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Policy update

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LIFE NEXUS

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Data Beneficiary

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1. Summary

The purpose of this report is to deliver on status of hydropower sector in three Life NEXUS target countries with special emphasis on state policy towards small hydro and especially hydraulic energy recovery in municipal water circuits of three European countries – Lithuania, Poland and Spain. The main part of the document are three national reports with the same structure comprising overview of the energy and electricity sector, statistical data on the hydropower (HP) and small hydropower (SHP) sector, reports on main hydropower policies and initiatives, and finally – policy recommendations for SHP development.

Substantial differentiation between state approach to hydropower and state policy towards SHPs can be noticed between the countries: from hostile attitude represented by Lithuanian authorities, through inconsequent, but generally unfriendly towards large hydro and tolerating SHP in Poland, to pretty pragmatic, but adhering environmental priorities in Spain. Hydraulic energy recovery from municipal water circuits is everywhere welcome and there exists still a potential for such installations – especially in Poland and Spain. Increasing sustainability of DWTP installations and their resilience to voltage outages and other unpredictable phenomena is strongly stressed in Polish and Spanish reports.

All 3 countries use pumped storage technology and invest in their PSPPs although the approach is not the same. While Lithuania increases capacity of its existing plant, Poland conducts environmental and feasibility studies of two new ones, 3 new Spanish projects are already on the list of European Projects of Common Interest.

All 3 reports emphasise the need for simplifying procedures necessary to start a project. In case of Lithuania it is stressed that the system of incentives for SHP investors should be restored. Lithuania is probably the only EU country where such incentives do not exist.

In all reports significance of educational activities is stressed. However, while the Spanish report emphasizes only the need to raise public awareness about the significance of hydropower, the Polish and Lithuanian report show also the need of intense capacity building. Especially the Polish report emphasises the losses in qualified professional staff due to multiyear state policy.

All reports mention National Energy and Climate Plan. However, it is only in Spanish document where hydropower sector is addressed with due attention. Relevant measures are cited in the report showing the significance attached by Spanish NECP to increasing system elasticity by pumped storage technology and to repowering aging SHPs.

All reports comprise a list of policy recommendations addressed to national authorities. Education needs at all levels are very strongly emphasised in Polish document. However, again it is the Spanish comprehensive list which can serve as a template for the hydropower sector needs in other countries.

2. Introduction

The framework of European's climate and energy policy is shaped by the international context. Recent events, such as the COVID-19 pandemic and the energy crisis triggered by Russia's invasion of Ukraine, have significantly impacted the energy system, prompting short-term responses from various institutions and sectors. However, these short-term challenges coexist with a broader structural framework, notably the 2015 Paris Agreement, which aims to limit global temperature increases to below 2°C above pre-industrial levels and strive for 1.5°C. Despite this, the IPCC's Sixth Assessment Report warns that current policies as of late 2020 are projected to lead to a global temperature rise of 3.2°C by 2100, while measures under Paris Agreement commitments would limit this increase to 2.8°C. The IPCC emphasizes that achieving climate resilience requires prioritizing equity, social justice, inclusion, and just transitions, while also highlighting the short- and long-term benefits of early climate action.

At COP 28, additional efforts to meet Paris Agreement goals were recognized as critical, with calls for accelerating the energy transition. This includes tripling renewable capacity, doubling energy efficiency improvements, phasing down coal use, eliminating inefficient fossil fuel subsidies, and fostering a fair and orderly transition away from fossil fuels. The EU has updated its energy and climate framework to address both the climate crisis and challenges arising from dependency on fossil fuels. COP 28 also urged countries to submit ambitious economy-wide emission reduction targets ahead of COP 30 to align fully with the 1.5°C goal.

The EU has increased its climate ambitions, committing to a 55% emissions reduction by 2030 and climate neutrality by 2050, supported by the European Climate Law and the "*Fit for 55*" package. The 2022 **REPowerEU Plan** addresses the energy crisis caused by the war in Ukraine by reducing dependence on Russian fossil fuels, boosting energy system electrification, and transforming energy-intensive industries. These efforts position the EU as a leader in global decarbonization, leveraging innovation to drive the energy transition.

Having said the above one should notice high differentiation in the results achieved so far by the EU member states which follow not only from the natural conditions, but also the national policy adopted (Fig.2.1). This situation is reflected in policy reports from three target countries of the Life NEXUS project Lithuania, Poland and Spain.

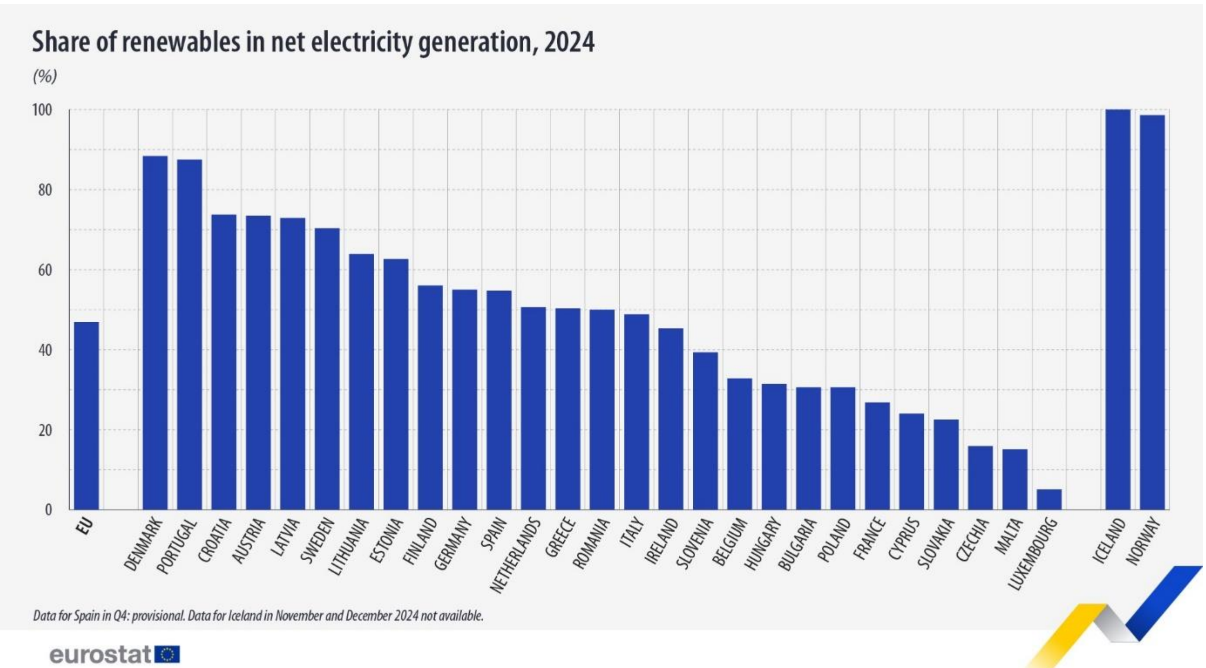

Fig. 2.1 Share of renewables in net electricity generation in EU and 2 other EERA countries, 2024. Source Eurostat

Table 2.1 Share of renewables in gross energy and electricity consumption in 3 Life NEXUS

Share of renewables	Lithuania	Poland	Spain	EU
in gross energy consumption	31,3	16,6	24,9	24,6
in gross electricity consumption	36,5	25,8	35,2	45,3

As it can be seen from Table 2.1 Lithuania shows the highest position in terms of some parameters of renewables share in the national energy mix. This is largely the consequence of EU requirement to shut down the Ignalina NPP as a condition for joining the European Union back in 2003. With no own fossil resources the country is importing 70 % of electricity consumed. The main portion of Lithuanian own electricity production comes from wind (45 %). The input of thermal and solar power plants is 23% and 11.1 %, respectively. The share of hydropower sector is 7.9 % with no prospects for development due to very strong position of green oriented politicians having introduced hydropower discriminating regulations. Development of micro hydropower plants recovering hydraulic energy at outlets of waste water treatment plants is perhaps the only opportunity for slight increase of hydropower electricity production, but the total available potential has been assessed at merely 500 kW. Therefore the policy recommendations of the authors focus on regulatory simplifications.

Despite showing quite similar share of renewables in gross electricity consumption, Spain conducts completely different policy. In view of advancing climate change the top priority in the environmental policy of this country is water retention which requires new dams and provides opportunity for hydropower development. Hydropower plays a significant role in the energy mix, providing 12 % of electricity. The rising demand for regulatory power capacity in the electric power system penetrated by intermittent electricity sources is the reason of systematic pumped storage sector development while the urgent need to further increase water retention and resilience to sudden flood threats provides an opportunity for further hydropower development. Even if progressing climate change results in the decrease of available discharges. The capacity of small hydro sector is 2145 MW out of which more than 1.3 MW are linked with energy recovery.

Out of 3 countries under consideration Poland was the last one to adopt decisive measures towards energy transformation. Due to extremely strong and very active coal lobby such measures have not been undertaken even under conditions of Polish coal mining industry losing its previous competitiveness. Therefore, its share of renewables both in the gross energy and electricity consumption is not high today despite decisive measures taken in recent years. The policy towards hydropower has been highly inconsequent over the years – due to powerful lobby of green NGOs also increasingly unfriendly. Due to this reason the loss of qualified staff may be called alarming. Nevertheless, the approach towards SHP allows for some small progress. The total capacity of Polish SHPs today is 297 MW of which 2.5 MW are linked with energy recovery. Such high value follows mainly from Skawina SHP (1.5 MW) recovering energy of cooling water flowing out of the Skawina thermal power plant.

Further details on the situation in each of the target countries are to be found in the next section.

3. Policy update

3.1. Poland

3.1.1. Overview of the energy and electricity sector

Following the data of the PSE SA (Polish Transmission System Operator), on the last day of 2023 the power capacity of electricity sources in Polish Electrical Power System was 67 770 MW and the electrical energy delivered in 2023 by these sources was 163 629 GWh. For long decades electrical power sector of Poland was based essentially on the coal and lignite fired power plants which is well illustrated by Figs 3.1.1 and 3.1.2 taken from an annual report of PSE SA . Please note that pumped storage sector is included in all data cited which may be misleading for the reader. In fact, still in mid nineties of the previous century the hard coal and lignite fired plants represented ca 94 % of the electrical power sector in terms of installed capacity and over 98 % in terms of net electricity generation. Hydropower was practically the only renewable electrical energy source with contribution close to 1,6 % and featured by a declining trend due to restricting sector development to small installations – mainly private ones. Coal lobby was extremely strong, leading even to declining the role of existing pumped storage power plants by expensive investments aimed at rising elasticity of thermal power plants and obliging some industrial clients to take part in system regulation. Already during the political transformation at the turn of eighties and nineties, green NGOs emerged fighting fiercely against nuclear and hydropower sectors and seeing no threat in still rising dependence on fossil fuels. Despite extremely fierce onsite actions they appeared unable to stop finishing construction of the Niedzica Dam and Hydropower Plant on Dunajec river (90 MW PSPP). However, they appeared strong enough to stop the highly advanced construction of the Zarnowiec Nuclear Power Plant (the most significant Polish power sector project at this time, continued consequently since the beginning of seventies) and to derail any further development of large hydro in Poland.

Despite the first commercial wind power plant (150 kW) having been commissioned in Poland in the end of eighties, one had to wait ca. 20 years until the first signs of renewables could have been seen on the PSE diagrams. Exactly at this time rising interest in biomass emerged. Biomass combustion and especially co-firing with hard coal in refurbished thermal power plant furnaces was considered at his time the Polish road to fulfilling the EU demands following from RES directives. Thanks to state support, the co-firing boom rose very swiftly, but even faster was its decline due to technological problems, unwanted impacts on various markets, rising protests of RES competition other affected economy branches, finally - criticism of powerful NGOs. Generally, Polish policy towards RES sector remained highly unstable and inconsequent throughout the whole previous decade which was manifested by extreme problems in reaching the 2020 RES target index after good progress in the beginning of the decade. In fact, the problems were direct consequence of a series of events: collapse of the green certificate system, swift departure from the co-firing technology, RES sector crisis due to prolonging deadlock in the new support system development, regulations hampering development of the land borne wind power plants while the off-shore farms were still only under discussion. It was only at the very end of the decade that Polish authorities started to change their course in view of threatening consequences from the European Commission. However, this was already the time of Green Deal and photovoltaic technology gaining enormous impetus.

