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RENEWABLE ENERGY RESOURCES IN ANTHROPOGENICALLY AFFECTED LANDSCAPE

Jaroslava VRÁBLÍKOVÁ, Petr VRÁBLÍK, Miroslava BLAŽKOVÁ, Eliška WILDOVÁ

J. E. Purkyně University in Ústí nad Labem, Faculty of the Environment, Králova výšina 3132/7, 400 96 Ústí nad Labem, Czech Republic
Jaroslava.vrablikova@ujep.cz, petr.vrablik@ujep.cz, miroslava.blazkova@ujep.cz, eliska.wildova@ujep.cz

Abstract

Utilization of renewable energy resources is mostly dependent on geographical, geomorphologic and climatic conditions of an area. Therefore, every area should be treated individually with respect to its current economical, social, and environmental conditions to secure sustainable development of the region. Very specific areas are those affected by anthropogenic activities, such as coal mining. Their structure has been destructed and their future development is unstable. An example of this area is located in the northern Bohemia (Chomutov, Most, Teplice, and Ústí nad Labem districts), where brown coal has been mined by open cast quarries for over 200 years. Thanks to the reclamation and restoration processes, the area is successfully restored; however the future of energy production after the termination of coal mining is not taken into an account. This contribution is focused on the energy potential of anthropogenically affected area considering renewable resources, which can solve a problem with future energy consumption of the society. With respect to natural condition of the region, the most suitable renewable resource of energy could be wind. Reclaimed surfaces within agriculture reclamation could also serve as a substrate for energy crops. The area also has a significant geothermal potential, because of the heat-flow anomaly, which is very unique in the Czech Republic.

Key words: *renewable resources, sustainable development, North Bohemia, coal mining*

Introduction

Not only the North Bohemia region, but the Czech Republic in general is dependent on energy from the heat power plants. Today, the ČEZ Group operates coal-fired power stations and heating plants in a total of 13 localities on the territory of the Czech Republic. Most of them burn North Bohemian brown coal and, for practical reasons, they are situated in the immediate vicinity of large quarries in North and Northwest Bohemia. They include the following coal-fired power stations: Ledvice, Počerady I., Počerady II., Prunéřov, Tušimice I. and Tušimice II., which currently have an installed capacity in all power station blocks of 3,620 MW [1]. This contribution contains a proposal for a possible change in the power industry, i.e. regarding the sources of renewable energy in the Podkrušnohoří region that could potentially be utilized after mining in individual quarries ends after 2050. Results of the research describe current share of renewable energy resources in the Podkrušnohoří region, and a future energy potential of the area considering sustainable development. Aim of this contribution is to determine, which renewable energy resources would be the most suitable for energy production after the end of brown coal mining. To achieve the objectives of sustainable development in the region, we must take gradual steps to secure the creation and development of legislation and measures in the price area, and limit the use of non-renewable sources. The main measures that will help us achieve these objectives are fuel economy and meeting consumption needs through renewable sources. From the perspective of sustainable development, it would be appropriate to differentiate fiscally between non-renewable and renewable sources. Impose tax penalties on non-renewable sources, particularly carbonaceous fuels, and provide tax breaks for demonstrably economical technology and business. A duty should be imposed on the import of energy-demanding technology, and, on the contrary, economical technology that utilizes renewable sources should be exempt from fees. At the same time, the sale of energy abroad should not be supported.

