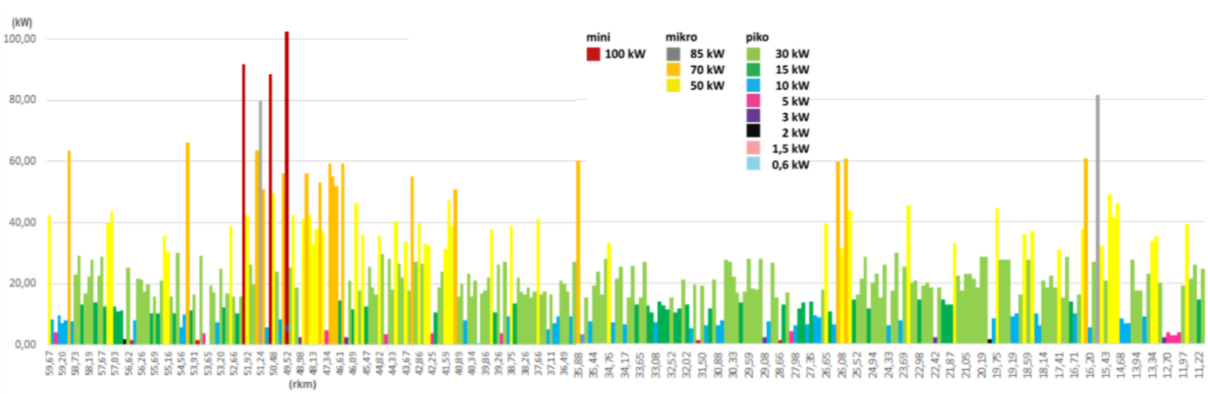


Figure 19 The usability of hydro mini, micro and pico power plants on the river Slaná [23]

The municipal authority’s electricity consumption in a medium-sized municipality with a population of 1 000 is at 16 MWh per year. On average, this means daily consumption, including public lighting, at a level of 44 kWh, so in order to ensure the supply of electricity in such a municipality, a water pico power plant with an installed capacity of 2 kW will suffice.

4. Policies vs reality of the use of RES in Slovakia

It is evident that the approach of the state and politicians to the issue of the necessity of intensifying the use of RES is irresponsible. This means that it is an irresponsible approach to citizens who are essentially the 'final beneficiaries' of the use of RES.

It is therefore necessary to immediately look for the causes of this unsatisfactory state, but especially the possibilities for its improvement. In our opinion, the following factors can be included among the causes of slow and frustrating developments in the use of RES in Slovakia:

- methodology for RES implementation procedures and rules;
- stability of legislation,
- common practices of competent authorities,
- **taking good practice from abroad,**
- targets for the share of RES in the energy mix;
- sustainability requirements,
- fees and bureaucracy,
- intelligent management of distribution systems, ...

The possibilities for improving the situation are identical to the causes, since by introducing clear and transparent rules, simplifying administrative procedures, cutting red tape and taking good practice from abroad, it is possible to reach the European level for the use of RES.

If a source mix of RES is created in the form of a stable source (water, biomass, geothermal energy, hydrogen) and a partially predictable source (PV and wind), diversification of energy sources with an emphasis on renewable energy sources can significantly boost the state's energy mix and reduce primary energy consumption.

5. Examples of the use of RES in Slovakia

Examples of the use of RES can be provided from available sources. In Slovakia, most operators of renewable energy sources from the business sector do not want to publish data on their technologies. Similarly, private owners, homeowners, apartments, etc. do not want to engage in surveys and publish their data.
Nevertheless, this negative phenomenon is beginning to gradually improve in Slovakia. This is evidenced by the following projects and technologies.

5.1. Solar energy

One of the first projects to use solar collectors for the preparation of hot water was an apartment building in Michalovce. [27] The solar system was installed in 2012. In total, it consists of 25 collectors and storage tanks with a total volume of 2 475 liters. The system can produce 35 % of the heat demand and the return was set at 11 years in that year. This means that currently hot water is produced at 35 % free.

Figure 20 Solar system on an apartment building in Michalovce [27]

A similar system was implemented in Detva on an apartment building. Residents decided to install a solar system without subsidies. [28]

Thermo|SOLAR Žiar [29] is a Slovak manufacturer of solar thermal collectors for more than 40 years. It was this company that designed and installed the entire solar system. In total, 35 collectors of the type TS500 are installed, which produce hot water for 48 apartments at the level of 50-60 %. In the summer months, residents are even completely independent of the heat supplier. The system's return with loan repayments is 10 years.

Figure 21 Solar system on an apartment building in Detva [29]

The inhabitants of the apartment building in Spišská Nová Ves had an interesting idea. In 2004, solar thermal collectors were installed to support the preparation of hot water.

In 2012, renewables added photovoltaic panels that supply electricity directly to the grid. The funds obtained are used to reduce the energy costs of a multi-apartment building. [30]

Figure 22 Solar and photovoltaic system on an apartment building in Spišská Nová Ves [30]

In general, it can be argued that photovoltaics is also the fastest growing sector in the field of RES.

One of the first industrial applications of the photovoltaic system with accumulation is located in the industrial area in Humenne. The textile plant of Muller Textiles Slovakia in Humenne is the first user of the new concept "Energy as a Service" in Slovakia. It is provided by one of the energy suppliers. The project was funded by the daughter of Slovenské elektrárne (SE), Slovenské elektrárne — Energy Services together with Fuergy partners and Viessmann, an international producer of heating, industrial and cooling systems. [31] The photovoltaic system has a power of 499 kWp and the energy that is not used directly at the plant is stored in a battery with a capacity of 432 kWh. The operating condition is that all electricity from the PV source is consumed directly at the plant.

Figure 23 Photovoltaic system as a local resource in an industrial enterprise in Humenne [31]

Almost 1 300 FV panels with a total output of almost 500 kWp are installed on the roof of the Aupark department store in Bratislava. This saves 250 tonnes of CO_2 emissions per year. [32]

Figure 24 Photovoltaic system as a local source on the roof of Aupark in Bratislava [32]

A similar installation can be seen on the roof of the Hornbach store in Nitra, where the FV power supply is also 500 kWp. [33]

Figure 25 Photovoltaic system as a local source on the roof of Hornbach in Nitra [33]

5.2. Wind energy

In Slovakia, the first and so far the only wind farm in the village of Cerová is currently in operation. The installed capacity of the power plant is 4 x 660 kW, electricity is produced by VESTAS turbines - V 47/660 with a mast height of 76 m and a propeller diameter of 47 meters. [34]

Figure 26 Wind farm Cerová [34]

Currently, more than 70 applications have been submitted for the construction of wind parks in the territory of Slovakia. We believe that the map of wind power generation will soon expand with many new installations.

5.3. Biomass

In Slovakia, biomass is used for energy purposes in large quantities. In addition to family and apartment buildings, municipal boilers and heating plants also use biomass. One of the first boiler houses for burning straw was the boiler house in the town of Turnňa nad Bodvou. The boiler house was put into operation in 2007 and supplies heat to an elementary school, about 300 apartments, commercial and other premises in the city administration. The fuel is wheat straw. The total heat output of the boiler room is 600 kW provided by the Verner Golem boiler. [35]

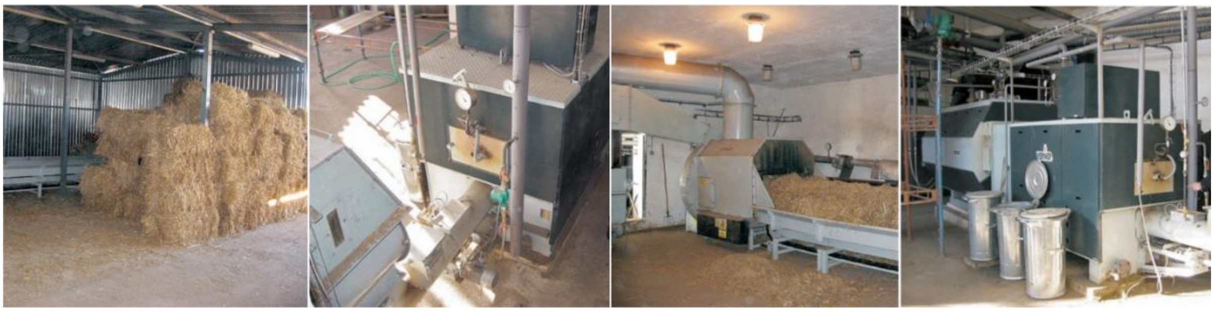


Figure 27 Boiler for straw Turnňa nad Bodvou [35]

In 2010, the biomass power plant in Bardejov was commissioned. To produce electricity and heat, it consumes 12-15 trucks of wood per day, i.e. 100 000 m^3 of wood chips. The electrical output is 8 MW and the thermal output is 25 MW. About 7 000 households are supplied with heat. [36]

Figure 28 Bardejov wood chip power plant [36]

5.4. Water energy

The largest hydroelectric power plant in terms of annual electricity production in Slovakia is Gabčíkovo with an installed capacity of 720 MW. It produces approximately 2 200 GWh of electricity annually.

Figure 29 Hydropower plant Gabčíkovo [37]

The largest pumping station in Slovakia is Čierny Váh. In terms of output, it is also the most powerful hydroelectric plant in Slovakia with an output of 734.4 MW. The upper reservoir, located at an altitude of 1 160 m, does not have its own tributary. Water is pumped into the reservoir directly from the river Váh. The power plant serves as a storage of peak electricity.

Figure 30 Čierny Váh pumping Hydropower plant [39]

5.5. Geothermal energy

Despite the huge potential, geothermal energy is only used to a minimal extent in Slovakia. The most common use is in the spa industry. Gradually, geothermal heat sources for cities are also starting to be built.

Geothermal water in Bešeňová has an interesting use. In addition to its medicinal use in the pools of the Thermalpark, the heat is used to heat administrative buildings, technical areas and even greenhouses where tomatoes and flowers are grown.

Figure 31 Thermal Park Bešeňová [40]

Galanta was one of the first towns in Slovakia to use geothermal energy. Two wells with a total output of 9.1 MW (1.8+4+2.3) are used for heating and hot water preparation.

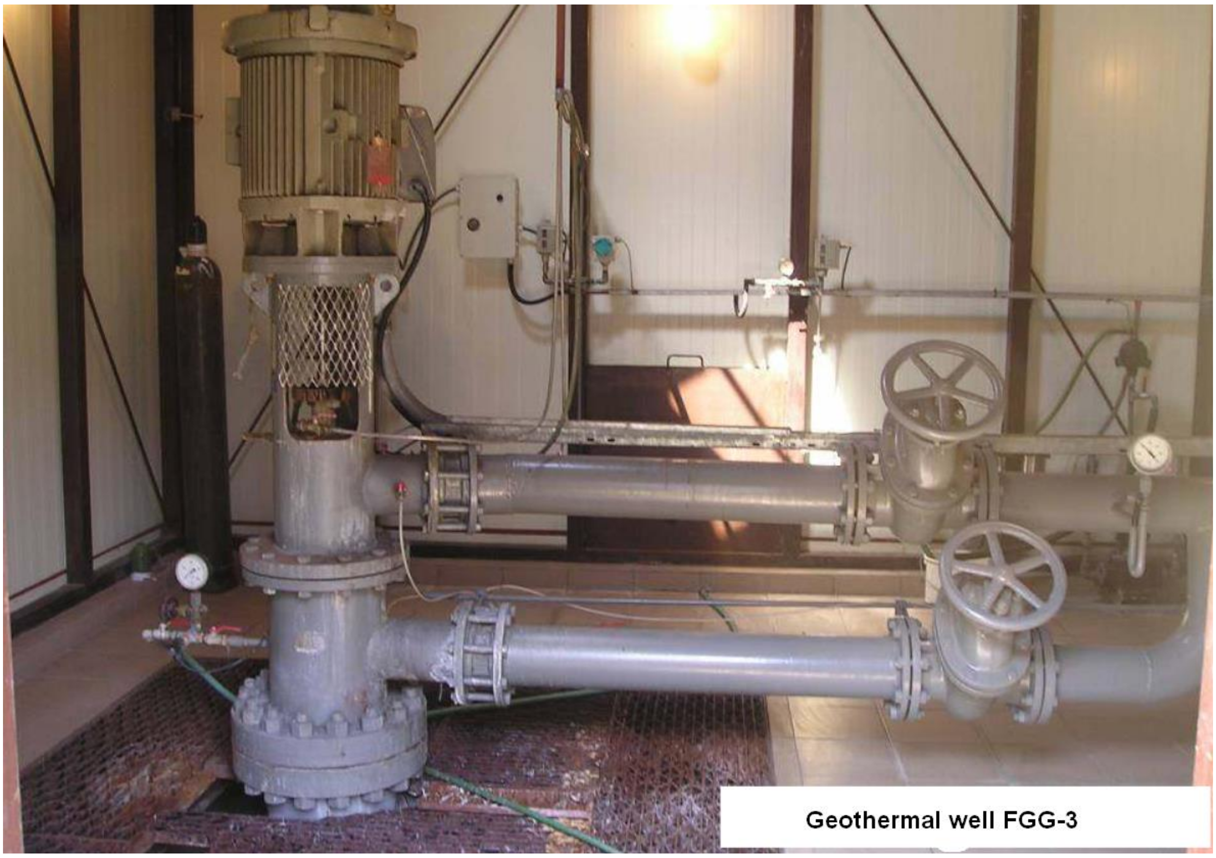


Figure 32 Geothermal well in Galanta [41]

6. Conclusion

Renewable energy sources are available in every country, not excluding Slovakia. The arguments advocating the lack of development of the use of RES do not stand either in the lay or in the professional community. This is evidenced by estimates of international experts exceeding those of the authorities responsible for implementing RES into the energy mix in Slovakia. Long-lasting excuses are alarming precisely in the current situation, which is a direct proof of the necessity of diversifying energy sources with an emphasis on the use of local renewable and alternative energy sources. In addition, if there are practical installations in the world proving the possibility of system solutions using the optimal combination of RES for heating, cooling and electricity supply to buildings, every day delays or hampering the development of RES is a threat to Slovakia and its inhabitants. In the paper we tried to highlight the possibilities offered by RES in the area of heating and cooling to buildings in Slovakia.

References

[1] https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2009/309/20220901

[2] https://www.economy.gov.sk/uploads/files/59a0GhtE.pdf

[3] https://www.economy.gov.sk/uploads/files/MuZlb3Ut.pdf

[4] https://www.economy.gov.sk/uploads/files/R6dmBHmE.pdf

[5] https://www.economy.gov.sk/uploads/files/krFyTZfZ.pdf

[6] https://www.economy.gov.sk/uploads/files/W58vMbYo.pdf

[7] https://www.economy.gov.sk/energetika/obnovitelne-zdroje-energie/koncepcie-a-akcne-plany

[8] https://www.economy.gov.sk/uploads/files/IjkPMQAc.pdf

[9] https://www.okte.sk/sk/zaruky-povodu/statistiky/narodny-energeticky-mix/

[10] Collective of the Department of Transversal Statistics of the Statistical Office of the Slovak Republic: Energy 2020, Statistical Office of the Slovak Republic, Information Service, ISBN 978-80-8121-834-7, available at https://slovak.statistics.sk

[11] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Feb/IRENA_REmap_EU_2018.pdf

[12] https://www.irena.org/publications/2020/Oct/Renewable-Energy-Prospects-for-Central-and-South-Eastern-Europe-Energy-Connectivity-CESEC

[13] European Commission, Directorate-General for Research and Innovation, A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment: updated bioeconomy strategy, Publications Office, 2018, https://data.europa.eu/doi/10.2777/792130

[14] https://bioeconomy.sk/o-nas/zakladne-informacie/

[15] Criteria for the sustainable use of biomass in the regions of Slovakia for the 2014-2020 Slovak programmes co-financed by ESIF — focusing on wood biomass, © 2017 KPMG Slovensko spol. s r.o., https://www.op-kzp.sk/wp-content/uploads/2017/06/Kriteria-udrzatelneho-vyuzivania-biomasy-v-SR-KPMG-06-20171.pdf

[16] https://www.energie-portal.sk/Dokument/spotreba-drevnej-biomasy-sa-presuva-od-energetiky-ku-drevospracujucemu-priemyslu-105404.aspx

[17] 2018 Forestry Report in the Slovak Republic, Ministry of Agriculture and Rural Development

[18] https://www.seas.sk/o-nas/nase-elektrarne/vodne-elektrarne/

[19] https://www.energie-portal.sk/Dokument/vodne-elektrarne-v-sr-100207.aspx

[20] https://www.urso.gov.sk/vyroba-elektriny-z-obnovitelnych-zdrojov-energie-2017-2022/

[21] http://apl.geology.sk/atlasge/

[22] https://www.energie-portal.sk/Dokument/vlastnici-fotovoltickych-elektrarni-v-sr-102346.aspx

[23] GAL, M.: Analysis of hydropotential of the Slaná river for hydroelectric power plant construction, Diploma thesis, FBERG TUKE, 2021

[24] https://globalwindatlas.info/

[25] IEA (2021), Heat pumps, IEA, Paris https://www.iea.org/reports/heat-pumps

[26] https://www.rehva.eu/rehva-journal/chapter/european-heat-pump-market

[27] https://www.asb.sk/stavebnictvo/technicke-zariadenia-budov/solarne-kolektory/solarny-system-v-bytovom-dome

[28] https://www.solarneslovensko.sk/solarny-ohrev-vody/slnecne-kolektory-bytove-domy.php

[29] https://www.solarneslovensko.sk/thermosolar.php

[30] Internal data of the community of owners of flats and non-residential premises, Filinský 9, Spišská Nová Ves

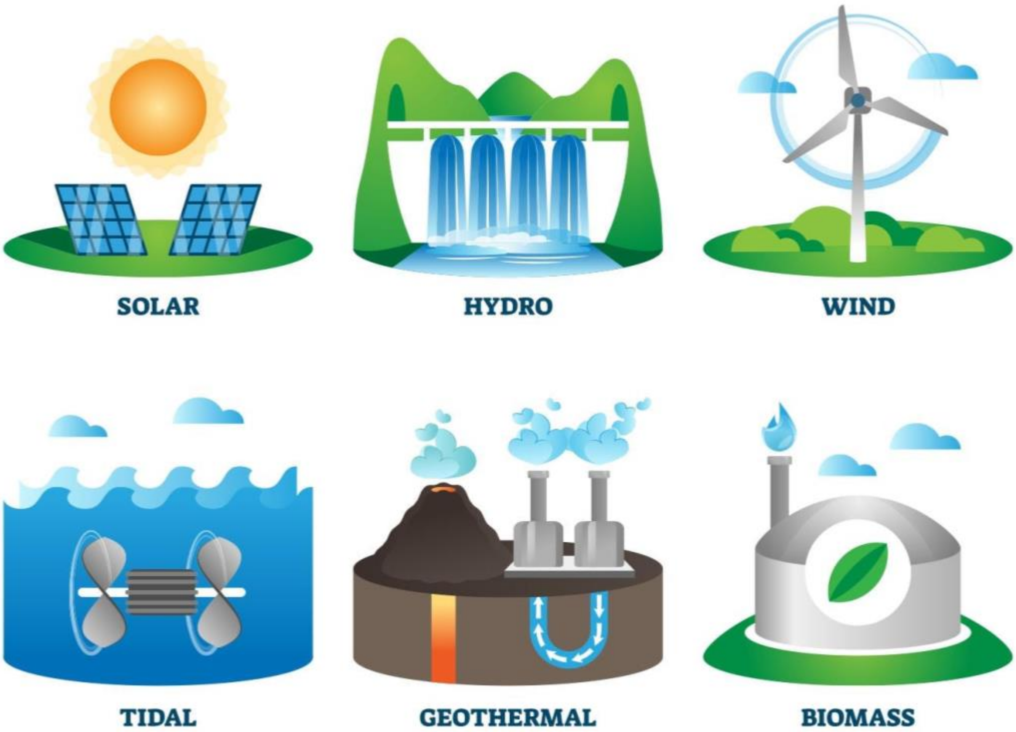
[31] https://www.energie-portal.sk/Dokument/energiu-zo-slnka-uklada-smart-bateria-zavod-v-humennom-vyuziva-lokalny-zdroj-na-prenajom-106508.aspx

[32] https://www.energie-portal.sk/Dokument/solarne-panely-aupark-108104.aspx

[33] https://www.energie-portal.sk/Dokument/fotovolticka-elektraren-pomoze-maloobchodnemu-retazcu-znizit-ucet-za-elektrinu-108108.aspx
[34] https://obeccerova.sk/o-cerovej/veterna-elektraren/
[35] https://www.asb.sk/stavebnictvo/technicke-zariadenia-budov/energie/slama-ako-efektivny-zdroj-tepla-na-vykurovanie-sidliska-v-obci-turna-nad-bodvou
[36] https://tehobardejov.sk/
[37] https://hnonline.sk/finweb/ekonomika/2108785-po-piatich-rokoch-ticha-je-tu-velka-oprava-gabcikova
[38] https://www.seas.sk/elektraren/pve-cierny-vah/
[39] https://www.visitliptov.sk/zaujimavosti/vodna-nadrz-cierny-vah/
[40] https://sk.mapy.cz/
[41] Kocskovics, M.: Skúsenosti s využívaním geotermálnej energie v Galante, Seminár Obnoviteľné zdroje energie – potenciál a obmedzenia, dostupné na https://adoc.pub/queue/skusenosti-s-vyuivanim-geotermalnej-energie-v-galante.html

Chapter 2

Renewable Energy Sources in Romania



Potential, use, policies

Use of renewable energy sources in Romania University POLITEHNICA of Bucharest, ROMANIA

Abstract

In the last century, the use of energy from fossil fuels (combustion of oil, natural gas, coal) caused disastrous environmental effects, greater than any human activity in history: the accumulation of harmful gases in the atmosphere, which started (possibly irreversible) processes such as: ozone depletion, global warming.
The use of renewable energy sources (solar, wind, hydro, biomass, geothermal) is becoming more and more important because: these sources are not consumed, produce much less emissions, reduce chemical, thermal, radioactive pollution and are available, theoretically, anywhere in the world.
Romania has the potential to develop production systems based on all types of renewable energy sources, depending on the specificities of each geographical area of the country. According to studies carried out in Romania, the potential for green energy production is 65% biomass, 17% wind energy, 12% solar energy, 4% micro-hydropower and 2% photovoltaic and geothermal.

Contents

1. Renewable energies policies

Promoting the use of renewable energy resources (RES) has been one of the priority objectives of the energy policy, Romania having a technical energy potential of RES assessed and published since 2003.

To exploit this potential and achieve the targets set in this area, Romania has created an appropriate legislative and institutional framework to promote RES.

In 2003, Romania adopted the "*Strategy for the exploitation of renewable energy resources"*, approved by Government Decision 1535/2003 [1].

Also, promoting the use of RES and increasing the share of RES in the national energy mix has been done through the energy strategies developed so far:

- Romania's Energy strategy for 2007-2020 [2]
- Romania's Energy Strategy for the period 2020-2030, with a 2050 perspective [3].

