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TREND EDITORIAL

The review of Polish formal and legal aspects related to hydropower plants

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Introduction

In recent years, dynamic growth of expenditure on environmental protection has been observed in European Union (EU) countries (Tsireme et al. 2012). Access to EU funds has allowed significant resources for the financing of investment and ecological activities to accumulate in some countries (Kulczycka and Smol 2016). Renewable power engineering sector investments are recognised, by virtue of the European Parliament and Council Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources as important sources of energy, supported due to the care about the environment. Thus, the benefits from execution of such investments are highly valued in both regional and global scale, especially in the aspect of climatic changes and progressing pollution of the environment (Mennicken et al. 2016). To confirm the priority of sources of energy recognised as renewable and friendly to the environment, the directive imposes the obligation of generating and managing resources of renewable source energy, thus defining the objectives for the member countries, including Poland—at 15 % of the gross final consumption of energy by 2020.

Research addressing the development of the use of hydropower engineering and its improvement (Kougias et al. 2016a, b) and improvement of conditions of the functioning of the facilities is conducive for new projects executed in many parts of the world (Chang et al. 2010) and Europe (Bodis et al. 2014, Pacesila et al. 2016). Consumption of energy generated in hydropower plants constitutes an important share in the final consumption of gross energy.

At the end of 2011, over 160 countries had hydropower resource capacity, with a total capacity of 936 GW across 11,000 hydropower stations. The leading generating countries were China (61.4 Mtoe per year), Canada (29.9 Mtoe per year), Brazil (36.9 Mtoe per year) and the USA (23 Mtoe per year), respectively, although it is worth noting that Norway and India both have significant hydropower generation, particularly relative to their size and total electricity supply (World Energy Council 2016). In Poland, installed power in hydropower plants in 2015 was estimated at 977,676 MW (URE 2016). Figures 1 and 2 present the data on installed power in Polish hydropower plants and forecasts resulting from EU obligations.

The legislation of the countries of the EU provides the basic definitions in the directives then determine the community attitude to many aspects, including to the use of renewable sources of energy. Unification of terms in the pursuit to achieve the ultimate objectives, defined in the basic community document (the said Directive 2009/28/EC), has the key significance and is focused on achieving the goal that is often commonly called "3 × 20". The definition of "renewable energy source" follows which has been evolving in the successive "power" directives (Table 1).

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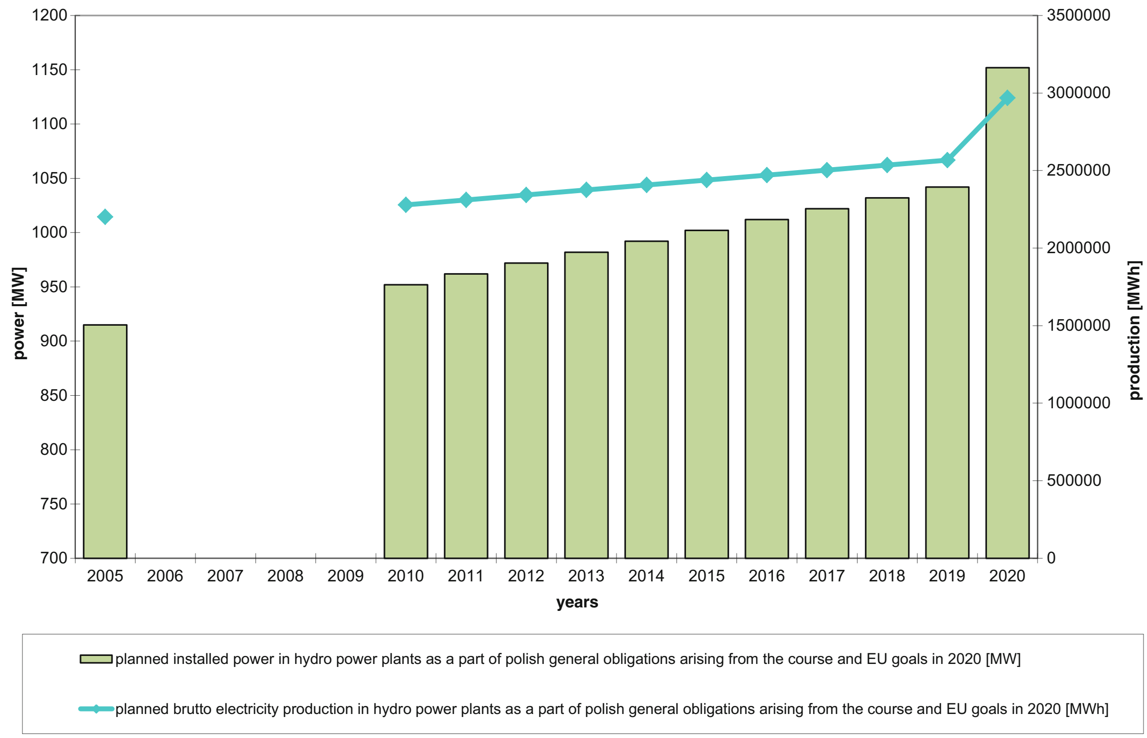

