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TRMEW


turn water
into profits

From The Editorial Office

Recently, there has been a buzz about the European Commission's plans to show that ambitious can be even more ambitious. We're talking about the intention to reduce CO_2 emissions in the EU economy, which, according to the latest initiative, is to reach a target of 90% in 2040 (a net reduction from 1990). One of the key pieces of this puzzle is a fully decarbonized electricity sector on a net basis, in which renewable energy sources are to play a dominant role (85% in 2040 and 90% in 2050). In order to achieve such exorbitant results, relying on unstable RES sources, it will not be without a revolution in the energy storage segment. This is a huge opportunity for the hydropower industry to strengthen its position in the European electricity system.

On the other hand, legal and market restrictions not only on a European scale, but generally worldwide, are a major inhibitor to the development of large-scale energy storage. These issues were discussed at the World Hydropower Congress in Bali, organized by the International Hydropower Association. The congress also provided an opportunity to present a call for building a global low-carbon economy based on sustainable hydropower. Among energy professionals, issues related to the needs of power systems, which are undergoing a turbulent transition in many cases, are well known. However, for the public and decision-makers, these issues are no longer so obvious. That is why a declaration has been formulated that makes the case for hydropower as an essential component of a sustainable economy of the future, as well as providing advice for decision-makers to streamline investment procedures. The Editorial Office of „Energetyka Wodna" magazine joined this initiative by publishing the content of the Bali Statement as the lead article of this issue.

From a national perspective, it is encouraging to see recent efforts to build pumped storage power plants, a confirmation that decision-making circles have recognized the urgent need for investment in large-scale energy storage. This trend was reflected in the debate dominated by PSH topics that took place at last year's HYDROFORUM conference. Its proceedings, as well as a detailed summary of the jubilee edition of this event, prepared by Janusz Steller, Ph.D., chairman of the Board of Polish Hydropower Association, can be found in the Practice section.

Interesting things are happening in Poland not only in the sphere of large hydropower investments. This is evidenced by the microgrid in Maków Mazowiecki, launched last autumn, with a small hydropower plant as its main power source. The local government decided to self-power public buildings due to the high uncertainty in the energy market, the desire to reduce operating costs and to ensure a stable supply of energy for its own needs in the long term. This investment is not only an emblematic example of thriftiness, but also of attention to flood safety and resident-friendly land use. For more information on this investment, see the article written by Wioleta Smolarczyk, a representative of IOZE hydro.

In January of this year, regulations went into force requiring companies to produce non-financial reports, covering environmental, social and corporate governance issues, among others. Although they will be implemented gradually and will cover the largest companies, smaller companies in their supply chain will also be forced to comply. You can find details in a publication prepared by Monika Kłosowicz, Environmental protection and sustainable development consultant at Antea Polska.

Enjoy your reading!

Michał Kubecki
Editor-in-Chief

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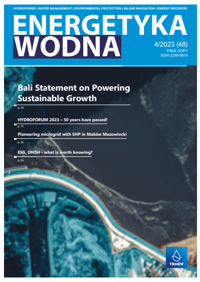

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NFEP&WM enters into a project for a pumped storage power plant

National Fund for Environmental Protection and Water Management and PGE Group have signed an investment agreement to finance the construction of the Młoty pumped storage power plant. If successful, it will be the first such investment of this kind in Poland for several decades.

Source: PGE S.A.

Photo. Visualisation of the Młoty PSH project

The Młoty pumped storage power station will be built near Bystrzyca Kłodzka in the Lower Silesian Province. The installation is expected to reach a capacity of around 1,050 MW (750 MW was previously mentioned). The Młoty pumped storage power plant project is being carried out by PGE Polish Group as part of its special purpose company PGE Inwest 12.

In April last year, PGE Group and the National Fund for Environmental Protection and Water Management received approval from the President of the Office of Competition and Consumer Protection for the PGE Inwest 12 concentration. Later, an agreement was signed last October, as a result of which NFEP&WM will become a shareholder in the special purpose company. PGE is to retain a 51 per cent stake in the company, with the remaining will be held by NFEP&WM. The Fund's involvement is aimed at securing financing for the construction of a pumped storage power plant in Młoty. Special purpose company PGE Inwest 12 is expected to obtain funds from its owners to finance the planned works, which in the near future will focus on launching the procedure for the general contractor for the investment. A few months ago PGE completed the preparation of a feasibility study for the Młoty PSH project. Its results were to demonstrate the legitimacy and technical feasibility of the construction of a power plant.

Currently, PGE is to finalise a complete nature inventory in order to submit an application for an environmental decision later this year. In addition, PGE has submitted an application to Polish Transmission System Operator to determine the conditions of connection for Młoty PSH. The plant is to be connected to the national electricity system via a 400 kV high-voltage power line. As part of the investment, it is planned to build of two water reservoirs, which will additionally have a flood control function and maintain the water retention in the region. According to the schedule, the investment is planned for completion in 2030. The lifetime of Młoty PSH is expected to be at least 40 years. Investors ensure that the construction of the pumped storage power plant will bring measurable benefits for the Bystrzyca Kłodzka, which will be able to count on millions budget revenues. PGE emphasises that the Młoty pumped storage project is key importance for maintaining the stability of the operation of the national power system in southern Poland.

– The construction of the Młoty green energy storage facility, the largest investment of this type in Poland, is an element of the energy transformation and the implementation of the PGE Group's strategy for ensuring national energy security. This investment will ensure the stability of operation of the National Power System, while cooperation with the National Fund for Environmental Protection and Water Management will open up an additional possibilities for the development of renewable energy sources – says Wojciech Dąbrowski, president of the Management Board of PGE Group.

– Without such energy storage facilities as the pumped storage power plant in Młoty, it will not be possible to dynamically develop renewable energy sources, especially unstable ones such as photovoltaic installations or wind farms – points out Artur Michalski, vice-president of the National Fund for Environmental Protection and Water Management.

Młoty is the most advanced PSH construction project in Poland, based on work that began in the 1970s but was suspended in the early 1980s. In 2013, the investment was included in the study of the conditions and directions of the Bystrzyca Kłodzka general urban ordinance plan (updated in 2018 and amended in 2020), as well as in the Lower Silesian Voivodeship Development Strategy 2020 and the Lower Silesian Voivodeship Spatial Management Plan.

There are currently six pumped storage power plants operating in the Polish power system, four of which are owned by the PGE Renewable Energy. These include Poland's largest pumped storage plant in Żarnowiec (716 MW), as well as the Porąbka-Żar (500 MW), Dychów (90 MW) and Solina (200 MW) facilities. One pumped storage power station is also owned by Energa (Żydowo, 156 MW) and Zespół Elektrowni Wodnych Niedzica operating a 46 MW plant. According to PGE estimates, more than 40 units of this type are currently in operation across Europe, and there are 10 new pumped storage power plants projects, which have been announced.

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National Shipping Programme until 2030

The Council of Ministers adopted a resolution on the establishment of the National Shipping Programme until 2030. The Ministry of Infrastructure is responsible for this scope.

The National Shipping Programme until 2030 will cover the following sections of inland waterways:

- E30 – Oder Waterway, part from Gliwice to the complex of ports in Szczecin and Świnoujście;
- E40 – the Vistula river from Toruń to Gdańsk.

The Ministry's statement aims to increase the role of inland waterway transport, which will be achieved by ensuring the conditions for navigation on the sections used for transport. In this way, the integration of seaports with the hinterland will be strengthened and inland waterway transport services should be developed.

The plan includes investments to ensure, among other:

- stable transit depths and lock availability;
- adequate clearances under bridges and other infrastructure that crosses waterways.

The National Shipping Programme until 2030 will be the first and most important planning document for the inland waterway sector. Its entry into force is expected to enable investment to be co-financed from EU funds in the 2021–2027 perspective.

Łukasz Madej
inzynieria.com

The die is cast – Siarzewo water barrage will be built

The Council of Ministers adopted a resolution on the establishment of the PLN 7.5 billion long-standing programme 'Development of the Lower Vistula'. The plan includes the construction of the Siarzewo water barrage.

The construction of the barrage is planned below Włocławek, at 706–707 km of the Vistula river. There will be built a dam, a weir, a navigable sluice with berths for vessels and icebreakers, a bypass channel, two fish ladders and downstream fish passage facilities. The construction of the barrage will create a water reservoir with a capacity of 135 million m³. A hydropower plant with a capacity of 80 MW is to be part of the investment. State Water Holding Polish Waters will be responsible for the construction of the Siarzewo barrage, which reports to the Ministry of Infrastructure.