Romania is a signatory to the United Nations Framework Convention on Climate Change, which it ratified by Law No 24 of 6 May 1994. Romania adopted the Kyoto Protocol to the United Nations Framework Convention on Climate Change on 11 December 1997, ratified by Law No 3 of 2 February 2001. In the first commitment period under the Kyoto Protocol, 2008-2012, most Member States, including Romania, assumed a target of reducing greenhouse gas emissions by 8% compared to the 1989 base year. Romania has achieved and exceeded its 8% greenhouse gas emission reduction target. Romania has ratified the Doha Amendment to the Kyoto Protocol which operationalises the second commitment period through Law No 251/2015 for the acceptance of the Doha Amendment. Romania signed the Paris Agreement in New York on 22 April 2016 and ratified it through Law No. 57 of 10 April 2017 for the ratification of the Paris Agreement [4], [5].

In 2018-2020, an expert group was formed to develop the Integrated National Energy and Climate Change Plan for 2021-2030 (PNIESC), in accordance with the provisions of Regulation (EU) 2018/1999 on energy union governance.

The PNIESC represents Romania's engagement to contribute to the ambitious European energy and climate targets established for 2030, by setting [6]:

- National targets for reducing greenhouse gas emissions, increasing the share of renewable energy in final energy consumption, improving energy efficiency in all economic sectors and increasing the degree of interconnection of the internal electricity market to the European energy market.
- Policies and measures to achieve these targets.

The PNIESC was approved by Government Decision No 1076/2021.

According to Eurostat, in 2017, Romania achieved the 2020 target of a 24% share of renewable energy sources in final energy consumption. For the year 2030, according to the projections made in the PNIESC, the RES share should be 30.7, possible by adding 7GW in renewable capacity. The figure below shows the estimates made regarding the share of RES in gross final energy consumption and the intermediate targets that should be reached.

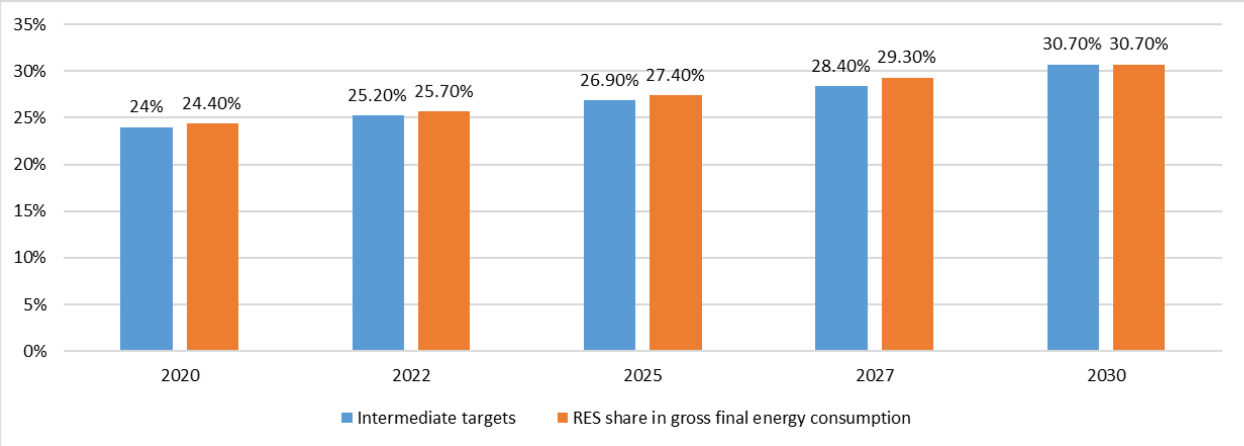


Figure 1. The share of RES in the gross final energy consumption and intermediate targets for the period 2020-2030 accordind to PNIESC [6]

In terms of the contribution of RES by sector, by 2030 a 49.4% share is expected to come from RES in gross final consumption of electricity (RES-E), a 33% share in the heating and cooling sector (RES H&C), and a 14.2% share in the transport sector (RES-T) (Figure 2).

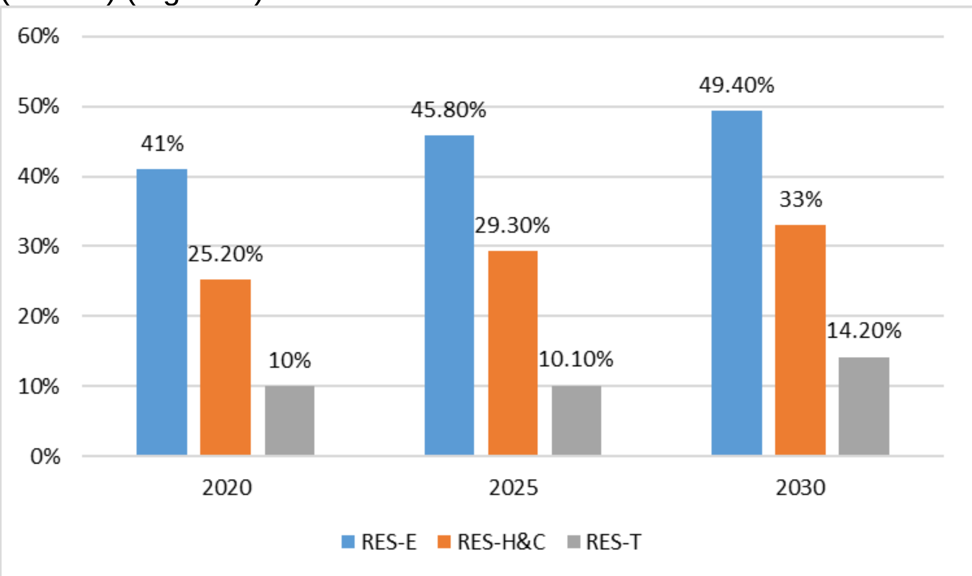


Figure 2. The share of RES by sector for 2020, 2025 and 2030 [6]

In Romania, the energy mix is varied and diversified, producing energy from both primary and renewable energy sources.

In the period 1.01.2022-30.09.2022 the total energy production in Romania was 41.71 TWh, of which 38% was produced from fossil fuels, 25.82% from hydro, 19.38% from nuclear and 16.59% from RES (wind and solar) (Figure 3) [7].

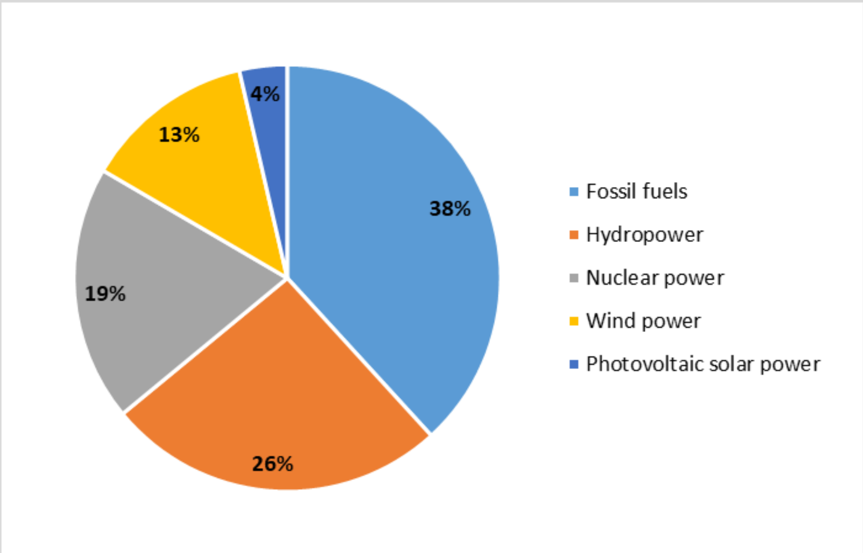


Figure 3. The energy mix of Romania in the period 1.01.-30.09.2022 [7]

Figure 4 shows the evolution of energy sources in energy production until 2050.

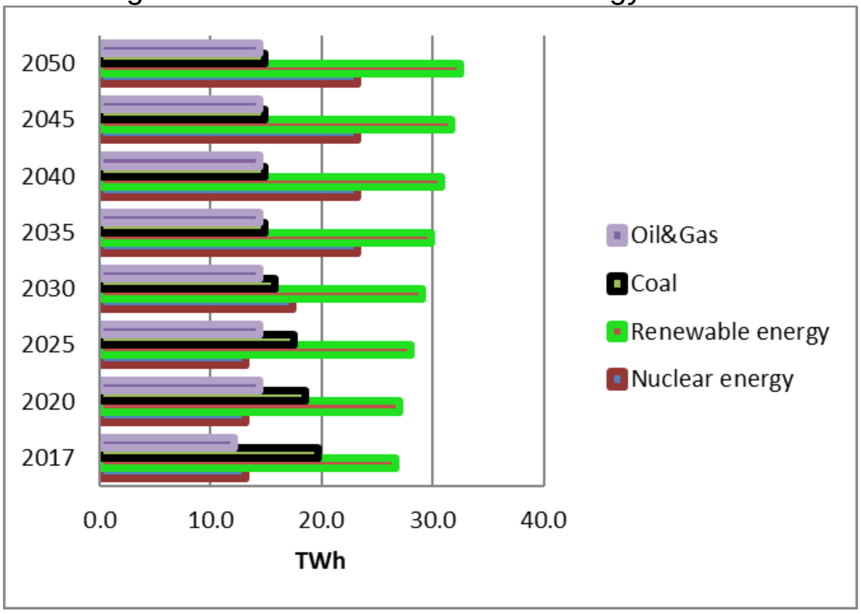


Figure 4. Evolution of electricity production by primary energy sources in the period 2017-2040 [3]

In terms of energy consumption, according to Eurostat data, in 2019, just over 24% of energy consumption was from renewable energy sources, placing Romania 10th in the EU and above the EU average.

Greenhouse gas emissions in Romania decreased by more than 50% compared to 1990 levels due to a significant reduction in energy demand and industrial activity, increased energy efficiency and progressive adaptation to more restrictive environmental standards. Today, the energy sector is still the main source of emissions, accounting for 2/3 of national greenhouse gas emissions, followed by agriculture and industry [8].

2. Renewable energies sources in Romania

The potential for electricity generation from renewable sources in Romania is significant. This is proven both by the existence of a diversified energy mix and by analyses that place Romania among the top the most suitable European regions from the point of view renewable energy potential for accelerating investment in this sector.

From all renewable energy resources available in Romania (wind, solar, hydro, geothermal, biomass), considering the distribution of renewable energy production projects, the most exploited is wind energy, solar and hydropower, as can be seen from the map below showing the use of renewable energy sources.

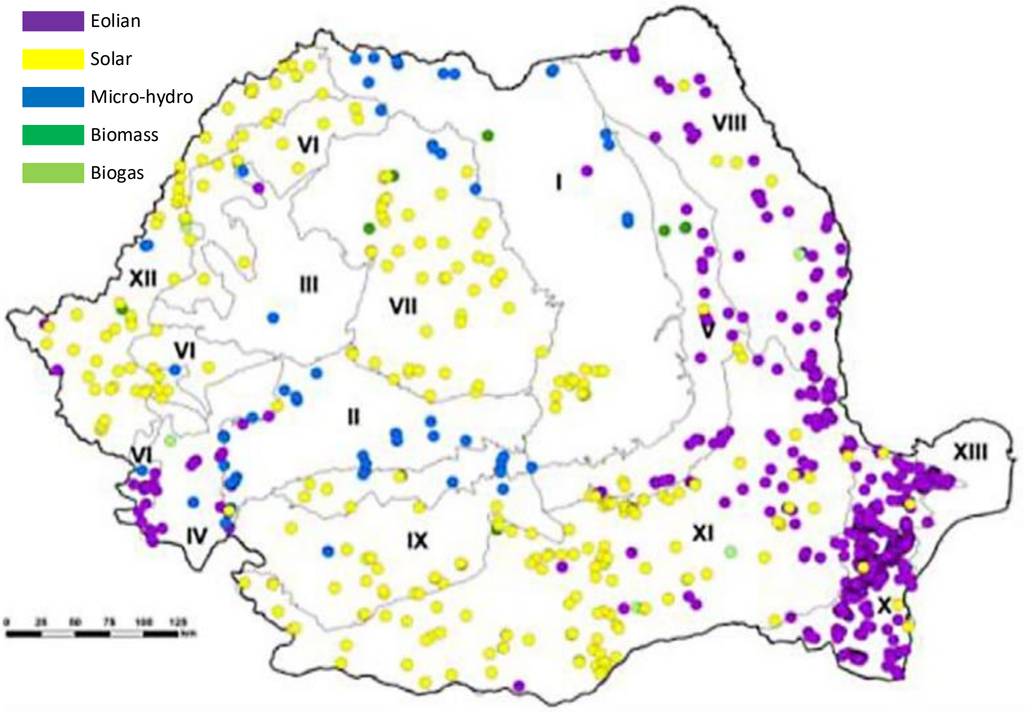


Figure 5. Distribution of RES projects [9]

The following table summarizes the annual energy potential of renewable energy sources in Romania.

Table 1. Potential of renewable energy sources in Romania [1]

Resource	Annual potential	Type of energy
Solar energy	1 433 000 toe / 1 200 GWh	Thermal and electric energy
Wind energy	23 000 GWh	Electric energy
Hydro energy	34 000 GWh	Electric energy
Micro-hydro energy	6 000 GWh	Electric energy
Biomass	7 597 000 toe	Thermal and electric energy
Geothermal energy	167 000 toe	Thermal energy

2.1. Solar energy

Romania is in the European sunny zone B, which offers real advantages to the inhabitants to save thermal energy and money if they use solar energy. Depending on the geographical area, Romania is divided into three main sunny zones:

- The red zone (>1650kWh/mp/year) is the southern area, namely Oltenia, Muntenia, Dobrogea and southern Moldova.
- Yellow zone (1300 - 1450 kWh/sqm/year) here we find the Carpathian and sub-Carpathian regions of Muntenia, Transylvania, the middle and northern part of Moldavia and the whole of Banat
- Blue zone (1150 - 1300 kWh/sqm/year) mountain regions

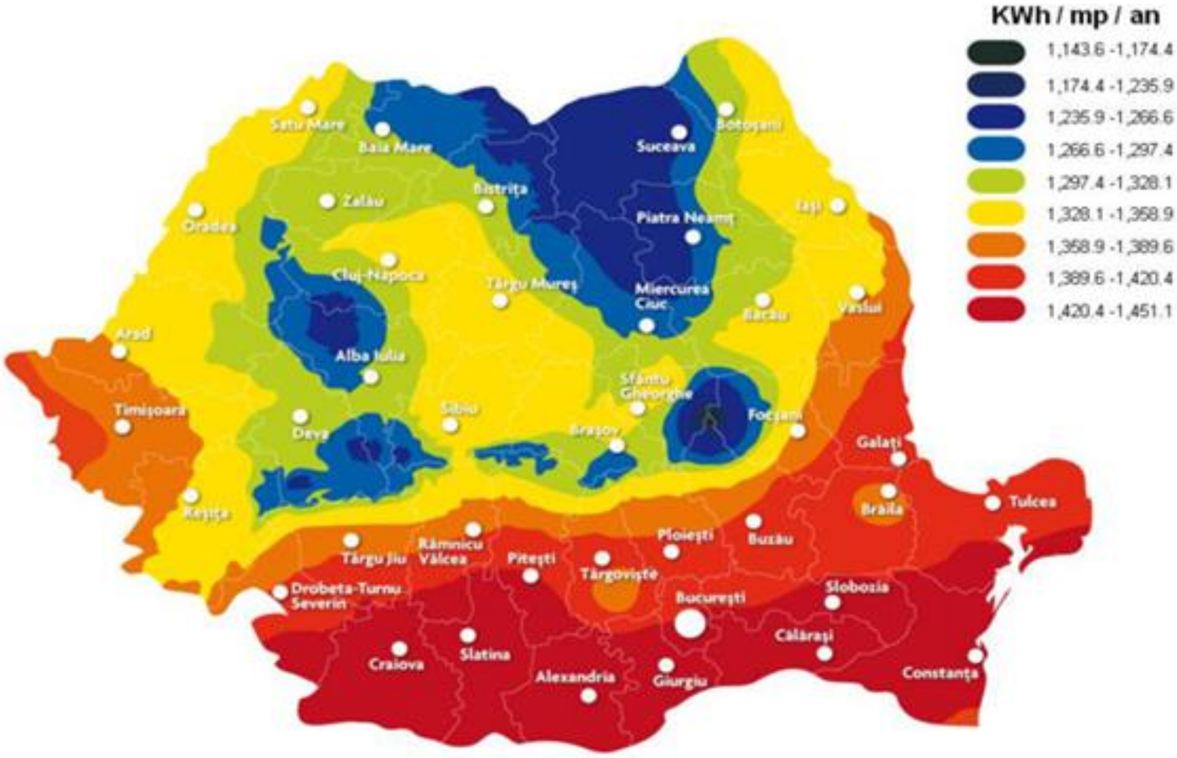


Figure 6. Solar radiation in Romania [10]

Romania is located in a geographical area with good solar coverage, with 210 sunny days per year and an annual solar energy flux between 1000 kWh/m^2/year and 1300 kWh/m$_2$/year. From this amount of energy between 600 and 800 kWh/m^2/year can be captured.

The potential for solar energy use in Romania is relatively large. There are areas where the annual solar energy flow reaches up to 1450-1600kWh/m2/year, in the Black Sea coast and Dobrogea area as well as in most southern areas.

The use of solar thermal energy is the conversion of direct and indirect solar rays into heat or hot water. This heat is produced by capturing the sun's rays by the solar collector, which heats water in a boiler via a heat exchanger. The heated water is used in the kitchen, bathroom or for heating the home. By investing in solar energy, we can protect the environment for our own comfort and safety and that of future generations.

There are many technologies for converting solar radiation into electricity. The easiest method is the use of photovoltaic panels, which convert directly to direct current using semiconductor materials that exhibit a photoelectric effect. Photovoltaics can be used on any scale, from residential applications to photovoltaic panel farms.

Indirect conversion is done using solar concentrators or lens systems. Light radiation is focused to a heat exchanger where the energy is transferred to a fluid, followed by a conventional energy production cycle (e.g., steam - turbine - electric generator).

A third category with commercial potential, also indirect, is the combination of a solar concentrator and a Stirling engine driving an electric generator. Systems in these two categories make use of direct solar radiation, requiring automatic orientation of the mirrors. Due to the technical complexity, a continuous process of specialised maintenance is required. This is why both technical and financial viability (initial investment and maintenance costs) are achieved in the case of implementation at centralised energy production level.

As of 31 December 2021, the total installed capacity of accredited photovoltaic power plants in Romania was 1 357 MW [11].

The largest solar parks in Romania are:

1. Photovoltaic power plant in Ciuperceni, Satu Mare – 56 MW (operated by GPSB Solaris 48 SRL). Also known as Livada Solar Park, the power plant in the village of Ciuperceni is built on an area of 135 hectares and is the first in this ranking of the largest solar power parks in Romania. A total of 230 000 photovoltaic panels have been installed here, after an investment of 105 million euros [12]. The solar park finished in November 2013 produces 67 gigawatt-hours (GWh) annually, enough to power about 60,000 average households.
2. CEF Izvoarele, Giurgiu – 42.5 MW (LJG Green Source Energy Gamma SRL). The photovoltaic park is the second largest photovoltaic park in Romania. It is built on an area of 125 hectares and has 215 000 panels producing electricity. The Izvoarele power plant was finished and commissioned in 2013 after an investment of around 77 million euros. The photovoltaic park produces 70 GWh annually, enough to supply electricity for 77 000 average households.
3. CEF Slobozia, Giurgiu county – 38 MW (LJG Green Source Energy Alpha SA). Slobozia solar park, Giurgiu is the third largest solar park in Romania. It is built on an area of 113 hectares and consists of 180 000 photovoltaic panels. It was completed in September 2013 after an investment of 100 million euros and generates around 60 GWh per year.

Figure 7. Solar park – Romania [13]

Figure 8 shows the estimated increase in electricity generation capacity from photovoltaic sources until 2029/2030, according to the two strategic documents developed at national level that include priority actions dedicated to the energy sector. However, the proposed measures have no strategic coherence, as there are significant differences in the estimates made in the two documents. For example, in the PNIESC for the year 2030, an increase in solar energy production capacity of 3692 MW is predicted, but in the RET Development Plan developed by Transelectrica for the period 2020-2029 an increase of only 900 MW is predicted in the green scenario [14].

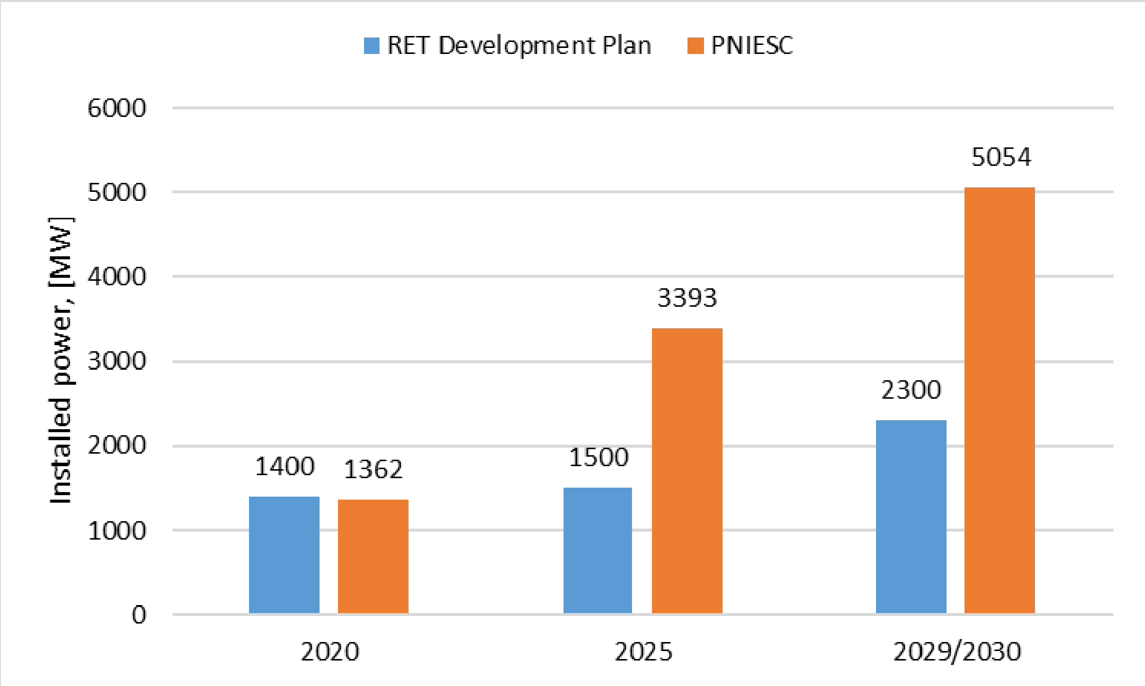


Figure 8. Estimated increase in photovoltaic solar power generation capacity [9]

2.2. Wind energy

In Romania, five wind energy zones have been identified, depending on the environmental and topographical conditions, considering the level of energy potential of this type of resources at an average height of 50 meters and above. From the results of the measurements recorded, it appears that Romania is part of a temperate continental climate, with a high energy potential, especially in the coastal and littoral areas (mild climate), as well as in alpine areas and mountain valleys (severe climate) [15].

