"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.023
DOI: https://doi.org/10.3846/enviro.2017.023

Towards the Development of Sustainable Hydro Energy in Lithuania

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Abstract. Development of renewable energy sources together with sustainable development covers a complicated range of issues which require complex assessment in the context of Lithuania's energy independence. Hydropower is an integral part of renewable energy resources and affects both the natural environment and human society. Although negative impact of hydropower on the environment is acknowledged, advances in modern technology can reduce the potential damage, especially when developing a network of small hydropower plants in Lithuania. Moreover, implementation and continuity of this kind of projects enables to improve the economic and social situation, e.g. by creating new jobs. Construction of small hydropower plants in combination with a sustainable development strategy would help to avoid the possible damage to the natural environment and would contribute to improvement of the country's economic and social landscape. Limitation of the negative impact on the environment is primarily based on technological solutions – the appropriate construction of fish ladders or other passes at dams enables fish migration. Meanwhile, contribution to improvement of the economic and social situation in the case of small hydropower plants depends on political decisions and activity of lobby groups.

Keywords: energy independence, environmental legislation, hydro energy, fish ladder.

Conference topic: Environmental protection.

Introduction

Issues of energy independence, a wider use and sustainable development of renewable energy sources (hereinafter – RES) remain among the most important political concerns of the Republic of Lithuania. The guidelines of the Lithuanian environmental and energy policy provide for increase of hydropower resources. The strategies also provide for promotion of national hydro energy development; however, due to objective reasons this process is difficult to implement. Special attention is given to the environmental protection requirements for construction of hydropower plants. Prohibitions against dam building in the river Nemunas and other ecologically and culturally valuable rivers have been imposed; moreover, prohibitions against putting dams, regulating rivers and changing river beds and the natural lake water level in natural and complex reserves have been introduced. Use of hydropower is restricted due to the existing prohibitions against construction of new dams or their reconstruction in ecologically and culturally important rivers (Official Gazette 2004). The EU directives promote hydro energy, meanwhile some Lithuanian laws and subordinate legislation are incompatible with the provisions of the EU legal acts and prohibit construction of new hydropower plants or adapting former dams for electricity production. Based on international experience, 20 percent of the world's electricity is produced by the hydro energy sector; in some countries, such as Norway, Paraguay and several other countries, the major part of electricity is produced by hydro energy capacity (Munoz-Hernandez *et al.* 2012; Ngo, Natowitz 2016), meanwhile in the EU an example of efficient use of hydropower to be mentioned is Austria, where approximately 55 percent of the electricity is produced in hydropower plants (Klinglmair, Bliem 2013). Drawing on international experience, the role of hydro energy is growing and has long taken a significant part of the electrical energy balance (Forsund 2015).

The European Union member states have been implementing specific national and collective programmes to encourage more efficient RES exploitation. The EU is an important energy consumer in the global energy scene; however, primary local energy sources at its disposal are limited. Meanwhile, hydropower is clean energy production which does significantly less damage to the environment than thermal or nuclear energy (Kaltschmitt *et al*. 2007). In the EU countries hydro energy is regulated by the existing state regulatory procedure which is ambivalent: it is both limited and encouraged. In Lithuania in respect of RES the first model has been entrenched. The breakthrough in the promotion system of Lithuanian hydro energy will be made in the event that it will follow the example of the leading EU countries in this regard.

Policy of the Republic of Lithuania in the area of hydro energy

The three key principles of the Lithuanian energy sector are based on energy independence, competitiveness and sustainable development. These principles are set forth in the long-term vision of the Lithuanian energy: by 2020 it aims to attain energy independence via synchronization with the EU electricity systems and integration into the Baltic Sea region markets, diversification of energy imports, while ensuring sufficient local capacities to meet domestic demand, and liberalization of the market; by 2030 it aims to create a competitive and sustainable energy sector by optimizing the fuel balance and implementing infrastructure development, as well as increasing energy efficiency and reducing pollution; by 2050 it aims to implement sustainable development of the energy sector by advancing new technologies and developing environmentally friendly energy.

