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Wierzbieniec Wacław, Ireneusz Thomas

The origin and meaning of the so-called "white energy" in Podkarpacie region on the example of the hydroelectric power plants

Elaboration concerns the development of hydropower in the Carpathian mountains. It presents a historical development of individual construction projects, including their technical parameters, as well as the overall situation of the climate, geological and ecological at regions where they are located individual hydro power plants. Were also analyzed concepts of future develop the various forms of green energy, especially hydroenergy both in Poland and Ukraine.

Key words: *water powers, hydro-ecology, Carpathians, electro-technology*

It is known that water power (hydropower) is a power derived from the energy of water and it deals with water conversion into mechanical and electrical energy due to the use of water engines (water turbines) and hydro generators in water power plants (e.g. mills) as well as in hydroelectric power plants. First of all, hydropower is based on the energy of inland waters (rarely on the energy of seas – in the tidal power) with high intensity flow and water fall, measured by the difference in water levels in the upper and lower flow, including water flow losses.

The use of inland waters' energy and tides marine waters in hydroelectric power stations consists in reduction of natural energy losses of water within a certain area (part of a stream, river or a bay) and obtaining its accumulation due to the level of the outflow[1]. Beyond production of electrical power, hydroelectric reservoir power plants can simultaneously fulfill other tasks: flood protection appliance, flow control in view of shipping and also the development of eco-tourism and water sports. Hydroelectric power plants use the kinetic and potential energy of water to generate electric energy. In the European Union the following kinds of hydroelectric power plants can be distinguished: small hydropower plants – with total capacity of 10 MW, the large ones – with total capacity of above 10 MW. According to the Polish Economic Chamber of Renewable Energy and the data of the Energy Regulatory Office, there were 770 hydropower plants with a total capacity of 966 MW in 2012. In many European countries, including Poland, water has been the dominant source

[1] Z. Wnuk, *Energia odnawialna. Słońce, biomasa, woda, wiatr, geotermia*, Rzeszów 2010, p. 73.

of energy generated from renewable sources[1].

The pumped storage hydroelectric power plants are of great importance in Poland, allowing the use of water as an energy store; the dominant hydropower role have the lower Vistula river, the Dunajec river and the San river in the south. Recently, more and more attention is paid to the energy use of small mountain watercourses, due to the construction of the so-called small hydroelectric power plants; it concerns, first of all, the courses, where piling equipment is installed and it is used for other purposes. The advantage of hydropower development is defined by the fact, that the cost of power production generated by the hydropower plants is lower than the costs of power produced by thermal power plants[2].

To illustrate the scale of hydropower possibilities in southern Poland, one must take into consideration the following amount of energy, which the local hydroelectric power plants produce:

Hydroelectric Power Station Porąbka–Żar (1979) – 550 MW
Hydroelectric Power Station Solina (1968) – 200 MW
Hydroelectric Power Station Niedzica (1997) – 90 MW
Hydroelectric Power Station Rożnów (1942) – 50 MW
Hydroelectric Power Station Porąbka (1953) – 12.5 MW
Hydroelectric Power Station Myczkowce (1961) – 8.5 MW
Hydroelectric Power Station Czchów (1954) – 8 MW

To emphasize the uniqueness of the phenomenon described, one can take into consideration, the fact that that the current energy production in Poland is focused exclusively on power plants, processing bituminous coal and lignite (about 74%), the rest constitutes thermal power stations and industrial power plants, (about 21% in all) hydroelectric power plants thus constitute only 2.5 % of domestic energy production. Moreover, water energy belongs to renewable energy sources with the ecological nature. Renewable energy is a defined category of energy sources, that uses the energy of wind, sunlight, geothermal heat, waves, flows and streams of seas, river falls as well as the energy, which is generated from biomass, landfill gas and biogas, formed due to the processes of industrial water treatment and decomposition of plant and animals. It is considered, that in Podkarpacie region the usage of water is above 22%, biogas – 5,6%, wind – 3 % and biomass – only 0.26 %[3].