Based on the assessment and interpretation of the recorded data, it results that wind power plants with a total capacity of up to 14 000 MW can be installed in Romania, which means an electricity supply of almost 23 000 GWh/year.

Based on preliminary assessments in the seaside area, including the offshore environment, in the short and medium term, the wind energy potential for development is about 2 000 MW, with an average electricity output of 4 500 GWh/year.

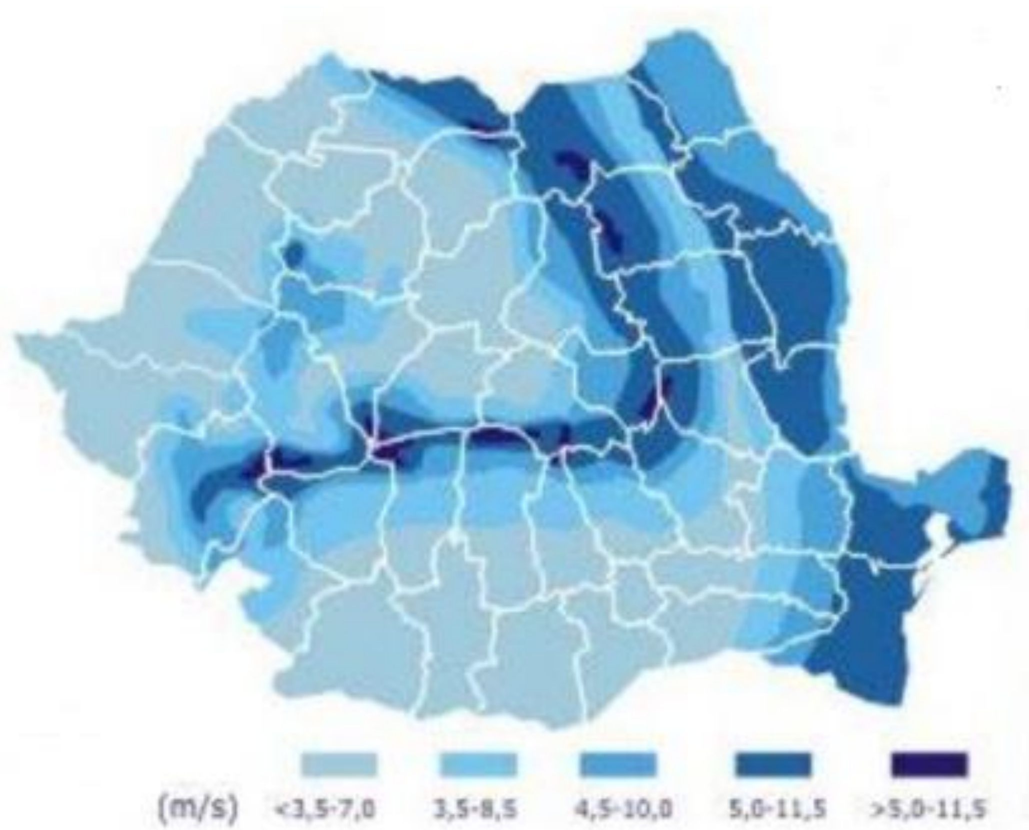


Figure 9. Wind speed in Romania [16]

To exploit the wind energy potential in an economically efficient way requires the use of suitable technologies and equipment (wind turbines with nominal power from 750 kW to 2 000 kW).

Worldwide, "wind energy" is at a stage of "technological maturity" but, in Romania, the share of electricity from wind sources in the energy balance remains for the moment below the real possibilities of their efficient exploitation.

The largest wind parks in Romania are in the eastern part of the country, in Dobrogea. At present, Romania has just over 3 000 MW of installed wind power capacity. These 3 000 MW represent 16.5% of Romania's total installed power generation capacity, according to ANRE data (National Energy Regulatory Authority) [17].

According to ANRE's list of accredited producers and renewable energy power plants, updated on 31 October 2021, the largest wind farm in Romania is Fantanele-Cogealac wind farm, which includes:

- Fantanele Vest – 262.5 MW (Tomis Team SA)
- Cogealac - 252 MW (Ovidiu Development SRL)
- Fântânele Est - 85 MW (Tomis Team SA)

Together, the above three power plants form the Fântânele-Cogealac wind farm, the largest in Romania and the third largest onshore wind farm in Europe.

In total, Fantanele-Cogealac wind farm, located on the territory of the two localities in Constanta, has an installed capacity of 600 MW. The wind farm belongs to the investor CEZ Group, a conglomerate of companies (most of them Czech) active in the field of production and distribution of electricity and heat.

Fantanele-Cogealac wind farm was built between 2008 and 2012, with a total investment of over 1 billion €. A total of 240 General Electric 2.5xl wind turbines were installed at Fantanele-Cogealac

Figure 10. Fantanele-Cogealac wind park [17]

Figure 11 shows the estimated increase in wind power generation capacity according to the national energy strategy documents. As in the case of solar energy, the PNIESC plan estimates significantly higher increase than the RET Development Plan for 2029/2030.

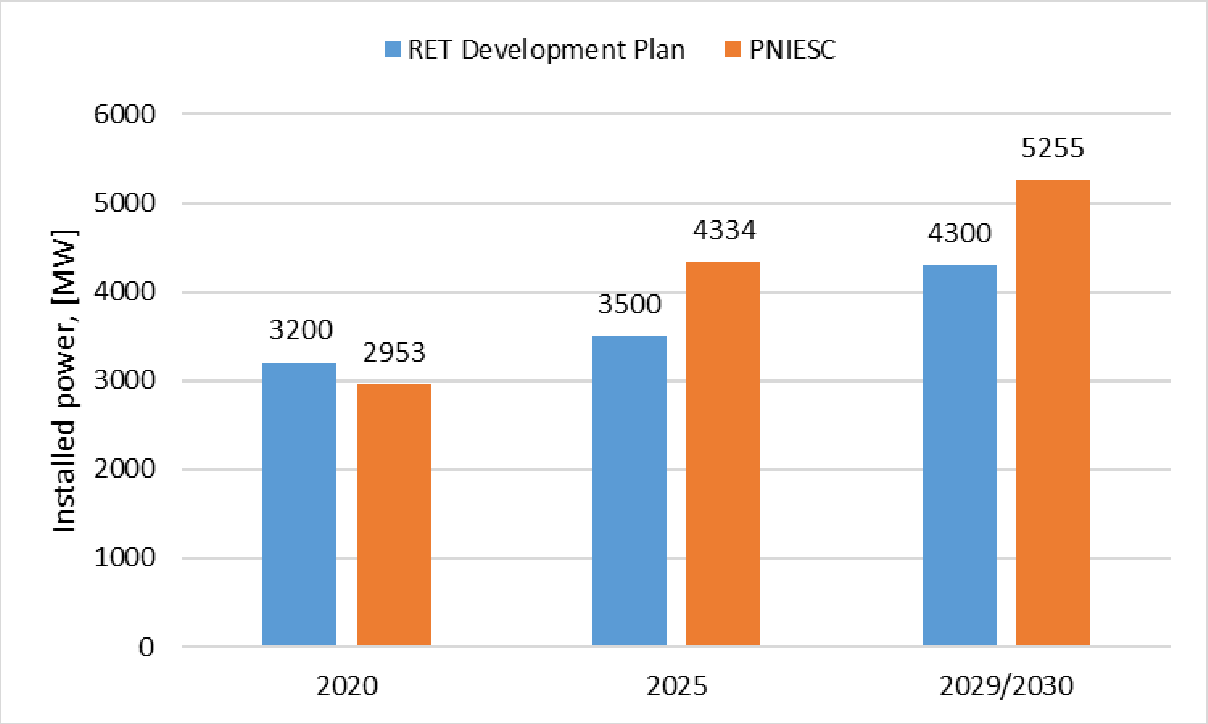


Figure 11. Estimated increase in wind power generation capacity [9]

2.3. Biomass

Regarding the energy potential of biomass, the territory of Romania has been divided into eight regions. In Romania, biomass represents 65% of the renewable energy potential. The biomass energy potential, estimated at about 7.6 million tonnes/year or 318,000 TJ/year, represents about 19% of the total primary energy consumption in Romania [18].

Biomass is a versatile resource that can be converted into energy in many ways. The most common techniques can be divided generally into thermochemical and biochemical processes. Biomass can be converted into three main types of products:

- electricity/heat,
- transport fuel,
- chemical feedstock.

In Romania the highest biomass potential is represented by agricultural waste, 63%, followed by forestry waste with 16% (Figure 12) [19].

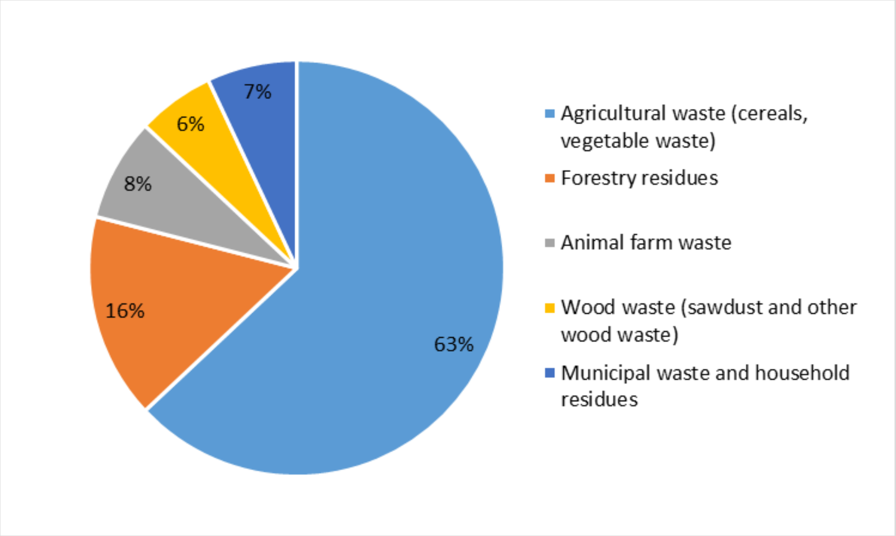


Figure 12. Biomass energy potential of Romania [19]

2.4. Geothermal energy

Geothermal energy is a form of renewable energy derived from heat released from the Earth's interior through underground rocks and fluids. Geothermal energy can be found in the form of volcanoes, hot water, and geysers. This clean energy is used in three energy directions: heating, electricity, and geothermal pumps.

Romania has a high potential for geothermal energy, being placed third in Europe, after Greece and Italy. However only one city in the country, Beius, provides heating for households entirely using this type of energy. The installed capacity of geothermal power plants for heating in Romania is currently about 158 MW_t [20].

Figure 13. Map of the main geothermal energy sources in Romania [20]

2.5. Evolution of renewable energy sources in Romania

At present, Romania has 3 036 MW of installed wind and 1 538 MW of installed photovoltaic power generation capacity. The map below shows the geographic location of renewable generation sources across the country [21].

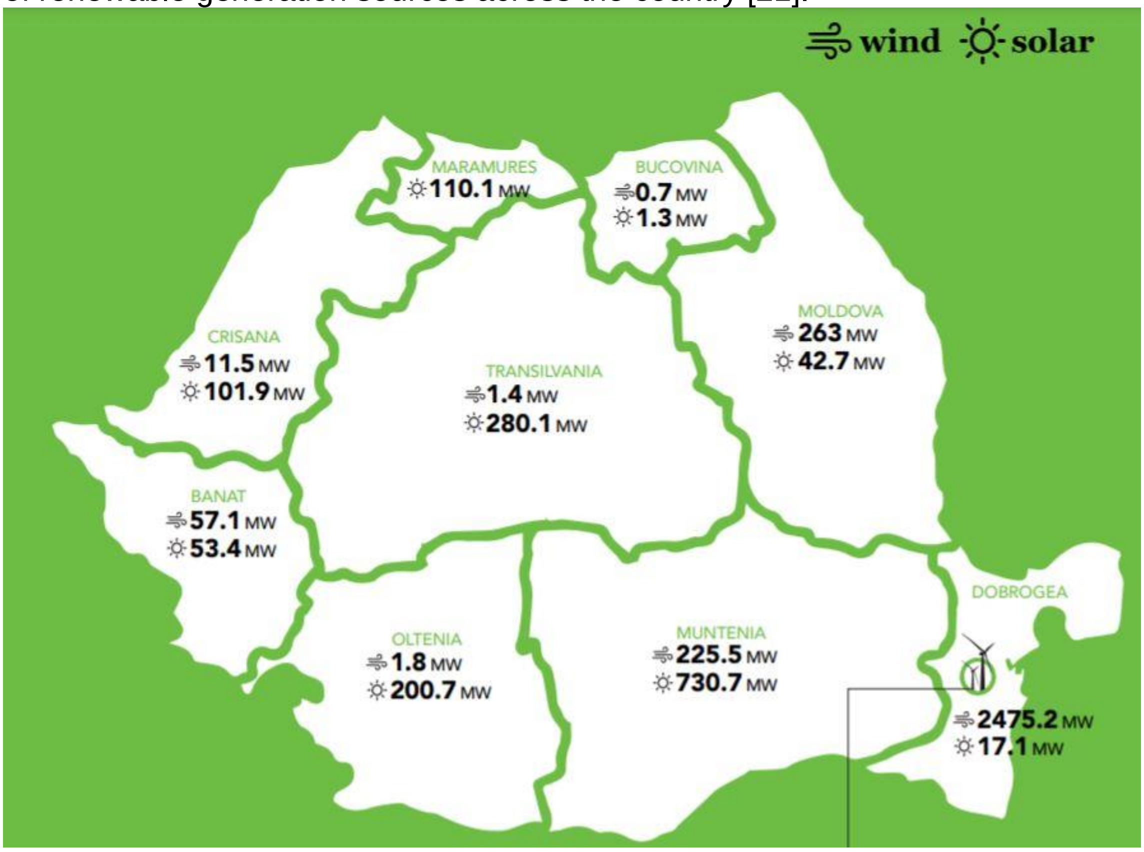


Figure 14. Solar and wind power distribution in Romania [21]

As can be seen, most of the installed wind power - almost 2 500 MW out of about 3 000 installed throughout the country - is in the Dobrogea area, which has practically become the main power generation area in the country. The two nuclear reactors, 1 400 MW combined, are also located in this area. Unfortunately, the least installed renewable capacity is in areas where Romania has a deficit of power generation: the center, north and west of the country.

Romania produces as much wind and solar energy in 2022 as it did in 2014 and still uses more gas and coal than sun and wind. The absence of investment in wind power plants and photovoltaic systems means that the production of "green" energy in 2022 will be at the same level as in 2014. Without a coherent strategy and without investments, it places Romania on one of the last places in Europe in terms of renewable energy production per capita. Romania is dependent on two primary energy resources, gas, and coal, which Europe wants to give up.

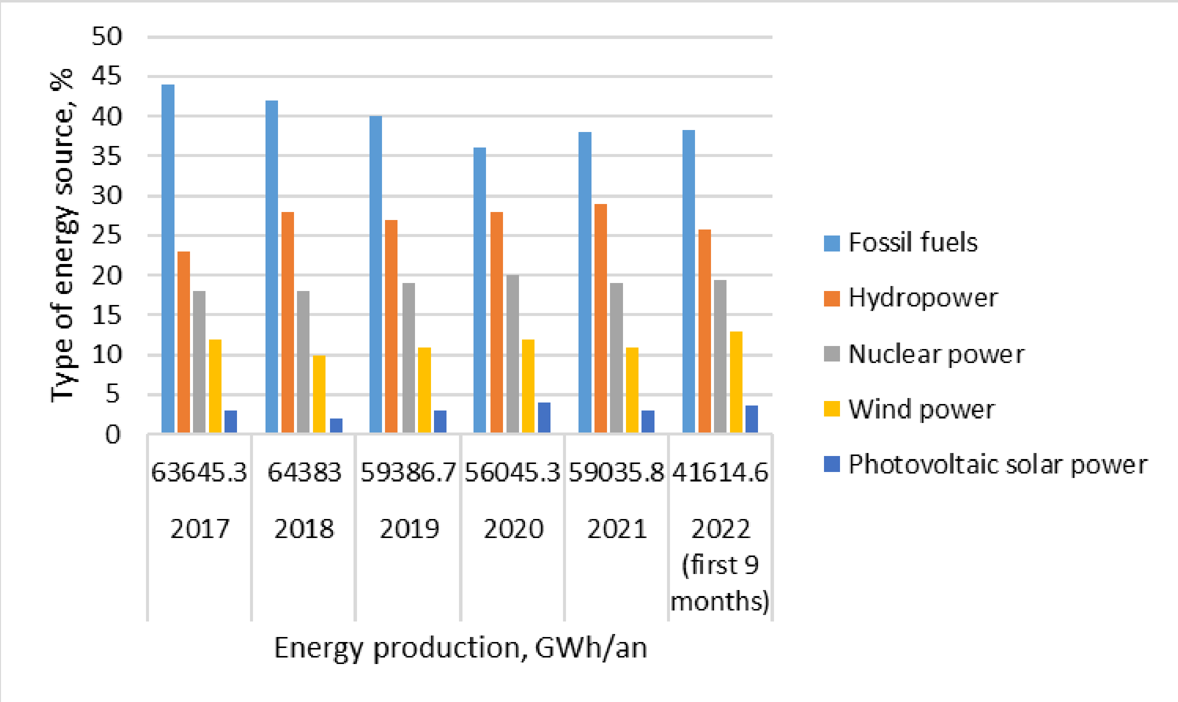


Figure 15. Energy production in Romania by energy source in 2017-2022 [22]

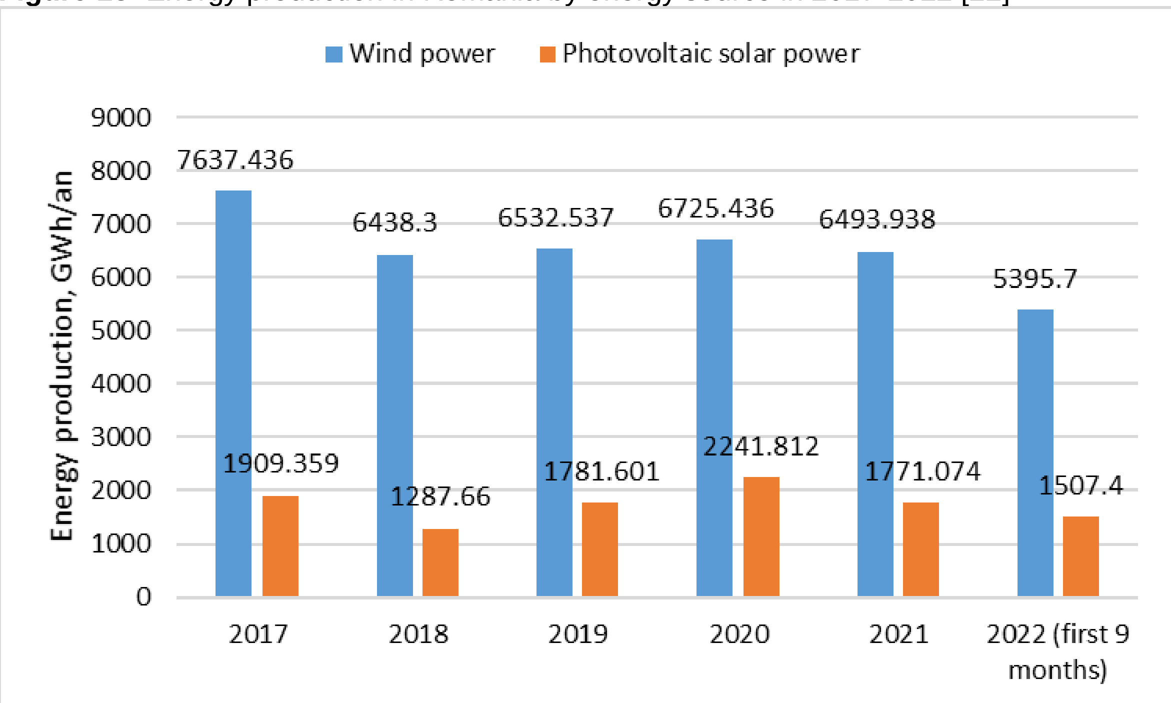


Figure 16. Energy production from renewable energy sources (wind and solar) in 2017-2022 [22]

Romania has failed in recent years to increase its capacity to produce energy from renewable energy sources. According to data from Ember-Climate, Romania's per capita installed capacity from solar and wind sources is only 0.229 kW, ranking 4th from the bottom.

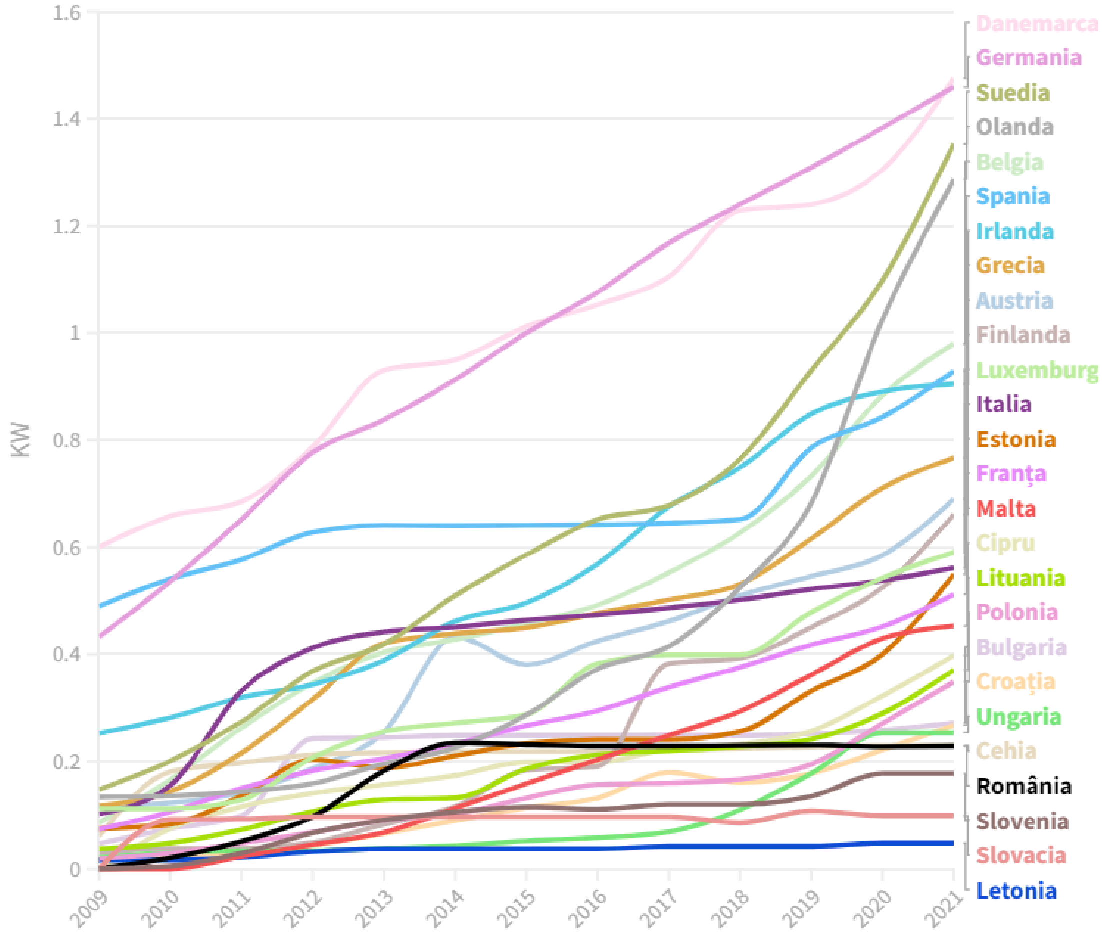


Figure 17. Wind & solar installed power/capita in EU countries [23]

Under the National Recovery and Resilience Plan (PNRR) approved by the European Commission, Romania has been allocated 1.6 billion € for energy, including investments in renewable energy production. The projects submitted for the installation of photovoltaic panels and wind power plants could lead to the installation of 600 MW of renewable energy.