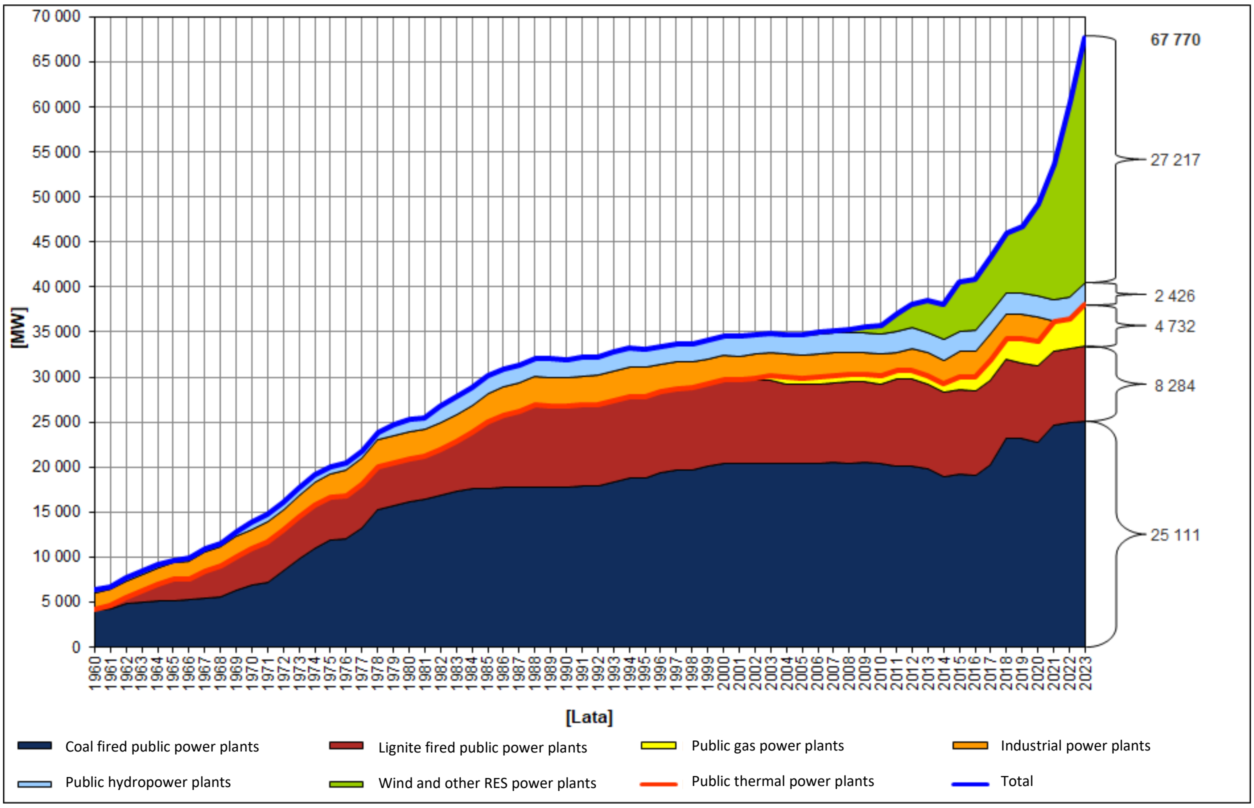

Fig.3.1.1 Installed power in the Polish electrical power system (source: PSE SA)

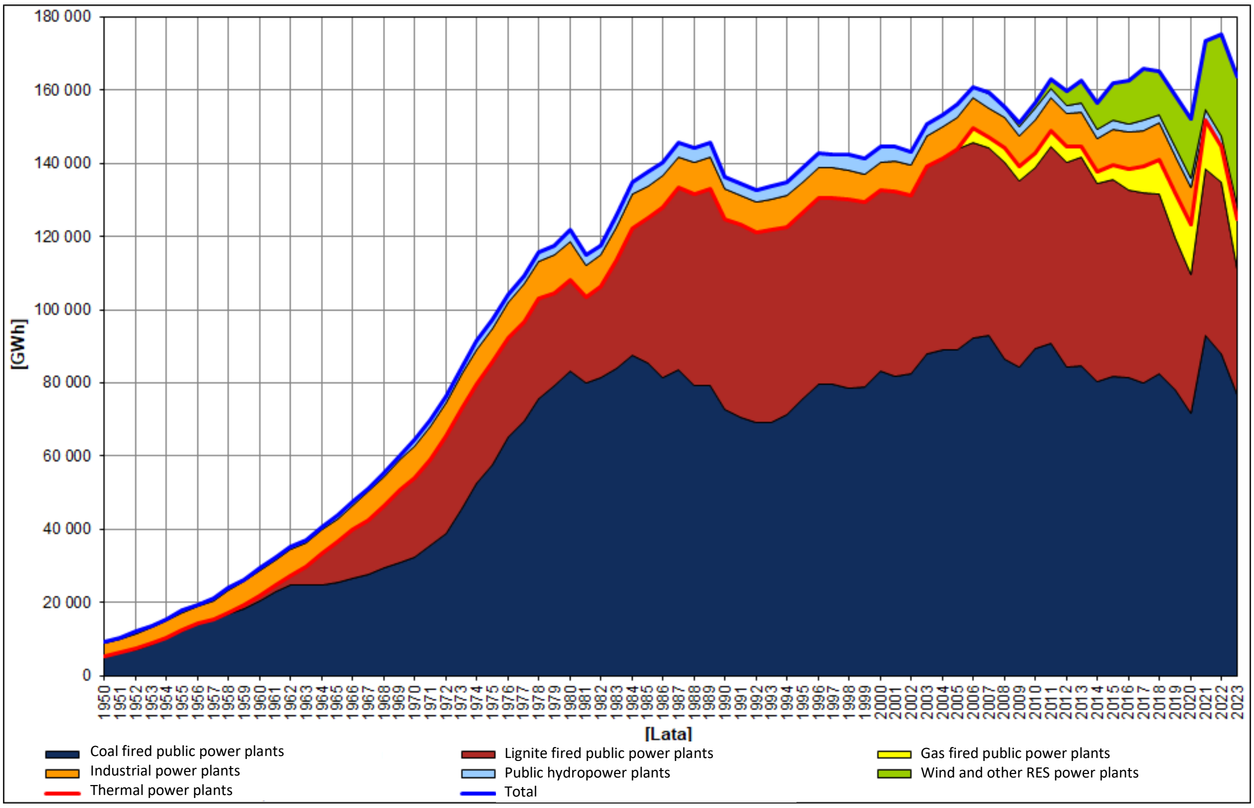

Fig.3.1.2 Energy generation in the Polish electrical power system (source: PSE SA).

Signing the Green Deal agreement - despite very strong doubts and even opposition from numerous Polish politicians, energy experts and coal lobby representatives - was a turning point in the way of thinking of Polish political and economic elites. Since then it has become clear to most of them there was no way back from the adopted decarbonising effort. Most probably it became also clear that the previously announced extensive electromobility development programme would make no sense so long as you do not decarbonise sufficiently your electric power sector – irrespective of some severe electrical car exploitation problems.

The real game changer in the campaign to increase RES contribution to the electrical energy mix of Poland may appear the off-shore wind power sector. The Polish off-shore wind potential is estimated as 33 GW and the European Green Deal only intensified preparations for its development. Following the document "Polish Energy Policy up to 2040" 11 GW should be developed till the end 2040. However, according to numerous announcements, the first 6 GW should be commissioned in the next few years. Furthermore, localisation concessions have been already awarded for the wind farms of 15 GW capacity (Fig.3.1.3). Following numerous expert opinions a greater advantage of Baltic off-shore locations is high wind stability.

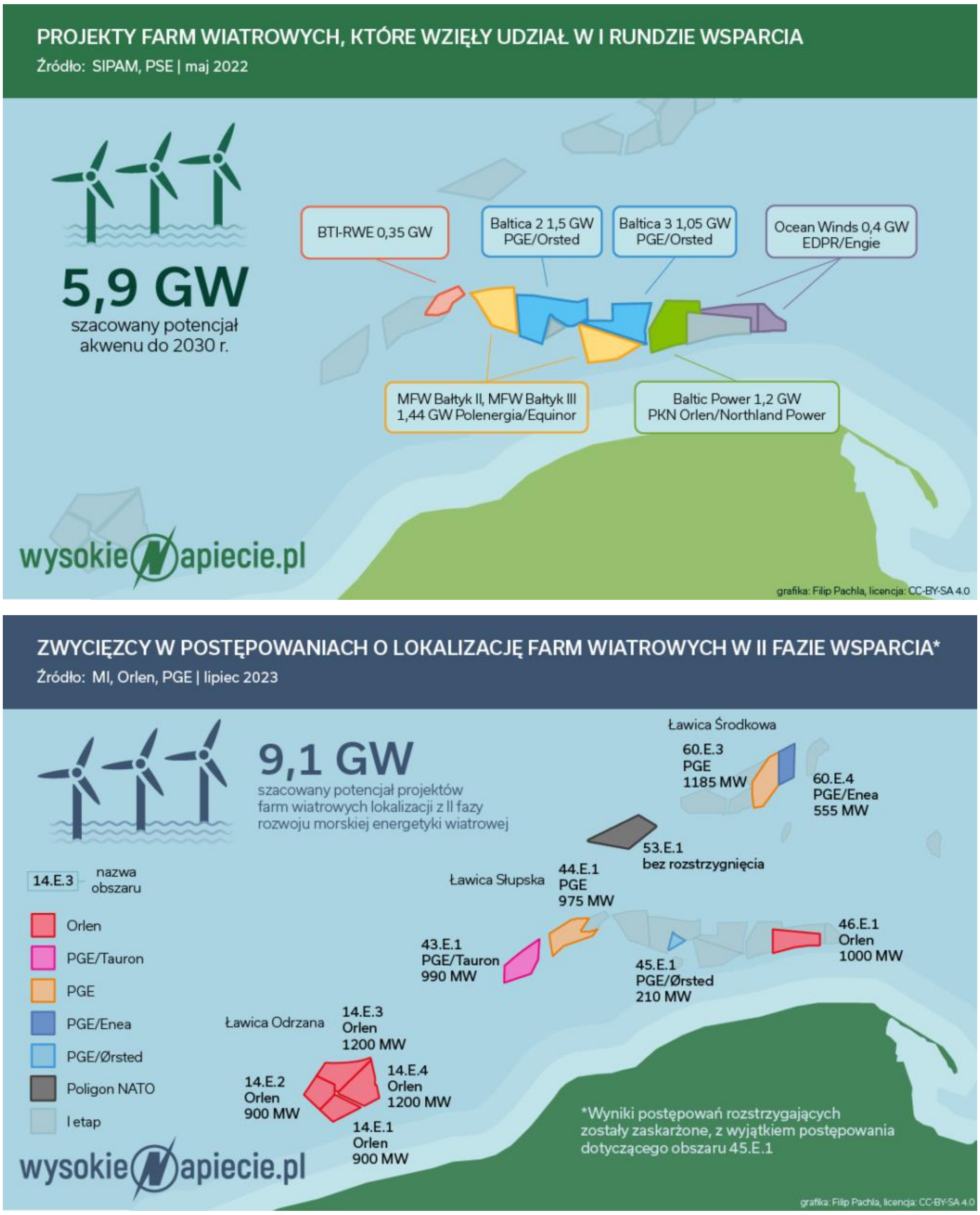

Fig.3.1.3 The winners of concessions for prospective off-shore wind farm locations in 2022 and 2023 (source: "Wysokie Napięcie", 2022, 2023)

After easing the restrictive law from mid of the previous decade, the on-shore wind farms are expected to restart soon their swift development, increasing thus the wind power sector contribution to the Polish electrical energy mix. However, while in the beginning of 2025 the total capacity of wind power plants was 10.1 GW, the capacity of photovoltaic installations appeared more than twice higher, reaching already the 21.5 GW level. Over half of this capacity (12.1 GW) belongs to over 1.5 million owners of prosumer micro-installations (< 50 kW). On the other end of the capacity range there are large commercial farms with the most powerful installation of 204 MW in Zwartowo (West Pomerania). As it can be seen from Figs. 3.1.4 and 3.1.5 the swift capacity and generation rise of wind power and photovoltaic installation is expected at least until 2040.