Electricity production in the Czech Republic

Given the level of GDP created, the Czech Republic consumes more primary energy sources (PES) and electricity than the average for EU countries. The relatively higher consumption of PES per unit of GDP in the Czech Republic is because the structure of the industry is different from the EU-15 sectoral structure, whereby domestic energy sources - black and brown coal, uranium and biomass - are utilized on a long-term basis. In 2016, a significant share of the power industry in the Czech Republic was taken up by coal and gas (approximately 64 %) as well as uranium, via nuclear energy (approximately 29 %). There has been a gross decrease in the share of renewable sources in electricity production in the Czech Republic of 1% compared to the previous year (8%). The share of RES in domestic gross consumption (MWh) was 12.97% in 2016. In comparison with 2015, this means an decrease in the share of RES in domestic gross consumption in the Czech Republic of 0.3%. Overall, landfill gas and biogas still assume the largest share of energy production from renewable sources (28 %), and this category has been constantly on the rise since 2006. In 2016, the share of photovoltaic energy was 23%, but compared with the previous year, there has been registered a slight decrease. The same development applies for biomass, which had a 22% share in the production of electricity from RES in the Czech Republic in 2016. Share of wind power on electricity production decreased by 1 % on current share 5 %. On the contrary, hydroelectric power stations above 10 MW saw great increase in their share (10%) of electricity production in comparison with 2015. The same case is observed concerning small hydroelectric power stations where the energy production increased by over 50 000 MWh compared to the year before (Fig. 1) [2].

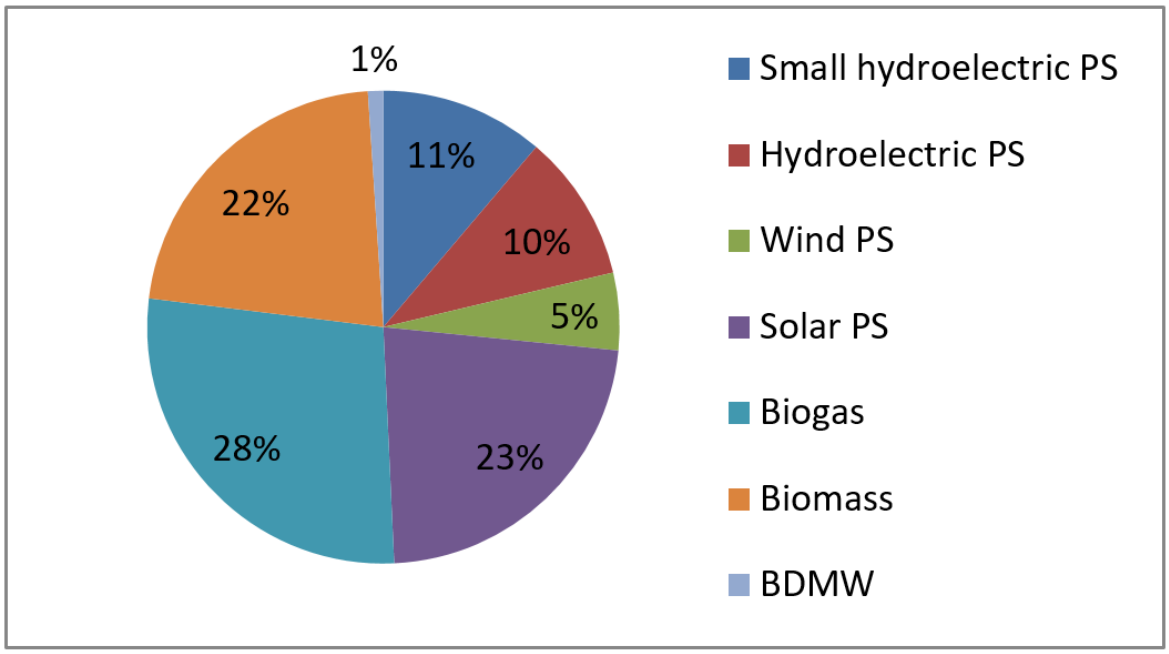


Figure 1: Energy production from renewable resources in the Czech Republic in 2016 (%) [2]

PS – Power station
BDMW – Biodegradable municipal waste

Materials and methods

Essential material used for writing the article was Annual Report on the Operation of the Czech Energy System [2], which is focused on individual shares of energy sources, including renewable ones, in the Czech Republic. Installed capacities of specific renewable sources in the model area were available online within web pages of companies that are concentrated on specific renewable source of energy. One of the methods was to study those materials very thoroughly. Professional experience and results of several researches done by Faculty of Environment of the J. E. Purkyně University pro-

vided necessary information to analyze potential of individual kind of renewable source considering geographical conditions of the model area. It must be said that economical aspect was not considered and further analysis is needed. The same cause is a geothermal potential of the area. Future of this source is significant for the area, but it requires more research support. There is a unique opportunity to define future of the area, with respect to the energy sources, after the termination of coal mining.