Romania has a high energy potential from renewable energy sources, which is not yet fully exploited. It has a great advantage due to the variety of resources available energy resources.

In addition to past investments, there is scope to increase production capacity in RES, especially for solar energy. Moreover, there is significant growth potential for hydropower and biomass, which can be solutions for the basic energy supply. Geothermal energy, which can be a renewable source of thermal energy, needs more attention. The existence of geothermal resources has been proven by geophysical studies carried out before 1990. At the time, few projects had been implemented, and geothermal resources were still largely evaluated by these studies, which were carried out more than 30 years ago. Consequently, Romania's geothermal potential is still underestimated. Increased investment in research could significantly improve the technical potential of geothermal energy [24].

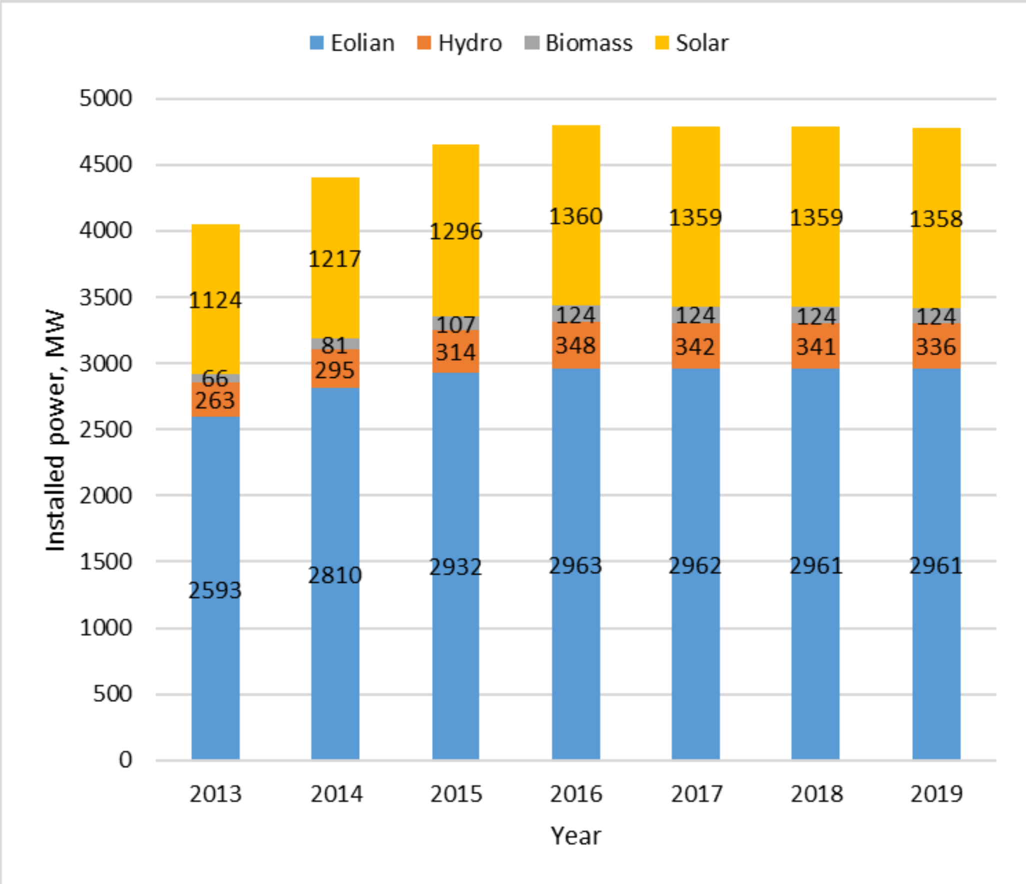


Figure 18. Installed power by type of renewable sources in Romania in 2013-2019 [9]

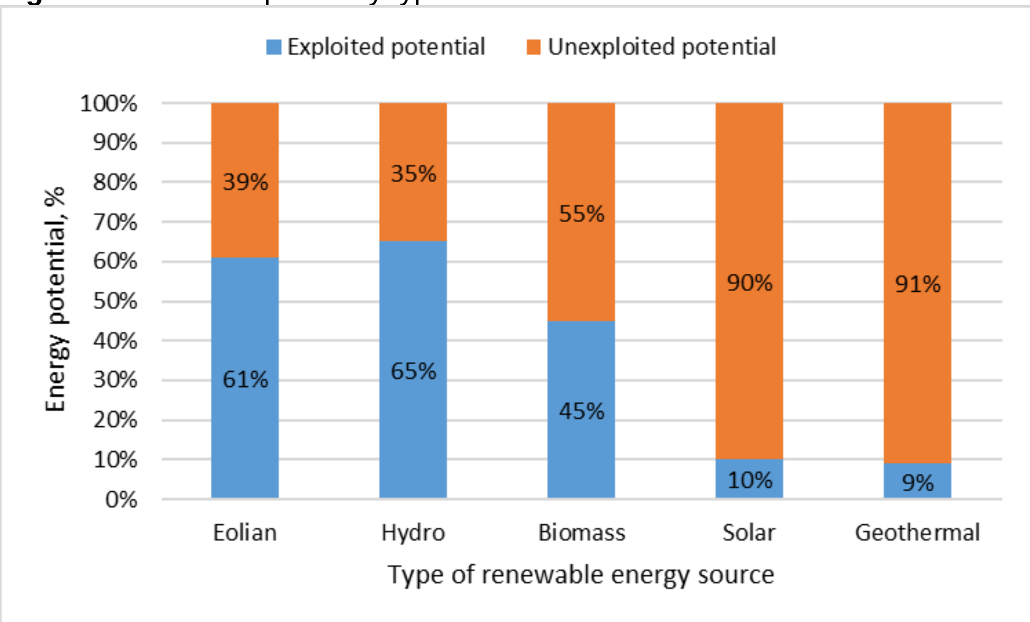


Figure 19. Exploited and unexploited potential of renewable energy sources in Romania [24]

3. Examples of communities from Romania that used renewable energies

- ***Solar photovoltaic power. Bosch factory, Blaj, Romania***

In 2021, Bosch factory from Blaj, Romania took the first step towards producing its own green energy by installing photovoltaic panels. In addition, the company is encouraging the transition to electro-mobility by installing two electric vehicle charging stations for employees at the Blaj factory at the end of 2021.

The photovoltaic panels installed at the site in Blaj in April 2021 generate green energy equivalent to the electricity consumption of 50 households.

Since December, the company has installed additional panels on the plant's office building, which is currently powered only by the renewable energy they produce.

Currently, 385 MWh/year are produced exclusively from renewable sources in the factory - the equivalent of 165 tonnes of CO_2 if energy were produced by the combustion of fossil fuels, and the company aims to produce another 3200 MWh/year in Blaj this year.

Figure 20. Photovoltaic system installed on Bosch factory [25]

- ***Geothermal city – Beiuș, Romania***

Beiuș, Bihor county, is the only town in Romania where the centralized heating system is supplied. 103 blocks of flats, 3 high schools, general schools, kindergartens, churches and the headquarters of the public institutions of the city benefit from the use of sustainable use of this resource.

In 2009 the project "Beiuș - Geothermal City" was started and submitted for funding under POS CEE 2007-2013, Priority Axis 4 - Increasing energy efficiency and security of supply in the context of climate change, Main area of intervention 4.2 - Exploitation of renewable energy resources for green energy production.

The project was valued at 4.3 million € and involved the start-up of a new plant for the underground re-injection of thermal wastewater, the extension of the thermal agent system with 10 km of pipeline, 8 km of return pipeline and 22 new thermal points for the distribution of thermal agent for heating and domestic hot water.

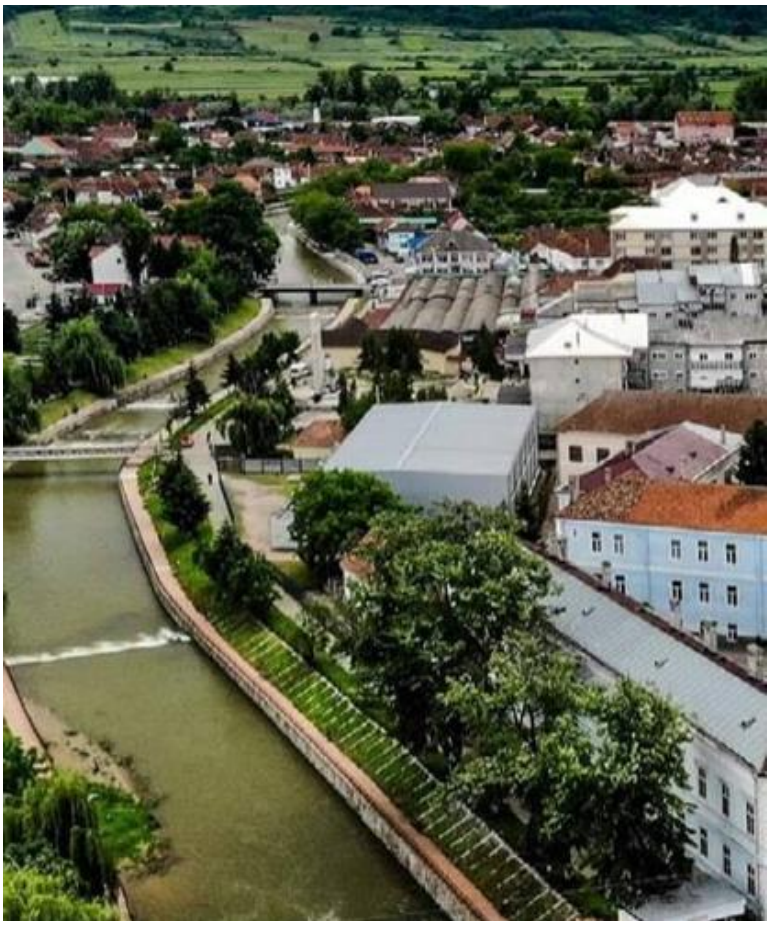


Figure 26. Beiuș – Geothermal city [9]

- ***Biomass cogeneration plant in Săcuieni, Romania***

Ecoland Bihor commissioned the biomass power plant in Săcuieni in 2016. The project was worth 23.6 million lei, of which 17.3 million lei was grant funding from the European Regional Development Fund.

The Săcuieni plant was built over a period of 41 months, between 2013-2016, and includes a complex co-generation plant, which converts a raw material consisting of green mass (70%) and animal waste (30%) into electricity. The installed capacity is 548 kW, with a total average annual feedstock consumption of 12,000 tonnes. The raw material used is taken from the area, primarily animal waste, and maize and rye silage will be purchased from local suppliers, helping to strengthen the local economy.


Figure 27. Biomass cogeneration plant [26]

- ***Biomass Power Plant in Reci, Romania***

The biomass power plant in Reci is a power plant located near the village of Reci, on the national road DN11 and is owned by Holzindustrie Schweighofer S.R.L. The start of the construction was in April 2014 and after six months of construction and execution, the power plant was finished. The scope of this industrial facility is to convert biomass from wood processing into electricity and heat. The power plant is built to produce 15 MW of electrical power and 38 MW of thermal power.

Figure 28. Biomass power plant [27]

- ***A school to nZEB standard***

As a result of extensive energy retrofitting through the Efficient Romania project, a school in Romania has become an nZEB (near-zero energy building) standard, an extremely ambitious level and one that is generally not achieved in Europe. With the investment made, the school building will have an average annual energy consumption reduced by about 60%, partly covered by its own production from renewable sources, an important transformation especially in the current context when energy has become so expensive. This renovation is a model for other schools in the country that can be brought up to the same standard.

Some of the works done to the exterior and interior of the building are:

- thermal insulation of exterior walls;
- installation of sunshades on heavily sunny windows;
- replacing the lighting system with an intelligent one;
- installing photovoltaic and solar thermal panels.

Figure 29. A school to nZEB standard [28]

- ***Cities consuming 100% "green" electricity***

Brasov City Hall consumes 100% "green" electricity. All the more than 500 electricity consumption points of institutions subordinated to Brasov City Hall - including public lighting, traffic lights, tens of educational institutions and the ski area - are supplied exclusively from renewable sources, after the municipality and the electricity supplier signed an agreement in this regard. Brasov thus becomes the first local public administration in Romania to benefit from 100% renewable energy. According to data provided by the energy operator for customers, for the Brașov City Hall, which benefits from the ECO 100% certified green energy service, the largest part, 98.78%, is produced by hydroelectric and 1.22% from biomass power plants [29].

Alba Iulia is a city in Romania, one of the few in Europe, included in the list of more than 100 cities that use more than 70% of electricity from renewable sources, according to a study by the Carbon Disclosure Project (CDP). Carbon Disclosure Project manages a global analysis system that allows companies, cities, states, and regions to measure and manage their environmental impact. According to the CDP website, it is the most comprehensive collection of environmental data reported by authorities worldwide. Alba Iulia uses 99% renewable energy, of which 96% is hydropower, 1% wind, 2% solar and 1% natural gas. Energy from hydropower plants is considered green, renewable energy. At the same time, the city has invested in several such energy projects. For example, 21 photovoltaic solar panels and solar water heating systems have been installed at the Olympic swimming pool in Alba Iulia, solar kits that are intended to ensure significant savings on utilities [30].

Conclusions

Renewable energy resources are those resources that are naturally replenished and can be used to generate green energy. Renewable energy sources include wind energy, solar energy (thermal, photovoltaic), hydropower, tidal energy, geothermal energy, and biofuels. The main benefit of using renewable energy sources is the reduction of greenhouse gas emissions.

In 2021, the European Commission has proposed several measures to reduce the share of greenhouse gases in the 27 Member States. According to researchers at council.science, by 2040, renewable energy sources could provide almost a third of the world's energy.

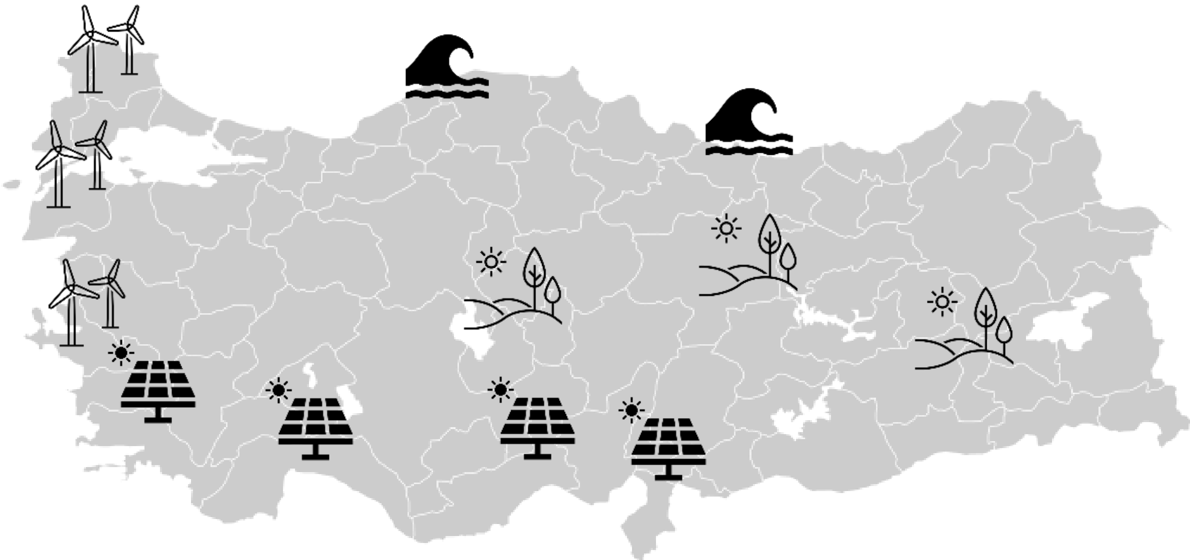
In 2020, Romania's renewable energy production accounted for 16% of the total. In terms of electricity in Romania, 12.4% was from wind power, 3.4% from solar photovoltaic panels and 27.6% from hydropower. Solar energy production in Romania increased by 11% in the first five months of 2022 compared to the same period last year. Overall, renewable energy production will reach a level of 49% in 2030, according to Romania's Energy Strategy for the period 2020-2030, with a 2050 perspective.

References

[1] https://lege5.ro/Gratuit/gq2dambu/strategia-de-valorificare-a-surselor-regenerabile-de-energie-hotarare-1535-2003?dp=gi2denjtgy3tg
[2] https://www.mfinante.gov.ro/static/10/Mfp/programe_strategii_ec/Strategia_16_mai.pdf
[3] https://energie.gov.ro/transparenta-decizionala/strategia-energetica-a-romaniei-2019-2030-cu-perspectiva-anului-2050/
[4] https://energie.gov.ro/home/informatii-de-interes-public/surse-regenerabile-de-energie-in-romania/legislatie-primara/
[5] http://www.mmediu.ro/categorie/cadrul-national/398
[6] https://energy.ec.europa.eu/system/files/2020-04/ro_final_necp_main_ro_0.pdf
[7] https://insse.ro/cms/sites/default/files/com_presa/com_pdf/energie09r22.pdf
[8] https://assets.ey.com/content/dam/ey-sites/ey-com/en_ro/news/21/4/ey-ro-en-report-the-european-green-deal.pdf?download
[9] https://cdn.cursdeguvernare.ro/wp-content/uploads/2021/03/Bankwatch-210303-Raport_Regenerabile.pdf
[10] https://www.panourisolareconstanta.ro/harta-radiatia-solara-in-romania
[11] https://www.anre.ro/ro/legislatie/surse-regenerabile/acreditare-sist-promovare
[12] https://www.legalmarketing.ro/ciurtin-asociatii-in-dezvoltarea-celui-mai-mare-parc-fotovoltaic-din-romania/
[13] https://cursdeguvernare.ro/cele-mai-mari-parcuri-de-energie-solara-din-romania-top-21-centrale.html
[14]https://www.transelectrica.ro/documents/10179/14441468/Planul+de+Dezvoltare+a+RET+perioada+2022-2031+aprobat.pdf/dd6c9e5c-067c-4d97-ab15-596c9ff8dd70
[15] http://free-energy-monitor.com/index.php/energy/harta_potential_eolian
[16] Centru, A. D. R. "Analiza potentialului energetic eolian la nivelul regiunii centru in perspectiva dezvoltarii economice durabile." (2010).
[17] https://cursdeguvernare.ro/cele-mai-mari-parcuri-eoliene-din-romania-top-14-centrale.html
[18] http://add-energy.ro/potentialul-energetic-al-biomasei-in-romania/
[19] https://www.madr.ro/attachments/article/342/ADER-2211-faza-2.pdf
[20] https://www.thinkgeoenergy.com/four-areas-for-potential-geothermal-power-generation-discovered-in-romania/
[21] https://www.economica.net/cum-si-au-impartit-vantul-si-soarele-harta-romaniei_513619.html
[22] https://romania.europalibera.org/a/energie-electrica-romania/32030238.html
[23] https://ember-climate.org/data/data-explorer/
[24] https://sandbag.be/wp-content/uploads/2020/10/Valorificarea-Potentialului-Regenerabil-al-Romaniei-RO.pdf
[25] https://www.g4media.ro/bosh-anunta-ca-isi-reduce-consumul-de-energie-cu-10-in-fabrica-de-la-blaj-prin-instalarea-de-panouri-fotovoltaice-385-mwh-an-sunt-produsi-exclusiv-din-surse-regenerabile-echivalentul-a-165-de.html
[26] https://www.energynomics.ro/ecoland-bihor-a-pus-in-functiune-instalatia-de-cogenerare-pe-biomasa-de-la-sacuieni/
[27] https://heberger.ro/projects/centrala-electrica-pe-biomasa-din-reci/
[28] https://energy-center.ro/actualitate-news/cum-a-fost-adusa-o-scoala-la-standard-nzeb-prin-proiectul-romania-eficienta-un-model-pe-care-multe-scoli-din-tara-l-ar-putea-urma/
[29] https://economedia.ro/primaria-brasov-consuma-100-energie-electricaverde.html#.Y7bhidVBw2w
[30] https://adevarul.ro/stiri-locale/alba-iulia/alba-iulia-in-top-100-orase-la-nivel-mondial-si-1847018.html

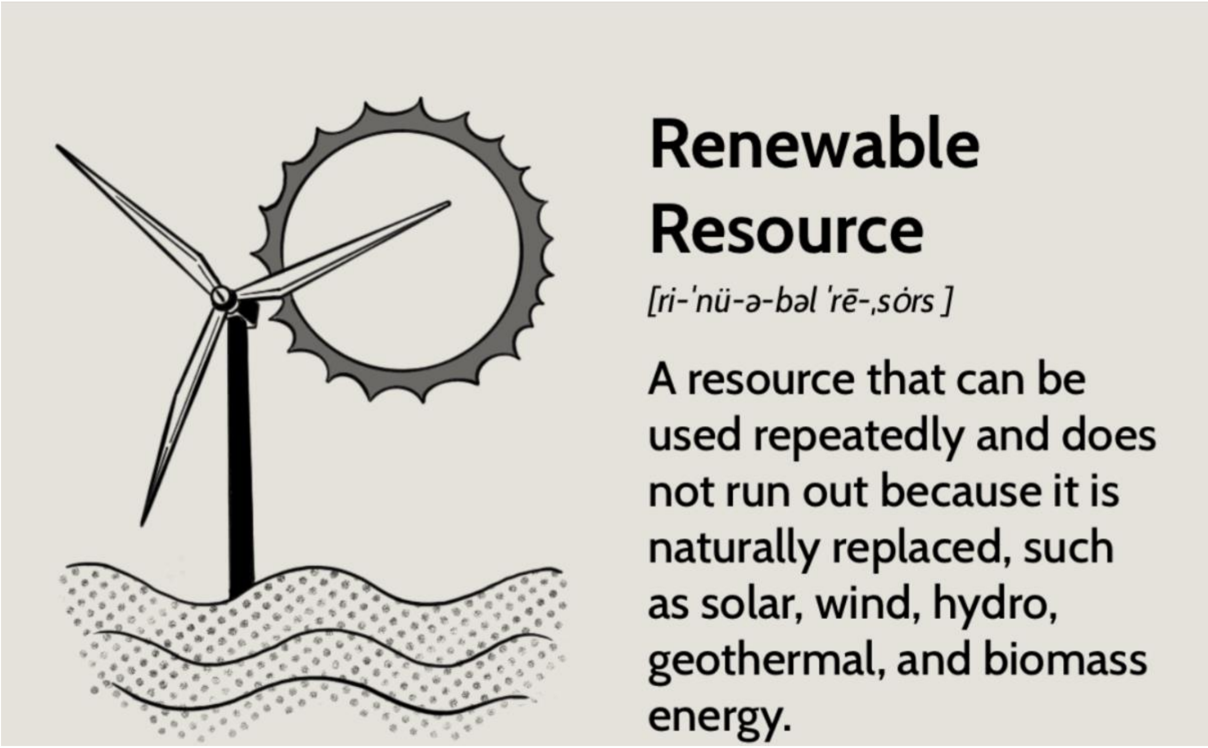
Chapter 3

Renewable Energy Sources in Turkey



Potential, uses, policies

Use of Renewable Energy Sources in Turkey



Abstract
The need to use local renewable and alternative energy sources as much as possible is highlighted by the current conditions in Turkey and around the world. This will enable more energy source diversity and improve the country's and its inhabitants' energy security. By streamlining the legislative processes required for their implementation, the State and the relevant institutions must encourage the growth of the use of these resources, if not economic tools. In this research, we highlight the potential for expanding the use of RES for building heating and cooling.