Such a huge number of unpredictable or hardly predictable dispersed installations creates obvious problems for grid operators who require often specialised power electronic equipment (energy storage, grid forming power converters) and reserve themselves the right to disconnect the electricity source from the grid as the ultimate grid balancing measure. Disconnection from the grid in case of power surplus is always unwanted and highly problematic measure in case of large wind or photovoltaic farms. It is also no solution in case of power deficit. The problem and its solution are well known from the experience of countries having developed intermittent electricity sources already in the very beginning of our century. Poland started to follow their experience in the mid of previous decade by increasing ever more investments in battery storage meant also for grid operator use. However, it was only after joining the European Green Deal that the need for energy storage and strengthening the electrical grid infrastructure became also properly acknowledged by the decision makers. Finally, in addition to extensive investments in the battery storage, the decisions have been taken to resume the pumped storage development programme. In 2023 the strategic document “The role of PSPPs in the National Power System: constraints and development directions” was issued by the Polish Ministry of Climate and Environment [1]. In the same time, the preparatory work (feasibility and environmental studies) on three sites - Mloty (Sudety Mountains, 1000 MW), Roznow II (Beskidy Mountains, 700 MW), Tolkmicko (Vistula Lagoon, 1040 MW) – were initiated.

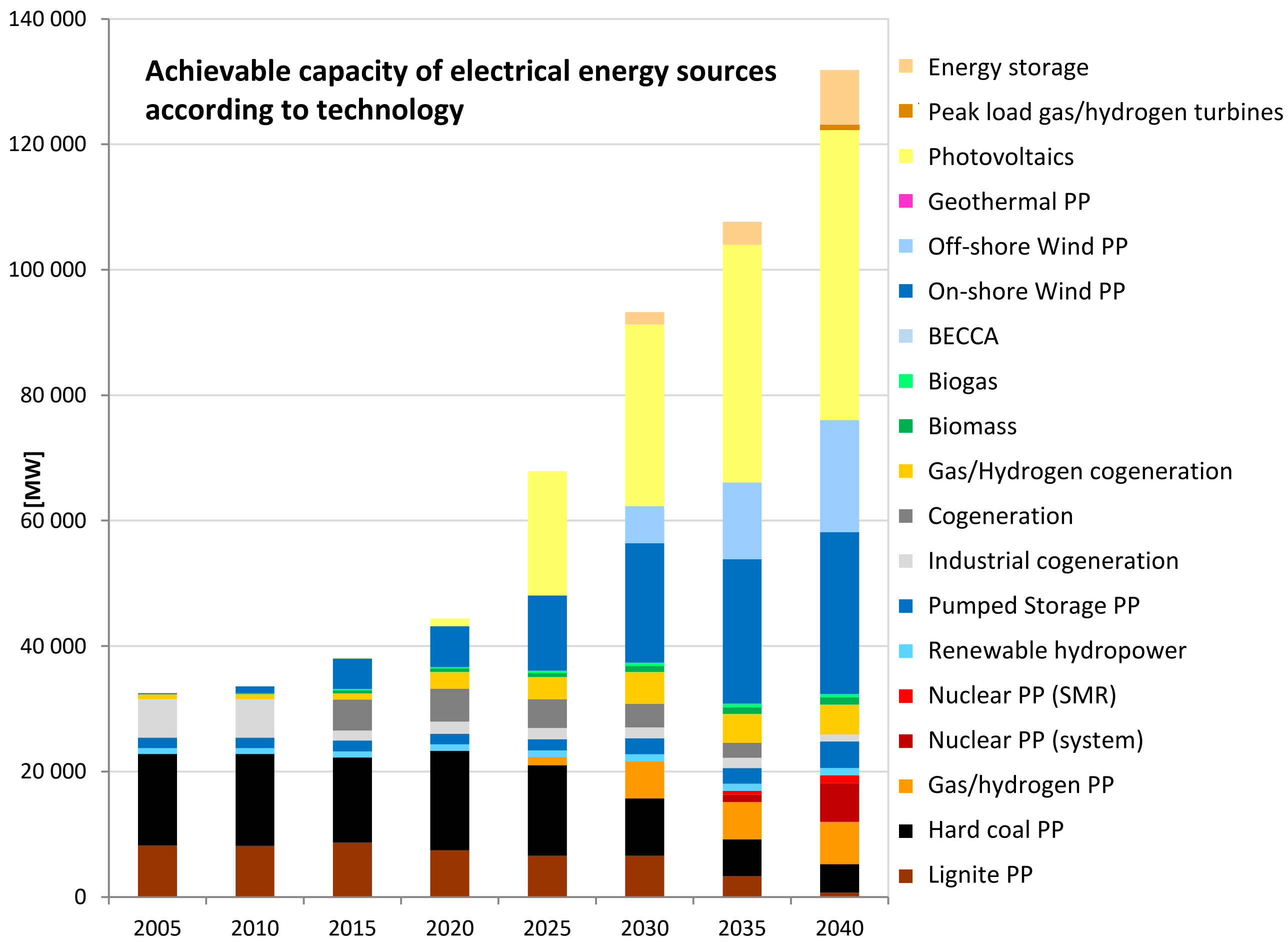

Fig.3.1.4. Achievable capacity of electrical energy sources according to technology (WAM scenario) [2]

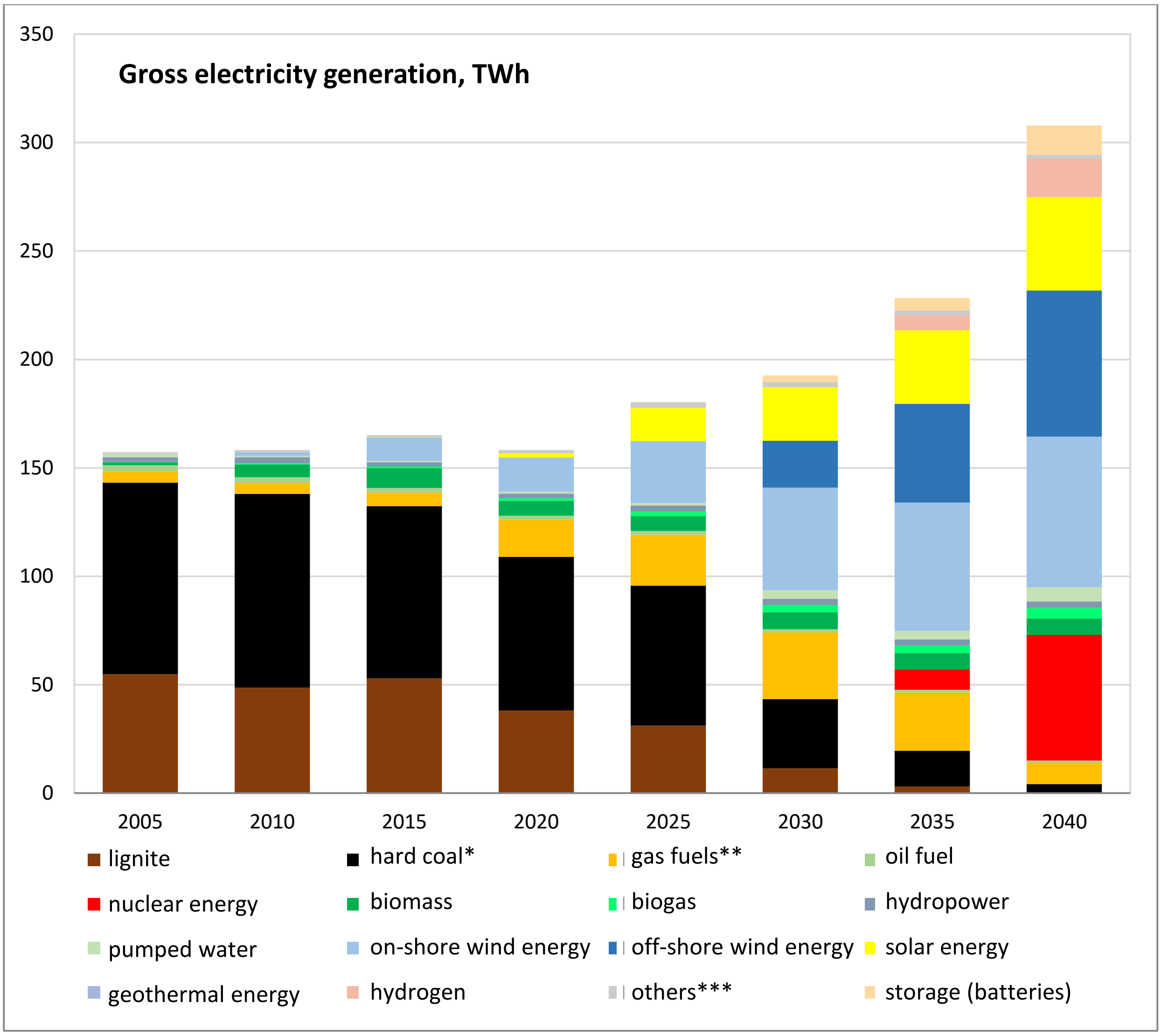

Fig.3.1.5.. Gross electricity generation in Poland according the energy source/fuel (WAM scenario) [2]

In this connection it is also worthwhile to mention that one of the first steps after joining the Green Deal agreement was restarting the nuclear energy sector development programme. Since the beginning of nineties there have been several such announcements by political forces responsible for stopping the Zarnowiec NPP project. This time the authorities took their promise seriously, initiated broad discussion among electrical power industry specialists and signed the first contracts with the US partners. Strangely enough, without any protests from the side of green NGOs this time. The reasons included probably understanding that some portion of electricity should be generated by a GHG emission free, but highly reliable energy source on the one hand, and the wish of Polish authorities to resign of gas and coal imports from Russia on the other one.

The updated action plan on energy and climate policy has been described in October 2024 by the Polish Ministry of Climate and Environment in a draft of the framework document **National Energy and Climate Plan** (aKPEiK). The document is meant to serve as a strategic national framework, integrating energy and climate policies with the 2030 time horizon. In alignment with Annex I to the EU Regulation 2018/1999 the main document includes the following sections:

1. Overview
2. National objectives and targets
3. Policies and measures
4. Current situation and projections With Existing policies and Measures (WEM)
5. Impact assessment of planned policies and measures (WAM, With Applied Measures)

In addition the following 6 appendices have been developed, including

Appendix 1. WAM scenario – active transformation scenario
Appendix 2. WEM scenario – business as usual scenario
Appendix 3. Analytical assumptions and forecasting methodology
Appendix 4. Description of energy efficiency
and the Primary Energy Factor improvement measures in the electricity grid
Appendix 5. Financing the climate and energy transition

The national targets and predictions following from the main document are as follows:

- **50.4 % reduction in GHG, compared to 1990;**
- **32.6 % renewable energy share in final energy consumption;**
- **10% improvement in energy efficiency in final energy use, compared to 2020** and 12.8 % compared to PRIMES2020;
- **56.1% renewable energy in electricity generation;**
- **2 million prosumers;**
- **Reduction of external energy dependency** below European average in 2030;
- **50.4 % reduction in GHG emissions in the whole economy** as compared to 1990 and **49% reduction in emissions from sectors under the emissions trading system** as compared to 2005.