Results and discussion

In order to ensure the sustainable development of the model area after the end of mining and the use of brown coal in the power industry, we have to carry out a detailed analysis of the potential of renewable sources to ensure that society's energy demands are covered. The essential part of our research was to indentify, and summarize the current installation of renewable energy resources.

Solar power stations

For now, the anthropogenically burdened territory of North Bohemia has the highest installed capacity within the scope of RES energy from solar sources (102,28 MW), as set forth in Table 1 [3]. The power plants are situated mostly in the central part of the region under the Krušné Hory Mts.

Table 1: Installed capacity of solar power in model area [kW] [3]

District	Installed capacity [kW]
Chomutov	46709,00
Most	6568,71
Teplice	38680,18
Ústí nad Labem	10319,50
Total	102277,39

However, this is not an efficient or sustainable choice, as this high installed capacity came about because the construction of a solar power station was economically advantageous while a subsidy program was in place. That is why all of the power plants in this region were built between the years 2008 – 2010. This was caused by the abnormal and unsuitable construction of solar farms without taking into account the return on investment or the suitability of the installation. Moreover, the seasonal and changing climate does not guarantee stable conditions for the production of energy from the Sun. At the same time, valuable land was removed from the Agricultural Land Fund. Figure 2 depicts annual intensity of solar radiation and proves very low (940 – 970 W/m2) intensity in the model area in the Podkrušnohoří region. Due to the facts mentioned above, the solar energy is not considered to be good solution for the future energy production in this area [4].

Wind power stations

As a landlocked state, the Czech Republic does not have very good conditions for the utilization of wind. However, contemporary technology can easily deal even with fluctuating wind velocity, relatively frequent change of wind direction and frost. The current trend is the construction of even larger machines. Thanks to geographic conditions, the model area has the potential for the utilization of wind energy, as the field of average wind velocity at an altitude of 100 m in the Ore Mountains area is 7.5 and over (Fig. 3). To calculate the field of average wind velocity at an altitude of 10 m above the surface, the same process and input data was used as for the "wind map" at an altitude of 100 m above the ground. The resulting wind map is a synthesis of the calculation of three models used on a long-term basis in the Institute of Atmospheric Physics at the Czech Academy of Sciences: VAS, WAsP and PIAP [5]. Table 2 describes all the wind power plants installed in the mountainous areas of the model region, whereby the largest one, with an installed output of 42,000 kW, is found in the municipality of Kryštofovy Hamry in the Chomutov district.