Fig. 1 Installed power of hydropower plants in Poland

The use of renewable energy in Poland is regulated in two legal acts:

- The act of 10 April 1997 on energy law (Dz. U. no. 2012 item 1059 as amended).
- The act of 20 February 2015 on renewable sources of energy (Dz. U. 2012 item 478 as amended).

These regulations, within its scope, have implemented the provisions of the Directive 2009/28/EC and define the term of

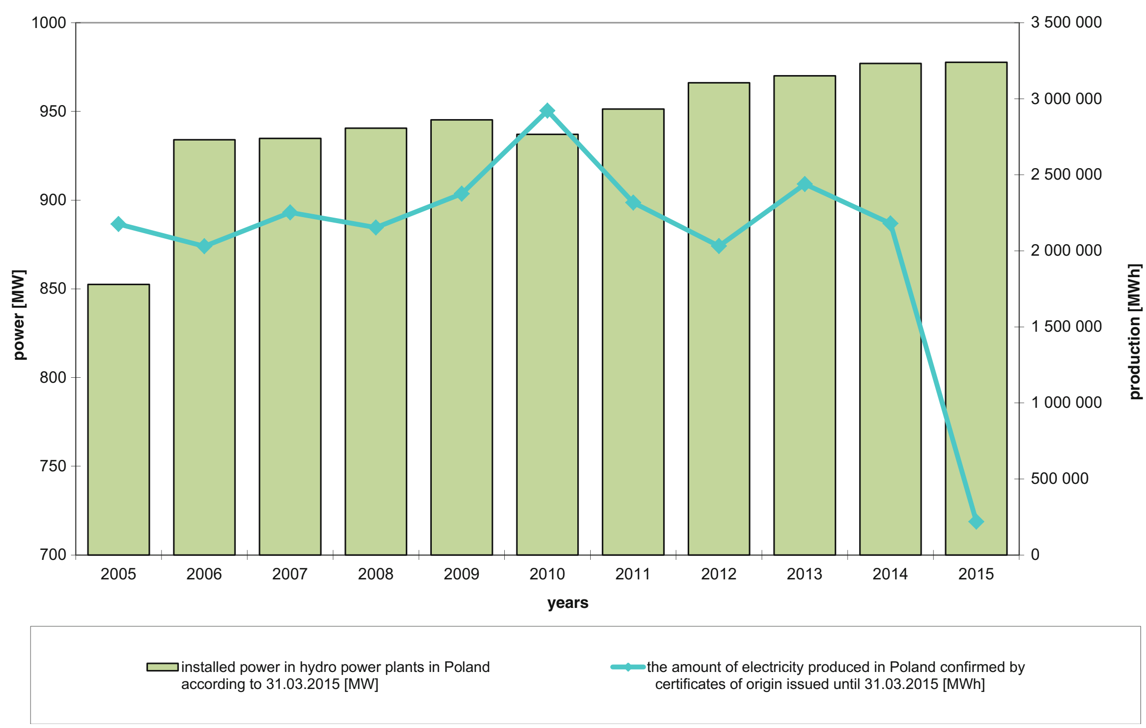

Fig. 2 Planned installed power in power plants in Poland by 2020

Table 1 Definition of renewable energy source in EU directive

Directive	Definition
DIRECTIVE 2001/77/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market (Official Journal of the European Communities L 283/33, 27.10.2001)	"Renewable energy sources" shall mean renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, **hydropower**, biomass, landfill gas, sewage treatment plant gas and biogases); "electricity produced from renewable energy sources" shall mean electricity produced by plants using only renewable energy sources, as well as the proportion of electricity produced from renewable energy sources in hybrid plants also using conventional energy sources and including renewable electricity used for filling storage systems, and excluding electricity produced as a result of storage systems
DIRECTIVE 2009/72/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC (Official Journal of the European Union 55/112L, 9002.8.41)	"Renewable energy sources" means renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, **hydropower**, biomass, landfill gas, sewage treatment plant gas and biogases)
DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Official Journal of the European Union L 140/16, 5.6.2009)	"Energy from renewable sources" means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases

"energy from renewable sources" as renewable, non-fossil sources of energy including wind, solar, aerothermal, geothermal, hydrothermal, hydropower, energy of waves, ocean current and tide, energy obtained from biomass, biogas, farming biogas and bioliquids. This term is compliant with the EU definition. In reference to water-power engineering, the legislator additionally defined the term "hydropower" as energy of gradient of inland surface waters, with exclusion of energy obtained from pump operation in pumped storage power stations or hydropower plants with the pump section. The above qualification caused certain controversies in the context of including many currently functioning small hydropower plants as facilities recognised to provide energy from renewable sources, thus resulting in the possibility of obtaining certificates of origin of energy generated in a renewable source of energy.