Strategies for implementation of the long-term energy vision have been amended several times according to the dynamically changing circumstances, needs and requirements. The first National Energy Strategy was approved by the Government of the Republic of Lithuania on 19 April, 1994 by Resolution No. 288. This strategy aimed to formulate the general provisions for restructuring and developing the energy sector for the period up to 2015, including an increase in RES balance, as its potential hitherto had been little used. Based on the second National Energy Strategy approved by the Seimas of the Republic of Lithuania on 5 October, 1999 by Resolution No. VIII-1348, the main provisions for encouraging the Government to restructure the energy sector for the period up to 2020 were set forth (Official Gazette 1999). The government, taking into account Lithuania's goal to become a member of the EU in 2004, in 2002 developed the third updated National Energy Strategy, which was approved on 5 July, 2002 by Resolution No. IXP-1773. The third National Energy Strategy provided for an increase in the share of hydropower sources in RES balance, as previously its potential had been used insufficiently; for example, it provided for renovation and modernization of Kaunas Hydroelectric Power Plant by 2007. Drafters of the fourth National Energy Strategy of 2007, approved by the Seimas on 18 January, 2007 by Resolution No. X-1046, took into account the most important recent changes in the economic and energy sector both in the country and in the region, and made use of the accumulated experience and the latest information. The strategy sets the ways and means to ensure the strategic security of energy supply by reducing or neutralizing the negative impact of dependence on the dominant supplier of primary energy and provides for promotion of the use of hydropower. To this end, the strategy aimed to increase the contribution of hydropower into Lithuanian RES balance, reduce dependence on fuel imports and alleviate negative effects of increases in fossil fuel prices. The fourth National Energy Strategy highlighted that with the aim to achieve the strategic energy objectives, connection with the Polish and Swedish electricity systems should increase the security of energy supply and allow for integration into the Western European electricity market. Construction of the new Kruonis Pumped Storage Hydroelectric Power unit was supposed to increase the balancing possibilities and use the power plants and electricity transit more efficiently. According to the principles of promoting sustainable development, the total installed capacity of hydropower plants with less than 10 MW capacity is set to be increased up to 40 MW. The strategy also provides for the analysis of the environmental requirements for construction of hydropower plants by using the potential of the Neris River and its watershed. The National Renewable Energy Resources Development Strategy, adopted by the Government of the Republic of Lithuania on 21 June, 2010 by Resolution No. 789, emphasizes that Lithuania has limited possibilities to use local fossil fuel resources for energy, thus it is essential to use renewable energy sources more extensively (Official Gazette 2010). In terms of the sustainable development policy it should be noted that the essence of this policy is to search for compromise between economic, environmental and political aspects. In recent years, the defined strategic goals in the area of renewable energy sources (RES) enabled rapid development of the local energy production capacity and development of renewable energy sources in Lithuania. Since 2007, the share of RES in gross final energy consumption has increased by 7.16 percentage points.

The three key principles of the energy sector have remained the same: energy independence, competitiveness and promotion of sustainable development. Lithuania continued to increase the use of RES for production of electricity and heat, as well as to exploit the hydro energy potential, which does not negatively impact the environment. In order to achieve this goal, Lithuania has planned to install hydropower plants with 141 MW capacity in 2020 (Official Gazette 2012).

A significant factor of the energy sector is promotion of sustainable development. The Lithuanian national sustainable development strategy was approved on 11 September, 2003 by the Government Resolution No. 1160. The Ministry of Environment was assigned with the responsibility of coordinating implementation of this Strategy. Biennial reports on implementation of this Strategy are due to be drawn up and submitted to the National Commission on Sustainable Development and concerned agencies, as well as presented to the public. Drafters of the strategy assumed that during the period up to 2020 development of Lithuania will be affected mainly by the euro-integration processes, thus the expected changes and their possible realization are directly linked to Lithuania's membership in the European Union. Attention should be drawn to the fact that the sustainable development strategy is viewed not as an alternative to the strategies that have already been designed or are under development, but as a document whose purpose is to harmonize the goals and objectives of different sectors and their branches as well as measures for their implementation on the basis of priorities and principles of sustainable development. The overall strategic objective of sustainable development is worded as follows: to align the interests of the environmental protection and economic

and social development, to ensure a clean and healthy environment, efficient use of natural resources, global economic welfare and strong social guarantees, and during the period of implementation of the strategy (by 2020) to achieve the current average level of the old members of the European Union according to economic and social indicators and efficiency of using natural resources, whereas the environmental pollution indicators should not exceed the EU permissible standards, and requirements of international conventions limiting environmental pollution have to be implemented.