Łukasz Madej
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Small hydropower plant to be built in Greater Poland

Financial support from the NFEP&WM for Alsus company will enable the construction of a SHP at the Walkowice water barrage no. 13 on the Noteć River in the Greater Poland Province. More than PLN 9.7 million in preferential loans will be granted for this purpose from the 'Energy Plus' priority programme.

The total capacity of the constructed power plant will be 480 kW and will allow the production of nearly 2,500 MWh of electricity from RES per year. The project plans the construction of a hydropower plant building with a power house and the construction of canals with bunds. There is also planned the construction of a culvert, access and manoeuvring areas and the installation of a hydraulic turbine with automatic control system. As part of the project, a water-legal report has already been carried out, a decision on environmental conditions and a legally binding construction permit have been obtained. The beneficiary – Alsus Sp. z o.o. – also has a signed agreement to connect the hydropower plant to the power grid. The environmental effect will be a reduction in CO_2 emission into the atmosphere. The project will be implemented in accordance with the principles of environmental protection, taking into account good pro-environmental practices. The investment, subsidised from the national pool of funds, will have a total net cost of approx. PLN 11.4 million.

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Otmuchów reservoir will be renovated

The Otmuchów reservoir on the Nysa Kłodzka river in the Opolskie Province is now more than 90 years old. Due to its age, its renovation is essential. During the works , it will be necessary to lower the water level.

The task includes the repair and reconstruction of the upstream slope insurance paving of the main dam of the Otmuchów reservoir along a 6 km section. A masonry riprap will be made (between the Kotwica and Hala leisure centres), concrete insurances from the Fala Brzeg sailing centre to Polish Tourist and Sightseeing Society branch will be demolished. Temporarily, the water level will decrease by approx. 4 m from the so-called normal to the minimum damming level of 206.70 m above sea level, which corresponds to a capacity of about 11 million m³. After the works will be completed, the facility will gradually be filled with water. The contractor for the PLN 17.7 million task is a consortium of companies Przedsiębiorstwo Robót Wodnych i Ekologicznych EKO-WOD and Naviga-Stal. The renovation will be completed in December 2025.

Wojciech Kwinta
inzynieria.com

Historic weir in Wrocław was renovated

One of the oldest hydrotechnical structures in Wrocław, the historic Psie Pole weir has been renovated. This is the last so-called needle-trestle weir built in 1892–1897.

The work included, among other, the replacement of the damaged steel elements of the weir, including the repair of the elements fixing the trestles to the ground, but also the reconstruction of the steel structure of the weir, including the supporting framework – trestles, mechanisms, the technological platform with balustrade and winch. The masonry cladding, brick structure of the abutments and pillars were repaired, as well as the upstream and downstream apron plates, weir span crests, expansion joints, banks, stilling basin protection and slope stairs. The storage yard for the needles and a new fence was build. Water level gauges, a network of benchmarks and new navigational markings were installed.

Trestles are installed in the weir to close the structure, as well as wooden needles, which are scantlings with metal fittings. In winter, the weir is laid down, while later on it is put up by lifting the lying trestles using a winch, activating a footbridge and then resting further needles against them, which together form a dam for the incoming water. The damming level is achieved by adding or removing spires.

Wojciech Kwinta
inzynieria.com

Modernization of Jeziorsko reservoir – important weir repaired

The renovation of the weir carried out as part of the modernization of the Jeziorsko reservoir (Łódź Province) has been completed. The effect of the investment by State Water Holding Polish Waters is to improve flood protection in the middle Warta valley.

The Jeziorsko artificial reservoir in the Warta river water region has been in use for 40 years. It captures excess water during surges and is a reservoir during periods of drought. As part of the modernization, the dam's upstream slope was repaired and a comprehensive renovation was carried out on the spillway weir located in the middle of the reservoir's main dam The hydraulic part of it was upgraded: new pumps, pressure regulating elements and reinforced hydraulic lines were installed. The purpose of the structure is to regulate water flow. The investment activities included hydrotechnical, hydraulic, electrical and mechanical scopes.

Efficient operation of the weir allows water retention in the Jeziorsko reservoir and increases flood protection. Part of the reservoir is a nature reserve. During the works, a more than 2-kilometer section of the provincial road leading to the dam was also reconstructed as part of an investment by the local government of the Łódź Province (PLN 5.5 million). The reconstruction of the weir and reinforced concrete dam's upstream slope consumed PLN 80 million, of which PLN 24.7 million was allocated to the weir. The work was carried out between 2020 and 2023. Jeziorsko is a dam reservoir on the Warta river, with an area of 42.3 km² and 202.8 m³ of capacity. It is the largest reservoir as well as retention reservoir in the Łódź Province.

Source: State Water Holding Polish Waters

Photo. Rebuilding of reinforced concrete upstream slope

Wojciech Kwinta
inzynieria.com

TRMEW news

A new year, a new government in Poland and new plans. Will it speed up the legislative work and hydropower plant owners will be able to benefit from the provisions of the RES law on modernization? We ourselves are curious to see what pace the work of those in power will take.

What about us? Last November, we held an informational workshop on the modernization of hydropower plants and the provisions on this topic in the RES Act. The formula of the event was slightly different from the traditional Hydroforum, but it was not at all different in terms of the quality and quantity of knowledge that the TRMEW Board provided to the participants. There were many people willing to participate in the workshop, unfortunately, some people's plans were spoiled by the weather and they did not make it due to the snowstorm, which happened just then. I sincerely hope that in June, during our Hydropower Congress, nothing will stand in our way and we will meet in a larger group! Even before the Congress we plan to organize a training course related to D and E energy licenses. I will inform about the specific date on our website and in the newsletter. The turn of the year is a good time to make a little summary of the past months. There has been a lot of work, but we ended the past year with a sense of a job well done. We are also very grateful to you – the Members of our association. We warmly thank you for:

- provision of various information related to your facilities, often providing substantive input to our correspondence with authorities and ministries,
- your time commitment during your SHPs presentations to students and supporters of hydropower industry,
- your financial TRMEW support, remembering about your dues and paying them regularly. This is what makes our organization working!

We form a really close-knit group and I wish myself and you that it will be successfully growing and continuing to operate so vigorously. Thank you for being with us.

Above all, in 2024, we wish you good health and unquenchable enthusiasm for operating, building or upgrading hydropower plants.

See you at the workshop or Congress!

Monika Grzybek
Office manager
TRMEW

Calendar

21–22.03. 2024 Salzburg, Austria	**RENEXPO Interhydro** Organiser – Messezentrum Salzburg GmbH	www.renexpo-interhydro.eu/de/
11–13.04.2024 Bucharest, Romania	**GREEN ENERGY EXPO & ROMENVIROTEC** Organiser – ROMEXPO	https://greenenergyexpo-romenvirotec.ro/en/home/
22–23.04.2024 Sophia-Antipolis, France	**SOLAR-HYDRO 2024** Organiser – Aqua~Media International Ltd	www.hydropower-dams.com/solar-hydro/
22–25.04.2024 Rotterdam, Netherlands	**World Energy Congress** Organiser – World Energy Council	https://worldenergycongress.org/rotterdam/
23–25.04.2024 Poznań, Poland	**GreenPOWER** Organizer – International Poznań Fair	https://greenpower.mtp.pl/en
24–25.04.2024 Warsaw, Poland	**Energy Transformation and Energy Storage 2024** Organiser – E-greenify	https://konferencja.e-magazyny.pl/en/

News from the Polish Committee for Large Dams

Last year, representatives of POLCOLD participated in the EURCOLD meeting organised as part of the 12th conference of the European Club of the International Commission on Large Dams in Interlaken (Switzerland) from 04.09.2023 to 09.09.2023.