The total installed capacity of Polish power system in 2020 was 39.54 GW, comprising several sources. Coal, lignite and gas were the most utilized sources of electricity production, accounting each for 80% of total electricity generation. This was followed by wind (10%) and biomass (4%) (see Table 3.2. and Figure 3.2.1.4). Of total capacity, 25% was from renewable sources and 75% from non-renewable.

Table 3.1.1. *Evolution of total installed electricity capacity (MW)*

	2020	2025	2030
Biogas	241	362	509
Biomass	534	669	983
Waste	210	260	290
Wind power	6,499	11,996	24,955
Solar power	1,229	19,726	28,976
Hydropower	987	1,008	1,118
Coal	25,279	22,845	17,457
Cogeneration	5,226	4,578	3,757
Gas & Hydrogen	2,688	4,847	11,028
Storage	1,705	1,817	4,485
Other	615	1,788	2,864
TOTAL (MW)	**39,535**	**69,634**	**96,131**

According to the targets and predictions defined in the aKPEiK, by 2030 the total installed capacity will be 96.13 GW, representing an increase of over 140% compared to the installed capacity in 2020. In this energy transition, the predominant sources will be solar power (over 2,250%), followed by gas power (over 300%) and wind power (over 280%). Of total capacity, 47 GW will be from renewable sources, representing 83%. Only **131 MW of renewable hydropower capacity and 1 PSPP of ca. 800 MW are planned to be installed during this 10 years period.** At this moment preparations to construction of two pumped storage power plants are fairly advanced. Both of them are at the stage of design and/or environmental studies. There are scarce chances for starting construction before 2030. By 2030, according to the KPEiK, the percentage of renewables in final energy consumption will be 32.6% and the percentage of renewables in electricity generation will be 56.1%.

Electricity, including electrical energy volumes in various delivery horizons, are traded at the Energy Commodity Exchange (Towarowa Giełda Energii SA) in Warsaw. Additionally there exists electrical power market at which PSE SA acquires power availability from major suppliers by a system of auctions. In the nearest future it is planned to introduce similar system for the elasticity services.

The main Polish electricity distributors are members (daughter and granddaughter companies) of the following capital groups and corporations: PGE SA, Energa SA (member of Orlen Group), Enea SA and Tauron SA. The average electricity price for household consumers including taxes is 0.14 EUR/kWh. This value results mainly from price freezing by the Energy Regulation Office and is expected to rise next year.

3.1.2. Statistical Data on the Hydropower (HP) and Small Hydropower (SHP) Sector

As compared with its surface area, Poland is a country of rather moderate hydropower potential which is often used as an excuse for complete underestimation or even excluding this sector from official strategies of the electric power sector development. In fact, the technical hydropower potential of Poland is estimated at the level of about 12 TWh/annum with ca.75 % located in the Vistula basin w ith Vistula river itself responsible for a half of it. So far, less than 20 % of this potential has been harnessed and the last classic hydropower plant (Wloclawek HPP, 162 MW) was commissioned over half a century ago. Due to economic and political crisis at the turn of seventies and eighties hydropower sector development after 1980 was limited to finishing construction of 3 pumped storage power plants – Zarnowiec (today: 760 MW), Porąbka-Żar (500 MW) and Niedzica (90 MW). Two other significant projects – Lower Vistula Cascade (1340 MW) and Mloty PSPP (750 MW) were abandoned. The period of complete stagnation in further development of classic large hydropower sector followed (Fig.3.1.6).

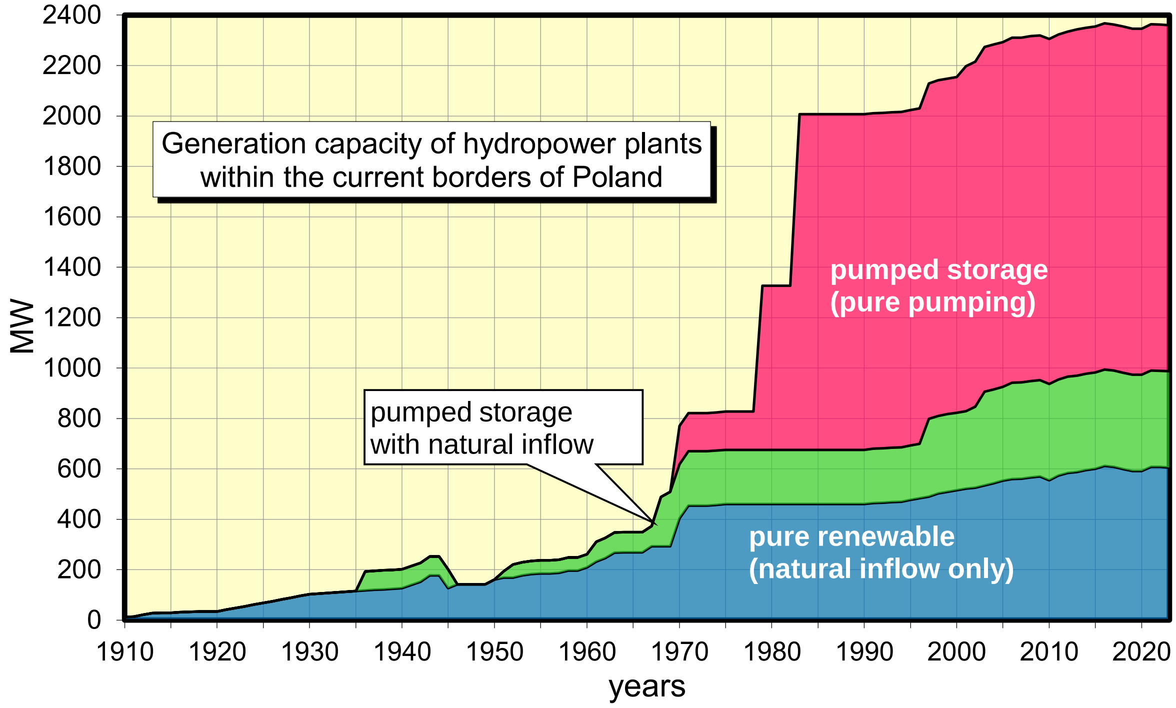

Fig.3.1.6 Generation capacity of hydropower plants within the current borders of Poland since the beginning of XXth century

In the beginning of 80-ies some Polish authorities initiated efforts aimed to revive private small hydropower sector which practically disappeared in the previous years due to politically motivated economic conditions. An important aspect of the state policy in 1980-ies was sparing a major part of still existing engineering and research & development potential for the time period of economic difficulties and creating foundations for small hydro oriented private industry. As it can be seen from Fig.3.1.6 and 3.1.7, the first results of this policy could have been seen only with development of private capital since the beginning of 1990-ies. In this period numerous rehabilitations of public sector hydropower plants were also initiated. One reason was poor technical condition and performance of existing, often quite old or degraded, infrastructure and electromechanical equipment, the other - complete blocking of new projects by green NGOs swiftly gaining public support and entering various kinds of interaction with politicians and coal lobbies. Another result of NGOs activity was introducing harsh water management regulations which did not allow to continue peak-load and regulatory operation by numerous classic storage power plants. Irrespective of the ongoing rehabilitations and upgradings, the resulting change in operation strategy has shown significant impact on the rise of electricity production by these power plants (Fig.3.1.8).

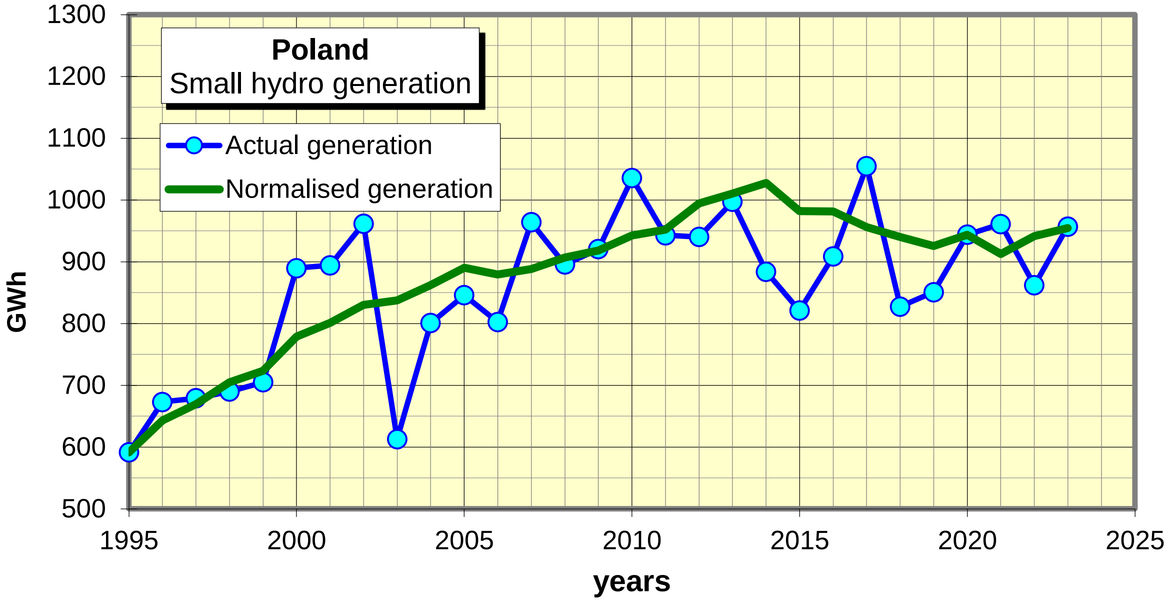

Fig.3.1.7 Small hydropower electricity generation in Poland

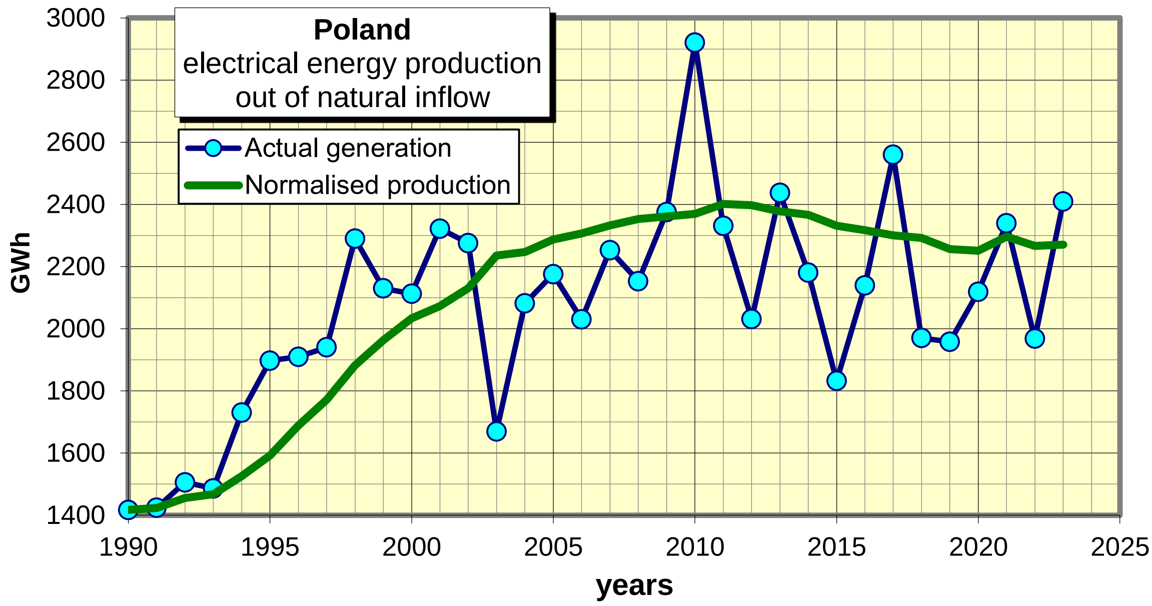

Fig.3.1.8 Hydropower electricity generation out of natural inflow in Poland

The status of Polish hydropower sector has not changed significantly since 2020. According to the data of the Energy Regulation Office (URE) there altogether 790 hydropower plants including 3 pure pumped storage power plants, 3 PSPPs with natural inflow and 10 classic power plants. Capacity in various hydropower plant categories is summarised in Table 3.1.2. The normalised generation over past decade is close to 2300 GWh/annum in the whole sector and 950 GWh/annum in the small hydro subsector .