The Lithuanian national strategies, in line with the EU policies, rely on the following trends – the EU directives promote hydro energy and construction of dams. However, some laws and subordinate legislation contradict provisions of the EU legislation and prohibit construction of new hydropower plants or adapting former dams for electricity production. For example, the order of the Minister of Environment of Lithuania "On Approval of the Action Plan on Conservation of Landscape and Biodiversity for the period of 2015–2020", 9 January, 2015, No. D1-12, raises the strategic goal of preserving landscape habitats of various territorial levels and their ecological potential, ensuring proper planning, management, use and sustainable development thereof, which is becoming a serious challenge with regard to promotion of hydro energy. The order of the Minister of Environment of Lithuania on the amendment of the order "On Approval of the Action Plan on Conservation of Landscape and Biodiversity for the period of 2015–2020", 14 March, 2016, No. D1-181, for instance, indicates river rapids with Kurkliai communities, landscape and biodiversity conservation, which also complicate development of hydro energy.

Moreover, the Law on Water of the Republic of Lithuania of 21 October, 1997, No. VIII-474 provides that legal and natural persons of the Republic of Lithuania, who use water reservoirs for hydro energy and other needs and install reservoirs, must comply with the rules on the maintenance and use of reservoirs, the regime of level fluctuations, let the environmentally protected debit through hydraulic structures, maintain accounting for the water flow through the facilities, maintain the hydraulic structures, ensure their safety, take the appropriate measures to eliminate the processes of erosion in the banks of the reservoirs, install and use effective measures for the protection of fish life (Official Gazette 1997). A more recent amendment of 2004 prohibits construction of dams in the river Nemunas and ecologically and culturally valuable rivers. The list of ecologically and culturally valuable rivers or their stretches is approved by the Government.

The National RES Action Plan covers objectives set to assess the development potential of the use of RES. Therefore, hydro energy should be seen as an important national task which ensures sustainable development of RES and national energy independence. It is also necessary to take into account the principles of the National Sustainable Development Strategy and to assess the country's possibilities to use hydropower sources for balancing and reservation needs. In this context, it is necessary to create simplified conditions for reconstructing the former water power plants, which have long proved their comprehensive (including environmental) acceptability (Ferreira, Camacho 2016).

According to Directive 2009/28/EC on the promotion of the use of RES, adopted by the European Parliament and the Council, Lithuania is committed to increase the share of RES in the country's gross final energy consumption to 23 percent by 2020, while the share of RES, in comparison with the final energy consumption in the transport sector should be increased in all modes of transport to not less than 10 percent (Ministry of Energy of the Republic of Lithuania 2016). The Law on Energy from Renewable Sources of the Republic of Lithuania of 12 May, 2011, No. XI-1375, whose aim is, as stated, "to ensure sustainable development of the use of renewable energy sources", provides for the increased installed total capacity of hydropower plants, connected to power networks, up to 141 MW, which has not yet been achieved.

The Law on Protected Territories of the Republic of Lithuania of 4 December, 2001, No. IX-628 and its subsequent amendments provide for the possibility to restore water mills in protected areas as objects of immovable cultural heritage, which provides additional possibilities to develop hydropower production (Official Gazette 2001).

The Republic of Lithuania Law on Energy from Renewable Sources has also set sectoral objectives – to increase the share of electricity produced from RES, compared to the country's gross final energy consumption, to at least 20 percent, to increase the share of centralized heating energy, produced from RES, in the heat energy balance to at least 60 percent, and to increase the share of renewable energy sources used by households in the balance of energy sources used for heating to at least 80 percent (Official Gazette 2011).