Delegates of POLCOLD, a member of the European Club of the International Commission of Large Dams, took part in voting on resolutions, discussing plans for the future, in setting up new initiatives in the form of working groups and in deciding on the admission of new member countries. They exchanged experiences on the operation, design, construction and safety monitoring of dam structures. At the EURCOLD meeting, on the basis of the approval given by the Polish Minister of Infrastructure, a proposal was made to organise the next (13th) EURCOLD conference in Poland in 2026, which was applauded by the delegates, especially after the presentation about dams in Poland and the possibilities of organising such a conference in our country. In agreement with State Water Holding Polish Waters and energy corporations, the idea of organising a conference in 2024 for managers of damming structures and hydroelectric power plants at large Polish dams was conceived. It would be a technical meeting, starting with a paper on water management on large reservoirs and developed with a discussion of current practical issues related to the problem. Changes in the hydrology of rivers require corresponding changes in water management instructions. Managers would have the opportunity to meet with other professionals and discuss the problems they are encountering.

Under the initiative of the Ministry of Infrastructure, POLCOLD also participated in the drafting of the 'Technical conditions to be met by damming structures and their location'. The new regulation will probably enter into force in 2024. POLCOLD's Young Engineers Club continues its activities. The first official meeting of the club was held on 11 May at the Institute of Meteorology and Water Management headquarters. The meeting was attended by eight people. During the discussions, they debated the possibilities of supporting POLCOLD with the activities of the Young Engineers Club and discussed the areas of interest of the individual members. Another informal YEF meeting was held on 12–15 September during the 20th International Technical Conference on Dam Control, which was attended by five club members. In addition, the YEF has been involved in editing and updating the POLCOLD website. For 2024, it is planned to participate in the organisation of the meeting of Large Dams Managers in Poland organised by POLCOLD.

At the work session of POLCOLD, several issues were adopted that will be important elements covered by the Polish Committee of Large Dams, among which we can mention the clarification of the definition of NadPP, the discussion on the provisions in water management instructions and water permits concerning the principles of water management in relation to climate change, the work on the regulation on the conditions of use of inland hydrotechnical structures, as well as the refinement of the rules of procedure of POLCOLD technical committees and the translation of ICOLD bulletins.

Piotr Śliwiński
Chairman
Polish Committee of Large Dams POLCOLD

Winners of the PGE Water Machines Tournament

The Warsaw University of Technology hosted the final of the PGE Water Machines Tournament 2023. More than 2,000 students took part in the competition, building more than 650 water turbines.

The PGE Water Machines Tournament is a technical competition aimed at promoting renewable energy sources and encouraging primary and secondary school students to put into practice the knowledge they have acquired at school in mechanical engineering. The competition popularises science and technical subjects among young people. It also helps develop manual skills. For the first time, not only students from Poland participated in the competition. In cooperation with the Polish embassy in Vilnius, regional preliminaries were organised for students from Polish schools in Lithuania. A total of 13 regional competitions were held. 80 teams qualified for the national final. The task of the participants in the competition is to build a model of a turbine converting the kinetic and potential energy of water into mechanical energy. Detailed guidelines are included in the regulations. The works made by the students are tested by the competition judges on a unique measuring station. The turbine's task is to perform a work of 100 J by lifting a 5 kg weight to a height of 2 m. In the "Power" category, the time taken to complete the task is evaluated, and in the "Efficiency" category, the amount of water used is evaluated.

In the final of the PGE Water Machines Tournament 2023 in the primary school category, the winning teams were:

- in the "Power" category, the "Wodniacy"team from the Centre for Environmental Education and Lake Revitalisation, Szczecinek Educational Complex, with a time of 7.93 s,
- in the "Efficiency" category – "Pontos" team from Juliusz Słowacki Primary School No. 1 in Stargard with a water consumption of 1.95 L.

In the secondary school category the winners were:

- in the "Power" category, "Pendolino" team from the Stanisław Stanisław Staszic Vocational Schools Complex in Aleksandrów Łódzki, with a time of 6.992 s,
- in the "Efficiency" category, the "Proton" team from the Armii Krajowej School Complex No. 4 in Szczecin with a water consumption of 1.9 L.

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From the World

02.10.2023 Fortum announces modernization project for historic Untra hydropower plant in Sweden

Fortum has unveiled an ambitious plan to breathe new life into the Untra hydropower plant, a historic facility dating back to 1911. With an investment exceeding SEK 700 million (over €60 million) earmarked for the period 2023–2030, Fortum is setting its sights on revitalizing one of Sweden's oldest hydropower plants. The Untra Hydropower Plant, boasting a current output of 42 MW, is set to undergo a comprehensive renovation. This includes the replacement of three turbine units and a substantial restructuring of the power plant, all aimed at enhancing Untra's ability to provide flexibility to the power system and to deliver fossil-free electricity to Sweden.

Thanks to the deployment of advanced turbine technology, annual electricity production is projected to increase from 270 GWh to approximately 300 GWh. Of the total investment, approximately half is classified as growth capital expenditure, already incorporated into Fortum's committed growth capital expenditure of €800 million for the years 2023–2025.

03.10.2023 Iraq plans to build new dams in 2024 to tackle drought and water scarcity

Iraq's Ministry of Water Resources has unveiled an ambitious plan to start construction of 36 new dams across the country in 2024, with the aim of mitigating the worsening drought and water scarcity issues, as reported by state media. Minister of Water Resources, Aoun Diab, revealed to state-owned newspaper al-Sabah that Iraq is preparing to embark on the construction of 36 water retention dams within the coming year. The decision to proceed with this substantial project comes in response to scientific predictions pointing towards early rains in the autumn and winter seasons, following a prolonged four-year drought period in Iraq. The first in line is the Abu Takiya dam, which will be situated near the Shingal and Rabia areas, located in the arid Badia desert in the northwest of Iraq. The second dam, named al-Masad, is designated for the western desert region. According to Diab, the construction blueprints for both dams are already finalized.

12.10.2023 Biden-Harris Administration unveils $38 million investment in US hydropower facilities

The Biden-Harris Administration, in line with President Biden's ambitious Investing in America agenda, has revealed an investment of over $38 million to bolster hydropower facilities across the US. This landmark initiative marks the most extensive single investment in the nation's waterpower production to date, with a focus on expanding access to affordable and clean electricity.

Under the provisions of the Bipartisan Infrastructure Law, the US Department of Energy (DOE) has declared that 66 hydro facilities situated throughout the nation will benefit from incentive payments tied to the electricity they generate and sell. These payments are aimed at supporting hydroelectric power generation and distribution from dams and other water infrastructure, particularly in areas with inadequate electrical service. This financial boost represents the DOE's most significant commitment to hydroelectric facilities to date and aligns with the Biden-Harris Administration's commitment to achieving ambitious clean energy objectives.

Furthermore, the DOE has released the revamped Hydropower Vision Roadmap, led by the Water Power Technologies Office. This initiative builds upon the Hydropower Vision report of 2016, aiming to make it a living document. The roadmap outlines key activities identified by the hydropower community to achieve a substantial increase in the United States' combined electricity generation and storage capacity, from the current 101 GW to nearly 150 GW by 2050. This growth is contingent on continued technological advancements, innovative market mechanisms, and an unwavering focus on environmental sustainability.

23.10.2023 Renovation complete at Grande Dixence hydroelectric project

Grande Dixence SA marked a historic milestone on October 20, 2023, with the official inauguration of the fully refurbished Fionnay and Nendaz power stations and the penstock connecting the Lac des Dix reservoir to the Rhone plain. Grande Dixence, which has been a cornerstone of Switzerland's electricity generation for nearly six decades, underwent a comprehensive renovation over a six-year period, gradually resuming operations at the beginning of the last year.

The initial phase involved a comprehensive analysis of the various components comprising the downhill route, leading to the identification of necessary renewal, repair, and restoration initiatives. This was subdivided into 89 distinct sub-projects and spanned from 2016 to 2023. Each of the six generating units at Grande Dixence's two power stations, Fionnay and Nendaz, has undergone a comprehensive retrofit, including the installation of new valves, turbines, alternators, automatic control systems, and auxiliary services.

The penstock, connecting Lac des Dix to the Rhône through the Fionnay and Nendaz power stations, has undergone a comprehensive overhaul. Specifically, the overhead segment of the penstock, spanning 850 meters between Péroua and Condémines, has been completely replaced, while the anti-corrosion protection of the subterranean portions has been renewed.

From the World

13.12.2023 Ukrhydroenergo secures €133 million from EIB for hydropower rehabilitation project

PJSC Ukrhydroenergo has received a €133 million tranche from the European Investment Bank (EIB) for the ongoing Hydro Power Plants Rehabilitation Project. Initiated in 2012, this project seeks to reconstruct 21 hydroelectric units across selected power plants in the Dnipro River basin, encompassing Kyiv pumped storage project and the, Kaniv, Kremenchuk, Seredniodniprovska, Dnipro 1, and Dnipro 2 hydropower plants.