Table 3.1.2 *Capacity of Polish hydropower plants (URE, 2024)*

Category	No. of plants	Capacity, MW
$P \leq 50$ kW	275	7.8
50 kW < $P \leq$ 1 MW	413	92.5
1 MW < $P \leq$ 10 MW	75	192.1
Total of small hydro	**763**	**297.4**
Classic large hydro	10	315.6
Pumped storage with natural inflow	3	379.4
Total of renewable hydro	**776**	**992.4**
Pure pumped storage	3	1 383.0
Total hydro	**779**	**2 375.4**

3.1.3. Main Hydropower Policies and Initiatives

There is practically no consequent hydropower policy in Poland. Small hydro may be tolerated, but large hydro finds really little or no support in the Ministry for Climate and Environment after parliament elections of 2023. Although several highly promising initiatives have emerged since 1990, they are hardly reflected in the aKPEiK document.

The majority of the initiatives mentioned emerged among or were supported by the (hydro) electric power industry, hydropower and hydraulic civil engineers, local societies and hydropower associations. Some of them were initiated by Polish authorities.

The most significant initiatives proposed or supported by Polish authorities include:

a) resuming development of river cascades (including Lower Vistula Cascade) under the programmes of flood protection and mitigation of drought effects as well as inland navigation development in accordance with the AGN agreement

b) resuming the programme of pumped storage development

Ad a) Resumption of this programme took place in the mid of previous decade although numerous attempts to restart the Lower Vistula project after its stopping in 1980 had been taken before. In numerous cases with strong support of local population strongly opposing green activists coming from large academic centres. Resumption of the Lower Vistula project was preceded by a comprehensive study of its socio-economic effects showing very high benefit to cost ratio [ ]. The main benefits were expected from inland navigation which should have solved the problem of Gdansk seaport overload and could be included into the European network of inland navigation. Other benefits included stopping river bed degradation downstream Wloclawek Dam and resulting threats to the Wloclawek Dam safety, flood protection, water retention and electrical power generation. Due to unfriendly position of green NGOs it was decided to erect the first barrage downstream Wloclawek Dam as a separate project. Furthermore, the project has been taken over by the State Water Water Holding *Wody Polskie* (Polish Waters) instead of Energa Co. as it was felt this would cause less procedural problems.

After long and cumbersome procedure the environmental decision was granted. Unfortunately, shortly after change of power in Poland it was withdrawn in result of protests of Polish green NGOs. Nobody knows whether the subsequent appeal of Wody Polskie will bring any positive result.

The work on the Lower Vistula project was conducted in parallel with the work on the cascades of Oder river and its tributaries (Nysa, Bober, Kwisa) which were initiated after the tragic flood of 1997. Unfortunately shortly after their initiation it turned out that the financing was insufficient and after several years of very intense publicity nothing was heard about the programme any more. The whole action was resumed in the mid of previous decade resulting in completion of one low head water barrage after over 20 years of erection and advancement of other studies. This time everything seems to have stopped after the allies of green NGOs won the election.

Ad b) This initiative was preceded by several attempts to resume construction of the Mloty PSPP in Sudety Mountains. Several attempts came from *Wroclaw Kogeneracja* Co. - the building site owner. There was also obvious interest shown by foreign capital (including *EdF*, Vattenfall and even *Iberdrola).* Unfortunately, Polish authorities showed little interest in increasing the regulatory power resources in the electrical power system using pumped storage technology. Therefore all the prefeasibility studies showed high economic risk instead of convincing justification of the project.

After joining the Green Deal agreement it became quite clear even for Polish authorities that the regulatory resources of the system were too small for ambitious energy transformation projects and intense investments in the electrochemical storage may appear insufficient. Due to this reason the programme for construction of 3 pumped storage power plants was initiated. Unfortunately the decision came with a delay of several decades after most of engineering resources got lost and with unrealistic deadlines. An example of wishful thinking is including commissioning of one PSPP till 2030 in the aKPEiK document. There are severe doubts whether the current authorities will show any consequence in continuing the initiated projects.

In February 2025 the Polish Hydropower Association issued an open address to Polish PM emphasising dramatic situation of Polish water management and hydropower sectors and the detrimenta impact of this situation on many aspects of economic and social life as well as the environment under climate change conditions. A comprehensive analysis of deep problem roots was conducted and relevant measures were proposed. Unfortunately, the response received from the Ministry for Climate and Environment shows no good will and wish of any professional dialogue.

3.1.4. Challenges and Barriers to SHP development

Basically, the challenges and barriers to hydropower development in case of small and large hydro are quite similar. However, there some significant differences.

1. Small hydropower plants are better tolerated than the large hydro by the hydropower opponents, especially green NGOs.
2. Small installation private owners and investors are generally more vulnerable to consequences of any technical or economic failures and disadvantageous administrative decisions.

Generally, the barriers to small or large hydro development can be divided into several categories of which the mental and educational ones are probably the most deep reaching and therefore also very important. In our opinion the main reason of numerous conflicts with green NGOs lies not so much in contradictory arguments and priorities as in different/unfair ordering of these priorities and lack of good will for an honest dialogue aimed at finding a reasonable compromise more or less satisfactory for all sides. Green NGOs are used to aggressive actions and using their powerful position among authorities to impose their own point of view.

Such global priorities as water retention and local flood protection as well as compensation measures too often loose to the arguments of unwanted interference into local environment and interests of other water users, such as angler's associations and kayak tourism stakeholders. It is important that those responsible for environmental decisions and water legal consents (water use concessions) represent more balanced, open-minded and truly independent approach, taking honestly into account various aspects of environmental protection and various kinds of water use as well as the weight of raised arguments and compromise solutions.

At this stage the final decision is usually affected by the social approach towards hydropower. This should be based on fair school education in natural sciences including basic knowledge of the laws physics, phenomena taking place in the widely conceived environment, especially in context of the progressing climate change, the basics of energy conversion technologies, their impact on environment. It should be avoided that this basic knowledge, so needed to take responsible decisions at the polling boxes is taken from media which provide it always in a very simplified version, often under influence of this or other political option, taking for proven something that is only supposed.

Insufficient educational basis at all levels for the hydropower technical staff, plant managers, owners and potential investors is a significant development barrier both for small and large hydro. The deficit of qualified engineering and other technical staff results essentially out of multi-decade hydropower unfriendly and water management disregarding state policy. Firm state intervention is needed to restore what has been destroyed and lost in the last decades.

Polish small hydropower sector will never be a great player at the Polish energy market. Nevertheless, due to various reasons its role should not be underestimated and its existence should not be merely tolerated but truly supported. Some reasons are summarised below together with main barriers to further functioning and development of the small hydropower sector.

1. Most of Polish small hydropower plants – especially private ones and having been commissioned since 1990-ies - emerged at the previously existing, sometimes rehabilitated, dams and weirs. This infrastructure plays also more or less important role in the water management system, mainly contributing to local water retention, but sometimes also to flood protection. However, the operation and maintenance costs of this infrastructure represent just another burden for the owner, adding to those following from various fiscal regulations and putting often in question economic justification of further running the hydroelectric installation. Such questions arise not only among private owners, but also in the state owned enterprises as the law does not allow them for non-profitable commercial activities.

   The problem is quite serious as stopping further operation and abandoning such sites – legally and practically quite difficult – implies increasing the cost burdened duties of the state water administration. While the authors of this report understand and agree with the European policy of supporting investment projects rather than to intervene at the energy market, they cannot accept situation, in which the owner risks closing his activity or at least falling into financial problems after the investment project support period has expired.

2. The above remarks refer not only to the feed-in-tariff or -premium systems which are available exclusively for the installations under 1 MW capacity, but also to the green energy auction system dedicated for those of higher capacity. The discouraging factors include both high irregularity in organising the

auctions and delays in announcing official results. Generally, the auction system does not function so smoothly as expected which contributes to delays in the investment processes.

3. Some excessive burdens to the investors of small hydropower installations follow from considering the smallest installations in the same way, irrespective of technology, by the distribution grid codes. Using electricity storage batteries and power electronic converters in micro hydropower may have numerous advantages and it is recommended under Life NEXUS project, but the regulatory requirement comes from volatile electricity sources, especially photovoltaic micro installations

4. Lengthy and expensive administrative procedures (especially environmental ones) with unknown result are traditionally one of the main barriers for hydropower development. There is no single-box practice. The problem has risen to even more painful since all the hydropower projects are considered potentially harmful for the environment.

5. Erecting a small hydropower plant together with a water barrage is possible only in the case such a barrage exists already in the water management plans developed previously by the Polish Water Holding "Wody Polskie". In practice these barrages are erected mainly by "Wody Polskie" which have also to pass the whole bureaucratic environmental procedure despite being also the only Polish water administrator issuing water legal consents (water use concessions). However, "Wody Polskie" are also owner of numerous existing dams and weirs which could be used for hydropower purposes. Most of them are blocked by "Wody Polskie" which are interested in conducting such investment projects by themselves without having sufficient financial means at their disposal. In case of water use concession procedure on these sites "Wody Polskie" are considered to act as a judge in his own deal.

   Following the study conducted under the RESTOR Hydro project by the Polish Association of Small Hydropower Development supported by of the Polish Water Management Board, there exist ca. 8 000 sites with damming infrastructure and discharge justifying consideration of their use for micro hydropower purposes. Due to low potential and technical difficulties the feasibility of their use must be put under question until more detailed studies are conducted. Anyway, ten years after concluding the project, access to valuable sites suitable for developing small hydropower installations is generally considered on of the main barriers of small hydropower development in Poland.

Of course, the problems with feasibility of harnessing hydropower potential of quite small damming sites, connecting remote installations to the grid as well as from quite natural conditions (drought due to climate change), cannot be considered in the same way as those following from state policy, administrative regulations and practice, finally from opposition of green NGOs and other stakeholders.

Hydraulic energy recovery in municipal and industrial water supply and treatment systems may be considered free of most of barriers typical for SHPs erected in natural environment and therefore especially profitable. However, one should mention some techno-economic barriers following from:

a) critical character of used infrastructure which requires piping redundancy
(energy recovery installation and the original throttling valve have to be mounted on parallel piping);

b) limited space available at the proposed site for mounting the energy recovery unit
with by-pass piping and additional fittings;

c) high hydraulic losses upstream the site which could have been desirable so long as lowering water pressure at site entrance was welcome, but may make the hydraulic energy recovery project economically unfeasible;

d) low potential available which results in problems
with finding an inexpensive hydropower unit (e.g. PAT) well matched to the existing conditions.

3.1.5. Policy Recommendations for SHP development

The policy recommendations can be divided into several groups. ar Some of them relate to the general state approach to various aspects of climate change and environmental policy, the others to educational policy, removal of some abovementioned administrative and economic barriers, finally to some auxiliary activities. The most important ones are listed below according to this order in as much as possible

1. It is needed to revise the state and local administration approach to all hydropower and water management projects according to the most hot requirements following from the already advanced climate change processes. Water and energy storage of all sizes should receive very high priority. Irrespective of others benefits, water retention should be considered prerequisite for most activities aimed at saving or creating environmentally valuable biotopes. Environmental compensation measures should be more boldly employed whenever deep interference into the local environment is needed for the sake of retention increase.

   Energy storage in water reservoirs of mini-hydropower plants should be considered a potential tool for local balancing and important component of smart grids, especially in case of critical situations resulting in a threat to electricity supply safety or even the national grid outage (black-down).