Content

1. Introduction

In today's 21st century, where the world population has increased more than ever before, the need for energy is increasing day by day. The majority of this energy need is met by fossil-based energy types. Which we are call it Non-Renewable Energy. The biggest problem with these species is that they all exist in limited. In addition, while carbon-based fossil fuel types release energy, carbon emissions cause global warming and the makes thinner ozone layer day by day. Unfortunately, they are not eco friendly at all with their ability to pollute the environment they are in. For that reasons, the use of clean, eco friendly, and most importantly renewable energy alternatives has started to gain popularity in order to suply the energy need. Renewable energy types are unlimited. Its sources are sun, wind, natural wastes, etc. These are the types of energy that can be produced as long as our world exists. Therefore, for the sake of the future of our world and cleaner life, we young engineers will work in this context and develop our projects with clean resources.

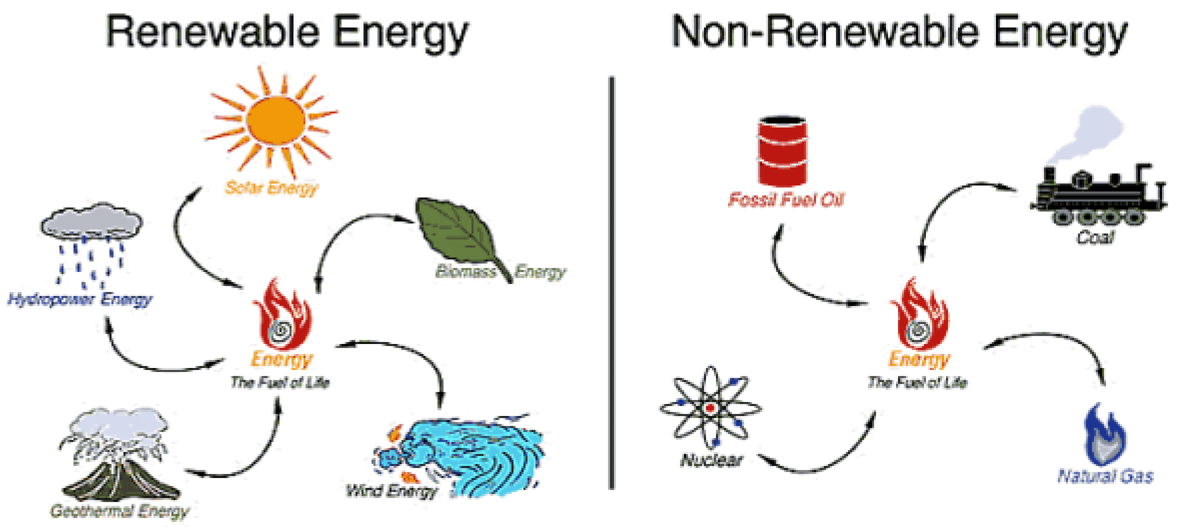


Figure 1. Renewable and Non-Renewable Energy Sources

2. Renewable Energy and Energy Policy in Turkey

The source of renewable energy is local, renewable and free. It will be an important step for balancing carbon emissions and reducing the effects of global climate change that using local and renewable energy sources for our country needs of electricity. Besides this, controlling the energy imports, which make up a large part of country's increasing external debt and current account deficit, will bring durability to the economy and reduce dependence on foreign countries. Making renewable energy sources are efficient and appropriate projects will ensure that national wealth is evaluated in the most accurate way. In this study, identfy the current status of renewable energy in Turkiye from history. Which are mention that stages to project development, essencial step for using renewable energy more widely for electricity generation. The aim of this study, to develop renewable energy policy by proposing ideas for utilities and private companies. [1]

2.1. Renewable Energy in Turkey

Turkey is located between 26–45 degrees' eastern longitude with 36–42 degrees' north latitude in the Northern Hemisphere. Therefore, the country is closer to Ecuador than the North Pole and it is in the temperate zone. With an area of 785,350 km^2, it is one of the largest countries of Europe and the Middle East. Its total electric energy consumption is 213.20 billion kWh per year. The per capita average energy consumption is approximately 2640 kWh [2]. More than half of Turkey's electrical energy is generated from fossil fuels. As a significant part of the energy sources are imported, it is necessary to reduce dependence on foreign sources, because this situation negatively affects the country's economy and current account deficit. In terms of the sustainability of the country's economy, efficient and diversified energy sources should be sought. Also, the cost of RES should be at an affordable level. Renewable energy is a great opportunity for Turkey because it has a significant geographical location in terms of its renewable energy capacity. Besides, Turkey can use almost all known renewable energy sources, such as solar, wind, geothermal, hydro, wave, and biomass. Today, renewable sources compose almost 45 percent of the whole energy producing capacity in Turkey. Hydropower has the preponderance of this generation. Energy generation with renewable sources is increasing globally. By the year 2030, Turkey's energy demands are expected to increase more than 100 percent compared to today. Thus, Turkey's passionate 2023 vision, declares especially attractive goals for the renewable energy sector. For this reason, the Ministry of Energy and National Resources (MENR) encourages to increase the share of RES in electricity generation and it is striving to improve the whole capacity of renewables to 61,000 MW by 2023. 34,000 MW of this total installed generation will be composed of hydropower; 20,000 MW of wind power, 1000 MW of geothermal, 5000 MW of solar, and 1000 MW of biomass energy. The total estimated cost of this object is almost 60 billion dollars. [3]

Table 1. Renewable Energy Sources Ratio

Renewable Energy Sources	2015	2017	2019	2023
Hydropower	25,526	28,763	32,000	34,000
Wind	5660	9549	13,308	20,000
Geothermal	412	559	706	1000
Solar	300	1800	3000	5000
Biomass	377	530	683	1000
Total	32,275	41,241	49,697	61,000

In 2015, investments in the field of renewable energy were equal to 1.9 billion dollars in Turkey and this quantity has been growing continuously. In 2002, Turkey's installed renewable energy generation was 31,846 MW, and it grew to 85,200 MW in 2017.

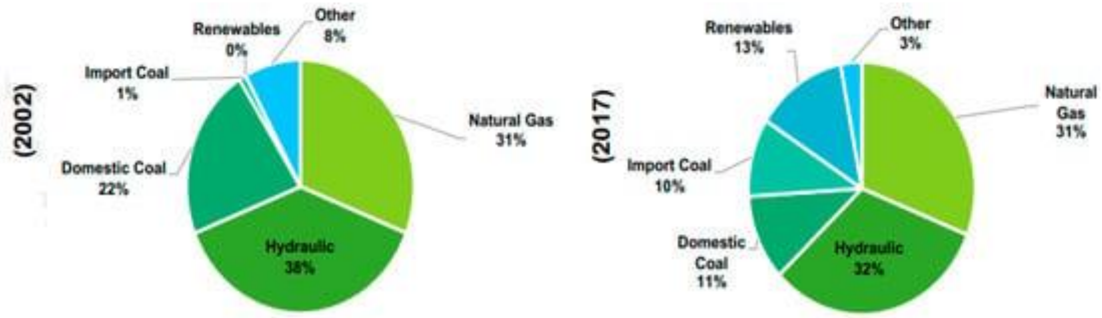


Figure 2. Comparison of installed capacity shares (%) in 2002 and 2017

The total share of renewable energy and hydraulic energy in installed capacity increased from 38% to 45% in 15 years. The rate of renewable energy rose from 0% to 13%. Besides, renewable energy sources (RES) have played a great role in reducing global warming and climate change concerns. The only way to reduce greenhouse gases that result from the energy production process of fossil fuels and cause climate change and pollutant emissions is RES. Besides, with increasing population, there is a growing energy demand in every region of the world. Current energy sources are not sufficient to meet this energy need. Therefore, more economical and clean energy source options should be found and preferred. Sources such as oil, natural gas, coal, and nuclear energy are considered fossil energy sources, while wind, sun, biomass, hydraulics, geothermal, wave, and hydrogen energy are described as RES [4]. At this point, RES can be offered as a solution to this energy demand. Turkey's national action plan for energy contains significant topics such as energy supply safety, diversified energy sources, usage of local energy resources to supply extra worth to economy, independent energy markets, and high energy yield. Therefore, priority is given to the use of local and RES. Growing urbanization, favorable demographic propensities, economic enlargement, and increasing per capita GDP are main determinants of energy necessity. Turkey is the world's 17th and Europe's 6th largest economy and with an ever-increasing demand for energy. The sum of investments demanded to encounter the energy necessities in Turkey by 2023 is forecasted to be approximately

USD 110 billion, greater than twice as much as the total investments in the last 10 years. Because of the present improvement in the renewable energy sector and the investor supporter opportunities such as the feed-in tariffs in the many renewable energy subsectors, can be attractive for the local or foreign firms, industries and other companies related with renewable energy. Turkey's energy market is Europe's fastest-growing market. The energy market has a growth rate of 5.1% since 2002 and has a higher growth rate than countries such as Brazil, Mexico, Iran, and South Korea [3].

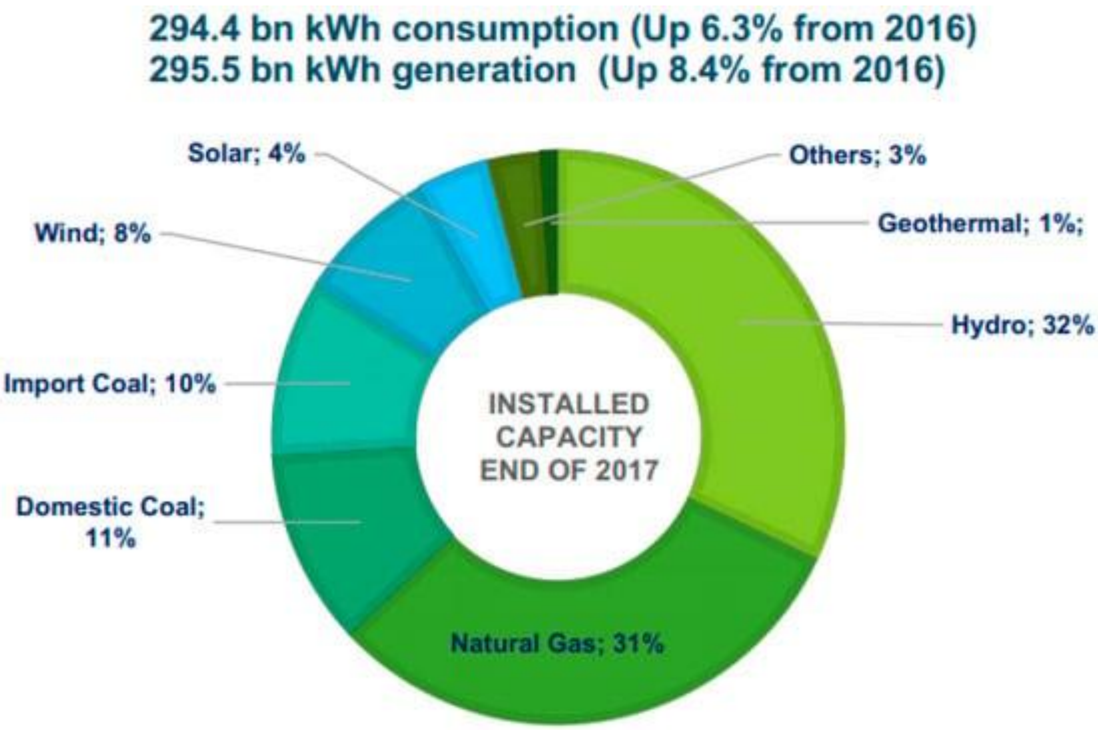


Figure 3. The share of energy resources at installed capacity as of the end of 2017

Energy consumption in 2017 increased by 5% compared to 2016. In 2017, there was an increase of 6.3% with 294.4 bn kWh energy consumption compared to 2016. Also, there was an increase of 8.4% with 295.5 bn kWh energy generation compared to 2016.

Energy demand projection (MW) of geographic regions for years 2017–2024 [5]. By the year 2024, Turkey's energy demands are expected to increase more than 45 percent compared to today.

Table 2. Energy demand projection (MW) of geographic regions for years 2017–2024 [5].

Region	2017	2018	2019	2020	2021	2022	2023	2024
South Eastern Anatolia	2,836,159	2,998,808	3,171,119	3,351,502	3,527,482	3,709,637	3,898,641	4,096,695
Mediterranean	6,882,584	7,277,290	7,695,442	8,133,181	8,560,235	9,002,277	9,460,938	994,156
Eastern Anatolia	154,867	1,637,484	1,731,573	183,007	1,926,163	2,025,628	2,128,833	2,236,979
Central Anatolia	6,459,915	6,830,381	7,222,853	763,371	8,034,539	8,449,434	8,879,928	9,331,034
Aegean	7,522,593	7,954,003	8,411,038	8,889,482	9,356,248	9,839,395	1,034,071	1,086,602
Marmara	1,746,127	18,462,650	19,523,510	2,063,406	2,171,751	2,283,898	2,400,261	2,522,196
Black Sea	3,671,808	3,882,380	4,105,461	4,338,992	4,566,822	4,802,648	5,047,341	5,303,749

3. Examples of the Use of Renewable Energy in Turkey

3.1. Solar Energy

Solar energy is a clean source of energy that is generated directly from sunlight without any harmful gas emissions. Some of the energy generated by the reactions in the sun is the radiation that reaches the earth. The process of converting this radiation into electrical energy by panels defines the solar energy system. The energy is used for cooling, lighting, heating, and other energy requirements [6]. The amount of annual insolation time is 2.737 h (a total of 7.5 h per day). Besides, the amount of solar energy generated annually is 1.527 kWh/m^2 per year (total 4.2 kWh/m^2 per day). The average solar radiation amount is 1500 kW/m^2-year [3]. When analyzed on a regional basis, the Black Sea region is the most inefficient region, while Southeast Anatolia is the most productive region. The second most efficient region in the production of solar energy is the Mediterranean Region. Photovoltaic generators are convenient for all regions apart from the Eastern Black Sea Region. Turkey is among the largest developing solar markets. By the year 2018, the amount of installed solar collector area in Turkey is calculated as almost 20,200.000 m^2. By using solar collectors in 2018, heat energy which is equivalent to approximately 876,720 TEP tons of petroleum was generated. About 600,000 TEP of heat energy was used in dwellings and 276,000 TEP was used for industrial aims. By the end of September 2018, the energy amount of 5868 solar energy plants was calculated as 5063 MW in December 2018. The share of total electricity production in Turkey increased to 2.5% with 7.477.3 GWh. Construction of a 1000 MWe capacity solar power plant in Konya-Karapınar that will be one of the world's largest solar power plants is underway [7].

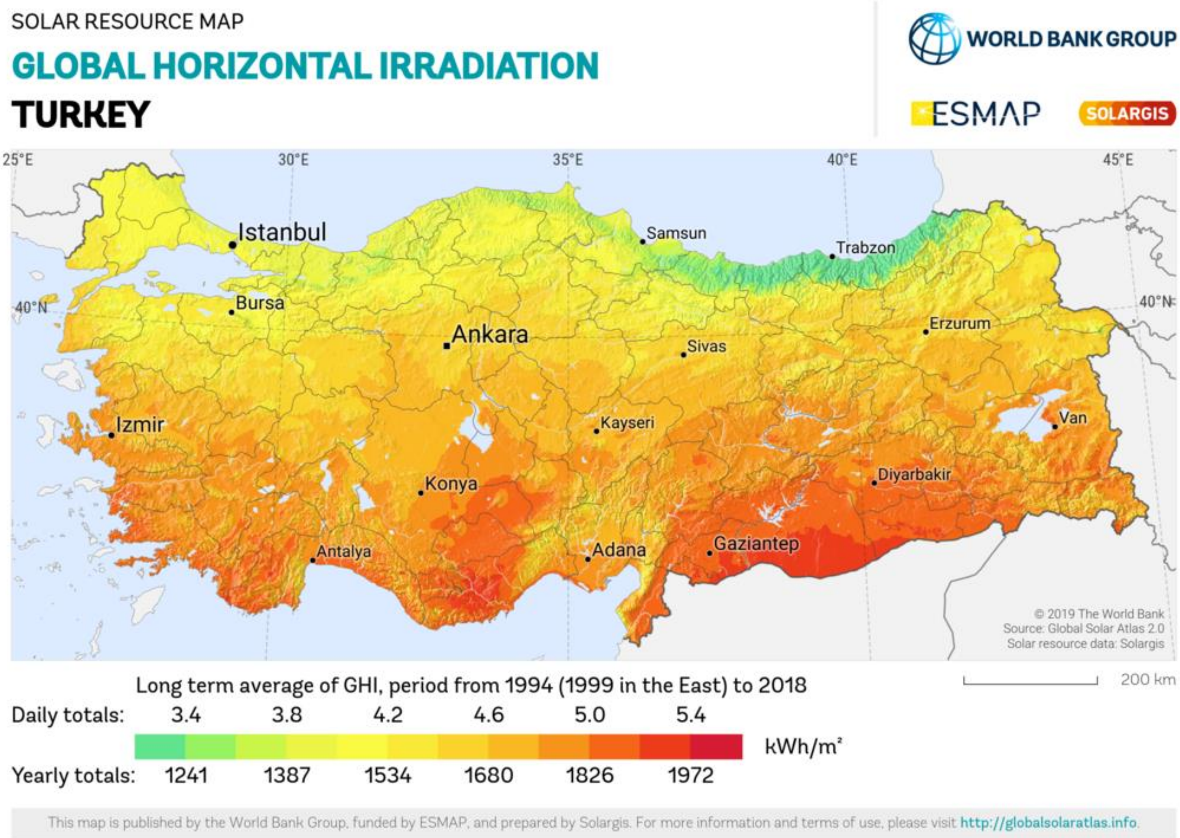


Figure 4. Solar Energy Map of Turkey

3.2. Wind Energy

Wind energy is a natural, renewable, clean, and endless power and its source is the sun. It is derived from the collision of air masses with distinct temperatures and electricity is generated by wind turbines [1]. Turkey's wind energy capability is forecasted as 48,000 MW. The entire area suitable to this capacity is approximately % 1.3 of Turkey's area. Besides, wind energy generation amount was calculated as 19,882 GWh in 2018 and the established potential of active wind energy plants has been determined as 7005 MW [7]. An 11GW reserve is estimated from the present projects. In addition, Turkey aims to reach a 20 GW wind energy potential in 2023 [8].

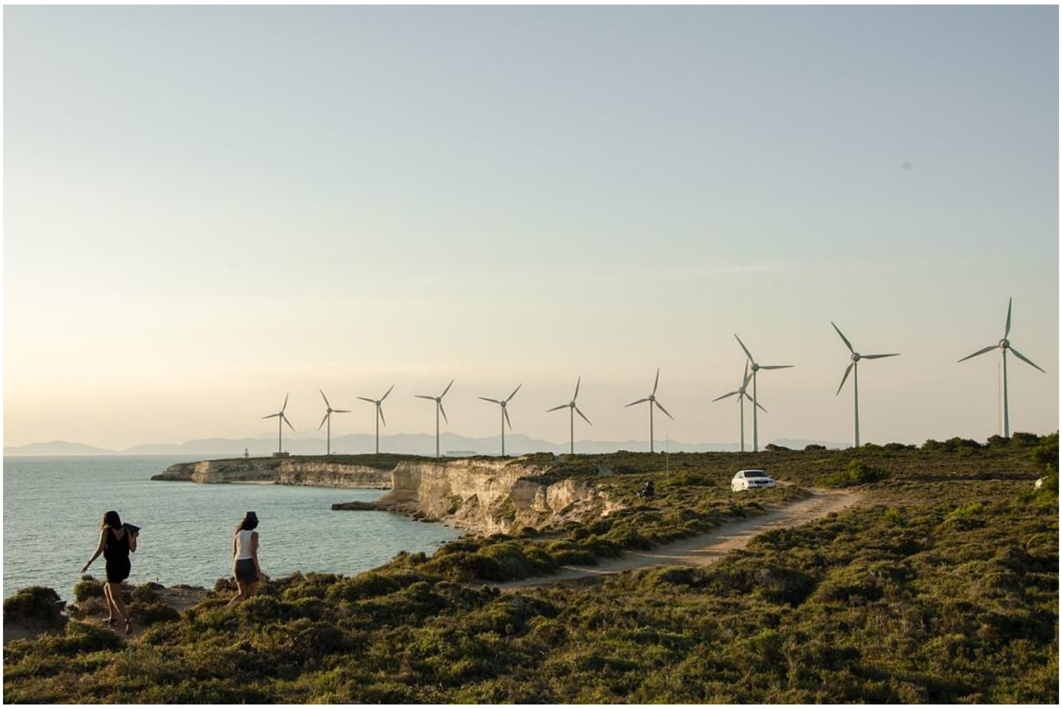
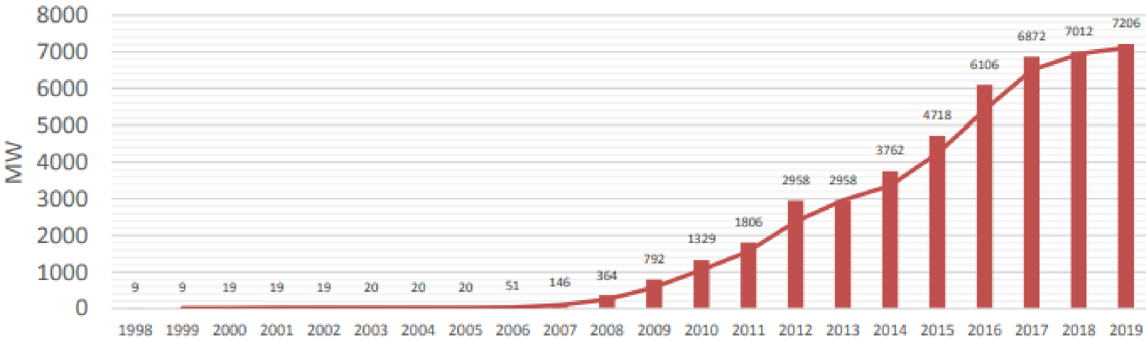


Figure 5. Wind turbines on Gökçeada Island, Çanakkale Province



Graph 1. Installed Capacity of Wind Power Plants by Years (MW)

3.3. Geothermal Energy

Geothermal energy is the internal temperature of the earth. This temperature spreads out from the central torrid zone towards the earth surface. Steam and warm water reservoirs beneath the Earth's surface have huge potential as a renewable energy source (RES) [9]. Turkey is also among the top five countries in the world in the use of these resources directly. Despite obtaining an unsatisfactory amount of electricity production from geothermal energy, Turkey has the second largest geothermal energy capacity in Europe. The country is the third largest geothermal energy market in Europe. The top 5 countries in geothermal heat and thermal water services are the

USA, Philippines, Indonesia, Turkey, and New Zealand. The nations with the highest amounts of geothermal energy-producing potential in 2016 were;

- United States (3.6 GW)
- Philippines (1.9 GW)
- Indonesia (1.6 GW)
- New Zealand (1.0 GW)
- Mexico (0.9 GW)
- Italy (0.8 GW)
- Turkey (0.8 GW)
- Iceland (0.7 GW)
- Kenya (0.6 GW)
- Japan (0.5 GW) [10].