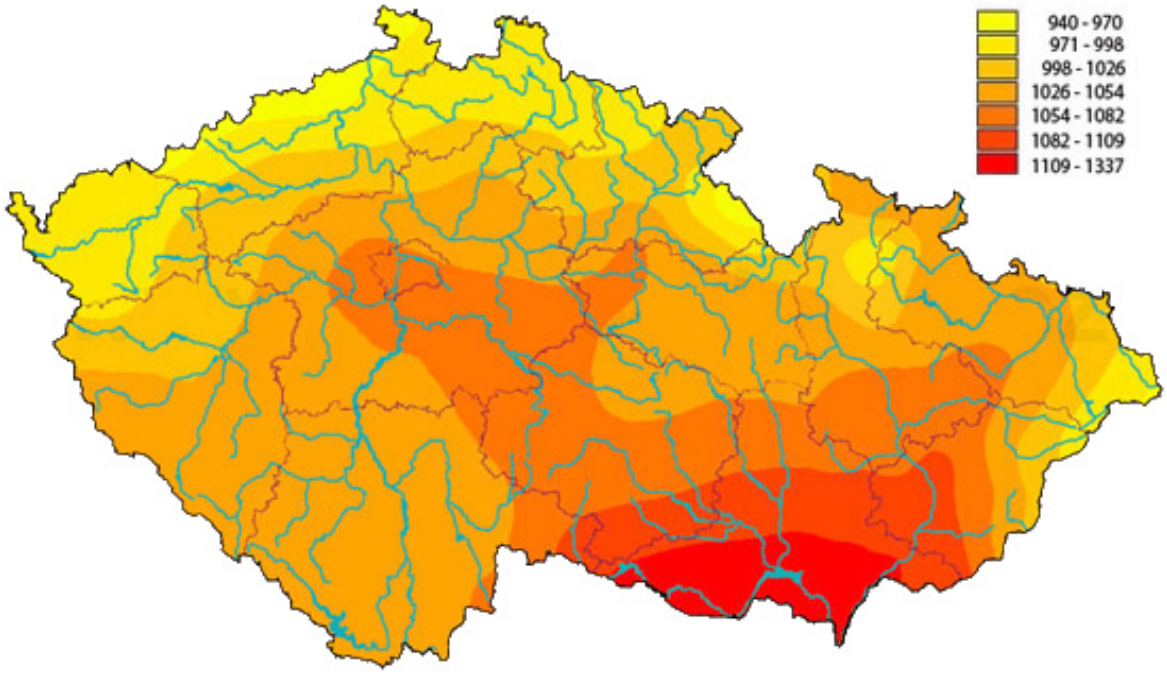


Figure 2: Annual intensity of solar radiation in the Czech Republic [W/m2] [4]

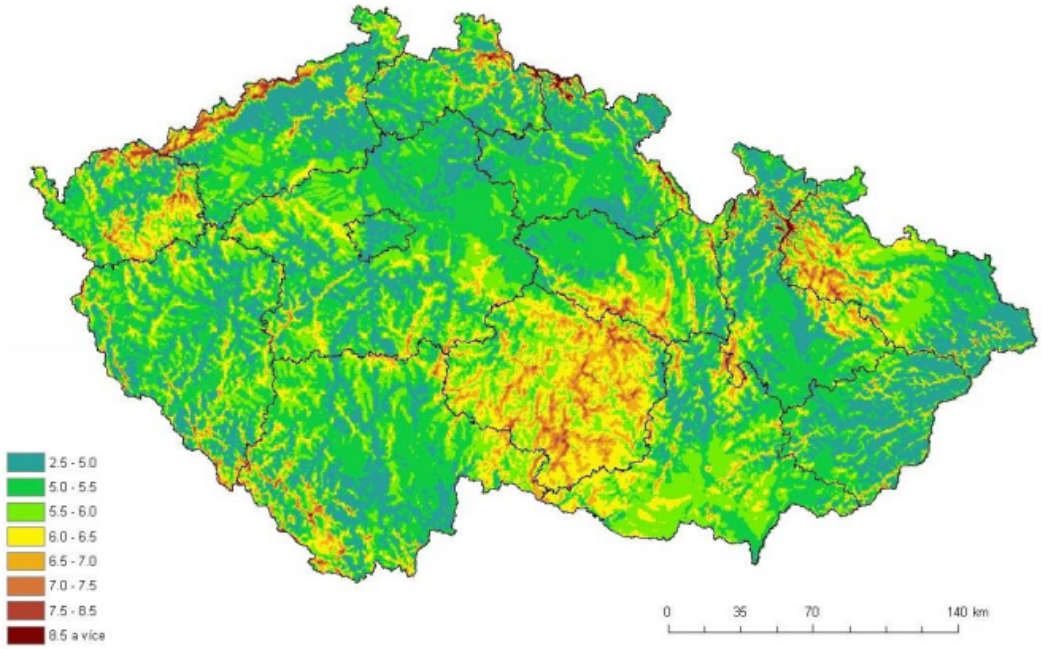


Figure 3: Average wind speed in 100 m over the surface [6]

Table 2: All wind power stations installed in the model area [kW] [7]