Ihor Syrota, Director General of PJSC Ukrhydroenergo, expressed appreciation for the invaluable support, emphasizing that the funding would empower the company to acquire critical equipment for emergency response, ensuring the swift restoration of both the company's power plants and the Ukrainian Unified Energy System. Syrota highlighted that the funds would also sustain the ongoing reconstruction of hydraulic units, thereby augmenting operational resilience and capacity.

The allocated funds will not only upgrade and reconstruct Ukrhydroenergo's hydropower facilities but also contribute to the restoration of damaged power facilities and capacities lost due to shelling. This is particularly crucial, given the partial damage to Dnipro and the complete destruction of Kakhovka.

15.12.2023 Mozambique signs agreements for Mphanda Nkuwa hydropower project implementation

The Government of Mozambique, represented by the Ministry of Mineral Resources and Energy (MIREME), has officially inked two partnership agreements with its Strategic Partner for the implementation of the Mphanda Nkuwa Hydropower Project.

The Strategic Partner, a consortium led by Electricité de France (EDF), comprising TotalEnergies and Sumitomo Corporation, will spearhead the development, construction, and operation of the project. This ambitious venture comes with an estimated investment of $5 billion. The project, situated on the Zambezi River in the northern province of Tete, involves the construction of a dam and hydropower plant with an initial production capacity of 1,500 MW. The Mphanda Nkuwa hydropower plant is expected to play a pivotal role in stimulating Mozambique's economy by providing clean energy for major industrial projects, supporting electrification initiatives, and exporting surplus energy to the region. The project timeline indicates that the first turbine is expected to be operational by 2031.

19.12.2023 African Development Bank's SEFA allocates $9.72 million to advance modernization of African hydropower fleet

The African Development Bank-managed Sustainable Energy Fund for Africa (SEFA) has granted $9.72 million to propel the Africa Hydropower Modernisation Programme (AHMP). This initiative, serving as a comprehensive platform, aims to revamp hydropower systems across the continent, augmenting their reliability and adaptability.

The infusion of funds will facilitate the expansion of AHMP's ongoing efforts, focusing on 12 private-sector-led projects spread across eight countries, selected through a competitive process. The initiative anticipates an additional 570 MW of available capacity, requiring an estimated investment of $1 billion, inclusive of contributions from the private sector. Furthermore, these projects are expected to curtail greenhouse gas emissions by 1,700 kilotons of CO_2 equivalent annually.

Speaking on the significance of the project, João Duarte Cunha, the African Development Bank Division Manager for Renewable Energy and SEFA Manager, emphasized: "About half of Africa's hydropower assets are over 30 years old and ageing fast; modernizing them with the latest electro-mechanical and digital technologies is the fastest and cheapest way to increase clean energy capacity and enhance system flexibility needed to accelerate energy transition efforts."

19.12.2023 Suomen Voima Launches new pumped storage project in Finland

Suomen Voima has announced details of a new energy storage venture named 'Noste' in the Kemijärvi region of Finland. The ambitious project involves the construction of 1–3 small-scale pumped-storage hydropower plants in Northern Finland, aimed at bolstering the country's green transition and enhancing energy balance. The estimated investment for this venture is set to reach up to €300 million. While this form of energy production is relatively unfamiliar in Finland, there is a substantial demand for efficient energy storage solutions. Noste is anticipated to contribute 100–200 MW of balancing power, providing a crucial element for Finland's move towards sustainable energy infrastructure. Each hydropower plant within the project is estimated to cost between €50–100 million, culminating in a total investment of up to €300 million.

The project aims to employ state-of-the-art technology, with a paramount focus on designing pumped storage facilities that minimize their impact on the northern environment and landscape. The first hydropower plant is slated to commence operations within the current decade.

HYDROFORUM 2023 – 50 years have passed!

At the beginning of October 2023, 50 years have passed since the HYDROFORUM'73 scientific and technical conference. The conference was organized by the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences (IMP PAN) and the Northern District Power Plants. The tradition of this event is continued by the HYDROFORUM Polish Hydropower Conferences, which are organised annually by the Polish Hydropower Association (TEW), IMP PAN and the Polish Association for Small Hydropower Development (TRMEW). The HYDROFORUM 2023 conference took place on 25–26 October in the four-star Scandic Wrocław hotel. The local coorganizer was the Faculty of Mechanical and Power Engineering of the Wrocław University of Science and Technology.

Source: Author's archive

Photo 1. Wrocław Electro-dwarfs

The idea of Wrocław as the venue for one of the HYDROFORUM conferences has accompanied the organizers for a number of years due to their intention of organizing a technical visit to Malczyce Barrage. The decision matured shortly after commissioning of Malczyce HPP and preliminary talks with representatives of State Water Holding Polish Waters (PGW Wody Polskie). An obvious candidate for a local scientific partner was the Faculty of Mechanical and Power Engineering of Wrocław University of Science and Technology, with which the organizers have remained in multiyear contact and which eventually became a coorganizer of the event. It is worth mentioning that the University was a coorganizer of the HYDROFORUM conference, which was held in 2005 at Kliczków Castle in Lower Silesia. The University and the IMP PAN held also the scientific auspices of the Hidroenergia international fair and conference in 2012. Until HYDRO 2018, it was the largest hydropower conference ever organized in Poland. Hidroenergia 2012 was held on the grounds of the Centennial Hall in Wrocław, and its coorganizers were: the already non-existent European Small Hydropower Association (ESHA) and TRMEW. The conference provided an opportunity to inaugurate the "Energetyka Wodna" quarterly.

Indeed, Wrocław has a number of other advantages that could attract attention of the HYDROFORUM organizers – including excellent logistics, as well as strong ties with water management, water transport and hydropower sectors. One should also mention a unique atmosphere and cultural richness of the city – largely resulting out of fortunate reconciliation of the heritage of those driven from behind the current eastern borders of Poland with respect to the history of the site they came to and understanding the difficult fate of those forced to leave their city forever in the 1940s.

A testimony to the links with water transport is the Wroclaw Water Junction with numerous weirs and 116 bridges over various branches of the Oder river. The links with hydropower are demonstrated by two hydroelectric power plants located in the city centre. Among the newest cultural landmarks of this area one should mention the bronze statues of dwarfs of various professional qualifications. Among them, there are also Elektroludki (Electro-dwarfs), which since the jubilee of the Wroclaw Branch of Association of Polish Electrical Engineers (SEP) celebrated in 2019 have been busily connecting the street lamp in front of the NOT headquarters to the network. During the inaugural session of HYDROFORUM 2023, the author of this text had the honour of receiving a cast of the basrelief of this scene from the hands of the President of Wroclaw SEP Branch, Edward Ziaja.

From the organiser's perspective

The event was attended by 116 people representing 50 institutions, enterprises and NGOs. Among the foreign participants, the largest group (7 people) represented the association "Hydropower of Ukraine". In addition, the conference was attended by 3 participants from Romania and single participants from the Czech Republic, Germany and Lithuania (including one person only remotely). More than half of the participants took part in a study visit to Malczyce Barrage on October 27th. During 10 conference sessions, 35 contributions were presented (including two occasional presentations and two remote ones). The meeting was held under the auspices of the Committee on Energy Problems of the Polish Academy of Sciences, State Water Holding Polish Waters (PGW Wody Polskie), the Association of Polish Electrical Engineers and the Association of Water and Land Reclamation Engineers and Technicians. It is worth emphasizing the participation of "Polish Waters", which practically joined the process of organizing the conference and was represented by two members of the Organizing Committee. The conference had two official partners: PGE Energia Odnawialna SA and consortium of the Life NEXUS European Commission project (coordinated by CARTIF Foundation, Spain).