To visualize described phenomenon of the historic development of the mountain areas in the south-east part of Poland, one should keep in mind the local

[1] Por. http://www.pigeo.org.pl/?menu=przegladaj&id=70 from 10.09.2013.
[2] W. Jabłoński, J. Wnuk, *Odnawialne źródła energii w polityce energetycznej Unii Europejskiej i Polski*, Sosnowiec 2004, p. 36.
[3] Ibidem.

specific natural conditions in the hydropower context[1].

In general,AlphaCzy to tłumaczenie jest lepsze od maszynowego? the Carpathian Mountains are the longest range of mountains in Central Europe, stretching to the north in a form of arc across the territory of the Czech Republic, Slovakia, Poland, Ukraine, Hungary and Romania. From the geological and geographical point of view, this arc is divided into several smaller parts. Two parts of the arc are in Poland: the large part of the Western Carpathians and a part of the Eastern Carpathians (Bieszczady Mountains). The Carpathians are characterized by high atmospheric precipitation, relative to the neighboring areas[2]. While in the lowlands the average precipitation for Poland is 500 – 600 mm per year, slope Carpathians get at the same time 800 – 1500 mm of water. The precipitation is a water supply of both, surface inland water and groundwater, and as a result, of the marine water dams, creating quite substantial resources of renewable energy, which is considered to be a vital one to the environment. This energy can be divided into two main types: surface energy of flowing water and geothermal energy[3].

The precipitation intensity in Carpathians is high. The streams and rivers carrying water from the high mountain slopes have large natural kinetic energy. Unfortunately, they have irregular inflow. They carry a lot of water after the spring thaw as well as after heavy rains and summer storms. Low water inflows can be observed mostly in late summer, early autumn and cold winter. To stabilize the water flow, the dams are built to store water in reservoirs and the hydroelectric power plants are built near them[4].

Most of the hydroelectric resources in south-east Poland are concentrated on the basin of the Vistula river and the San river, especially in their right-hand tributaries. One can see favorable conditions for the construction of small hydroelectric power

[1] G. Haczewski, J. Kukulak, K. Bąk, *Budowa geologiczna i rzeźba Bieszczadzkiego Parku Narodowego*, Kraków 2007, p. 5.

[2] Por. http://www.e-gory.pl/index.php/Gory/Geografia-ogolna-Karpat/Klimat.html from 12.09.2013.

[3] Generation of both types of energy here refers to the water circulation cycle in nature, operated by solar energy.

This cycle occurs continuously and is based respectively on: atmospheric precipitation, the confluence of surface and seepage into the rocks and the evaporation of inland and ocean waters. Then, the evaporating water is transmitted in the form of clouds to fall back as rain or snow. Because of this effect, water resources are constantly renewed in nature. Precipitation, while hitting the surface of the earth, has a potential energy depending on the location. The reference level is the main recipient of water – the sea or ocean. The larger the difference in space and sea level, the greater is the potential energy of water stored by the river in the place of precipitation. Thus, the flow of water in the river is caused by the difference in potential energy of water in the upriver and downriver (or in the upriver and in the dam area) and the potential energy turns into kinetic energy of flowing water. This fact is used in hydroelectric power plants by passing through water turbines flowing water of river. The quantity of energy that can be obtained theoretically, depends on the quantity of flowing water and the height from which the water may fall.

[4] P. Migoń, *Geomorfologia*, Warszawa 2006, p. 145–146; E. Bajkiewicz-Grabowska, Z. Mikulski, *Hydrologia ogólna*, Warszawa 2006, p. 170.

plants in the Carpathians, in the Sudeten and Roztocze areas, as well as over the Baltic rivers. The Odra river potential is of great importance in Poland too. However, the rivers damming with large flows require the construction of large objects (artificial water reservoirs), which on one hand, are used to regulate water levels in rivers, for example, during the flood, but on the other hand, they make adverse changes in the eco-system of these rivers.