Title	District	Municipality	Installed capacity [kW]
Loučná	Chomutov	Loučná	1 800
Kryštofovy Hamry	Chomutov	Kryštofovy Hamry	42 000
Rusová- Podmíleská výšina	Chomutov	Rusová	7 500
Hora Svatého Šebestiána	Chomutov	Hora Svatého Šebestiána	4 500
Nová Ves I	Most	Nová Ves	1 500
Nová Ves II	Most	Nová Ves	1 500
Strážní Vrch	Most	Nová Ves	8 200
Mníšek (Nová Ves)	Most	Nová Ves	2 000
Klíny	Most	Klíny	4 000
Nové město- Vrch tří pánů	Teplice	Nové město	6 000
Habartice u Krupky	Teplice	Krupka	4 100
Petrovice	Ústí n/L	Petrovice	4 000

Hydroelectric power stations

Energy obtained from hydroelectric power plants, particularly from power plants of above 10 MW, recorded a significant overall growth in the Czech Republic in 2016 compared to the previous year, from 793,010 MWh to 947,388 MWh. It was the same in the case of small hydroelectric power plants of up to 10 MW, where the gross electricity generation increased from 1,001,797 MWh to 1,053,100 MWh [2]. There are a total of 7 hydroelectric power plants in the model area, but only one of these is ranked as large. This is the Střekov constant load power plant, with an installed output of 19.5 MW, which is located on the locks of the Elbe River (Tab. 3).

Table 3: All hydroelectric power stations in the model area [2]

Title	Installed capacity [MW]	Type	Production [GWh]	Launch	Location	Watercourse	District
VE Střekov	19,5	flowing	96	1936	Zdymadlo Střekov	Labe	Ústí n/L
VE Nechranice	10	accumulating	61	1968	VN Nechranice	Ohře	Chomutov
ŠVE Meziboří	7,6	accumulating	7,6	1964	VN Fláje	Flájský potok	Most
MVE Hradiště	3,2	...	8,2	1976	VN Přísečnice	Přísečnice	Chomutov
Kadaňský stupeň	2,28	...	10,2	1972	...	Ohře	Chomutov
Želina	0,64	...	...	1994	...	Ohře	Chomutov
Fláje	0,016	...		1964	...	Flájský potok	Most

Biogas

Biogas stations are modern and environmentally friendly facilities which are regularly operated in the Czech Republic and around the world. They can process a wide range of materials and waste of organic origin via an anaerobic digestion, without air access, in closed reactors. The result of the process is biogas, for now most commonly used for the production of electricity and heat, as well as digestate, which can be used as a high-quality fertilizer (similar to compost) [8].

Biogas stations can effectively process a wide range of biowaste and raw materials, including those which are otherwise difficult to process:

- biowaste from the maintenance of public greenery (grass and leaves, but not wood)
- biowaste from households and gardens
- out-of-date food and biowaste from supermarkets
- remains of food from canteens, restaurants and hotels
- biowaste from commercial operations (bakeries, distilleries, breweries, sugar factories, meat processing plants)
- waste from the breeding of farm animals (slurry, dung, bedding etc.)
- purposefully cultivated biomass (e.g. corn, beet, haylage)

There are a total of 12 biogas stations in the model area, of which half process products from agriculture, 3 utilize waste from sewage treatment plants, and 3 utilize landfill gas (Tab. 4). The largest biogas station is found in the municipality of Málkov in the Chomutov district. Its installed output is 800 kW, whereby the station accepts raw materials such as poultry bedding, corn silage, abattoir waste, kitchen waste, freshly mowed grass, sediment from treatment plants and digestate for recycling [9].

Table 4: Biogas power stations in the model area [kW] [10]

Title	Type	District	Municipality	Installed capacity [kW]
BPS Ahníkov	Agricultural	Chomutov	Málkov	800
BPS Velké Chvojno	Agricultural	Ústí n/L	Velké Chvojno	750
BPS Všebořice	Agricultural	Ústí n/L	Ústí n/L	550
ČOV Bystřany	WTP	Teplice	Bystřany	280
ČOV Most- Chanov	WTP	Most	Most	140
ČOV Neštěmice	WTP	Ústí n/L	Neštěmice	460
Skládka TKO Modlany	Landfill biogas	Teplice	Srbice	400
Kogenerace Vysoká pec- Jirkov	Landfill biogas	Chomutov	Vysoká pec	190
Litvínov CELIO a.s.	Landfill biogas	Most	Litvínov	630
BPS Hrobčice- Razice	Agricultural	Teplice	Hrobčice	659
BPS Moldava	Agricultural	Teplice	Moldava	150
BPS Odolice	Agricultural	Most	Bělušice	550