Balancing conference budget despite numerous discounts and exemptions from the conference fee appeared possible thanks to a number of sponsors. The group of sponsors included: Energa from the Orlen Group, Hydro-Vacuum, T.I.S. Polska in the "Premium" category, while Belse, Institute of Renewable Energy Sources (Instytut OZE), KSB Poland, PFTechnology and Niedzica Group of Hydropower Plants sponsored the event in the "standard" category. Traditionally, "Energetyka Wodna" together with ZEK Austrian publishing house took over the media patronage over the conference was held. The electronic version of HYDROFORUM 2024 Book of Abstracts was published on the TEW website a few

Source: Author's archive

Photo 2. „Oslo" lecture room in Scandic Wrocław hotel during HYDROFORUM 2023 inauguration session. In the first row: Prof. W. Jędral and Prof. J. Plutecki

of the organizers. In fact, the decision to close the cycle was taken after HYDROFORUM 2005. However, the cycle was resumed already in 2011 – mainly due to the support and encouragement of colleagues from the Polish Hydropower Association and participation in the SHP STREAMMAP project. This time, however, a different formula was adopted. The top priority has been attributed to the most hot problems of the Polish hydropower industry. Strategic, legal, economic and environmental issues have taken an important position in the agenda. In order to respond to the rapidly changing legal and economic conditions, it was decided to link the conference with the annual TEW National Assemblies and with the RENEXPO Poland Renewable Energy and Energy Efficiency Fair, taking place for the first time in our country. Due to this reason the RENEXPO Poland naming has been adopted. Initiating the annual conference cycle turned out to be possible thanks to entrusting most of the organizational tasks to the Polish Hydropower Association, shortening the debate time, resigning of parallel sessions, and replacing extensive conference proceedings with a book of abstracts. Shortly afterwards, the adopted model of cooperation between the three permanent coorganizers, the local coorganizer and the "Energetyka Wodna" quarterly began to provide good results (Fig. 1).

Therefore, already after two years, the naming "Polish Hydropower Conferences" came into use with reference to the entire new cycle. In 2016, the duration of the conference was extended to 2 days, and

days before the conference whereas the printed version was distributed among the conference participants at the registration desk. The Book of Abstracts of HYDROFORUM 2024 includes not only extended summaries, but also typical mini-articles. Therefore, the volume of the book has grown to 158 pages [1]. Some of the contributions have already become the basis for post-conference papers published in "Energetyka Wodna". Some others will be recommended for submission to the peer-viewed scientific journal "Transactions of the Institute of Fluid-Flow Machinery"

Jubilee

The conference was started by the author of this text welcoming the delegates on behalf of the Polish Hydropower Association and the HYDROFORUM Organizing Committee. The author presented also some excerpts from the 50 years long history of the entire conference cycle. On this occasion he recalled the contribution made by the Department of Dynamics of Liquids of the Institute of Fluid- of the Polish Academy of Sciences, and in particular by its long-time head and initiator of the series, Prof. Kazimierz Steller (Photo 3). It was also a good opportunity to recall some of the Department activities throughout over 30 years of its existence. In the further part of his speech, the author pointed out out that it was the success of the first HYDROFORUM conferences that allowed to obtain a good brand, which has survived to this day, attracting numerous specialists in the field of hydropower and other people directly or indirectly involved in the development of the sector. At the same time, he reminded the moments when it was intended to end the entire cycle, in recognition that HYDROFORUM formula had been exhausted, and the organizational effort was in too clear collision with the daily professional duties

Source: Author's archive

Photo. 3. Prof. Kazimierz Steller (1925–1992)

Source: Author's archive

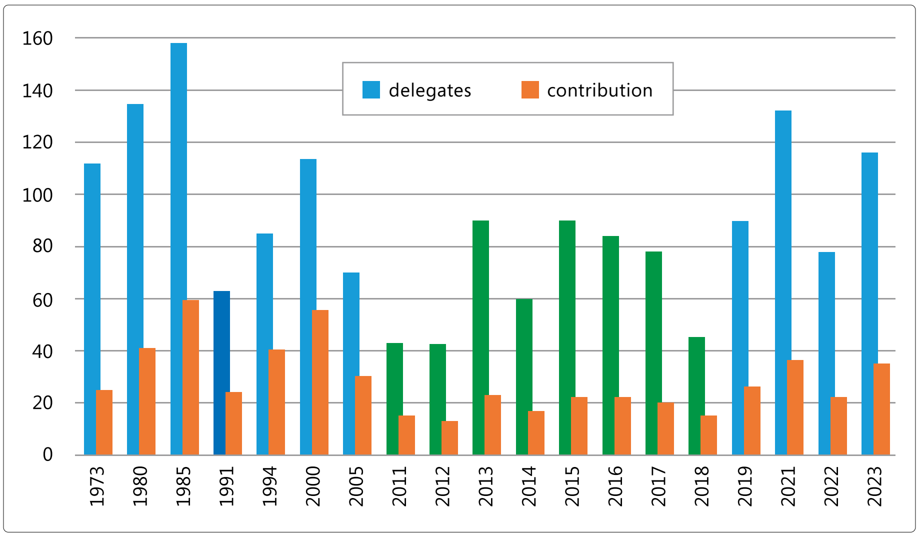
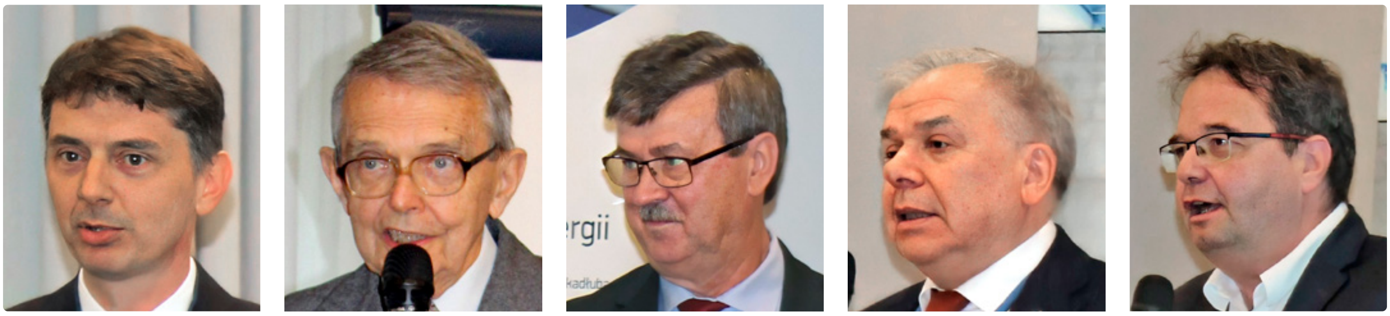


Fig. 1. The number of delegates and conference contributions to the HYDROFORUM events. The navy blue colour denotes Symposium'91, whereas the green colour – the RENEXPO Poland conferences



Source: Author's archive

Photo 4. The list of Inauguration Session speakers included among others Prof. P. Szulc, Prof. W.Jędral, Director D.Karkos, President Y.Bondarenko and Prof. M.Lackowski (order from the left to the right)

since 2018 the conferences have been organized outside Warsaw again with study visits included again. Finally, in 2019, the naming HYDROFORUM was reinstated. Although the last two decisions resulted primarily from the permanent withdrawal of the RRECO GmbH (RENEXPO fair organizer) from the Polish market, they undoubtedly increased the attractiveness of the entire series for Polish participants. The decision has appeared fully justified as the practice did not confirm the positive impact of choosing Warsaw as the conference venue on participation of the decision makers.

Inauguration

In the further part of the session, some Honorary Committee members and Conference guests took the floor. First of all, the conference delegates were welcomed by Prof. Piotr Szulc, the Dean of the Faculty of Mechanical and Power Engineering [WME] of the Wroclaw University of Science and Technology who presented also the activity profile of the Faculty, on the threshold of its 70th anniversary. Prof. Szulc emphasized the compliance of the Faculty activities with the UN Sustainable Development Goals No. 7 (clean and affordable energy), 9 (innovation, industry, infrastructure) and 13 (climate action). Referring to hydropower related activities, he mentioned involvement in the Horizon Europe D-HYDROFLEX project. The Faculty is a member of a consortium consisting of 18 partners from 5 European countries. The aim of the project is to increase the productivity, reliability and flexibility of hydropower plants by digitising the control of operational processes.

The next speaker was Prof. Waldemar Jędral, an eminent Polish authority in the field of impeller pump design, and the head of the Chair of Pumps, Drives and Power Plants at Warsaw University of Science and Technology in the years 2000–2011. Prof. W.Jędral reminded the figure of Prof. Stanisław Zwierzchowski, the pre-war head of the Chair of Water Engines and Pumps of the same university and an excellent designer of high-speed Francis turbines. His special achievements included the in-depth study of propeller turbines with self-adjusting runner blades.