Theoretically, Turkey's geothermal potential is 31,500 MW. 78% of these geothermal areas are located in Western Anatolia, 9% in Central Anatolia, 7% in the Marmara Region, 5% in Eastern Anatolia and 1% in the other regions. 90% of geothermal sources are low and moderate temperature and are convenient for heating, thermal tourism, minerals production, etc. and 10% is appropriate for electric energy generation. 55% of the geothermal fields in Turkey are appropriate for heating applications. Geothermal energy potential grew five times in five years. The 165 MW Kizildere geothermal energy plant was established in 2017. Turkey has 2 GWe potential in 25 reserves. By June 2015, a total of 28 plants with a potential of 654.67 MW were licensed and 431 MW was under process. After Turkey had opened 10 plants in 2015, the country constructed at least extra 10 new geothermal power plants in 2016, increasing the capacity by approximately 200 MW for a total of 821 MW. Turkey has maintained a fast increase in electricity produced from geothermal energy; production grew 25% in 2016 alone, to 4.21 TWh [11]. Also, the installed capacity of geothermal energy was 14.06 GWe in 2017

Figure 6. Kızıldere geothermal power plant in İzmir Province

3.4. Hydroelectric Energy

The power of flowing water is converted into electrical energy by hydroelectric power plants. Hydroelectric power plants are considered positively because they are environmentally friendly and have low risk potentials. Turkey has 1% of the world theoretical hydroelectric potential, and its economic potential is 16% of Europe. Furthermore, Turkey has 433 billion kWh hydroelectric RES potential and technically its consumable potential is 216 kWh. Also, the economic potential is 140 billion kWh/year. By the end of 2013, there were 467 hydroelectric power plant with a total power of 22.289 MW. This corresponds to 34.8% of the total potential. The hydropower capacity grew over 0.8 GW in 2016, so the total installed capacity was 26.7 GW. After an obvious improvement in production in 2015, hydropower amount remained stable in 2016, at 66.9 TWh. [12]. In 2017, Turkish hydropower consumption was equivalent to roughly 13.2 million metric tons of oil, Turkey was the eighth most rapidly developing hydro market in 2017 with 0.6 GW installations, and the country surpassed Japan and France.

Figure 7. Atatürk Dam, part of the Southeastern Anatolia Project, is the largest hydroelectric energy source in the country.

3.5. Biomass Energy

Biomass may be interpreted as the entire quantity of existing organisms that belongs to a society makes up of species. Biomass is described as an organic carbon. Active biodiesel potential is 160,000 tons in Turkey. Total waste from forests is 4,800,000 Tons (1.5 MTOE-600 MW) and from agriculture is 15,000,000 Tons (300 PJ). The amount of biomass capacity in Turkey is equivalent to approximately 8.6 million tons of petrol (MTEP). Also, biogas amounts that may be generated from biomass are 1.5-2 MTEP. In 2018, 3216 GWh electricity was produced from biomass energy plants with a whole installed capacity of 811 MW. It is forecasted that there is almost 1.2 million tons/year biodiesel generation potential and 0.7 million tons/year bioethanol as considering potential 2.7 million hectares of agricultural land. The country has 1.5–2 MTOE biogas capacity. Also, 20 installed biogas plants have approximately 180 million m^3/year biogas generation potential. Moreover, agricultural crops, municipal solid waste, animal manure, and urban waste water treatment sludge are the other biomass resources in Turkey. Agricultural products are recommended for energy production when compared with others [13].

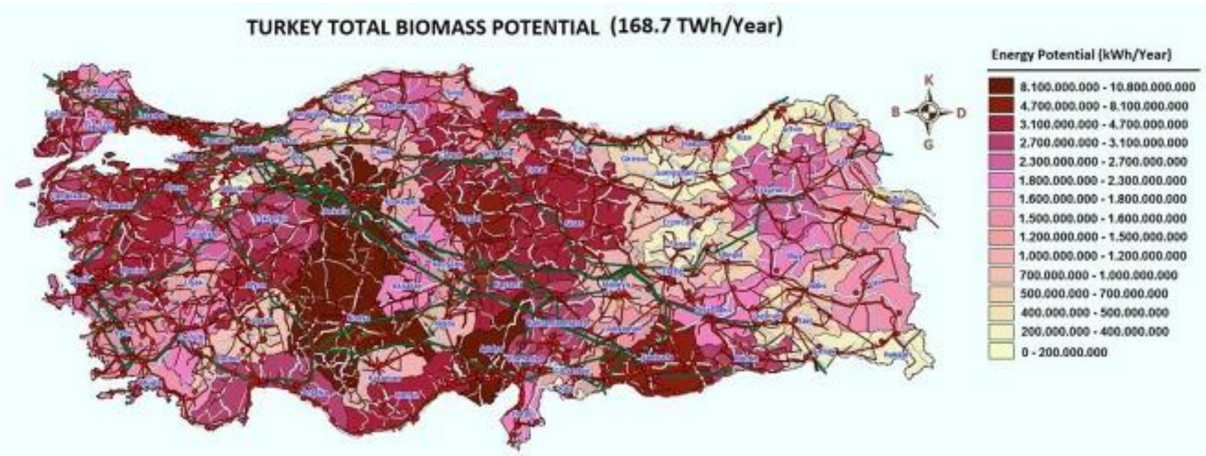


Figure 8. Turkey Total Biomass Potential (kWh/Year)

4. Turkey Renewable Energy Law

Studies carried out by public institutions on the use of domestic and renewable energy resources to meet the increasing energy need have been accelerated. One of the main topics of the plan is “efficient and effective raw material use, raw material supply security” under the natural resource's title in the 2015-2019 strategic plan published by the Ministry of Energy and Natural Resources (MENR). One of the targets within the scope of this plan is “Increasing the share of renewable energy sources in electrical energy supply and researching new sources will be provided.” The article also shows that renewable energy sources are given priority. The ETKB paved the way for projects with high installed capacity. In 2017, YEKA (Renewable Energy Resource Area) GES 1 (1000 MW) and YEKA RES 1 (1000 MW) tenders, in 2019 YEKA SPP 2 (1000 MW) (canceled) and YEKA RES 2 (1000 MW) Significant steps have been taken to increase [1].

Laws on Energy Policy (Date in order from new to oldest).

- Electricity Market Law No. 6446
- Law No. 5346 on the Use of Renewable Energy Resources for the Purpose of Electricity Generation
- 5686 Geothermal Resources and Natural Mineral Waters Law
- Petroleum Market Law No. 5015
- Natural Gas Market Law No. 4646
- With the Build-Operate Model No. 4283, the Establishment and Operation of Electrical Energy Production Facilities and the Energy
- Law on Regulation of Sales

- Law No. 3996 on the Making of Some Investments and Services within the Framework of the Build-Operate-Transfer Model
- Law No. 3154 on the Organization and Duties of the Ministry of Energy and Natural Resources
- Electricity Generation, Transmission, Distribution and Trade of Organizations Except for the Turkish Electricity Authority No. 3096
- Law on Appointment with

5. Renewable Energy Project Development Process

The development of wind and solar projects is an issue that deserves special attention. Choosing the right project locations directly affects the production. Production capacity, on the other hand, is related to the feasibility of the project as it can find financing. In addition, site selection and administrative criteria must be met [1].

5.1. Project Development Process for Wind Energy

In order to develop a wind power plant project, apart from the meteorological data of the region (wind speed, direction, temperature, humidity, pressure), topographic data, roughness maps (land use) are required. Meteorological data (wind speed and direction, temperature, pressure and humidity) measured in IEC (International Electro technical Commission) standards for at least one year in the region where the power plant is planned to be established are important for detailed energy production calculation work. Full years of data are needed to capture the wind pattern of the region (12 months and multiples). This data is compared with the long-term meteorological data and the production calculation required for the investment plan is made. While making the power plant plan, its suitability for construction is also taken into consideration. With the development of technology, turbine installed powers increase, while blade and tower dimensions are constantly increasing. Likewise, the turbine foundation and the platform area should be designed in accordance with the selected turbine model and wind regime (load) specific standards. Administrative and environmental criteria are also seriously examined in wind farm design. The flora and fauna of the region are researched by preparing environmental impact assessment reports, and observations are made during migration periods throughout the year to determine bird migration routes. Likewise, the distance of the power plant to the residential areas, the ownership status of the areas, the class of use (such as pasture, forest, agricultural land), their suitability for the zoning plan, their proximity to nature and natural areas, their proximity to archaeological sites and historical monuments, mines and DSI (State Hydraulic Works).) irrigation areas, proximity to dams and basins, and mining areas are taken into account, and the power plant layout is designed.

5.2. Project Development Process for Solar Energy

Technical criteria such as latitude, topography, slope, aspect, meteorological data should be carefully reviewed while developing a solar power plant project. Using all of these data appropriately, the solar potential can be calculated accurately. In addition, administrative criteria such as settlement, transportation, protection areas, touristic areas, agricultural quality of the area, property information, suitability according to the zoning plan should also be considered. Finally, with the compliance of all these criteria, financing service can be obtained and the project can be started actually.

6. Example of Renewable Energy Application in Turkey

6.1. Solar Energy

Karapınar YEKA-1 SPP is located in Karapınar district of Konya. The power plant belonging to Kalyon Holding Energy Group company is Turkey's 30th and Konya's largest power plant with an installed power of 756.05 MWe. The facility is also Turkey's largest Solar Power Plant. The power plant has only been partially commissioned and when the production starts at full capacity, the installed power will be 1,000 MWe. Kalyon PV brand photovoltaic solar panel was used in GES. Karapınar YEKA-1 SPP, with an average of 724,159,797 kilowatt-hours of electricity production, can meet all the electrical energy needs of 199,383 people in their daily lives (such as housing, industry, metro transportation, government offices, environmental lighting). Karapınar YEKA-1 SPP produces electricity that can meet the electrical energy needs of 242,437 residences when only residential electricity consumption is taken into account.

The land with an area of 27 million 186 thousand 31 m2, which was declared as a Renewable Energy Resource Area (YEKA) in the Karapınar district of Konya, is referred to as the "Karapınar Energy Specialized Industrial Zone 1st Section". The solar power plant with a total power of 1,500 MWe to be installed in Section 1 will be installed in two stages, the first of which will have an installed capacity of 1,000 MWe and the other 500 MWe. On the other hand, the 2nd Section in the Karapınar YEKA area has an area of 32 million 400 thousand 845 m2 and it is aimed to install a SPP with a power of 1,800 MWe in this area. When all businesses are activated, the total installed power in this region of Karapınar will reach the level of 3,300 MW and it will be the world's largest solar power plant region with May 2021 data.

With the 1,000 MWe solar power plant to be established in Karapınar YEKA 1-1, approximately 2 thousand GWh of electrical energy will be produced annually. This amount of energy corresponds to 0.6 percent of the total energy consumed in Turkey as of 2021, and 24 percent of the total annual consumption of Konya. With the commissioning of the facility, almost all of the energy consumed in Konya at noon will be met from this power plant, and there will also be energy flow to the surrounding provinces via transmission lines on the interconnected system.

The balanced distribution of power plants throughout the country significantly reduces the technical losses in the transmission line, which results in an efficiency increase of 1-2% [15].

Figure 9. Karapınar YEKA-1 SPP

6.2. Wind Energy

Soma Wind Power Plant - WPP is located in Soma district of Manisa. Soma Enerji Elektrik Üretim A.Ş., which is a subsidiary of Polat Enerji. Operated by the power plant, with an installed capacity of 288.10 MWe, it is the 67th largest power plant in Turkey and the third largest in Manisa. The facility is also Turkey's largest Wind Power Plant. 181 Enercon wind turbines were used in the RES. With an average of 611,160,912 kilowatt-hours of electricity production, Soma Wind Power Plant can meet all the electrical energy needs of 168,271 people in their daily lives (such as housing, industry, metro transportation, government offices, environmental lighting). Considering only the residential electricity consumption, the Soma Wind Power Plant produces electricity that can meet the electrical energy needs of 204,607 houses [15].

Figure 10. Soma Wind Power Plant – WPP

6.3. Geothermal Energy

Kızıldere 3 Geothermal Power Plant is in Sarayköy district of Denizli. Zorlu Doğal Elektrik Üretimi A.Ş., a subsidiary of Zorlu Energy, Operated by the power plant, with an installed capacity of 165 MWe, it is Turkey's 97th and Denizli's third largest power plant. The facility is also Turkey's largest Geothermal Power Plant. Kızıldere 3 GPP can meet all the electrical energy needs of 224,452 people in their daily lives (such as housing, industry, metro transportation, government offices, environmental lighting) with an average of 815,209,117 kWh electricity production. Kızıldere 3 GPP produces electricity that can meet the electrical energy needs of 272,919 residences when only residential electricity consumption is taken into account [15].

Figure 11. Kızıldere 3 Geothermal Power Plant

6.4. Hydroelectric Energy

It is planned to produce 1 billion 888 million kilowatt-hours of electricity annually with Yusufeli Dam, which will be built on the Coruh River and will rank 7th in the list of the highest dams in the world with its body height of 270 meters and will have an installed capacity of 540 MWe. This production amount corresponds to 7 per thousand of Turkey's electricity consumption.

Yusufeli Dam, with a storage capacity of 2 billion 130 million m3, has the highest storage capacity among the HEPPs that are in operation or to be established on the Coruh River. The storage capacity of the dam corresponds to approximately 30% of the annual flow of the Coruh River. With this feature, the energy production efficiency of the four dams located at the lower elevations of the Yusufeli Dam will also increase.

With the impoundment of Yusufeli Dam, Yusufeli town center and 3 villages will be flooded. For this reason, the works to relocate the Yusufeli district with a population of approximately 20 thousand continue [15].

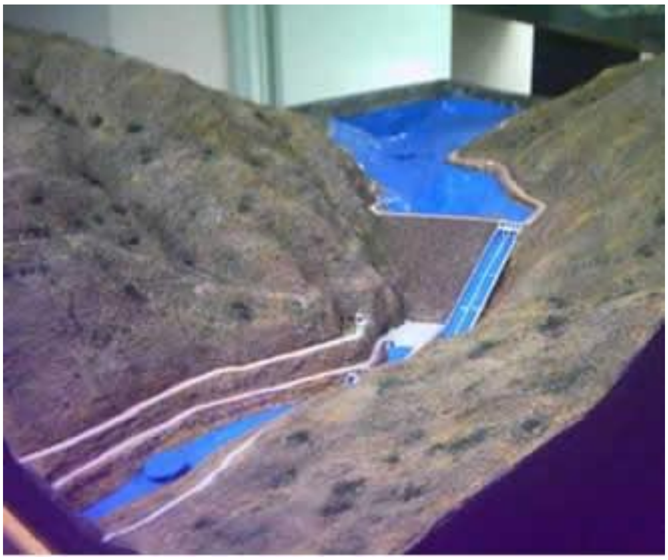


Figure 12. Yusufeli Dam

6.5. Biomass Energy

Odayeri Landfill Gas Plant - Biogas It is located in the Odayeri region of Eyüp district of Istanbul. The power plant belonging to Ortadoğu Energy company is Turkey's 377th and Istanbul's 14th largest power plant with an installed power of 33.81 MWe. The facility is also Turkey's 4th largest Biogas Facility. Odayeri Landfill Gas Power Plant can meet all the electrical energy needs of 68,090 people in their daily lives (such as housing, industry, metro transportation, government offices, environmental lighting) with an average of 247,302,876 kilowatt-hours of electricity production. Odayeri Landfill Gas Power Plant produces electricity that can meet the electrical energy needs of

82,793 residences when only residential electricity consumption is taken into account [15].

Figure 13. Odayeri Landfill Gas

Conclusion

The paper detailed energy targets and opportunities within the framework of the 2023 strategic plan in the introduction and alternatives sections. The need for energy in Turkey until 2023 is expected to increase between 4–6 percent annually, so Turkey aims to increase the capacity of RES energy to 30 percent by 2023. The estimated energy investment will be approximately 110 billion dollars up to 2023. Therefore, Turkey is a significant market for companies and investors operating in the energy sector. Turkey has great potential with respect to RES. Wind and solar energies are at the top of the Turkish renewable energy market and they have become attractive for local and foreign investors since 2010, because many positive regulations and incentive plans came into force. The paper also aims to inform all local or foreign investors related to energy and especially RES. At this point, the site selection for energy investment is very important problem. In this study, multi-criteria decision making (MCDM) method was applied to decide on the most appropriate renewable energy sources based on seven geographical regions in Turkey. The proposed convenient renewable energy sources (RES) for electricity production in Turkey are solar, hydroelectric, wind, biomass, and geothermal power. The Mediterranean region is identified as the most suitable geographical region for renewable energy, and the ranking is Mediterranean, Central Anatolia, Southeastern Anatolia, Aegean, Marmara, Black Sea, and Eastern Anatolia respectively. The Mediterranean region is suitable for all renewable sources. According to the final result, solar and biomass energy for Central Anatolia region; solar and hydroelectric energy for the Southeastern Anatolia; solar and biomass energy for the Eastern Anatolia regions; wind and geothermal energy for the Aegean; geothermal, wind, and biomass energy for the Marmara; and hydroelectric energy for the Black Sea are recommended.

The way of using and generating energy should not cause a negative effect on society's health and environment. We should stop ignoring or avoiding environmental problems. It is required that policy makers compose a strategy to stimulate the larger use of renewable resources. Accelerating support of research and development, education, and public consciousness will help to carry out renewable energy goals. There are endless, fresh, and unused resources at our fingertips. The economy and simplicity of fossil fuels should not blind us to the truth that they are a seriously finite source, and damaging to our ecosystem. With the support of renewable energy resources such as hydroelectric, solar, wind, geothermal, and biomass, we may move towards a sustainable world.

References

[1] https://obs.hkmo.org.tr/show-media/resimler/ekler/534254789aea533_ek.pdf

[2] World Data. Turkey Energy Consumption. Available online: https://www.worlddata.info/asia/turkey/energy-consumption.php

[3] MENR. Strategic Plan. Available online: www.enerji.gov.tr/tr-TR/Stratejik-Plan

[4] Şengül, Ü.; Eren, M.; Shiraz, S.E.; Gezder, V.; Şengül, A.B. Fuzzy TOPSIS method for ranking renewable energy supply systems in Turkey. Renew. Energy 2015, 75, 617–625.

[5] Aksoy, A. Integrated model for renewable energy planning in Turkey. Int. J. Green Energy 2019, 16, 34–48.

[6] Kabak, M.; Dağdeviren, M. Prioritization of renewable energy sources for Turkey by using a hybrid MCDM methodology. Energy Convers. Manag. 2014, 79, 25–33.

[7] MENR. Solar Energy Report. Available online: https://www.enerji.gov.tr/en-US/Pages/Solar

[8] Reve. Turkey Aims to Add 20 GW of Wind Energy, 5 GW of Solar Energy and 1 GW of Geothermal Energy by 2023; Reve: Madrid, Spain, 2015.

[9] Kahraman, C.; Kaya, İ. A fuzzy multicriteria methodology for selection among energy alternatives. Expert Syst. Appl. 2010, 37, 6270–6281.

[10] REN21. Renewables Global Status Report; REN21 Secretariat: Paris, France, 2017.

[11] Ruggero, B. Perspectives for Geothermal Energy in Europe; World Scientific: Singapore, 2017.

[12] Melikoglu, M. Pumped hydroelectric energy storage: Analysing global development and assessing potential applications in Turkey based on Vision 2023 hydroelectricity wind and solar energy targets. Renew. Sustain. Energy Rev. 2017, 72, 146–153.

[13] Cebi, S.; Ilbahar, E.; Atasoy, A. A fuzzy information axiom based method to determine the optimal location for a biomass power plant: A case study in Aegean Region of Turkey. Energy 2016, 116, 894–907.

[14] Tasri, A.; Susilawati, A. Selection among renewable energy alternatives based on a fuzzy analytic hierarchy process in Indonesia. Sustain. Energy Technol. Assess. 2014, 7, 34–44.

[15] https://www.enerjiatlasi.com/

Chapter 4

Renewable Energy Sources in North Macedonia

Potential, uses, policies

1. Renewable energy policies

As part of the EU harmonization process, the Macedonian Parliament adopted the new Energy Law in May 2018 ("Energy Law") which harmonized the energy legislation of North Macedonia with the EU Third Energy Package. To implement the provisions of the Energy Law, appropriate secondary legislation has been adopted. The purpose of the new law was to create an effective legal framework for cooperation, mutual reporting and coordination of the activities of the competent authorities of North Macedonia with the relevant institutions of the European Union Energy Community.

Also, the Energy Law set the foundations for stability, competitiveness, and economic functionality of the energy sector. As a priority, the Energy Law fostered the promotion of renewable energy sources (RES) and encouraged energy efficiency. This, in a short time, has contributed to increased investments in the field of renewables.
As the Government has a strategic goal to invest in renewables, it regulates supportive measures such as the Energy Law, to help electricity producers that use renewables and looks to assist investors hoping to obtain the status of privileged power producer. For the first time, the privileged power producer may now obtain the right to use premiums, alongside the existing option to use the feed-in tariffs. The premiums can be awarded to privileged energy producers producing energy from wind power plants and photovoltaic power plants only. [1]

The Law on Energy ("Official Gazette of the Republic of Macedonia" no. 96/18) [1] determines the adoption of the following bylaws, which refer to preferential electricity producers from renewable energy sources:
1) Decree on the measures for supporting electricity production from renewable energy sources, by the Government of the Republic of North Macedonia in accordance with Article 187 paragraph (3) of this law,
2) Decision on the installed capacity of preferential electricity producers, by the Government of the Republic of North Macedonia in accordance with Article 187 paragraph (4) of this law,
3) Rulebook on Renewable Energy Sources, by the Ministry of Economy, in accordance with Article 185 of this law, and
4) Rulebook on Preferential Producers that Use Preferential Tariff by the Energy Regulatory Commission, in accordance with Article 191, paragraph (1) of this law.