WTP – Wastewater treatment plant

Geothermal power

Geothermal energy is now becoming one of the most attractive sources of renewable energy. The geothermal potential in the individual parts of our region varies considerably, particularly in relation to geothermal, geological and hydrogeological conditions. Based on experience from other countries with similar geological structures, the Czech Republic also has potential geothermal energy sources. Heat flow anomalies have been registered in the area of the Ohárecko Rift, i.e. the Podkrušnohoří region, the western part of the Czech chalk table and the Ostravsko-Karvinská basin. These are so-called low temperature hydrothermal sources, i.e. to a temperature of 100 degrees, and the geothermal energy of so-called hot dry rocks, whose potential at depths of 3,000-5,000 m is considerably higher. Research concentrated on utilization of these sources should be supported more in the future. [11]. Geothermal energy is utilized in the model area, particularly in the city of Ústí nad Labem, where it is used to heat swimming pools; since May 2006 it has also been used to heat the Ústí nad Labem Zoological Garden. In Děčín, there is a unique project which utilizes geothermal energy for heat production. A heating plant on Benešovská Street has been operating since 2002. It is the only one in the Czech Republic which uses geothermal energy, and it supplies half of the city with heat. In November 2006, the digging of an experimental borehole for a geothermal power plant began

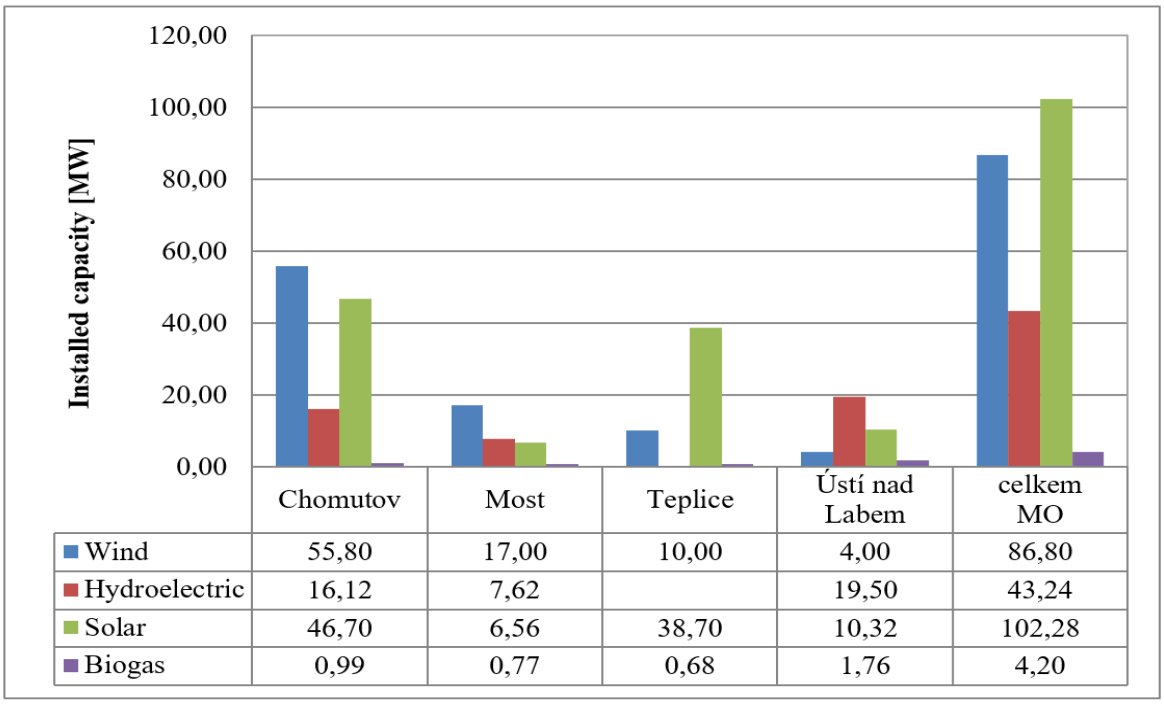
in Litoměřice - when it is completed, it is expected to be 2,500 metres deep. If the measurement results are favorable, two more boreholes - this time production boreholes - will begin to be dug. These boreholes are expected to reach a depth of as much as 5,000 metres. The power plant will be based on the HDR method, which has not yet been used in Central or Eastern Europe. This method consists of water being pumped into one borehole and drawn from another, whereby it is heated at depth. It involves the closed circulation of water. Thermal energy can be converted to electrical energy. In the winter, the energy will be used mainly for heating, while in the summer it will be used to generate electrical energy. The costs of digging the boreholes and constructing the geothermal power plant are expected to be around CZK 1.11 billion, of which part will be funded by the EU. The power plant is to have a thermal output of 50 MW and an electrical output of 5 MWe [12].