2. There is an urgent need to revise educational programs in primary and secondary schools in the field of natural sciences – including physics, chemistry and all sciences related to the natural environment. The basics of most significant fossil and renewable energy technologies should be included with fair discussion of their socio-economic and environmental impact. Due attention should be paid to the water-energy nexus and significance of multipurpose water reservoirs.

3. Deep change in the state educational policy is urgently needed in technical schools of various levels, with special emphasis on technical universities. The change should be aimed at restoring and further development of qualified engineering staff at various stages of competence in the fields of hydraulic civil engineering and hydropower. In some cases reconstruction of inadvertently destroyed laboratory basis and redevelopment of educational staff are needed.

4. Increasing the role of small hydropower both in generation and local grid balancing may be achieved by easing environmental requirements on keeping the storage reservoir water level and developing hybrid installations. Such measures can be highly beneficial for the local grid on the one hand and improve economic situation of the power plant owner on the other one.

5. Another measure in the same direction is increasing plant independence of the external grid and enabling its isle operation which is of special significance in the times of increased international tensions. This goal may be achieved by:

   a) avoiding the use induction generators during rehabilitation or erection of new installations instead of induction ones (starting from capacities of several hundred kW);

   b) installing battery energy storage.

   Ad a) This additional investment effort should be compensated in the contract with local distribution or smart grid operator

   Ad b) This solution may be recommended for smaller installations, especially those of hydraulic energy recovery in existing critical infrastructure.

6. Both in the case of new of new projects and running the already existing ones it is important to develop some general rules on collaboration between the plant operator and the owner of the damming structure (usually water administrator) on this structure maintenance. In some cases it may be reasonable to include all water reservoir beneficiaries.
7. Introducing more transparent rules for access to the potential sites owned by the Polish Waters (Wody Polskie) is highly needed. Joint venture enterprises and public-private partnership schemes may be considered as well.
8. Efforts are needed to shorten and simplify the administrative procedures (especially environmental ones). One-box solution should be considered the preferable solution.
9. It is also important to follow the realistic generation costs in order to establish well justified public support parameters (feed-in-tariffs and energy auction reference prices).
10. The effectiveness and transparency of the energy auction system has to be decisively improved.
11. All public support mechanisms should be featured by long horizon stability. It is unacceptable that the installation looses its profitability immediately after the support period is over. Appropriate measures are needed for the sake of keeping economic sustainability afterwards (e.g. minimising the other burdens or elongating the support period).

References

[1] "The role of PSPPs in the National Power System: constraints and development directions" (*Rola elektrowni szczytowo-pompowych w Krajowym Systemie Elektroenergetycznym: uwarunkowania i kierunki rozwoju*). Expert Team of the Polish Ministry for Climate and Environment, Warsaw 2022

[2] "National Energy and Climate Plan" (*Krajowy Plan w dziedzinie Energii i Klimatu do 2030*,) Draft document of 10.2024, Polish Ministry for Climate and Environment, Warsaw 2024

3.2. Spain

3.2.1. Overview of the energy and electricity sector

In recent years, Spain, within the framework of the EU, has pursued an ambitious ecological transition agenda. This transition presents an opportunity to promote territorial cohesion, improve public health and environmental conditions, and advance social justice. Recent data shows that Spain is particularly well-positioned due to its abundant renewable resources and its human, technological, and industrial capacities to successfully undertake this transformation.

The **National Integrated Energy and Climate Plan (PNIEC)** serves as the strategic national framework, integrating energy and climate policies with a 2030 time horizon, in alignment with both national and European regulations. The latest PNIEC 2023-2030 has been launched in September 2024. It has renewed the intermediate targets for 2030, with the final the goal of making Spain a carbon-neutral economy by 2050.[1] Those include:

- **55% reduction in GHG, compared to 2005, equivalent to a 32% reduction compared to 1990.**
- **48% renewable energy share in final energy consumption.**
- **43% improvement in energy efficiency** in final energy use, compared to projections of a reference scenario without measures.
- **81% renewable energy in electricity generation.**
- **19 GW of self-consumption capacity** and **22.5 GW of storage capacity.**
- **Reduction of external energy dependency** from 73% in 2019 to 50% in 2030.
- **42% reduction in emissions from diffuse sectors** and **70% reduction in emissions from sectors under the emissions trading system**, compared to 2005.
- **Achieve an electrification rate** of the economy of **35%.**

The total installed capacity of the Spanish power system in 2020 was 115.02 GW, comprising several sources. Wind power and combined cycle gas turbines were the most utilized sources of electricity production, accounting each for 23% of total electricity generation. This was followed by hydropower (12%), solar power (10%) and coal (9%) (see Table 3.2.1 and Figure 3.2.1). Of total capacity, 54% was from renewable sources and 46% from non-renewable sources.

Table 3.2.1. *Evolution of total installed electricity capacity (MW)*

	2020	2025	2030
Biogas	210	240	440
Biomass	609	1,009	1,409
Waste	609	470	342
Wind power	26,754	36,149	62,054
Solar power	11,004	46,501	76,277
Solar thermal power	2,300	2,304	4,804
Hydropower	14,011	14,261	14,511
Coal	10,159	0	0
Combined cycle	26,612	26,612	26,612
Cogeneration	5,276	4,068	3,784
Fuel and Fuel/Gas	3,660	2,847	1,830
Nuclear power	7,399	7,399	3,181
Storage	6,413	9,289	18,913
Other	0	25	80
TOTAL (MW)	115,016	151,174	214,237

[1] National Integrated Energy and Climate Plan (PNIEC) (2023-2030)

According to the targets defined to the PNIEC, by 2030 the total installed capacity will be 214.24 GW, representing an increase of nearly 90% compared to the installed capacity in 2020. In this energy transition, the predominant sources will be solar power (36%), followed by wind power (29%), combined cycle power (12%) and storage (9%). Of total capacity, 160 GB will be from renewable sources, representing 75%. **500 MB of new hydropower capacity will be installed during this 10 years period.**

By 2030, according to the PNIEC, the percentage of renewables in final energy consumption will be 48% and the percentage of renewables in electricity generation will be 81%.

The specific distribution of renewable technologies between 2021 and 2030 will depend on their relative costs, as well as the feasibility and flexibility of their implementation, including viability from an environmental perspective. Consequently, their relative share proposed by PNIEC may vary, within certain margins, from the figures presented above. The path outlined to achieve the targets set for 2030 is based on the principles of technological neutrality and cost-efficiency. To this end, the energy modeling conducted considers the evolution of performance and costs of all technologies and is grounded in cost minimization.

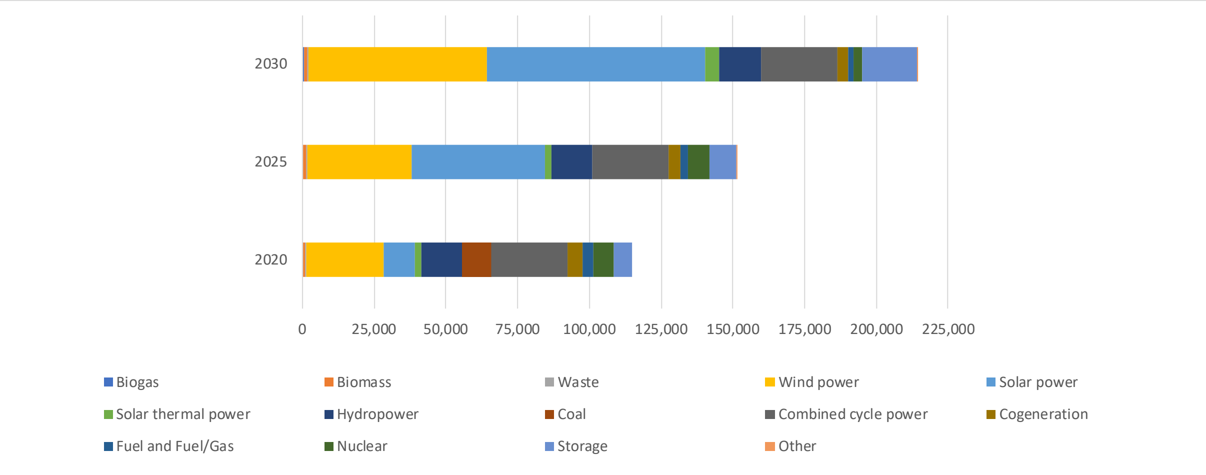

Figure 3.2.1. Installed electricity capacity (MW) by source in Spain in 2020. Source: PNIEC 2023-2030

The Spanish wholesale market is part of the Iberian power market (Mercado Iberico de Electricidad – MIBEL), which includes Spain and Portugal. OMIE in Spain manages the spot market, while OMIP in Portugal manages the futures market. Red Electrica de Espana (REE) and Red Electrica Nacional (REN) are the two system operators.

Endesa, Iberdrola, Gas Natural Fenosa, E.ON and HC Energia- EDP are the five major distributors. However, there are more than 300 smaller companies that also provide distribution services.[2] The electrification rate in Spain is 100%. The average electricity price for household consumers including taxes in the second half of 2022 was 0.23 EUR/kWh (0.24 US$/kWh).[3]

[2] Red Eléctrica de España (REE) (2022). *Estructura De La Generación Por Tecnologías.* Available at https://www.ree.es/ es/datos/generacion/estructura-generacion [in Spanish] (Accessed 25 April 2022).
[3] Endesa (2022). *Electricity Tariffs.* Available at https://www. endesa.com/en/catalog/light (Accessed 27 April 2022).

3.2.2. Statistical Data on the Hydropower (HP) and Small Hydropower (SHP) Sector

According to the World Small Hydropower Development Report (WSHPDR), HP installed capacity in Spain (also including storage) was 20,425 MW in 2022. Hydropower generation in Spain reached 32,244 GWh/year, contributing 12% of the national total, making hydropower the forth largest generation technology in the country.[4]

In Spain, hydropower plants with an installed capacity of less than 10 MW are classified as small hydropower plants (SHP). In 2021, the SHP installed capacity was **2,145 MW from 1,098 plants** throughout the country.[5] In comparison with the WSHPDR in 2019, installed capacity has increased by 66 MW (3%). Most of the SHP activity in Spain is concentrated in four regions of the country: Galicia, Catalonia, Aragon and Castile and León. Together they represent almost 62% of SHP installed capacity and over 70% of SHP electricity generation in the country

The SHP potential is estimated at 2,185 MW[6]. Considering the already SHP installed capacity, it can be concluded that that nearly all potential has been developed. Active development of the SHP sector in the country has been continuous since the 1980s, but it remains unclear what additional SHP projects can be realized in light of the increasingly limited remaining undeveloped potential.

3.2.3. Main Hydropower Policies and Initiatives

In Spain, there are no specific governmental plans targeting the development of HP or SHP. However, this renewable energy source is implicitly included in national plans and programs related to the energy transition. In addition to the previously mentioned PNIEC, there are other strategic programs to promote HP improvement projects, as described below.

PNIEC 2023-2030

In previous PNIEC 2021-2023, there was only one single reference to the SHP technology: "During the 2021–2030 decade, approximately 22 GW of renewable electrical power will have exceeded its regulatory useful life. Without a specific plan for the technological renewal of these projects, it is foreseeable that there will be a reduction in the renewable installed capacity, mainly made up of old wind farms and mini-hydropower plants […]. In order not to lose their energy contribution, it is necessary to contemplate a specific plan for the technological renovation of these facilities".

The updated PNIEC launched in 2024 includes 110 different measures, of which only four of them directly mention HP or SHP:

Measure 1.1: Development of Renewable Energy Compatible with Biodiversity and Ecosystem Protection

This measure emphasizes compliance with **ecological flow regimes in HP projects**, aiming to avoid alterations to river systems and maintain river connectivity to prevent increased barrier effects. When environmental impact assessments require compensatory measures, these must be rigorously implemented, particularly in ecosystem restoration at alternate sites. These actions will offset biodiversity and landscape impacts caused by energy infrastructure.