Based on the Energy Law and the Energy Development Strategy of North Macedonia until 2040 ("Strategy"), the ultimate goal is to significantly increase the use of RES sustainably, to a point where renewables make up 45% of total energy consumption by 2040. Also, it is expected that photovoltaic and wind power plants will be the fastest growing technologies for electricity production in all scenarios (up to 1,400 MW for photovoltaic and 750 MW for wind).

In 2019, the Government adopted the Decree on Support Measures for Electricity Production from RES ("Decree"), which regulates the conditions and manner for determining the Premiums and Feed-in Tariffs.

To further improve the conditions for large investments in general, particularly for foreign capital, the Parliament of the North Macedonia in January 2020 adopted the

Law on Strategic Investments of North Macedonia (SIL). With this opportunity, potential investors in RES could initiate a large investment cycle in the country.
Furthermore, pursuant to SIL, the Government in May, 2020 announced a Public Call for submission of a request for determining the status of a strategic investment project (SIP).

2. Sources of renewable energies

North Macedonia's state-owned power company was unbundled and partially privatized in the early 2000s. Austrian utility company EVN has been responsible for electricity distribution in North Macedonia since entering the market in 2006. State-owned MEPSO (Makedonski Elektronprenosen Sistem Operator) is the country's electricity transmission system operator, while ESM (Elektrani na Severna Makedonija/Power Generation Plants of North Macedonia; formerly ELEM) is North Macedonia's state-owned electricity producer. [2]

The electric power production system in North Macedonia consists of two coal power plants with a total installed capacity of 825 megawatts (MW), several hydro power plants with a total installed capacity of 695 MW, one combined generation power plant, a heavy oil plant, a few solar power plants, a few biogas plants, and one wind power farm. The two coal power plants produce approximately 55 percent of the country's annual electricity consumption.
In 2020, North Macedonia recorded energy dependencies of more than 50 %, more precisely 63.3 %. Despite some investments in regular maintenance and minimal modernization, domestic production of electricity decreased by more than 25 percent over the last ten years, and electricity imports in 2021 reached 33.2 percent of total use.

According to the data of the State Statistical Office, in July 2022, the total consumption by types of energy commodities was: 525 730 MWh of electricity, 12.592 mil. nm3 of natural gas, 466 130 tonnes of coal and 97 117 tonnes of petroleum products. Gross national electricity production participated with 82.4% in gross national electricity consumption, while 98.3% of the total national consumption of coals were used for generation of electricity. [3]

The share of RES in the total energy supply and consumption in North Macedonia is very small and there is a need to develop the energy sector in that direction.
In the past years, more studies have been done to determine the most suitable locations for the construction of wind power plants in Macedonia, as well as an assessment of the potential wind energy at the respective locations.

ESM owns and operates North Macedonia's only wind farm, a 36.5 MW park in the southern part of the country. It plans to increase capacity with two separate 14 MW investments in the same area. The government also designated a 415 MW wind park project with German company WPD Group as a "strategic investment" in the country's northeast, also some other wind park projects are in process of construction or final approval for construction (more data below).
The renewable energy sources in Macedonia that are mainly used are the hydroelectric power, biomass energy (mainly woods) for the households, geothermal energy for the greenhouses, and small percentage of the solar energy for the households.

Installed capacity and production of electricity from renewable energy sources in 2021 according to technology. [4]

Type of Power Plant	N.of Power Plants	Installed capacity (MW)	Share in the installed Capacity (%)	Production (GWh)	Share in total production (%)
Total	352	2.117	100,00%	5.284	100,00%
HEC	5	1.034	48,85%	2.105	39,84%
TE-TO	3	287	13,58%	1.517	28,71%
Renewable	344	795	37,57%	1.662	31,45%
HEC	10	587	73,76%	1.662	68,12%
VEC	1	36,8	4,63%	103	6,20%
Small HEC	107	119	14,97%	321	19,34%
FEC	220	45	5,69%	51,46	3,10%
Biogas	3	7	0,88%	54	3,25%
Biomass	1	1	0,08%	0	0,00%

Within the total 352 domestic electricity producers, 344 use renewable energy sources. In 2021, 49 new Power Plants using renewable energy sources have initiated operations: 1 Hydro Power Plants and 48 Photovoltaic Power Plants.
The entire electricity produced by the Wind Power Plant VEC Bogdanci, the Biogas Thermal Power Plants, and the Biomass Thermal Power Plants, is purchased by the Electricity Market Operator under preferential tariffs.

3. Examples of communities using renewable energy sources

3.1. Energy efficiency projects in the municipality of Kavadarci

Some of the solar plant parks installed on the territory of the municipality of Kavadarci:

- Solar power plant Garnikovo has a surface of 76.212 m² and power of 0.8MWp.
- Solar power plant Stragovo, Kavadarci, with a power of 2MWp


Figure 1. Solar power plant SPP Garnikovo (source JES Global)
Figure 2. Solar power plant SPP Stragovo (source JES Global)

- Solar power plant SPP Vitac, Kavadarci, with a power of 2MWp
- Solar power plant SPP Marena, Kavadarci, with a power of 0.6MWp


Figure 3. Solar power plant SPP Vitac (source JES Global)
Figure 4. Solar power plant SPP Marena (source JES Global)

The high school 'Gjorche Petrov' in Kavadarci becomes energy efficient with a grant from Kingdom of Norway. [5]

The agricultural and forestry high school ‘Gjorche Petrov’ in Kavadarci has increased its energy efficiency with grant support from the Kingdom of Norway. The completion of the works on the school facade and roof has significantly improved the energy efficiency of the school constructed in 1956, and 290 pupils and employees of the school have benefited from improved working and teaching conditions.

Figure 5. Agricultural and forestry high school ‘Gjorche Petrov’ in Kavadarci

These types of investments that lead to increased energy efficiency are of great importance for the municipality of Kavadarci because they enable savings of public finances and further improvement of the educational process, and also contribute to increased health of the employees and the pupils.

The reconstruction of the school building included installation of an 1,200 sqm of energy efficient thermal-insulation façade and replacement of the 1,500 sqm asbestos roof with new, energy efficient construction. It is expected that these improvements will lead to energy savings of up to 35% of the energy bills and that the savings will be used to further improve the conditions of the school.

Replacement of fossil fuels with vine prunings in Kavadarci municipality

Pilot project “Dobri Daskalov” high school

Municipality of Kavadarci is the largest municipality in Macedonia with vineyards. In Kavadarci region availability of vine residuals is around 20,000 ton/year, one hectare can provide 1,5-2 tons of vine branches.
Vine branches average characteristics:
• heating value 4 MWh/ton with humidity of 25%
• 200-300 kg/m3 density

Figure 6.Mulcher for the collection of pruning residues (source:https://www.nobili.com/trp-rt-rtt/s9caf9640)

The aim of the pilot project is to replace fossil-fuel based heating with heating based on biomass waste from vine pruning in in a public school in Municipality of Kavadarci, and this way assess the potential of a wider use of waste biomass generated by the wine industry, for heating purposes. It is estimated that the volume of biomass generated in the pruning season in Kavadarci, which today is treated as waste, is sufficient to cover the heating demand in all public buildings in the municipality. As Pilot project is taken Gimnasium Dobri Daskalov, where one of the boilers will be replaced with a boiler working on grape residues.

Scope of work

– Switch from oil to biomass fuel in 1 secondary school
- Remove old boiler
- Reconstruction of boiler room
- Install new biomass boiler with feeding system

– Organise production, storage and distribution of biomass (chopped vine branches)
- Capacity building of local government and grape producers
- Obtain establish system for production of biomass fuel
- Value of the biomass

Installation of photovoltaics on 11 public institutions in Municipality of Kavadarci [6]

The Municipality of Kavadarci with its own budget has financed a project for energy efficiency by installing 10 photovoltaic centrals (30 panels on each 30x640w=192kw) on 10 public buildings: Municipality's building, 6 primary schools, 2 high schools and Sports Centre „Jasmin“.

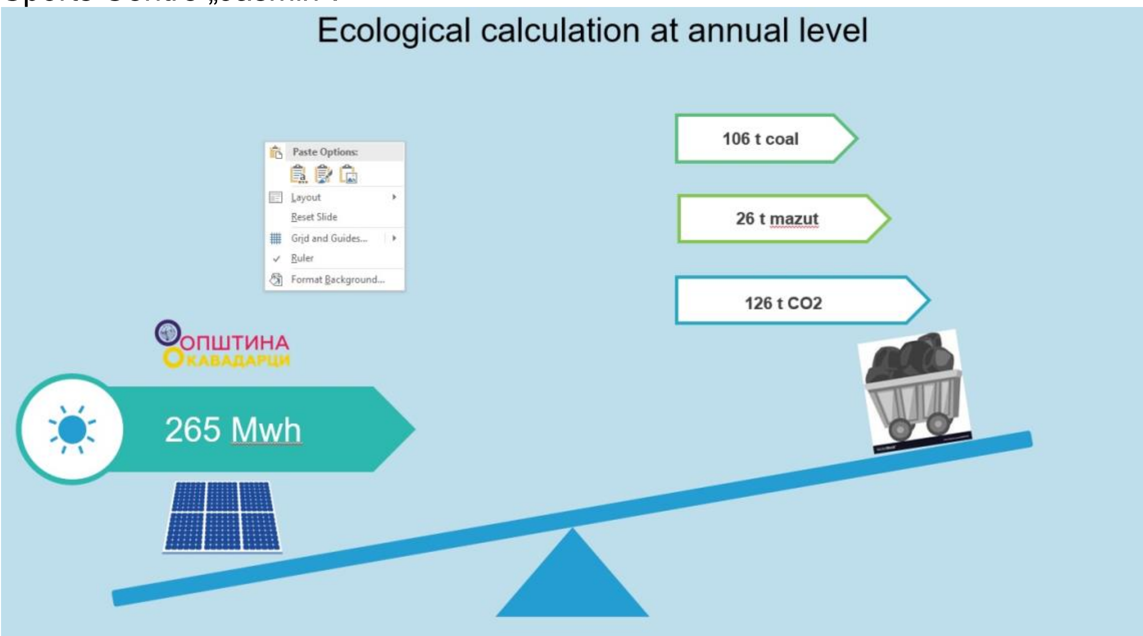


Figure 7. Ecological benefits at annual level from using the 10 photovoltaic centrals

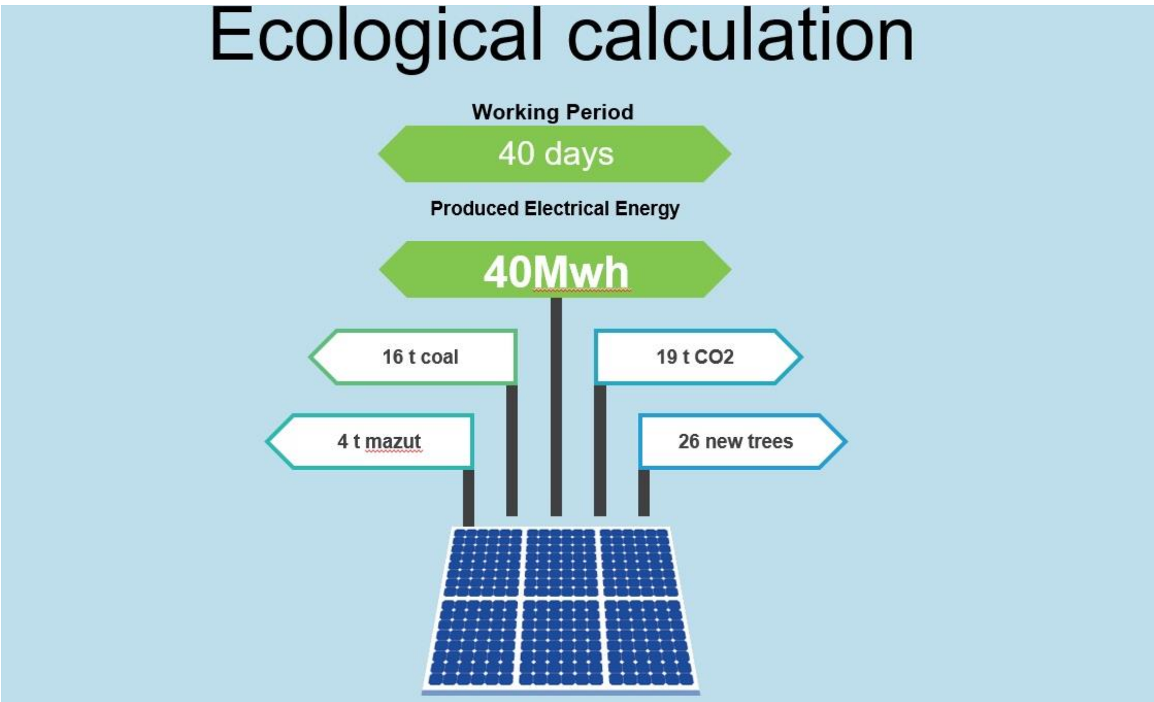


Figure 8. Ecological benefits from using the 10 photovoltaic centrals in a period of 40 days

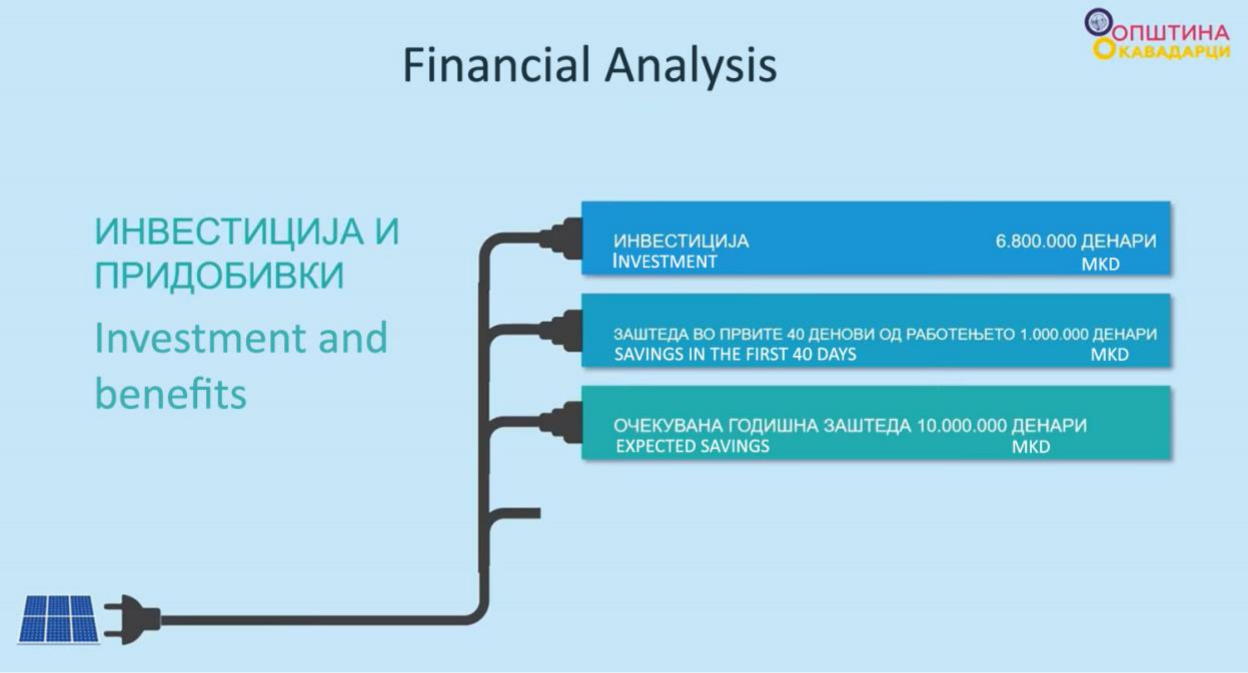


Figure 9. Return of Investment of the 10 photovoltaic centrals in period of the first 40 days of work and at annual level
Source figure 7-9. Documents from the Municipality of Kavadarci

WIND PARKS

Wind Park Bogdanci [7]

Figure 10. Wind Park Bogdanci (source: https://www.esm.com.mk/?page_id=2088&lang=en)

Due to its favorable climatic conditions, Bogdanci was selected as the location of the first wind park in North Macedonia.

In 2008, WBIF supported the development of the feasibility study of this renewable energy infrastructure; the conclusion of this document argued for the implementation of the investment in two phases.

Phase I of the project was completed in March 2014 and has a capacity of 36.8 MW, which supplies green energy for approximately 16,000 households in the south of the country.
The construction of Phase I of the wind park was financed by loans from KfW and the electricity generation company, ELEM (AD ELEM Macedonian Power Plants Elektranina Makedonija). This Phase entailed the installation of 16 wind turbines - with a combined capacity of 36.8 MW - and the construction of a 5.5 km long 110 kV transmission line, a substation and access roads which connect the wind park with the energy network.


Figure 11. Bogdanci Wind Park (source:Wikipedia)

Phase II is ongoing and will add 14 MW in electricity generation capacity to the existing facilities. This wind park proves that renewables are a realistic alternative to conventional energy sources and sets a precedent in North Macedonia that could attract private investments in green energy.

The Public Company ELEM is implementing the second phase of the project in order to increase the total capacity of the wind park up to 50 MW/123 GWh on an annual basis.The Wind Park Bogdanci – phase II has 4 to 6 wind turbines (type SWT 2,3 – 93), each with nominal value of 3 to 4 MW and it will have total installed power of 13,8 MW and nominal annual electricity production of 37 GWh. In addition, the park includes construction of access roads and 20 kV cables.
Savings of the emission of CO_2 of approximately 35.000 t/annually.

Currently, 30% of North Macedonia's electricity demand is covered from imports; therefore, the development of the wind park is crucial for demonstrating that other sustainable sources of energy can reduce the country's dependency on fossil fuels and energy imports. The southeastern part of North Macedonia has a large wind energy potential due to high regular average wind speeds; Bogdanci area is thus classified as a good inland wind site with a high probability of reaching the targeted annual production of electricity. [8]

Wind Park Bogoslovec

Wind Park Bogoslovec is the first project of wind farm in the eastern part of the country in the region of Sv. Nikole and it is the first private wind farm in North Macedonia. The investment is more than 51 million euros, the construction work has started in July 2021 and is expected to start working in the spring 2023. The park is expected to produce green energy in the next 25 years covering the energy needs of 20.000 households. It is a wind power plant of 8 wind turbines with aggregate power of 36 MW. The Park will contribute to decreasing the CO_2 emissions for 87.000t annually. [9]

Virovi wind farm

The Virovi wind farm will comprise 69 wind turbines and will be built between Kumanovo, Staro Nagoričane and Kriva Palanka. The Government of North Macedonia has given the green light to a German wind developer for the 415 MW wind farm worth 500 million euro.The wind farm will produce enough electricity to meet the needs of 290,000 households. [10]

PHOTOVOLTAIC POWER PLANTS

Some of the photovoltaic power plants installed in North Macedonia

The first photovoltaic power plant in North Macedonia that simultaneously produces electricity from the sun and the reflection of light was installed by EVN Macedonia in 2020. It is made of bifacial panels, which also use the reflection from the material placed underneath them, in this case white gravel.

The Oslomej 1 photovoltaic plant, one of the projects from the European Union's Economic and Investment Plan for the Western Balkans, started its test operation in April 2022. The 10 MW facility was built at a former lignite mine belonging to the old thermal power plant of the same name in the municipality of Kičevo in the western part of North Macedonia.

Figure 12. Oslomej 1 solar power plant (source WeBalkans.eu)

Both the coal complex and the solar power unit belong to state-owned electricity utility Elektrani na Severna Makedonija (ESM), which already has one wind park, Bogdanci, and plans to expand it.

North Macedonia has received aid to install three photovoltaic facilities. Oslomej 1, Oslomej 2 and Bitola are going to be located on the site of the exhausted coal mine in Oslomej, and adjacent to the Bitola coal-fired plant.

The Oslomej 1 Solar Photovoltaic Power Plant and Oslomej 2 and Bitola Photovoltaic Power Plants are part of the 21 flagship projects in the Western Balkan region, selected for the EU financing in 2022 through the WBIF. [11]

Other energy efficiency projects

Energy efficient rehabilitation of student dormitories in North Macedonia North Macedonia (2021-2025)

The Project "Energy efficient rehabilitation of student dormitories in North Macedonia" concerns the promotion of energy efficient reconstruction and modernization of selected public buildings in the education sector (state owned Student dormitories) in North Macedonia, specifically the increase of energy efficiency, structural integrity and basic comfort. The project has focus on state owned dormitories in the following cities: Skopje, Prilep, Bitola, Ohrid and Stip. Together with the energy efficient rehabilitation of the buildings and structural strengthening, basic comfort measures will be a substantial part of the project, such as renovation of sanitary installations, renewal of electrical equipment, safety measures, common study rooms, etc. in order to improve the living and learning environment for the students. In addition, renewable energy (e.g. PV or solar thermal energy or biomass) will be used where possible. The overall goal of the project is to contribute to Climate Protection activities through CO2-savings and to contribute to better living and learning conditions for the students.

Figure 13. Student dormitory Goce Delchev (source Wikipedia)

The current rough estimate is that on average the student dormitories in North Macedonia are consuming 290kWh.m2/year (average 2015-2018). After project completion of all measures the student dormitories should reduce their energy consumption by min 30% and/or ideally reach 150kWh/m2/year under the same occupation and utilization circumstances in comparison to the reference year. This would account for approximately 2400 t CO2/year savings.

The aim, beyond energy efficient refurbishment, is to also intervene in the eventual structural issues of the buildings so their lifetime is prolonged and as well, to improve the comfort level for the students. [12]

Energy Efficiency Homes for Low Income Households

Since 2009, Habitat Macedonia has been actively involved in energy efficiency retrofitting of multi apartment buildings. Energy efficient reconstructions have been carried out on more than 60 apartment buildings in Macedonia with over 1900 apartments, resulting in overall annual energy savings of 7910 MWh and annual reductions of CO2 emissions of 3670 t. As a result of Habitat involvement in energy efficiency retrofitting of MAB, several local governments in the Republic of North Macedonia introduced subsidy schemes to support homeowners. Also, microfinance organizations, which are long term partners of Habitat Macedonia, were motivated to develop and promote loans for energy efficiency in housing, reaching more homeowners among vulnerable groups and in rural areas.

Key benefits
The key benefits include subventions from the municipal budget for energy efficiency upgrades of multi-family apartment buildings and the involvement of motivating the Microcredit Foundations to develop and offer loans to vulnerable groups and to homeowners in rural areas.