Summary and discussion

A comparison of individual districts in terms of individual renewable energy sources is shown in Figure 5. The largest proportion of renewable energy sources is taken up by solar power plants (108.21 MW), which are nevertheless not recommended as a sustainable method of obtaining energy, particularly due to the occupation of the ZPF (agricultural land resources) and unfavourable returns of investments. The map of annual intensity of solar radiation in the Czech Republic [4] confirms our conclusion, that there are not suitable conditions for this kind of renewable source of energy. Photovoltaic cells are mainly used in the Chomutov (47.3 MW) and Teplice (40.82 MW) districts. Wind power plants have much better potential in higher areas of the model region, as there are favourable wind conditions. A map of average wind speed in 100 m over the surface [6] goes hand in hand with our assumption, that this is a suitable renewable source, but economic costs are not considered in this case. In total, 86.8 MW have been installed in the model area, mainly in the Chomutov district (55.8 MW). The third place in the utilization of renewable energy sources is represented by hydroelectric power plants, which have a share of 43.24 MW of the total installed output; of this, the largest power plant is in the Ústí nad Labem district (19.5 MW). This kind encounters problems especially with the constructions within the hydroelectric power plant and with the nature of the flow of rivers in the model area. In comparison with other renewable energy sources, the utilization of biogas is negligible (4.2 MW) (Fig. 4), but wider use should be considered, because biogas power stations accept raw materials and waste from agriculture [9]. Geothermal energy has a considerable potential in the model area, but requires more intensive research and support as the Podkrušnohoří region is located near the heat flow anomalies [11].

Conlcusion

The power industry is important for human survival, and unfortunately is also very demanding on the environment overall; one of the possible solutions is greater support of renewable, or alternative, energy resources. The improvement of the environment and the better utilization of sources go hand in hand with permanently sustainable development, which also ensures that the environment remains unchanged for future generations. Today's unsustainable situation is a consequence of the fact that humankind is drawing on natural wealth too much and too quickly. While the existence of the Earth is calculated in billions of years, human existence takes up only a fraction of that time. However, even this short time has been more than enough for people to change or directly destroy that, which existed in peace for so long. The area of interest (Chomutov, Most, Teplice and Ústí nad Labem regions) has a unique opportunity to define future of energy sources. This topic should be dealt with now, before the termination of brown coal mining to ensure sustainable development of the area. Current installed capacities of individual kinds of renewable sources are: 108, 21 MW of solar power, 86, 80 MW of wind power, 43, 24 MW of hydro electrical power and 4, 2 MW of biogas power. The conclusion is that the best potential is in wind power thanks to the geographical conditions of the area, but further analysis of economical cost should be made in the future to prove this statement. Geothermal potential of the area is exceptional, but a further research of this energy source should be more supported.



	Chomutov	Most	Teplice	Ústí nad Labem	celkem MO
Wind	55,80	17,00	10,00	4,00	86,80
Hydroelectric	16,12	7,62		19,50	43,24
Solar	46,70	6,56	38,70	10,32	102,28
Biogas	0,99	0,77	0,68	1,76	4,20

Figure 4: Overview of installed capacity of renewable resources in the model area [MW]

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