In the next speeches, the conference delegates were welcomed by Mrs. Ewa Malicka, President of the TRMEW Board, and Mr. Dariusz Karkos, director of the Regional Water Management Authority in Wroclaw (RZGW Wroclaw). Mr D.Karkos also read a congratulation letter by the President of PGW "Polish Waters", Dr. Krzysztof Woś. The welcome address on behalf of the Main Board and the Wrocław Branch of SEP was delivered by Mr. Edward Ziaja, who represented also SEP authorities together with Ms. Mirosława Bożentowicz, Chair of SEP Power Engineering Section.

An understandable interest was aroused by the speech of Mr. Yurii Bondarenko, the Vice-President of "Hydropower of Ukraine" Association and the General Director of ENPAS Electro Ltd. from Kiev. Mr Y.Bondarenko has started his speech with congratulating the organisers the 50th anniversary of HYDROFORUM events. Afterwards the speaker presented assumptions of an innovative plan for reconstruction of the Ukrainian energy sector after the devastation caused by the ongoing war. In autumn last year the damage covered 75% of thermal power plants and 60% of substations from 100 to 750 kV. The destruction of Kakhovka Dam was the most spectacular single event. However, the takeover of the Zaporizhzhia NPP by Russian forces alone has led to the 6 GW loss in Ukrainian power grid. The priority tasks of the innovative post-war reconstruction plan include among others: (a) investments aimed at balancing and improving regulation of the power system (including: commissioning of another 3 units in the Dniester PSPP (3×320/430 MW), erection of the Kanevskaya PSPP (1 GW), construction of gas turbine sets with high control capacity and 100–450 MW power (total capacity up to 5 GW), reconstruction and construction of new 400 kV transmission lines); (b) development of distributed power supply network (including cascades of Tisa, Teresva and Stryi rivers); (c) the development of smart local grids. The opening session ended with a speech by Prof. Marcin Lackowski, Director of the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences, who welcomed the participants on behalf of the Institute and officially opened the Conference.

Hydropower potential and multipurpose plants

The first working session was chaired by Prof. Michał Habel Head of the Department of Waterways Revitalization at the Casimir the Great University (UKW) in Bydgoszcz. In the speech of RZGW Wroclaw representatives – Deputy Director, Mr. B. Wszołek, and Head of the Energy Department, Dr. B. Głuchowska – the participants were informed about the structure and activities of the Water Management Authority – especially about recent infrastructure investments and hydropower installations in operation. On the other hand, numerous investments of Polish Waters on the Oder Waterway were the subject of a paper by the team of authors representing the National Water Management Authority. The paper was presented by Dr. K. Wrzosek, an expert on strategic projects in the Department of Investment Preparation and Implementation of Polish Waters. For obvious reasons, information about technical solutions of Lubiąż and Ścinawa barrages was of particular interest for conference delegates. Other presentations concerned the prospects for development of water transport and hydropower in the war-torn Ukraine.

Source: Ukrhydroprojekt 2022

Photo 5. On the left: Kakhovka dam together with Kakhovskaya I HPP prior to destruction. On the right: the view from the side of Kakhovskaya II HPP under design after planned dam

The representatives of the Ukrhydroproject design bureau, which were the core of the Ukrainian delegation, presented results of the study work carried out so far on the Baltic-Black Sea waterway and the reconstruction of the Kakhovka dam. The current political situation makes it more and more likely that in the first case the pre-war concept of the San/Dniester connection will be chosen instead of the Bug/Pripyat route, which has been preferred for a long time. It is difficult to say when this investment could be launched. In the case of both variants, decisions on the Polish side are of key importance.

After cessation of war hostilities, it seems more realistic to start reconstruction of the Kakhov dam (Photo 5), the destruction of which not only led to a catastrophic flood, but also significantly hindered water supply to the Zaporizhzhia Nuclear Power Plant, Crimea and the Kryvyi Rih Basin. The authors of the barrage reconstruction study proposed carrying out the necessary construction works within 8 years. Ultimately, it is assumed that the installed power capacity on the dam will increase from 335 to 585 MW through construction of the Kakhovskaya II HPP in the earth dam on the right bank of Dnieper.

The last presentation of this session concerned the assessment of the theoretical potential of the rivers of Ukraine, which was carried out using GIS methods by a team of employees of the T. Shevchenko State University in Kiev led by Prof. O. Obodovsky (now also UKW Bydgoszcz). The result of this assessment is similar to previous ones and indicates the value of 42.3 TWh/year, i.e. almost twice as much as in Poland. It can be expected that a similar proportion applies to the technical potential of both countries.

Pumped storage sector

Documents published this year [2, 3] and studies already undertaken indicate that after decades of stagnation and neglect, the decision-making circles of our country have noticed the need for energy transition requiring not only investments in renewable energy sources, but also in the power grid and large-scale energy storage. Finally, the necessity to resume development of pumped-storage was acknowledged. It is to be hoped that the political changes taking place in Poland since the end of 2023 will not cause further delays and waste of effort. Unfortunately, the publicly announced planning assumptions exhibit many wishful thinking features after allowing the design potential and project execution capacities to decline in the previous decades. It is for these reasons that it is so important to rationalise efforts to increase the flexibility of the electricity grid. In the opinion of numerous experts, the efforts should include not only the necessary investments in new large pumped-storage power plants, but also goals achievable in the nearest future – such as the removal of legal and economic obstacles to use regulatory capacities available already today, and increasing the storage capacity of reservoirs of classic HPPs and PSPPs (both physically and by changing the relevant regulations), equipping certain reservoir power plants with pumped and photovoltaic components, erection of pumped mini-power plants for local balancing purposes. These issues dominated the HYDROFORUM Debate conducted in the form of a panel discussion by Mr. Stanisław Lewandowski, Honorary President of TEW and former Director for Operation and Development of ESP S.A. (today PGE EO).Together with President S. Lewandowski, Ms. Katarzyna Trojanowska, Secretary of TEW Board of, and the writer of these words sat at the panel table. The following persons took part in the debate as experts: Mr. Leszek Bajorek, President of Niedzica HPP Group Board, Ms. Katarzyna Serca (Chief Investment and Development Specialist at Energa Wytwarzanie S.A.), Mr. Przemysław Mandelt (President of Tauron Ekoenergia Board) and Mr. Stefan Traczyk (Vice-President of Enea Nowa Energia Board), (Photo 6).

The debate took the form of a discussion on individual subissues formulated in the moderator's speech. Traditionally, also the audience was given the floor. The starting point was a series of columns published by the moderator on the TEW website, as well as paper [4], previously published in the "Energetyka" SEP monthly. Among the issues raised, there were questions about the operating parameters of pumped-storage power plants, which are crucial for increasing power grid flexibility, as well as the previously mentioned activities leading to the same goal. The participants agreed on the advisability of undertaking various

Photo 6 Participants of the HYDROFORUM 2023 Panel Debate. From the left: S.Lewandowski (TEW, moderator), K.Trojanowska (TEW), J.Steller (TEW/IMP PAN), L.Bajorek (Niedzica HPP Group), K.Serdeczna (ENERGA Wytwarzanie), P.Mandelt (Tauron Ekoenergia), S.Traczyk (Enea Nowa Energia)

Source: Author's archive

activities, provided that they are carefully planned, guaranteeing optimum use of the allocated funds. It has been proposed to prepare an open letter addressed to Polish authorities on this issue, which would be written after the new government has been formed.

The panel debate followed directly a lecture session dealing with pumped-storage sector. The session was chaired by Mr. Janusz Łobacz, a member of the Żarnowiec PSPP management staff – a person with high competences in the debate field. Review papers presenting the growing importance and prospects for pumped storage development both worldwide and in Poland were presented by:

- Mr. Michał Kubecki, president of the RES Institute Board and a member of the government expert team, having prepared a report on the conditions and directions of pumped storage sector development in Poland [2];
- Dr. Klaus Krüger, senior expert on power plant safety and energy storage at Voith Hydro Holding.