Overview of the state of hydropower plants of the Republic of Lithuania

According to the data of the Department of Statistics of Lithuania, Lithuania has already reached the target of 23 percent – in 2014 the share of RES in the national energy balance took more than a fifth and amounted to 23.86 percent (increased by 0.91 percentage points compared to 2013). In 2015 the amount of electricity produced by using RES made up 1,740.7 GWh; however, hydro energy accounted for only a relatively small part. The largest part of electricity was produced by wind power plants – 48 percent, and by hydropower plants – 24.6 percent (by comparison, electricity produced by biofuel power plants amounted to 23.2 percent, and by solar power plants – to 4.2 percent) (VKEKK 2015).

The initial draft of the national energy strategy prepared by the Lithuanian Energy Institute and submitted for discussions on 16 December, 2015 states that in 2014 12.6% of electricity consumed for all country's needs and

47.0% of the heat supplied to the central heating network was produced from renewable energy sources. The share of electricity produced from renewable energy sources in the total electricity consumption of the country increased from 3.4% in 2000 to 12.6% in 2014. The share of electricity, gas, and steam supply and air conditioning activity in the structure of gross value added in Lithuania in 2014 amounted to about 2.2% and was higher than the EU average (1.9%). The role of employment in this economic activity within the total employment structure in recent years declined and in 2014 amounted to 0.7%, however it was still ahead of the EU average (0.6%). Taking into account the fact that local and renewable energy sources in Lithuania are very limited, they are an important element of the country's energy that provides the maximum energy security and energy independence. Production of local and renewable energy sources in 2000–2014 increased by 52.8%, while their share in the balance of primary energy consumed in the country increased from 15.9% in 2000 to 24.9% in 2014. The growth of renewable energy sources consumption is highly significant, which during the period of fourteen years has increased to 89.8%, while the share of these sources in the country's total primary energy balance increased from 9.4% in 2000 to 18.3% in 2014. However, attention should be drawn to the fact that this growth is mainly due to significant increase in consumption of firewood and wood waste usable as fuel from 646 thousand toe in 2000 to 1085 thousand toe in 2014, or 68.0% (LEI 2015). The project of the national energy strategy drafted in 2016 by the same Lithuanian Energy Institute, in the analysis of local and renewable sources indicates the following amounts of usable energy – hydropower ~ 1.9 TWh / year (~ 163.4 ktoe). Currently about 0.4 TWh / year (~ 34.4 ktoe) is used. It is stated that only a very limited power gain is possible. The most important factor that limits a more significant development is the environmental requirements. According to conducted studies, it is necessary to note that the Lithuanian river hydrokinetic energy sources to date have not been assessed and require detailed research (LEI 2016).

According to the latest data of 14 November, 2016, 2529 power plants were installed in Lithuania, with permits to produce electricity from renewable energy sources. The overall cumulative installed capacity of these power plants reached 787.951 MW, out of which 2,231 were solar power plants (72.28 MW), 150 were wind power plants (parks) (493.781 MW); 11 were solid biomass power plants (59.96 MW), 38 were biogas plants (34.021 MW), and 99 were hydropower plants (127.909 MW) (LEI 2016). Two major hydropower plants produce the largest share of energy: Kaunas Algirdas Brazauskas' Hydroelectric Power Plant (with a capacity of 100.8 MW and 4 units 25.2 MW each, sold 0.27 TWh of electric power in 2015) (LE 2016a) and Kruonis Pumped Storage Plant (with a capacity of 900 MW and 4 units 225 MW each, sold 0.67 TWh of electric power in 2015) (LE 2016b). Kaunas Algirdas Brazauskas' Hydroelectric Power Plant is the largest power plant which uses renewable sources in Lithuania – the power plant annually produces about 4–6 percent of electricity consumed in Lithuania (Marčiukaitis *et al.* 2016).