The paper presents considerations for the regulated market of energy in Poland in the scope of assessment of legal qualification of selected hydropower engineering facilities and including them in renewable sources.

Hydropower plants in the light of the legal regulations in force

Directive 2009/28/EC specifies that electricity produced in pumped storage units from water that has previously been pumped uphill should not be considered to be electricity produced from renewable energy sources. This statement has also been reflected in Polish regulations, as water-power engineering facilities no longer include those in which energy is obtained from pump operation in pumped storage power stations or hydropower plants with the pump section. However, the quoted national definition of hydropower is controversial due to its phrase that recognises "energy of gradient of inland surface waters" as hydropower. It appears that this phrase has been perceived too literally by the institutions that regulate the market of energy in Poland. Governing bodies decided that only power plants located directly on rivers can be indisputably recognised as renewable sources. The said overinterpretation of this definition gave rise to conflict situations, with many investments in the Polish market losing the status of a renewable source of energy. The consequence was the loss of certificates of renewable electricity, the so-called green certificates. This factor was reflected in the sudden loss of the volume of electricity generated and confirmed with certificates of origin, recorded in 2015 (Fig. 1).

Pursuant to the new act "on renewable sources of energy", the system of "green certificates" will be replaced with a new support programme, the so-called bidding system, starting on 1 July 2016. Only those renewable projects will be supported that win the auction announced by the Energy Regulatory Office President offering the lowest price of sale of energy generated in the renewable source. This support will be available only for 15 years. The auctions planned to be announced will be only open to the installations whose status as renewable energy source facilities is unquestionable.