The situation with small hydroelectric power stations is different, they do not require the construction of high dams (just a relatively small weir is enough, damming the water up about 1.5–2 m), and thus, it minimizes the impact on the environment. A small hydroelectric power plant does not require the construction of an artificial water reservoir (it uses only the amount of water that flows at a given moment in the river).

From the historical point of view, small hydroelectric power stations derived from the operating water wheels on the rivers, which were used to drive the mills, sawmills, fullers, granaries with water. They were used as early as in the fifth century B.C, while they have been known in Poland since the thirteenth century. Then, in the course of time, they were substituted by water turbines due to their low efficiency. It allowed to obtain much more power under the same water conditions. The turbine speed however is too high to drive directly the machines. Hence, electric energy is produced in a turbine[1]. Unfortunately, the process of water mills substitution for hydroelectric power plants was postponed in Poland in the post-war period.

Thus, the idea of building the reservoirs in Solina and Myczkowce refers to the interwar period. The concept was created by one of the best hydrologist in Poland at that time – professor Karol Pomianowski. The construction of the Myczkowce water reservoir started in the twenties of the 20th century. The underground tunnel and a channel were built to supply part of the dam and part of the building, where the hydroelectric power plant was located. However, the investment was not completed and the project was put on hold when the Second World War began. The construction of the dam was completed in 1960, whereas the concrete dam and hydroelectric power plant was built in Myczkowce. Myczkowce water reservoir had to stop water flowing through the turbines of the Solina, the water had to flow at night through the reversing turbines back to Solina. However, the construction of the dam in Solina started in the early sixties of the twentieth century. A complex of two cooperating hydroelectric power plants was built in 1968. A pumped storage was built in Solina and a run-of-the- river power plant was built in Myczkowce[2].

Despite the fact that Solina areas were depopulated after the Second World War

[1] A. Hrynkiewicz, *Energia – wyzwania XXI wieku*, Kraków 2002, p. 65–66.
[2] M. Motyka, Bieszczady i Pogórze Przemyskie, Bielsko-Biała 2005, p. 55.

and after the "Operation Vistula", it was necessary to relocate the inhabitants of several surrounding villages. When the construction works connected with a dam started, it was obvious that such villages as Solina, Teleśnica Sanna, Sokole, Zadział, Podleszczyny, Polana, Berestyszcze, part of Wolkowyj, Chrewt and Rajskie were under water. The residential buildings and outbuildings as well as churches were demolished, the cemeteries were exhumed, the deforestation was conducted[1]. As it occurred later, wrong decisions had been taken at that time. The church in Wołkowyi should not have been demolished, as flood waters did not reach the place where the church was built. Not all the trees had been cut out and nowadays, while swimming in the lake, one can see a dead forest, which is submerged, or stands in the water. The construction of the dam was a huge investment for former Rzeszów region, the project was realized by the Carpathian Dams Construction Company "Hydrobudowa-10".

At that time, the largest dam in Poland was built, impounding water of the San river, the Solinka and a lot of other smaller rivers and streams in Bieszczady Mountains. The tourist promenade is located on the dam, from this place one can see the Solina lake and Myczkowce reservoir located below, as well as the scenic hills surrounding the lake. Nowadays it is allowed to tour the dam from the inside, several years ago it was forbidden to use a camera to take photos of strategic facilities, and in case of breaking the ban on photographing strategic facilities, including so important for tourists railway stations and bus stations, border crossings or even industrial enterprises, your camera could be confiscated. Recent support for the development of ecological power engineering links with the Carpathian natural environment should be based on the availability of these modern investments in tourist management. In fact, the process of energy generation from flowing water is presented by the individual, visiting the administration building of the local power plant located at the foot of the water dam, the workers of the Information Centre for Renewable Energy organize special excursions to the interior of the dam, preceded by general introduction, emphasizing the typical factors concerning the geomorphologic and climate conditions of Bieszczady.