Considering the proposed production volume of energy from RES by 2020, it is necessary to draw attention to the fact that the planned total volume of 18720 GWh and the share of hydro energy in it is conditioned by the restriction of hydro energy potential with regard to the environmental requirements and therefore biomass and wind energy sources have significant potential to reach the target of electricity production from RES. Meanwhile, the planned electricity production in small hydropower plants (<10 MW) is estimated with an assumption that by 2020 the potential limited by the environmental requirements will be used in full, which restricts the use of the current potential. By comparison, it is worth mentioning that according to the electricity sector description data of 1935, out of 309 power plants 96 were hydropower plants and hydropower hybrid plants, with 102 hydropower units of total capacity of 1,432 kW, which produced electricity. Each year they produced 835.6 thousand kWh. At that time, this accounted for about 2.5 percent of the produced electricity (LHA 2012). According to the data of 1958, there were 320 hydropower plants (HPP, mills, sawmills, etc.) with a total capacity of about 17.6 thousand kW. Since 1954 electrification of the rural areas from the state power gridline was allowed, therefore, since 1959 liquidation of small HPP was started. 32 HPP stopped functioning, whose installed capacity was about 3.3 thousand kW, whereas electricity production was 12.9 million kWh per year. After the restoration of Lithuania's independence, in the beginning of revival of small HPP (in 1993) in Lithuania there were 12 small HPP with the installed capacity of 5.3 thousand kW and production of electricity of 13.2 million kWh. Electricity production in 1998 amounted to 26.3 mln. kWh, i.e. it doubled in comparison with 1993 (Burneikis, Jablonskis 1998). In 2000, 28 small HPP were functioning, their capacity increased to 8.8 thousand kW; in 2004, 77 small HPP were functioning with the total capacity of 21.3 MW (Katinas 2007).

After Lithuania joined the EU in 2004, the HPP construction rate decreased – in 2010 there were 89 small HPP. Currently, Lithuania has 98 small HPP with a total capacity of 26.73 MW. Small hydroelectric power plants produce an average of 60–80 GWh electricity per year, which accounts for less than 1% of the total electricity consumed in the country (LHA 2012). The installed capacity of hydropower plants in Lithuania during the last decade has remained largely unchanged: the major hydropower plants (> 10 MW) accounted for 101 MW, whereas plants with small capacity (<10 MW) accounted for about 27 MW during the last decade (Official Gazette 2006). The National Energy Efficiency Programme for 2006–2010 provides for an increase in the total capacity of hydropower plants (including Kaunas A. Brazauskas HPP) to 141 MW by 2020.

Ruined former water power plants (which currently amount to about 200) hinder the rational use of rivers and streams. Due to the above-mentioned legal prohibitions, interested persons for decades have been refused permits to fully restore or reconstruct water power plants in rivers; buildings of water mills on land are recognized as heritage

objects, whereas hydro-technical structures in rivers are ignored. P. Punys and B. Ruplys note that there are cases of unauthorized initiative, which is legally persecuted, taken out of despair to handle the environment of water power plants at risk of huge fines (Punys, Ruplys 2012). Reconstruction of these power plants has to ensure that impact on the environment is minimal and that backflow is within the natural river flood limits. The multi-purpose use of water bodies is also provided for, highlighting the social effect on the countryside environment (Punys *et al*. 2010).

Besides, attention should be drawn to the fact that despite the significant studies that have been carried out, there are extensive research areas awaiting explorers. For example, to date only theoretical hydrokinetic power of flow of the Neris river and density in cross profiles has been assessed. The average power density of the Neris River is about 0.3 kW / km^2 and the average cross profile power is about 50 kW (the National Programme for the Development of Renewable Energy Sources by 2020). Theoretical research results on hydrokinetic power of the river will be used in assessing the technical potential to use hydrokinetic energy resources of the Neris river. Although hydrokinetic power of Lithuanian rivers is not high, promotion of advances in technologies can be expected to contribute to production of electricity. From the technological point of view, perspectives of the near future are linked to the traditional hydro energy.

Application of environmental measures to reduce the impact of hydropower plants

Construction of dams in rivers prevents not only fish passage, but also free movement of other animal species. However, prohibition to construct dams limits the development of hydro energy as a promising renewable energy source. To ensure fish migration up and down the river, dams are equipped with fish ladders, or other facilities, like chutes, to allow the fish to migrate freely along the river. For quite a long time a lot of countries have set legal requirements to install fish passes or other devices (WCD 2000), whereas the United States as early as in 1911 enacted the requirements to install fish passes or chutes when constructing dams (Dyche 2012).