The act on energy law states that the methodologies and definitions used in the calculation of the share of energy from renewable sources are specified in the Regulation of the European Parliament and of the Council (EC) no. 1099/2008 of 22 October 2008 on energy statistics (Dz. U. L304 of 14. 11. 2008). This resolution, in Annex B Chapter 5, lists "water energy" as the first example of energy from renewable sources, as "potential and kinetic energy of water converted into electricity in hydroelectric plants". This definition recognises all installations for recovery of energy from water in hydropower plants as sources of renewable energy, i.e. in hydropower plant facilities. Hydropower plants that use gradient of surface streams (both natural rivers and artificial canals), especially along with the traditional infrastructure (weirs, the power plant building, turbine sets, etc.), should be thus regarded as sources of renewable energy.

In the context of the quoted definition of hydropower plants, attention has also to be paid to the provisions of the act of 18 July 2001 (the consolidated text: Dz. U. 2015, item 469, as amended). It breaks down inland waters into the following:

1. flowing waters, which include waters:

   (a) in natural streams, canals and sources from which watercourses originate.
   (b) in lakes and other natural water reservoirs with continuous or periodical natural inflow or outflow of surface waters.
   (c) in artificial water reservoirs on flowing waters.

2. still waters, which include waters in lakes and other natural water reservoirs not connected directly, in a natural way, to surface flowing waters.

It considers hydropower engineering facilities to be water devices, stating at the same time that the designed method of use of water for hydropower engineering purposes should use hydropower engineering potential in a way that is technically and economically justified. However, the act does not define in any way the issue of "gradient of inland flowing waters".

Pursuant to the provisions of the water law, inland flowing waters include both natural waters as well as waters in canals and artificial reservoirs.

Hydropower engineering facilities

The main principle in designing a small hydropower plant is optimisation of the annual production of electricity. For this purpose, parameters of the installed turbo set are adjusted in reference to the existing local conditions, i.e. the head at the weir and characteristics of flows in the design cross section. These parameters are strongly dependent on the selection of a specific location, and their correct specification determines cost-effectiveness of the investment.

Impounding structures

The hydraulic gradient of rivers results from natural conditions and usually, under Polish circumstances, assumes per mille values. For this reason, achieving the expected benefits and taking into account the currently available technological solutions (the turbine equipment of hydropower plants), majority of power plants feature hydrotechnical structures in the form of weirs or barriers (Fig. 3). Impounding height of building structures is dependent on a number of local conditions. In this context, practically 90 % of hydropower plants do not make use of the natural "river grade" alone. It is rather a head of the hydrotechnical structure, and its value does not depend only on the natural river grade but also, among others, on the cross section of the river bed or on the location of the groundwater level in the surroundings that determines the possibility of rising the surface water level (Operacz et al. 2012, 2014).

The literal application of the provisions of the definition provided in the act on renewable sources of energy should thus suggest a risky thesis whether only installations operated within the river bed, without the necessity of barriering the stream with a hydrotechnical structure, should be regarded as hydropower plants? Concepts of such solutions (turbine sets anchored in the bottom or on floating platforms) are rather unknown and practically unused in Poland, though. Exclusion of other power plants operated owing to the existence of hydrotechnical structures from renewable sources would result in breakdown of the market. This is why often times all power plants (both based on flows and reservoirs) located on rivers are regarded as renewable sources. They in fact do not use river grade, but only local possibilities of barriering streams with hydrotechnical structures in order to achieve the highest head possible (the difference between the upper and the lower levels of water for the structure).

Derivation-type power plants

Weir power plants, located in the main river stream, which are unquestionably (in the meaning of the act) sources of renewable energy, are only one of the commonly used water-power engineering solutions. Derivation-type power plants are another commonly known type of hydropower plants, located on the so-called bypass. Derivations most often have inlets and outlets within the same stream, although it is neither a rule nor a requirement.

Small derivation-type power plants located on the so-called mill streams are very common in the area of Poland. Although not located on natural rivers, they are regarded as hydropower plants and are included in the group of renewable sources of energy. In the interpretation of the provisions of the law, the scale of derivation is not a criterion.