From the point of view of the adopted technological solutions, the report provided by Dr K. Krüger appeared to be of particular interest. The report included an information on a reversible variable speed hydraulic unit in Kruonis PSPP (Lithuania). The capacity of the unit is 110 MW (over 2 times less than that of 4 already operating fixed-speed units). The session ended with a speech by Prof. Bogdan Popa (Bucharest University of Technology, Photo 7), who characterized the state of hydropower in Romania and ambitious plans for the development of photovoltaic and wind energy. The latter circumstance resulted in it a decision to invest in pumped-storage power in this country despite the large number of already available classic storage installations. Today, all Romanian pumped-storage power plants use natural inflow, and the total capacity of pump units is only 91.5 MW. However, Romania has excellent hydrographic conditions for the development of classic pumped storage power sector. As a result of recent analyses, 6 particularly favourable locations for power plants with potential capacity of 500 to 1,000 MW have been identified. The most attractive location is Tarnița-Lăpuștești, where erection of a pumped-storage power plant has been planned for 50 years. Finally, in July 2023, the Ministry of Energy decided to resume the investment process. Concluding his speech, Prof. B. Popa drew attention to the need to ensure appropriate economic conditions for the operation of pumped-storage energy in Romania, and in particular to make a reliable valuation of ancillary services.

Research & development and promotion & educational projects

The last session of the first day debate was chaired by Dr. Przemysław Szulc (Wrocław University of Science and Technology). During the session, Dr. Artur Machalski, representing a team of authors from the Chair of Energy Conversion at the Faculty of Mechanical and Power Engineering, presented the basic assumptions of the aforementioned D-HYDROFLEX project. The concept of the project assumes developing a virtual model of a hydroelectric power plant. In the next speech, Dr. Sebastian Muntean from the Timisoara Branch of the Romanian Academy shared information about the PEN@Hydropower (Pan-European Network for Sustainable Hydropower) project implemented under the European Commission COST action with the participation of 200 persons representing 38 countries. The aim of the project is to facilitate mutual contacts, cooperation upskilling of participants involved in sustainable hydropower activities. The implemented activities include various types of meetings and conferences, training trips, and granting conference grants.

Photo 7. Session II heard contributions by: Mr. M. Kubecki (IOZE), Dr. K. Krüger (Voith) and prof. B. Popa (Bucharest University of Technology)

Source: Author's archive

The Polish representative in the 34-person Management Committee is Ms. Ewa Malicka, President of the TRMEW Board. The session ended with a report from the Second Intercollegiate Camp of Student Science Clubs DYCHÓW 2023. The aim of this valuable initiative is to familiarize interested students of selected faculties with some aspects of hydroelectric power plant operation. The HYDROFORUM organizers promised to support such activities by offering a number of interested students free admission to conference rooms in the following years.

At 8:00 p.m. of the same day, a toast with a glass of sparkling wine opened the HYDROFORUM jubilee reception. The reception took place in an uninhibited, truly friendly atmosphere – partly to the sounds of guitar, as well as harmonicas and other musical instruments of the delegates. The last guests left the Oslo conference hall after midnight.

Small hydro and hydraulic energy recovery

On the following day, the meeting began with a report by Mr Michał Lis, the managing editor of "Energetyka Wodna", on a study trip of the HYPOSO project partners to European SHP equipment factories (Austria, Italy, Germany) and selected small hydro installations. The HYPOSO project was implemented between 2019 and 2023 by a consortium consisting of 13 partners from Europe, selected countries in Africa and South America, and the USA. Its aim was to promote European SHP technologies in the countries of the so-called emerging economies. It was from the countries of Africa and South America that 23 trip participants came. The Polish consortium members of the project were TRMEW Sp. z o.o. and the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences. The trip itself was organised by "Energetyka Wodna" team in cooperation with Frosio Next Co. (Prof. B. Pelikan) and the project coordinator (WIP GmbH, Mr. Ingo Ball). A comprehensive report was published in print in the 2/2023 issue of "Energetyka Wodna" [5], and the report in the form of a video file was made available at the project website. Despite some technical problems during the online connection, the report was received with great interest by the delegates. Changes in Polish legal regulations with direct impact on the SHP operation conditions were discussed by the President of the TRMEW Board, Ms Ewa Malicka. The amendments to the RES Act include, among others the rules for granting support for SHPs, introduction of the cable pooling mechanism and the rules for operation of energy clusters. The amendments to the Power Law concern, among others, the electricity generation activities by supplying the customer with a direct line and the possibility of limiting the guaranteed connection capacity. In addition, the President of TRMEW discussed the amendments to the Planning Act and the Act on the Oder River Revitalization.

The last two presentations of the same session were prepared by the teams of Warsaw companies: Institute of Technology Optimization (IOT) and CIM-Mes Employees of IMP PAN and the Wrocław University of Science and Technology participated in the IOT team work. Both presentations concerned hydrokinetic units with a design following the Fritz Mondl's Strom-Boje concept and consti-tuted a summarisation of the already completed project POIR.01.02.00-00-0268/17: "Highly efficient turbine generating set of a floating hydropower plant as driven by the water current". The project was implemented as a part of the "Smart Growth" Operational Programme for 2014–2020.

Sessions VI and VII were chaired by Prof. W. Jędral and Prof. J. Plutecki, retired professors of Warsaw and Wrocław Universities of Science and Technology, respectively. The main topic of the sessions was recovery of hydraulic energy dissipated in municipal and industrial water circuits. In this way the sessions referred to the Life NEXUS Project Symposium held last year in Warsaw as a part of the HYDROFORUM 2022 event [6]. The project has been implemented since 2018 within the European Life programme by a consortium consisting of partners from Spain, Lithuania and Poland (IMP PAN).

Session VI began with a speech by Mr Kazimierz Oboza, a retired director on operational maintenance at the water supply and sewage company in Bielsko-Biala city (Silesia, South of Poland). The presentation concerned the water intake at the Wapienica dam in Bielsko-Biała [7]. This location was one of candidates for a preliminary feasibility study for energy recovery to be conducted within the Life NEXUS project. Finally, a tubular unit with rated power of 9 kW, equipped with a propeller turbine with fixed guide vanes and a generator with permanent magnets was installed. The supplier of the hydraulic unit was MEW Co. located in Kościerzyna (Kashubia region, Pomerania). In the same session, Mr Mariusz Piękoś, shared his experience on an energy recovery installation at Cracow Municipal Heat Energy Enterprise, while the results of Life NEXUS preliminary feasibility studies of energy recovery installations in Lithuania and Poland were discussed by Prof. Petras Punys of Vytautas Magnus University in Kaunas (presentation reproduced from the video recording) and the author of this text, respectively.

An important contribution to the VIIth session was made by Mr. Arkadiusz Krawiec and Mr. Adam Chlapek – representatives of the Polish subsidiaries of the international concern KSB AG and the Italian holding T.I.S. SERVICE S.p.A., respectively. Centrifugal pumps designed for turbine operation by KSB and diaphragm valves of the T.I.S. holding were recommended in the Life NEXUS studies as the basic equipment of the hydraulic energy recovery installations in the water supply networks of the Municipal Economy Company in Krosno and the SEWIK company in Zakopane. While the basic production offer of KSB is quite widely known in Poland, the operational capabilities of T.I.S. diaphragm valves have become the subject of a lively discussion.

The attractiveness of using pumps as turbines (PaTs) instead of classic hydraulic turbines in the smallest hydropower plants is due to significantly lower prices of hydraulic units from large scale production than those from unit or small-batch manufacture. However, the disadvantage of PaTs as compared to conventional turbines is usually lower efficiency and much worse controllability. A compromise is the use of pumps equipped with a special impeller design, and sometimes – with specially mounted vanes with adjustable blades (Photo 8). The development of a series of types of this type of machines has been recently undertaken by Hydro-Vacuum SA pump manufacturers in cooperation with the Chair of Energy Conversion Engineer-

Source: Author's archive

Photo 8. Expositions by Hydro-Vacuum SA and T.I.S. Polska Sp. z o.o. were an important completion of lectures delivered during the Life NEXUS project session

ing at the Wroclaw University of Science and Technology. An report on the research aspects of this cooperation was provided by Dr Paweł Janczak and Dr Witold Lorenz from the Research and Development Department of Hydro-Vacuum S.A. Session VII was closed with a speech by Dr. Mariusz Lewandowski, representing the authors' team from IMP PAN, PKN Orlen concern as well as T-G DNALOP and Easy Serv companies. Using among others the commissioning test results of energy recovery installations with a long supply pipeline, the authors of discussed mitigating the risks due to hydraulic transients in this type of installations. In this way, they referred to the earlier speeches of director A. Chlapek and the author of this text.