Hydro energy development has to be consistent with the principles of sustainable development, i.e. economic and social benefits have to be balanced and environmental requirements have to be applied, reducing the negative impact on aquatic ecosystems and the environment. It has been previously found that dams have impact on the entire aquatic ecosystem, i.e. aquatic flora and fauna, and quality of water in rivers, morphology of river beds, soil, etc. (Stull *et al.* 1987). This is confirmed by current studies (Kang, Kazama 2012; Rydgren *et al*. 2013; WCD 2000). The complex impact of backflow on ecosystems is a very broad topic, so due to its narrow scope, the work is limited to a brief overview of the influence of dams equipped with fish ladders on migrating fish.

One of the most important environmental measures is to install appropriate fish ladders, because improperly installed fish ladders are inefficient and do not ensure fish passage. Thus improperly installed fish ladders in dams of hydro power plants have comparable effects as blocking fishways. The prevailing view both abroad and in Lithuania is that it is necessary to develop hydro energy, install a variety of fishways, which would allow migration of fish, and apply other environmental measures such as reinforcement of waterfronts (Punys *et al*. 2010; WCD 2000).

There is evidence that fish can successfully cross only fishways of appropriate construction, besides they have to be installed in the principal channel of the river (WCD 2000). It has been estimated that in properly installed fihsways mortality rate of juvenile salmonids can reach only about 3 percent (Muir *et al.* 2001). Successful fish migration depends on properly equipped fish ladders and their types, which increase the possibility of fish migration. It is also necessary to install protective measures for returning fish so that they would not fall into turbines. These are safety nets, screens, and grilles, which prevent fish from entering the turbines. The Water Framework Directive (Directive 2000) does not prohibit construction of dams; however, it points out that the impact on the aquatic ecosystems has to be minimal.

In Lithuania installation of fish ladders is regulated by the Order of Minister of Environment (Official Gazette 2003) on approval of 'Technical Construction Regulation STR 2.02.03:2003 'Fish Ladders. Main Provisions' (17 November, 2003 No. 565). The list of rivers important for fish migration, where dams have to be equipped with fish ladders, is approved by the Order of the Minister of Agriculture (Official Gazette 2007). In Lithuania, according to the preliminary data, there are about 1500 different dams, but only 24 are equipped with fish ladders. Two different types of fish ladders are effectively installed in the Vilnia River (Vilnius city). It is estimated that salmonid fish successfully pass them and create fish nests above the fish ladders. Every year the number of fish nests increases. In 2016 their number increased by 12.2 times in comparison with 2015 (EPA 2016). This proves that the efficiency of the two fish ladders is high. Efficiency of fish ladders has not been studied in all other rivers.

As shown by the research on fish migration through fish ladders in the Vilnia river, properly installed fish ladders are a good environmental measure. Hence, the existing dams with properly equipped fish ladders cannot impede minor hydro energy in Lithuania. However, there are other opinions, that dams have a negative impact. This view could be accepted only in case that dams are not equipped with appropriate fish ladders.

Conclusions

The policy of the Republic of Lithuania in the field of hydro energy is defined in the Law on Renewable Energy. This law and its subsequent supplements regulate the RES sector in detail; however, in case of the hydro energy sector, individual amendments for this specific area should be provided.

So far, the Republic of Lithuania has no separate and officially approved hydro energy strategy or development programme. Meanwhile, laws of the Republic of Lithuania on water, protected areas, etc. are not favourable for development of hydro energy. Permission to build dams in ecologically and/or culturally significant territories in order to restore the cultural and technical heritage objects, while ensuring biodiversity and landscape protection, would contribute to development of the country's hydro energy.

The evaluation of compatibility of the Lithuanian legislation with the EU requirements leads to the conclusion that when transposing provisions of the European directives into the national legislation, Lithuania has established extremely strict ecological requirements and completely suspended development of both large and small HPP. Perspectives of hydro energy development are linked to the increase of additional quota for small hydropower plants, which use traditional backflow technologies, having relaxed environmental requirements.

Construction of new dams from the environmental point of view is inexpedient, in spite of the need for hydro energy as a renewable energy source. The existing dams must be equipped with only properly constructed fish ladders or other facilities. Improperly constructed fish ladders are inefficient and do not ensure fish and other animal species migration.

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