Summing up the issue of energy generation from the water flow in the ecological context, it should be noted, that hydroelectric plants have many advantages, but at the same time, they pose some problems that should be properly taken into account just before the designing. These disadvantages are: taking an area suitable for forestry and agriculture, interference in the natural environment resulting in the degradation of plants, which are protected, the necessity of the population relocation, as well as changes in the biological structure in rivers and climate

[1] Z. Kozicki, *Zespół elektrowni wodnych Solina-Myczkowce*, Zieloczyn 2011, p. 136–137.

changes, which have become actual nowadays[1].

Generation of energy from hydroelectric power plants is very beneficial, both for environmental and economic reasons, because it provides ecologically clean energy and regulates water balance by increasing local surface water retention, thus improving crop conditions and supply conditions of the population and industry with water. Electric energy produced in hydroelectric power plants is usually fed into the national electricity transmission system. A large power plant can even feed a town with the population of few thousands inhabitants. In this context, it is worth noting, that small hydroelectric power plants, while supplying electricity to their owners, do not pollute the environment and can be installed in various places on small water courses. They can be designed and built within 1–2 years, their technical equipment is now quite common and technologically simple[2]. Such hydroelectric power plants can be built by using local materials and their simplicity results in high reliability and long operating. The supervision can be automated additionally, reducing personnel costs at the same time. However, the distribution of hydroelectric power plants in the region shortens the distance of energy transmission and thus, it also reduces the associated fixed costs[3].

You should therefore agree with the opinion of professor Zygmunt Wnuk, who in his book entitled "Ecology and Environment" noted, that the works connected with the use of renewable energy sources (water, wind, solar energy, geothermal and biomass energy) should be intensified, and thus, more attention should be paid to energy and biological renewable raw materials[4].

Taking the above mentioned into consideration, we should therefore be ready for the construction of new hydropower plants – that is, small hydroelectric power plants. The Ukrainian plans to build small hydropower plants in the Carpathians may frighten by its assumptions. For example, for the realization of the programme on complex utilization of water resources in Zakarpacki region, it is planned to build 330 small hydropower plants and according to various sources, it is planned to build from 50 to 150 hydroelectric power plants in Iwano-Frankiwsk region. About 20 hydropower plants must be built in Lviv region and Czerniwecki region. However, the implementation of these projects will lead to environmental destruction of the Carpathian rivers.

The Ukraine has decided to support the idea concerning the renewable energy sources. This support is based on the electricity generation stimulation by building

[1] G. Jastrzębska, Odnawialne źródła energii i pojazdy proekologiczne, Warszawa 2007, p. 57.
2 W. Lewandowski, Proekologiczne odnawialne źródła energii, Warszawa 2007, s. 98.
3 www.ecoportal.com.pl/energia-wody/elektrownie-wodne and

http://www.ekoportal.eu/reportaze/zespol_elektrowni_wodnych_solina-myczkowce.html from 12.09.2013.
4 Z. Wnuk, Ekologia i ochrona środowiska (red.), Rzeszów 2010, p. 304.

solar and wind power plants, as well as hydroelectric power plants with capacity up to 10 MW (Article 1 of the Law of Ukraine "About power industry"). A green tariff proved to be sufficiently powerful incentive for the entrepreneurs. It is based on the fact, that the state stimulates those, who produce electricity without harm or with little harm to the environment. In this context, "green tariff" has become only economic motivation, the way to transfer money from the budget, while the environment protection is disregarded openly. That is why, the Ukrainian society – environmentalists, tourists and other categories of indifferent citizens are opposed to the uncontrolled, environmentally dangerous, mass hydroelectric installation in the Carpathians. The purpose of this conflict is to protect the natural environment of Carpathians, its conservation for tourism, as well as to defend the green energy from attempts to use it only as the source of individuals enrichment at the expense of the destruction of our common environment[1].

A pumped storage and the Solina lake should be a simple example of these activities local attractive tourist facilities with renewable energy. The construction of hydroelectric power plants on the upper reaches of the river is at least strange, because the variable flows have much smaller economic benefit, than stable accumulation of water. Unfortunately, many years have passed before Poland could reach a balance between energy and environmental protection, the situation today is much better and even strongly restrictive. The Ukraine has not seen yet the effects of the environment devastation at the expense of renewable energy.