Installation on natural rivers and artificial canals

A natural surface stream features changing flows, daily, annual, and measured in a long-term perspective. The correct selection of the turbine equipment, used by the leading

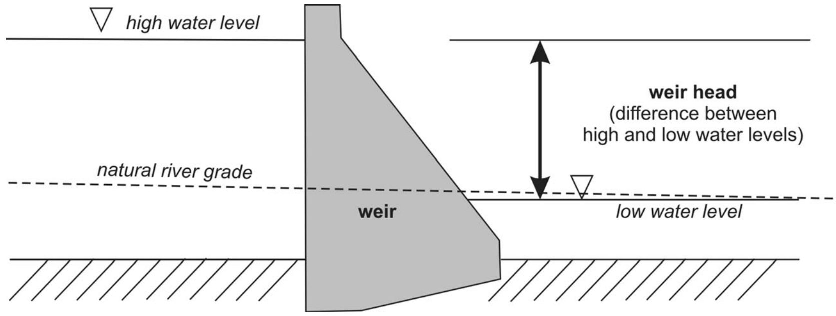

Fig. 3 Head of the structure and natural river grade

producers of turbines, requires knowledge of the curve of sums of flows observed in the river over long terms of studies. The number and parameters of turbines should be individually designed in order to adjust their hydraulic parameters to the hydrological parameters of the location. This allows to obtain the maximum effective use of the watercourse.

The curve of the sum of duration is basically a cumulative curve of daily flow frequency. It results from summing up frequencies of daily flows, starting with the smallest or highest values. The design practice usually employs the curve of sums of flow duration along with the higher values. The weir head of the impounding structure is closely dependent on the current flow of water and may even become zero at high flows. The curve of the sums of flow duration including higher values and its relation to the head for a typical river are presented in Fig. 4.

The minimum process flow varies, depending on the type of the selected turbine. For example, it is 50 % of the installed discharge capacity for the Francis turbine, 30 % for a semi-Kaplan, 15 % for a Kaplan turbine, 15 % for a Pelton turbine and 75 % for a propeller type unit (the figures are given only for information purposes) (Steller 2010).

Figure 5 shows the example of efficiency of the turbine in the function of flow, which confirms the thesis that turbine parameters may be designed for stable and foreseeable flow of process waters so as to maintain the maximum possible

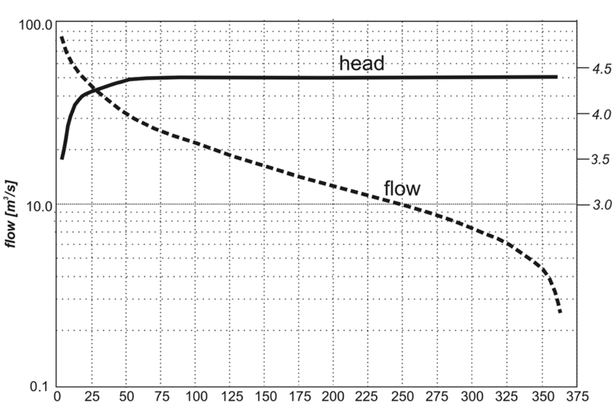

Fig. 4 The curve of the sums of flow duration and its head for a typical river

effectiveness over the maximally long period of time. However, on natural streams, large fluctuations of flows are recorded in the last 10 years in Poland. Periods of draught may last for 2 or even 3 months with low water level, especially in the summer season. The minimum required flow for the turbine installed in the power plant is then not possible to achieve (Fig. 5). There are also periods of freshnet and floods, resulting in disconnection of hydropower plants from operational use.

Domestic experience shows that structures built on artificial canals, running the so-called process waters, supplied to or discharged from industrial plants are operated in a considerably more stable way. These are hydropower plants installed, among others, on the waters used in open cooling systems in conventional power plants, industrial plants, waters in navigable canals, etc. They make use of waters at basically flat flow intensity in the function of time and usually with the natural gravitational gradient of water. These facilities, pursuant to the new definition of hydropower, have been excluded from the group of facilities included in renewable sources of energy.