List of technical measures implemented
• Replacement of windows and balcony doors in apartments
• Installment of thermo façade
• Repair and/or replacement of roofs
• Retrofitting of common spaces in MAB (windows, entrance door, plastering) [14]

References

[1] CMS web page https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/north-macedonia

[2] Law on Energy https://erc.org.mk/odluki/2ENERGY%20LAW%20MACEDONIA%202018%20.pdf

[3] International Trade Association https://www.trade.gov/country-commercial-guides/north-macedonia-energy#:~:text=The%20electric%20power%20production%20system,plants%2C%20a%20few%20biogas%20plants%2C

[4] State Statistical Office of the Republic of North Macedonia

[5] Energy and Water Services Regulatory Commission of The Republic of North Macedonia https://www.erc.org.mk/page_en.aspx?id=395

[6] Nordic Support for Progress of North Macedonia https://www.nordiskapoddrska.org.mk/en/vtext/srednoto-uciliste-orce-petrov-vo-kavadarci-stana-energetski-efikasno-so-grant-od-kralstvoto-norveska

[7] United Nations Economic Commission for Europe (UNECE) https://unece.org/fileadmin/DAM/energy/se/pp/eneff/eneff_feei_Skopje_EE_RE_IntTrainBPlan_June2011/30/04_PP_DobriDaskalov_Kavadarciy.pdf

[8] YouTube channel of local TV station RTK Kavadarci https://youtu.be/8E4C6IwcuJ4 and documents from the Municiplaity of Kavadarci

[9] ELEM https://www.elem.com.mk/wp-content/uploads/2017/04/Windpark_15_EN.pdf

[10] WBIF https://www.wbif.eu/10-years-success-stories/success-stories/north-macedonia-plugs-greener-future-through-wind-power

[11] Balkan Green Energy News https://balkangreenenergynews.com/eu-allocates-eur-339-million-for-clean-energy-environment-projects-in-western-balkans/

[12] WBIFhttps://wbif.eu/storage/app/media/News/2022%20Endorsed%20flagships%20February/WBIF%202022%20Endorsed%20Flagship%20Projects%2024.02.22.pdf

[13] https://euprojects.mk/maps/report/1708

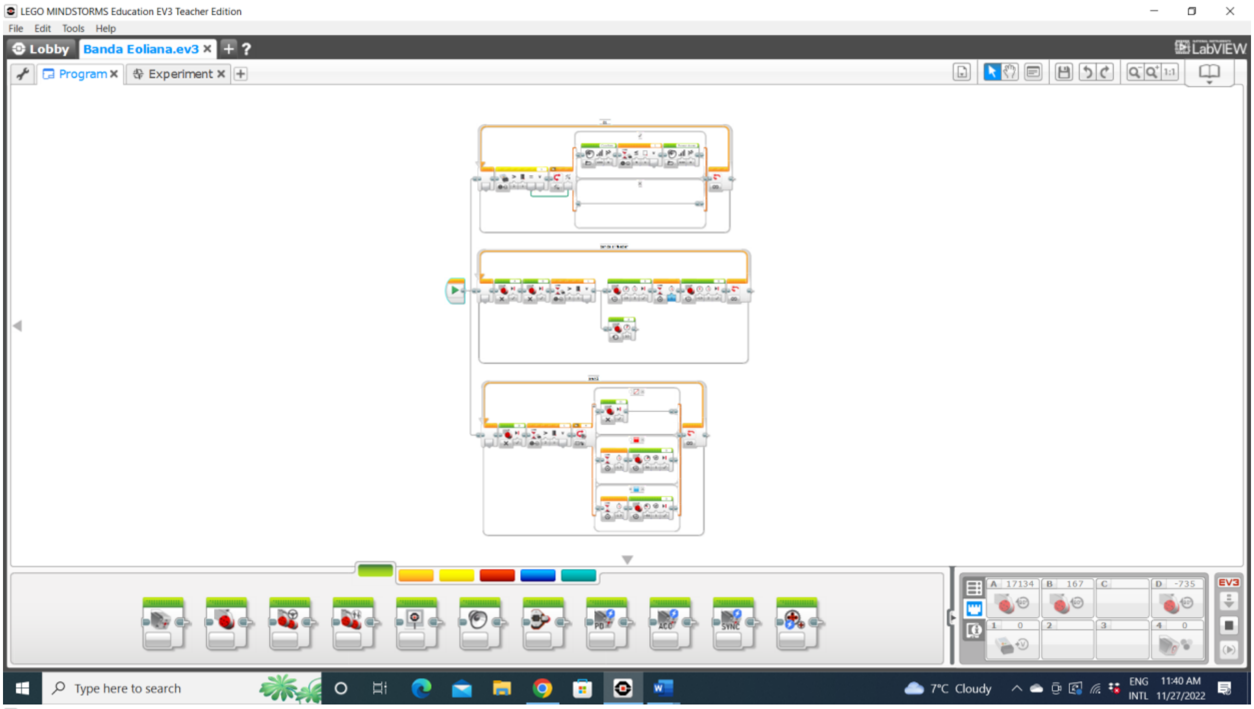
[14] https://mon.gov.mk/en/

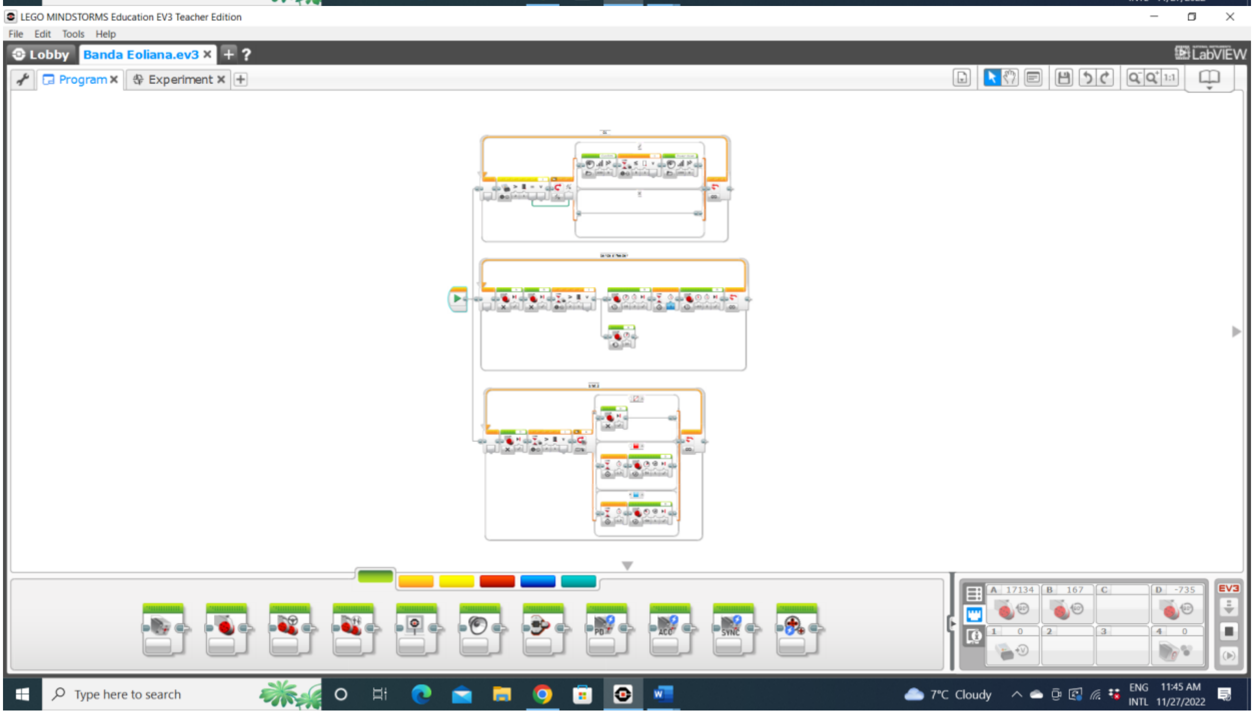
Chapter 5

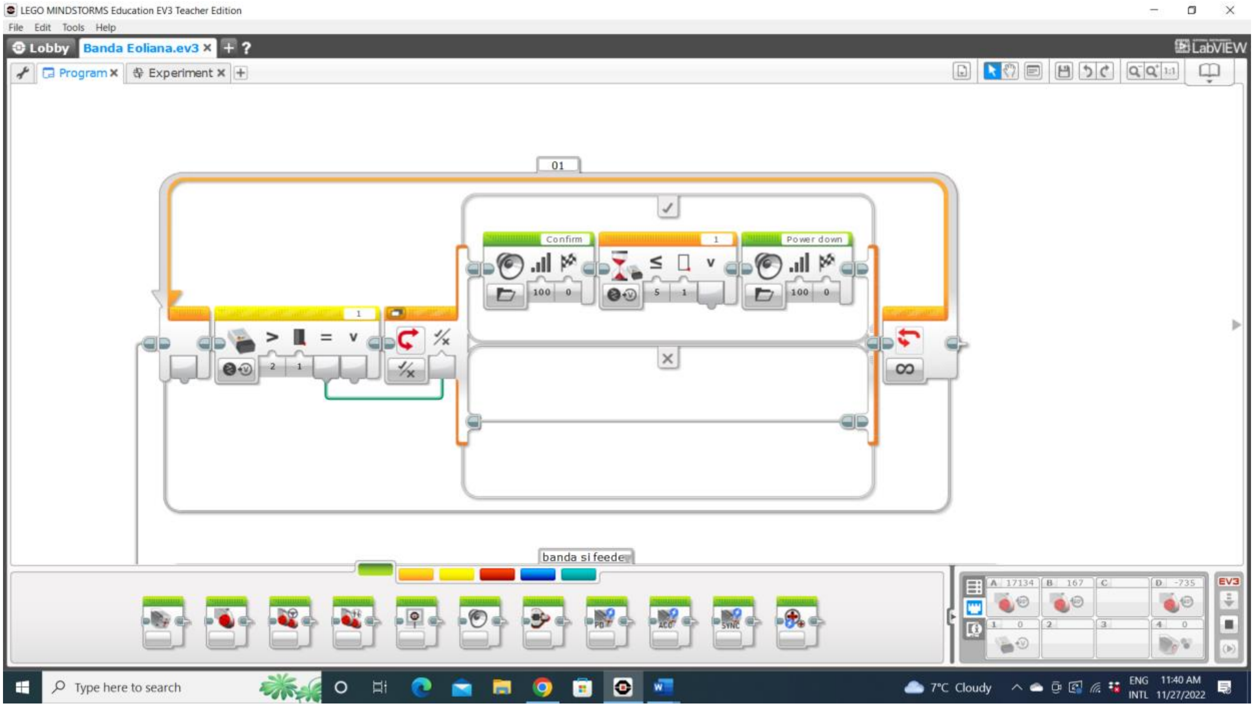
Application using EV3, Lego and Mindstorms programming

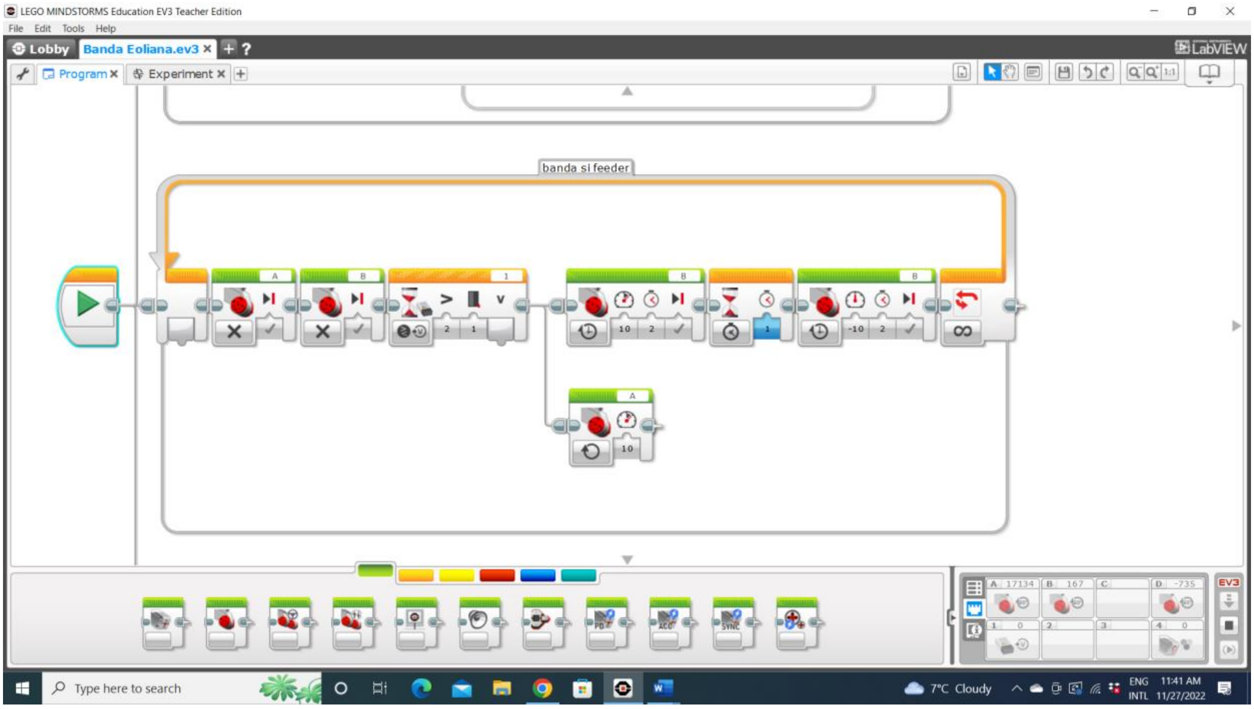
Source Code

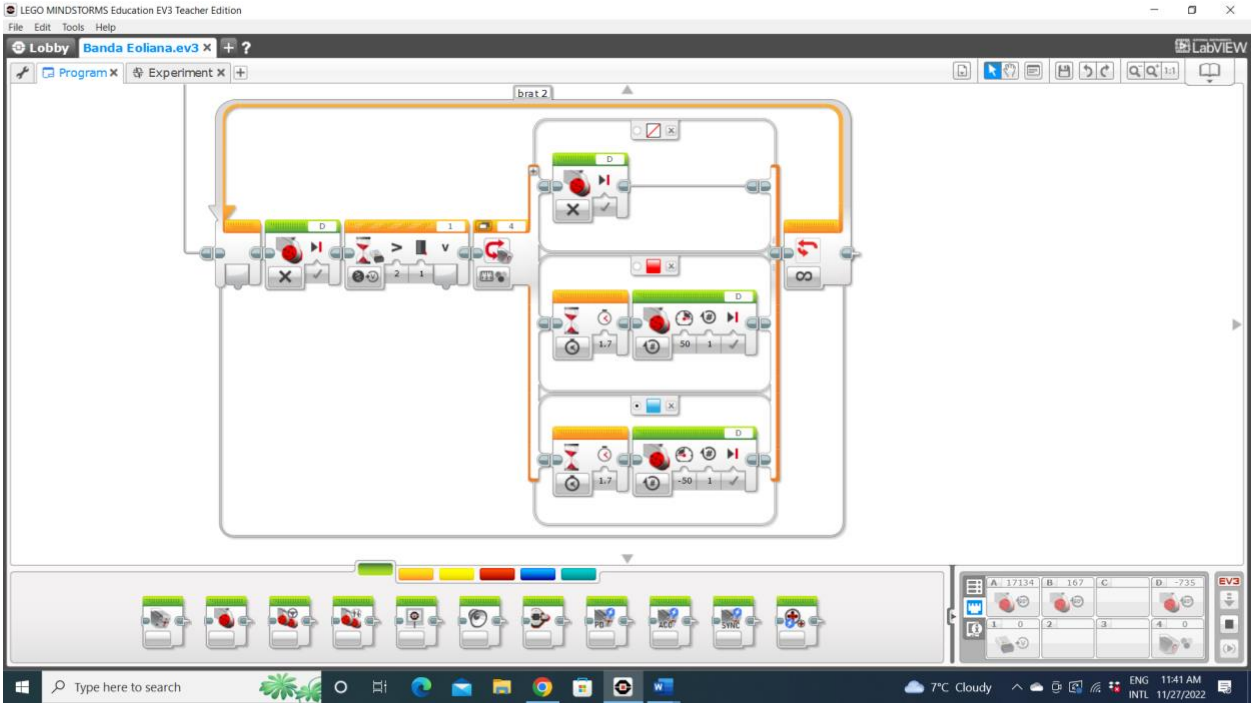
As an application, the team of University Politehnica of Bucharest created a sorting station.

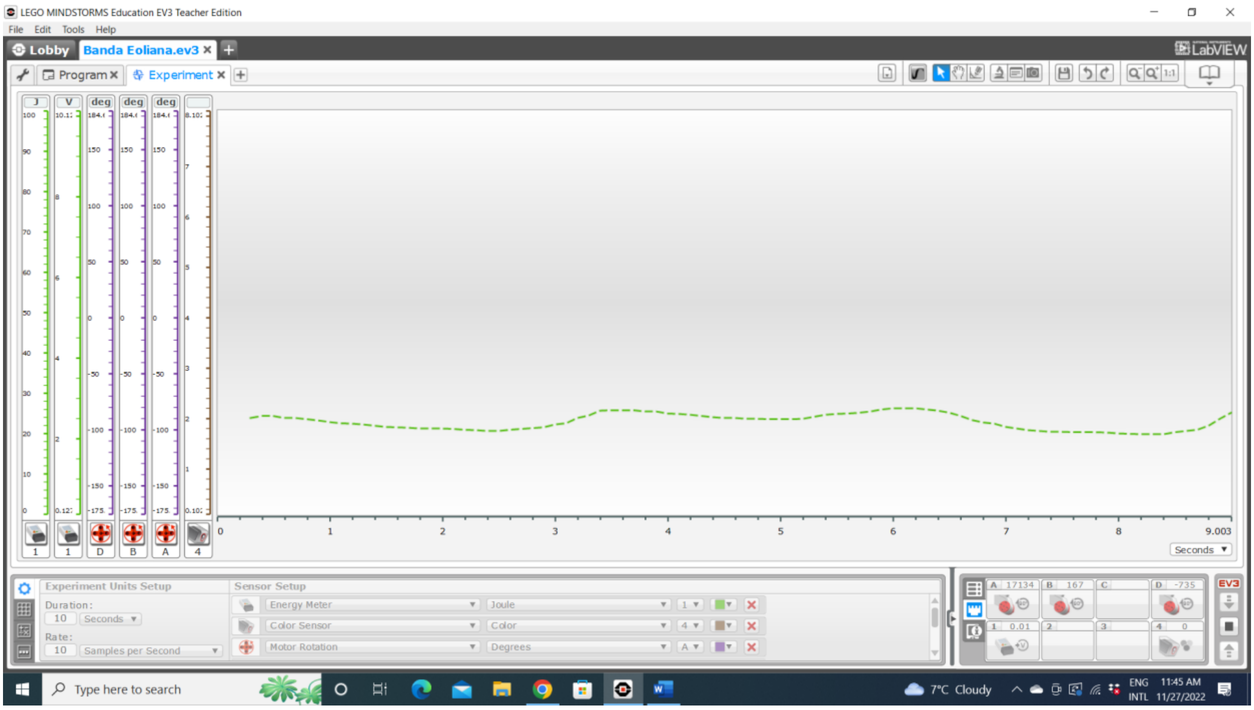


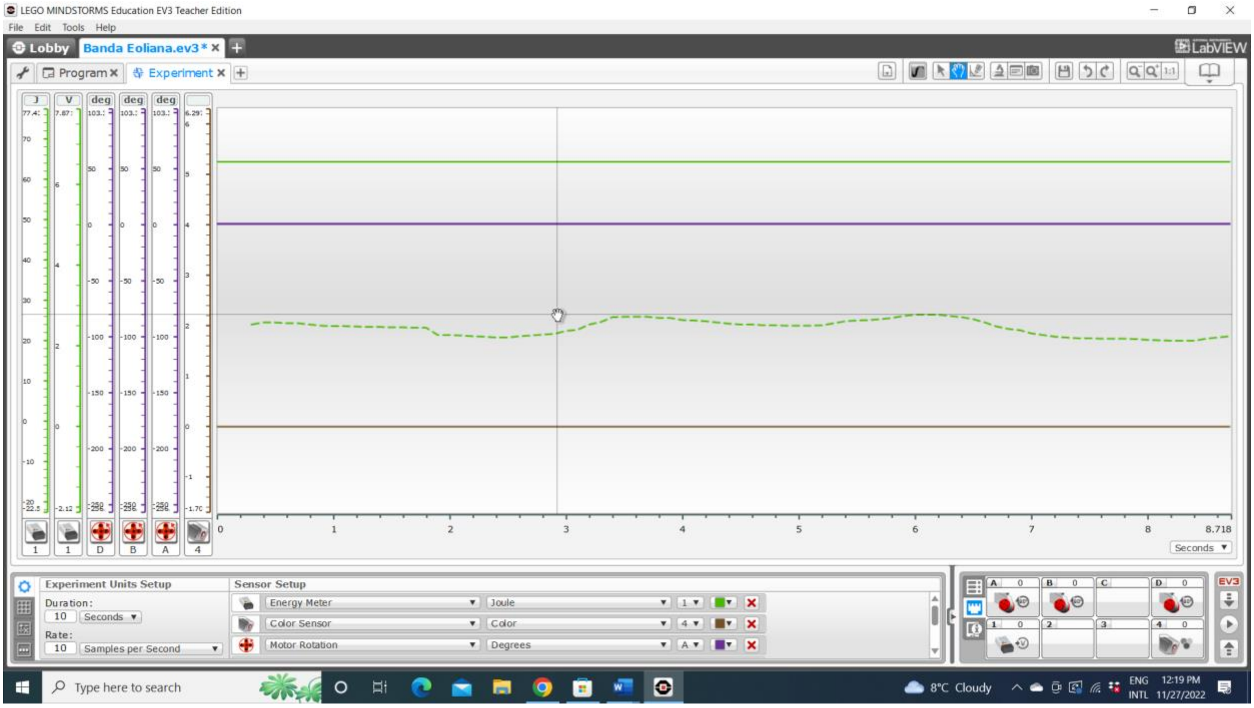







LEGO MINDSTORMS Education EV3 Teacher Edition
File Edit Tools Help
Lobby
Banda Eoliana.ev3
Program
Experiment
brat 2
Type here to search
7°C Cloudy
11:41 AM
11/27/2022


LEGO MINDSTORMS Education EV3 Teacher Edition
File Edit Tools Help
Lobby
Banda Eoliana.ev3
Program
Experiment
Seconds
Experiment Units Setup
Duration:
10 Seconds
Rate:
10 Samples per Second
Sensor Setup
Energy Meter
Joule
Color Sensor
Color
Motor Rotation
Degrees
Type here to search
7°C Cloudy
11:45 AM
11/27/2022


LEGO MINDSTORMS Education EV3 Teacher Edition
File Edit Tools Help
Lobby
Banda Eoliana.ev3*
Program
Experiment
LabVIEW
Experiment Units Setup
Duration:
10 Seconds
Rate:
10 Samples per Second
Sensor Setup
Energy Meter
Joule
Color Sensor
Color
Motor Rotation
Degrees
Seconds
8.718
Type here to search
8°C Cloudy
12:19 PM
11/27/2022