Conclusions

The majority of electricity generation from renewable energy sources in Poland comes from water sources. Poland is no exception in this case. In many developed countries, hydro power energy provides the greatest amount of electricity of renewably energy of all types. However, for the developing countries, which possess water resources, the hydroelectric power plants are the main source of electricity generation. Water energy provides about 16% of the total electricity in the world. A greater amount is produced only from coal and natural gas.

The theoretical hydropower resources in the world are estimated at about 40.700 TWh/year thus, exploitable resources are estimated at about 14.400 TWh /year. The largest hydroelectric power supplies are in China, Russia, Brazil, Canada, Congo, India, the USA and Indonesia. The hydroelectric potential of Poland is low due to very heavy rainfall, a lowland terrain, high permeability of land[2]. Water and energy resources of Poland are concentrated mainly in the Vistula basin (about 68%). The rest of resources falls on the Odra river basin and the rivers of Pomerania. The most promising areas for the development of hydropower is Masuria, Pomerania, the

[1] http://www.zielonekarpaty.org.pl/EnergiaWodKarpckich.html from 14.09.2013.
[2] R. Tytko, *Odnawialne źródła energii*, Warszawa 2009, p. 209–210.

Carpathians and the Sudeten.

Polish hydropower resources are estimated at about 0.1% of the world's resources. The theoretical potential is estimated at 23 TWh, while the technical potential is estimated at 12 TWh per year. The resources of Poland are used therefore only at 12%, while in France, for example – at almost 100%, Norway – at 84%, and in Germany – at 80%.

It should be noted, that above 6,5 thousand hydropower plants operated in the fifties of the twentieth century. Nowadays there are only 750 operating hydropower plants and over 81% of the national technical potential is not used. According to current estimates, there are about 7.5 thousand hydropower plants in Poland that are not used for energy purposes. Thus, Poland has favorable conditions for the development of hydropower, especially for the development of small hydropower plants, but the pace of starting up new power generation is still too low.

That is why, water energy in Carpathians, which is relatively easily generated, raised great interest in Poland. A lot of researches, monitoring projects and expertise are made on tanks filling and the reservoir shallow because of stuff flowing, on the size of the area protected against floods, etc. Numerous studies show significant advantages arising from the construction of dams and reservoirs near them, emphasize the balance sheets of costs and low degree of impact on the environment. That is why, the production of electricity from renewable energy sources in the EU is in fact a priority task. In 2010, in Poland, according to EU directives, 7.5% of produced energy should come from renewable sources, including the above described hydropower plants. In 2020, renewable energy should total 14% of the energy used in our country.

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Вежбенець Вацлав, Іренеуш Томас

Походження і значення так званої "білої енергії" в Підкарпатському воєводстві на прикладі гідроелектростанцій

Робота присвячена дослідженню розвитку гідроенергетики в Карпатах. Розглядається історичний розвиток окремих будівельних проектів, включаючи їх технічні параметри, а також загальна кліматична, геологічна і екологічна ситуація в регіонах, де розташовані індивідуальні гідроелектростанції. Також проаналізовано майбутні концепції розвитку різних форм зеленої енергетики, особливо гідроенергетики як у Польщі, так і в Україні.
Ключові слова: водні ресурси, гідроекологія, Карпати, електротехнології.

Вежбенец Вацлав, Иренеуш Томас

Происхождение и значение так называемой "белой энергии" в Подкарпатском воеводстве на примере гидроэлектростанций

Работа посвящена исследованию развития гидроэнергетики в Карпатах. Рассматривается историческое развитие отдельных строительных проектов, включая их технические параметры, а также общая климатическая, геологическая и экологическая ситуация в регионах, где расположены индивидуальные гидроэлектростанции. Также проанализированы будущие концепции развития различных форм зеленой энергетики, особенно гидроэнергетики как в Польше, так и в Украине.
Ключевые слова: водные ресурсы, гидроэкология, Карпаты, электротехнология.