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4 UNIDO, ICSHP (2022). World Small Hydropower Development Report 2022. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR2022.

5 National Commission of Markets and Competition (CNMC) (2022). *Información Mensual de Estadísticas Sobre las Ventas de Régimen Especial. Contiene información hasta febrero de 2022.* Available at https://www.cnmc.es/estadistica/informacion-mensual-de-estadisticas-sobre-produccion-de-energia-electrica-partir-de-3 [in Spanish] (Accessed 20 May 2022).

6 UNIDO, ICSHP (2019). World Small Hydropower Development Report 2019. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www. unido.org/WSHPDR.

Measure 1.5: Energy Storage

To support renewable energy goals, new non-flowing hydraulic concessions for electricity generation will prioritize integrating non-manageable renewable technologies into the grid. Special emphasis is placed on **reversible HP Plants** for managing renewable production while adhering to environmental flow regimes. This ensures compatibility with sustainable water management and flood/drought regulation. Regulatory updates (RDL 8/2023) have removed barriers to promoting hydraulic energy storage, and programs under the National Recovery, Transformation and Resilience Plan (PRTR according to the Spanish acronym). allocate €20 million for storage systems in wind and SHP projects.

Measure 1.9: Development of New Hydroelectric Storage Capacity (Pumped-Storage HP Plants)

This measure builds on the existing energy plan to **enhance storage and flexibility**. It introduces new initiatives to expand hydroelectric storage capacity, particularly by **utilizing existing reservoirs**. Capacity markets and electricity market reforms will drive medium- and long-term investments, accelerating the deployment of storage systems.

Measure 1.17: Repowering and Modernization of Existing Renewable Energy Projects

For SHP Plants, this measure aims to modernize aging infrastructure, improve efficiency, and adapt to new environmental or hydrological conditions. It includes actions to protect ecosystems and integrate plants into their territories. The "**Circular Repowering" program**, governed by Order TED/1071/2022, allocates €222.5 million for **repowering** wind farms, SHP plants, and innovative recycling of wind turbine blades. Regulatory updates are also proposed to ensure continued investment and operation of hydropower plants after concessions expire, aligning with hydrological planning objectives.

European Projects of Common Interest

It also has to be mentioned the **European Projects of Common Interest** (PCI), launched in 2013. To date, six PCI lists have been published. The latest list (the first list of PIC and Mutual Interest (PMI) was approved by the Commission on November 28, 2023, and includes 166 PCIs in Europe. Among these, there are three **Pumped-Storage HP** projects located in Spain: Navaleo, Los Guajares and Aguayo II.

National digitalization plans

Finally, there are two national Strategic Plans focus on **digitalization** that are related to HP and SHP projects:

Digital Spain 2026: This strategic plan by the Spanish government aims to drive digital transformation across various sectors, including energy, by promoting advanced technology adoption and improved digital infrastructure.

PERTE for Water Cycle Digitalization: Approved in 2022, this Strategic Project for Economic Recovery and Transformation (PERTE) aims to mobilize 3.06 billion € to digitalize water management, including aspects related to hydropower.

3.2.4. Challenges and Barriers to SHP development

Although SHP has played an important role in electricity generation in Spain, the main barrier to future SHP development is the almost-fully developed identified SHP potential. Apart from this, the development of SHP in the country is currently facing the following challenges and barriers:

- Some potential SHP sites have not been studied in detail, thus there is lack of knowledge regarding their **actual potential**;
- SHP projects have to **compete with other water uses** (i.e. with irrigation) over the **limited resources**;
- In order to use water for HP purposes, licences need to be issued, which is a **complex administrative process** involving multiple regulatory levels which imply the need for coordination across administrative bodies. It also requires an environmental authorization approval. The excessive waiting time to get approvals from regional and local organs slows the development of potential projects;
- Difficulties in renewing the **water concession periods** of the current SHP plants mean that there is the risk of some existing SHP projects being abandoned;
- **Aging Infrastructure**: Many SHP plants in Spain are decades old, which complicates the integration of modern digital technologies.
- **Climate change:** The amount of water available in reservoirs is decreasing dramatically in some areas of Spain (especially in the south), which is making it necessary to consider repowering the current turbines that have fallen outside the new operating ranges.

There are no clear enablers to further development of SHP in Spain other than the liberalized structure of the country's electricity market, which favours private electricity producers.

In the mid-term future, a good part of the thousand existing SHP plants in Spain will be at the end of their concession. For this reason, it is necessary to work on the regulation of this concessional end to guarantee the investments that allow the operation of the plants. Administrative simplification or a call for auctions for technological renewal projects are measures that must be considered.

3.2.5. Policy Recommendations for SHP development

Policy recommendations for SHP development in Spain, addressing different regulatory, environmental, economic, or social aspects are described below:

1. Regulatory Framework and Streamlining Procedures

- **Simplify permitting processes**: Streamline the application, approval, and concession renewal processes for small hydropower projects to reduce bureaucratic delays and uncertainty for developers.
- **Harmonize regional policies**: Ensure consistency between national and regional water and energy policies to avoid conflicting regulations.
- **Establish clear concession timelines**: Define clear rules and conditions for water use concessions, ensuring predictability for investors while maintaining environmental safeguards.
- **Create fast-track mechanisms for repowering**: Allow expedited approval processes for upgrading existing SHP facilities, focusing on modernization and environmental adaptation.
- **Align with the PNIEC goals**: Ensure SHP development is integrated into Spain's National Integrated Energy and Climate Plan, particularly for reaching renewable energy targets by 2030.
- **Incorporate SHP into grid planning**: Prioritize SHP projects in energy planning to enhance grid stability, especially in regions with high renewable penetration.

- **Promote hybrid energy solutions**: Encourage SHP integration with other renewable energy sources, such as solar or wind, to maximize efficiency and output.
- **Conduct periodic policy reviews**: Regularly assess SHP policies to identify gaps, incorporate stakeholder feedback, and adapt to evolving technologies and environmental challenges.

2. Environmental and climate Safeguards

- **Mandate ecological flow requirements**: Enforce regulations that guarantee the maintenance of ecological flows to preserve river ecosystems.
- **Promote cumulative impact assessments**: Develop policies requiring the evaluation of cumulative impacts from multiple SHP projects within the same watershed.
- **Encourage ecosystem restoration**: Require compensatory measures for habitat restoration as part of the project approval process, particularly in cases where SHP development affects natural ecosystems.
- **Develop guidelines for sustainable SHP design**: Provide developers with technical standards for low-impact designs, including fish ladders, sediment management systems, and measures to prevent river fragmentation.
- **Adapt SHP to climate change**: Develop policies requiring SHP projects to account for future hydrological variability caused by climate change.
- **Incorporate risk management measures**: Mandate flood and drought mitigation strategies in SHP designs to ensure sustainable operation under extreme conditions.
- **Promote water-energy nexus projects**: Encourage SHP projects that contribute to efficient water management, such as irrigation systems powered by renewable energy.

3. Financial Incentives and Support Mechanisms

- **Expand funding for modernization**: Allocate more resources to programs like the "Circular Repowering" initiative for technological and environmental upgrades of aging SHP facilities.
- **Provide tax incentives**: Offer tax reductions or credits for SHP projects that meet stringent environmental and efficiency criteria.
- **Encourage public-private partnerships (PPPs)**: Facilitate collaborations between public authorities and private developers to share risks and attract investment in rural or less-developed regions.
- **Support energy storage integration**: Provide subsidies or low-interest loans for SHP projects that include pumped-storage systems or hybrid solutions with other renewable technologies.

4. Foster Innovation and Technological Development

- **Invest in R&D for SHP technologies**: Promote research into advanced turbines, smart monitoring systems, and AI-driven optimization tools for SHP plants.
- **Support pilot projects**: Provide grants for innovative SHP pilot projects, particularly those integrating digitalization, hybridization with solar/wind, or low-impact designs.
- **Encourage circular practices**: Fund projects focused on recycling or reusing equipment, such as turbines, to align with Spain's circular economy goals.
- **Establish monitoring frameworks**: Require regular reporting on the environmental, social, and operational performance of SHP facilities.
- **Incentivize transparency**: Develop platforms for public access to data on SHP projects, including their impacts and benefits.

5. Cross-Border and EU Collaboration

- **Leverage EU funding**: Advocate for SHP projects to be included in EU frameworks like the Projects of Common Interest (PCI) and access funding through mechanisms such as the Just Transition Fund or Horizon Europe.
- **Align with EU directives**: Ensure SHP policies comply with European environmental and renewable energy directives to strengthen Spain's leadership in sustainable hydropower.

6. Support Rural and Regional Development

- **Prioritize rural regions**: Focus SHP development in underdeveloped or remote areas to boost local economies and enhance energy access.
- **Create regional funds for SHP**: Establish dedicated funding programs to support small hydropower projects that align with regional development goals.
- **Integrate SHP into water management strategies**: Ensure that SHP projects contribute to regional water management plans, including irrigation and flood control.

7. Promote Community Engagement and Public Acceptance

- **Ensure local participation**: Involve local communities in the planning and decision-making processes to address their concerns and foster support for SHP projects.
- **Emphasize social benefits**: Highlight the role of SHP in creating jobs, supporting rural development, and enhancing energy security in remote areas.
- **Develop educational campaigns**: Raise awareness about the benefits of SHP and its role in Spain's energy transition to gain public trust and acceptance.

By implementing these policy recommendations, Spain can accelerate the development of sustainable small hydropower projects, contributing to its renewable energy goals while preserving environmental and social values.

3.3. Lithuania

3.3.1. Overview of the energy and electricity sector

The National Energy Independence Strategy was renewed in 2018 and it sets ambitious targets for 2050. This includes a 100% share of consumed electricity to be generated domestically and an 80 per cent share of renewable energy in final consumption. The goal for 2050 is to generate all electricity from renewable energy sources.

The total installed capacity of the power plants operating in the Lithuanian power system was 6394 megawatts (MW) as of 22 October 2024 (Fig.3.3. 1)

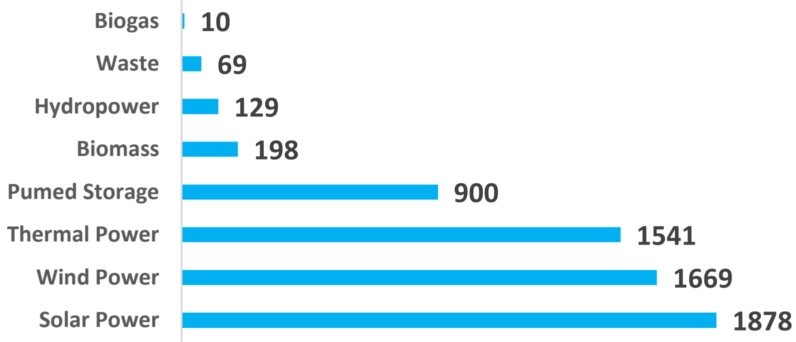

Fig.3.3.1. Installed electricity capacity (MW) by source in Lithuania in 2024. Source: LitGrid

In 2023, wind was the most utilized source of electricity production in Lithuania, accounting for 45% of total electricity generation. This was followed by thermal plants (23%), solar power (11.1%), pumped storage (9.2%), and hydropower (7.9%).

The reliability and security of Lithuania's energy system are ensured by the state-owned company Ignitis Gamyba. The company owns and develops strategic electricity generation assets in Lithuania, including the Kruonis Pumped Storage Hydropower Plant, the Kaunas Hydropower Plant, and several thermal power plants. A historic transition to synchronize the electricity grids of the Baltic States with Continental Europe is planned for 2025. Currently, Lithuania's electricity system is synchronized with the so-called BRELL ring, which includes the Russian Federation.

Lithuania follows the European Green Deal objectives and has new goals set by the National Energy and Climate Plan (NECP) for 2030. These include a 45% share of renewable energy in the final energy consumption and a 45% share of renewable electricity. All renewable energy power plants of smaller capacity are owned by the private sector.