Hydropower plants executed on natural rivers and using process water both generate electricity from the difference of water level at the inlet and outlet of the power plant, which means the difference between potential energy upline and downline of the power plant. Electricity thus is generated on the basis of potential energy of water and this issue is not questionable. Hydraulic gradient that is the entire difference of potential energy of water upline and downline of the hydropower plant may be natural or anthropogenic in nature, though. The thesis may be thus formulated that irrespective of the fact whether the hydropower plant is operated on natural waters or on process waters run to it with an artificial canal, the use of the difference in potential energy of water over a certain section is renewable energy. This thesis may be proven on the basis of assessment of flow conditions of process waters in the canal and finding whether the entire difference of potential energy upline and downline of the power plant is natural. One should thus determine whether water achieves additional "height" in artificial sections, thus gaining higher potential energy. The factors to be verified include the following:

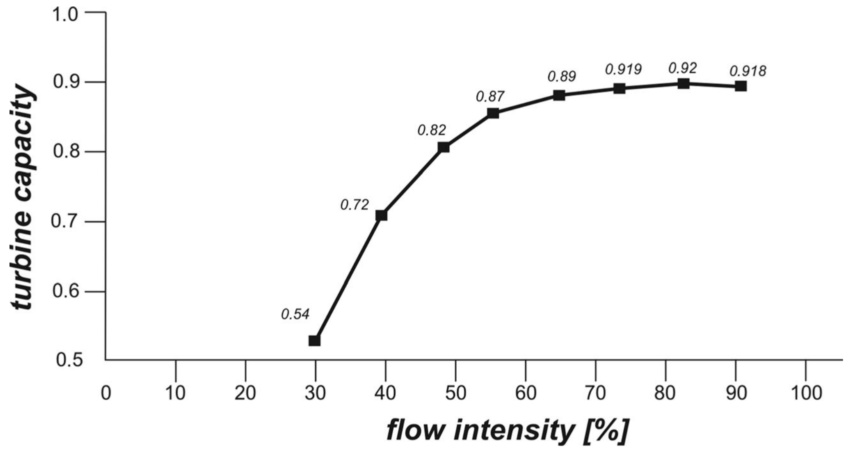

Fig. 5 Example of turbine efficiency curve in the function of flow (on the basis on Steller 2010)

1. Examination of all technological processes including water from the intake from the natural source to the natural receiver.
2. Determination that the ordinate of free water level at the intake is higher than the ordinate of free water level at the discharge to a natural reservoir.
3. Ensuring that all technological processes outside of the power plant, from the intake to the discharge of water, have negative energy balance of potential and kinetic energy.

The fact of maintaining gradient of water surface along the whole section of the artificial canal running process water is crucial. It guarantees gravitational flow of the medium, thus ensuring that potential energy of water is not increased, for example by pumping.

Conclusions

Resources of flowing waters constitute a major source of renewable energy whose use is the obligation in the context of the 3 × 20 climate package. Using them in a rational way is thus recommendable.

This rational use leads to some investment activities, and their execution must respond to clear formal and legal requirements. A very difficult situation arises when the status of engineering and power facilities is changed due to changes in the regulations of the law. Any investment in hydropower engineering consumes significant financial expenditures, investment expenses, and the possibility of acquiring additional financial support on the basis of certificates of origin constitutes an additional incentive for prospective investors. Thus, it is immensely important that formal and legal issues are stable and foreseeable in a longer perspective. Under Polish legal circumstances, legal acts and resolutions are often changed, which sometimes adds chaos, doubts and investment uncertainty.

In the context of the issue examined in the work, related to the definition of hydropower introduced to the law, it appears justifiable that the doubts whether energy acquired in a hydropower plant comes "from a renewable source" should not be decided about a legal definition, but by physics of power processes. If a hydropower plant converts potential energy of water gained by water in a natural circulation in the nature, this energy should be regarded to be renewable. Thus, it appears that the abbreviation of river grade energy has been applied in the current law only for convenience.

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