In accordance with EU Directive 2009/72/EC, which establishes common rules for the internal electricity market, Lithuania has liberalized its electricity sector. The National Energy Regulatory Council (VERT) is responsible for overseeing the state's energy sector, including electricity, renewable energy, district heating, natural gas, oil, and water supply and wastewater management. According to Eurostat, in 2024, the average electricity price for household consumers in Lithuania was €0.23 per kWh.

3.3.2. Statistical Data on the Hydropower (HP) and Small Hydropower (SHP) Sector

In Lithuania, hydropower plants with an installed capacity of less than 10 MW are classified as small hydropower (SHP) plants. In 2020, there were 97 SHP plants, with a total installed capacity of 26.9 MW. These plants generate up to 80 GWh/year of normalised electricity.

The theoretical potential of SHP in Lithuania is estimated at 417 MW, technical at 172 MW, economic at 121 MW and environmental at 58 MW. As of 2024, no new small hydropower (SHP) projects have been announced in Lithuania.

More than 20 potential sites for installing hydropower turbines were identified in urban water networks (Figures 3.3.2 and 3.3.3). Most of them were located in the sewage network, while only one site was spotted in the drinking water distribution network with a pressure-reducing valve. Their preliminary power capacity was estimated as less than 100 kW with a total of approximately 0.5 MW. These potential sites with preliminary key characteristics, including those operating in other countries, are freely available.

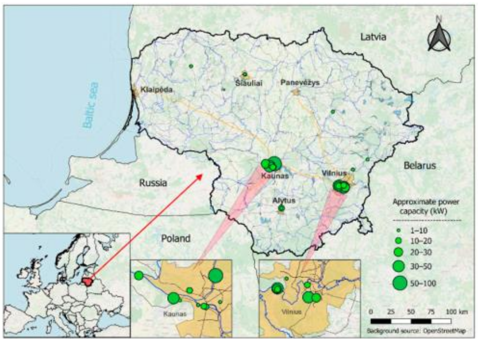

Fig. 3.3.2. Energy recovery potential in the municipal water infrastructure of Lithuania.

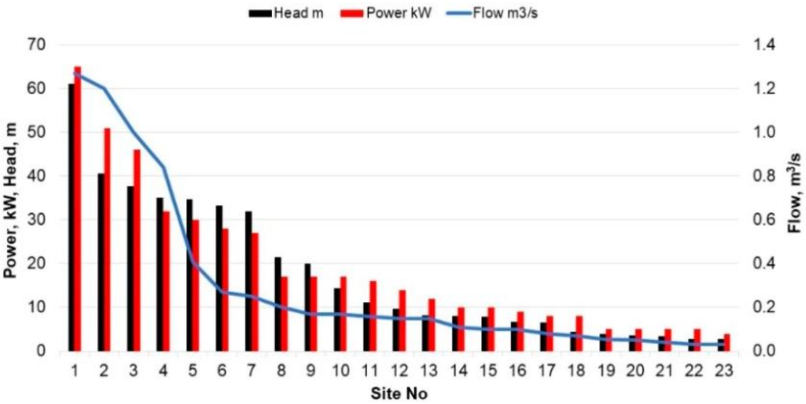

Fig. 3.3.3. Key data of potential sites in urban water network (mostly wastewater) for installing hydro turbines.

The most significant potential lies within sewage networks, particularly where their collectors (mains) descend into deep river valleys. Notable examples include two large cities, Vilnius and Kaunas, as well as the town of Alytus, all of which are located near the largest rivers, the Nemunas and the Neris. It is worth highlighting that 58 wastewater treatment plants (WWTPs) are currently operating in the country. However, most of them lack a significant elevation drop (either at outlets or within the water treatment installations).

There are two potential layouts for installing a hydro turbine in sewage networks: upstream or downstream of the operating WWTP. In the first case, untreated wastewater flows through the turbine, which can negatively impact its operation. To address this, the hydro turbine must be highly corrosion-resistant, and the intake should be equipped with a trash rack. The second case, where the turbine is positioned downstream of the wastewater treatment plant, is far more practical since the hydro unit would encounter treated wastewater.

3.3.3. Main Hydropower Policies and Initiatives

There are no specific governmental plans or programs targeting the development of small hydropower (SHP). In general, the current legislation and regulations are discouraging for SHP developers. The Renewable Energy Resources Law of the Republic of Lithuania, which came into force in 2011, guarantees a simplified authorization process for new renewable energy plants with an installed capacity below 350 kW—except for hydropower. This simplified procedure is available only for damless (free-flow) hydropower plants. At present, no hydrokinetic power plants are operating in Lithuania. The SHP market in Lithuania is relatively small, with the interests of SHP producers represented by the Lithuanian Hydropower Association, established approximately 30 years ago.

Since 2021, existing small hydropower (SHP) plants are no longer supported by the state through feed-in tariffs (FIT) and instead sell the electricity they generate at market prices. Additionally, a water tax for SHP plants was introduced in the country traditionally considered to have a medium to high humidity rate.

3.3.4. Challenges and Barriers to SHP development

Lithuania is a lowland country with modest hydropower resources; however, large parts of the hydropower potential remain untapped. Over more than 100 years of operation, hydropower in Lithuania has proven to be a reliable, efficient and safe source of electricity. Nevertheless, the development of SHP in Lithuania is hindered by strict environmental regulations. The 2019 amendment to the Water Law prohibits dam construction in protected areas and forbids such constructions if they do not meet the good water status requirements according to Directive 2000/60/EB.

No dam was built for SHP development since the country regained its independence in 1990. Only existing in-stream structures have been retrofitted for electricity generation. The typical cost per kW of installed capacity for such a type of development ranged from EUR 1,000 to EUR 2,000.

Subsidies and public support schemes are limited in Lithuania. As a result, most funding for hydropower projects comes from the private sector. Additionally, it is possible to obtain funding from the EU’s structural funds for heritage sites, such as the refurbishment of old water mills. However, in practice, this funding is not feasible in protected areas, which were designated a few decades ago.

The impacts of climate change are already affecting small hydropower (SHP) plants and may continue to influence their development in the future. Droughts caused by hot and dry summers are becoming more common, alternating with flash floods due to excessive rainfall. Winters in Lithuania are now warmer, meaning that long-term snow cover no longer forms, and the peak of spring floods is shifting to the winter months, with a decreasing trend. Currently, no practical assessments have been carried out to estimate how much electricity is lost due to the impacts of climate change or what adaptation measures will be required in the future.

The public perception of small hydropower (SHP) in Lithuania is becoming slightly negative. This is influenced by environmental non-governmental organizations and the Ministry of Environment, which advocate for the removal of instream hydraulic structures in the country. A few of these structures have already been removed. While their dams did not have SHP plants installed, this movement could create uncertainty for the future of SHP development.

The main barriers for SHP development in Lithuania are:

- Political: There are no governmental incentives, plans or programmes targeting SHP development. Strategies and regulations for the development of renewable energy in Lithuania prioritize other renewable energy sources. Since 2021, the Government does not support SHP plants via the FIT scheme.
- Environmental: The environmental laws in Lithuania are strict. Retrofitting in-stream structures for electricity generation is prohibited if they are located in protected areas or if they cannot ensure good water status. Additionally, the removal of existing in-stream structures on rivers designated for long-distance migrating and protected fish species has already begun in Lithuania.
- Financial: The majority of investments into the SHP sector come from bank loans. Combined with the cancellation of the FIT, this prolongs the payback period, which can make it unsuitable for investors. In the future, it is very likely that hydropower will have to compete for further support with other renewable energy technologies in reverse auctions.

According to our survey, no operational hydropower turbines were identified in the water supply or sewage collection networks of the Baltic states, including Lithuania. The primary reason for this is a lack of awareness about such technology. Furthermore, the Renewable Energy (RE) Law of the Republic of Lithuania does not account for this technology, resulting in a lack of incentives to promote its implementation. In contrast, some EU countries have implemented government-funded financial incentives for RE generation from gravity-fed systems from engineered water conduits, thus encouraging water companies to implement SHP schemes.

The lack of in-depth studies on wastewater quality's impact on hydro turbines, particularly the risk of clogging them in sewage networks upstream of WWTPs, can be a severe problem.

3.3.5. Policy Recommendations for SHP development

- Regulatory Simplification

Urban water management is known to be very energy intensive. Therefore, engineers and researchers worldwide are looking for ways to recover the energy residing in water networks supplying drinking water or collecting sewage water and their treatment plants. The untapped potential of small, mini, and micro hydropower systems in engineered water conduits has largely remained unexplored, and this alternative energy source is receiving more attention from regulators in a number of countries.

Unlike conventional hydropower systems operating in rivers, hidden or in-conduit hydropower systems have a minimal environmental impact as these systems are fully integrated into existing infrastructure. These hydropower systems specifically harness the excess energy of water being used for a purpose other than energy generation. Public water systems and publicly owned treatment works, including wastewater facilities, could benefit from installing an in-conduit hydropower system.

Currently, the Renewable Energy (RE) Law considers hydropower only in the context of natural streams or rivers, typically involving their damming. The option of hydropower generation from urban water networks or engineering conduits is entirely excluded. **Therefore, the Law should be amended to include this unconventional form of hydropower and provide it with the same incentives as those available for solar, wind, and other renewable energy sources.** This means that a simplified procedure for their development must be made available.

And finally, develop funding models and incentives that encourage water utility companies to invest in hydropower solutions.

- Training and Capacity Building:

According to our survey, no operational hydropower turbines were identified in the water supply or sewage collection networks of the Baltic states, including Lithuania. The primary reason for this is a lack of awareness about such technology. Despite the availability of good practices in several countries, challenges persist during the planning phase of hydropower development. A significant obstacle is the limited access to data on water supply and wastewater (WSW) distribution networks, which hinders the quantification of water power potential and the identification of suitable sites. Furthermore, while newer or emerging technologies offer innovative approaches to in-conduit hydropower generation, they are not always the most cost-effective option. Training and capacity building are essential to address these challenges effectively.

Development of pilot projects and demonstration sites is essential for gathering data on performance, economic viability, and public acceptance, ultimately accelerating the widespread adoption of in conduit hydropower technologies.

- Promotion of Public-Private Collaboration

The "Law on Drinking Water Supply and Waste Water Management" of the Republic of Lithuania establishes the principles for state management and regulation of drinking water supply and wastewater management. This law outlines the responsibilities of water suppliers and sets strict standards to ensure the safety and quality of drinking water.

These legal frameworks highlight the complexities and potential constraints associated with introducing external investments into public water systems, particularly for projects like hydropower installations. Any proposed interventions would need to navigate these regulations carefully to ensure compliance and protect public health interests.

Given these stringent regulations, integrating external investments for the construction and operation of hydropower installations within public water systems presents significant challenges. The primary concern is maintaining the integrity and safety of potable water, which is a critical public health priority.

4. Conclusion

The conducted overview shows that despite the EU co-ordinated climate and energy policy there exist significant differences in national approach towards hydropower sector. All European governments have to count with opinion of strong green lobbies which in practice often sacrifice global goals of water and energy access for the sake of local ones.

In fact some European goals are contradictory and a true good will is needed to find reasonable compromise to numerous problems. Even if the climate crisis is already an indisputable fact and therefore ordering of environmental priorities should not be so difficult. Unfortunately, even the will of fair dialogue seems to be in deficit from various sides.

Generally large classic hydro encounters strong opposition green NGOs whereas the small hydro is tolerated. As in many cases hydropower plants are erected at the multipurpose reservoirs a severe conflict in European countries lies not so much between hydropower sector and ecologists as between various approaches to water management and techniques to mitigate the climate change effects.

In some countries the existing situation has already lead to complete disorientation of the society and loss of qualified engineering staff. Therefore fair educational effort at all levels is of paramount significance.

Hydraulic energy recovery in municipal water and industrial circuits is free of all these dilemmas. Therefore it should be always supported if only economic justification for a project under consideration exists.