Performance and dynamic hydraulic unit properties

The last two sessions were of a scientific and -technical nature. They were chaired by Prof. Janusz Skrzypacz from the Chair of Energy Conversion Engineering at the Wrocław University of Science and Technology and Prof. Grzegorz Żywica, Deputy Director on Science at the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences (Photo 9). Session VIII began with a speech by Maciej Kaniecki, (T-G DNALOP) on improving cavitation properties and extending the operation range of modernized turbines by design methods. Particular attention was paid to counteracting cavitating vortex ropes developing beneath the runner operated out of the best efficiency point. This problem was discussed also by Mr. Jacek Bieńkowski, member of the authors' team from the Wrocław University of Science and Technology. The speaker presented, among others, results of his own numerical simulations of breaking the vortex by the obstacles located below the runner. On the other hand, the results of simulation studies on the possibility to reduce the intensity of undesirable secondary flows in the suction pipe elbow of the modernized storage pump were presented by Dr. Sebastian Muntean from the Academy of Romania.

Source: Author's archive

Photo 9. Sessions VIII and IX were chaired by Prof. J. Skrzypacz (left) and G. Żywica (right)

The other two presentations in this session concerned tests carried out under operational conditions. Prof. G. Żywica shared his experience from diagnostic tests aimed at detecting and eliminating sources of excessive vibrations of small hydraulic units. The speech was very informative in terms of reasoning process leading to the final conclusions. In all cases, mechanical resonance turned out to be an important cause, in one case the forcing vibrations were caused by the misalignment of the shaft lines. Experience following from acceptance tests of a small hydroelectric power plant equipped with three hydraulic turbines with turbines of two types (2 x Francis + 1 x Pelton) was shared by Mr. Lukas Rinka representing the OSC company from Brno. The special character of these tests resulted from the way in which the guarantee conditions were set. The guarantees concerned the average annual production of electricity by the entire power plant. The result therefore also depended on the way in which the power plant operation was controlled. Continuous flow measurement lasted the whole year and was carried out using the ultrasonic method, calibrated with Gibson measurements. Guaranteed production was exceeded by 2%.

Biofouling and erosion

Biofouling occurs both in the hydropower and heat power industries – on devices such as inlet screens, running water filters or heat exchangers. They can be counteracted by electroplated copper coatings with hydrophobic surface nanostructure (nCu). The research on the effectiveness of these coatings in hydropower was the subject of presentations by Dr. Janusz Krasucki (CIM-mes Projekt) and Mrs. Karolina Górlicka (PFTechnology) which opened Session IX. In the same session, a representative of BELSE Co., Mr. Artur Nawłoka, discussed applications of Belzona polymer composites to protect and regenerate the surface of components exposed to various types of erosion – abrasive, hydroabrasive, droplet and cavitation ones. The problems of cavitation erosion were also discussed in two presentations by the author of this text and Dr. Vladimir Safonov, a researcher at Kharkiv Institute of Physics and Technology, at the time of the conference – employed

Source: Author's archive

Photo 10. A study visit at Malczyce Barrage (view from the head water side)

at the IMP PAN. The first of these presentations dealt with flow velocity related cavitation erosion scale effects. Their direct link with physical fundamentals of the phenomenon was explained. The subject of the second presentation was modelling erosion course of structural materials and their protective coatings. In particular, the author discusses the concept of cavitation fatigue strength and the general and specific equation of kinetics of protective coating polyfractional erosion process. The equations are expected to become one of the basic theoretical tools for further studies of cavitation erosion process of such coatings.

Closure of the debate

It was already past 6:30 p.m. when the jubilee HYDROFORUM 2023 conference concluded its debates. As usual on such occasions, the time came to thank each other, say goodbye, but also announce the next year meeting – this time during HYDROFORUM 2024. The signals received from the participants both immediately after the conference and in the following days confirmed that the met the expectations associated with it. Nevertheless, the organisers remain aware that there are still a number of tasks to be done, including the preparation of a special issue "Transactions of the IFFM" and the work on an open letter on pumped-storage power plants. And, of course, the start of preparations for the next HYDROFORUM

On the evening of October 26th, however, everyone needed some relaxation after two intense days. An evening walk around the Old Town of Wroclaw was a great opportunity for conference delegates.

Study trip

Already on the first day of the conference, it turned out that more than a half of the delegates were interested in visiting the Malczyce Barrage (Photo 10). No wonder, this investment has become a legend in Poland. The first ship locking took place in 2018, more than 20 years after starting the construction and more than 40 years after starting of the study works. The power plant was commissioned in 2021. With the installed capacity of 10.7 MW, it is the largest hydroelectric power plant launched in Poland in a quarter of a century (not counting numerous modernizations of existing installations). However, the achievable capacity is lower an amounts 7.5 MW. The power plant is equipped with 3 units with tubular turbines from Mavel. Like the weir, the power plant is operated by Wroclaw Regional Water management Authority. The projected annual production is 50 GWh. The barrage is equipped with a number of state-of-the-art pro-ecological devices, including two fish ladders, a barrier to deter fish coming to the inlet trashracks, and a migration route for amphibians. Further information on the barrage and the power plant can be found in the review paper by RZGW Wroclaw included in the HYDROFORUM 2023 Book of Abstracts.

Some of the delegates used the opportunity to visit the post-Cistercian monastery complex in Lubiąż. This magnificent religious building is one of the largest in Europe. It is a testimony to the advanced economic activity in the nearby areas since the Cistercians were brought here in the 12th century. The enormity of the reconstruction and renovation works carried out by the local foundation with little support from the state authorities makes a strong impression. After visiting the Malczyce Barrage, the group having previously visited the monument stopped at the local Cistercian Inn for a farewell dinner. Despite the cloudy weather, everyone went home in good moods, with a baggage of good memories.

Janusz Steller
President of the Polish Hydropower Association Board
Institute of the Polish Academy of Sciences

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Improving the efficiency of water pumps and turbines

Many issues concerning technology and operation of machinery and equipment consider in detail the properties of the surface layer and its formation. The surface layer of a material formed as a result of physical or chemical processes, which differs in properties from its substrate, determines the resistance to wear and surface fatigue, i.e. the durability of the surface.

Photo 1. BELZONA(1341) SUPERMETALGLIDE, a coating whose surface is 20 times smoother than polished stainless steel

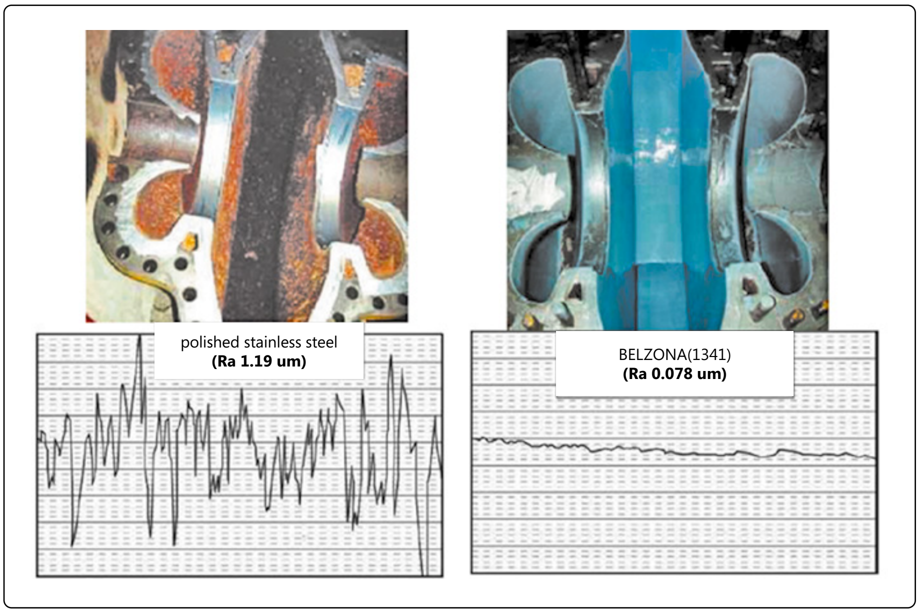


Photo 2. BELZONA(1341) composite coating a) b) summary of other pump components

Characteristics of interatomic interactions include attraction from a greater distance and repulsion from a shorter distance. This 'tug-of-war' is related to changes in the energy (loss-gain) that is involved in the interaction between atoms/particles of the surface and its surroundings. An example of this might be adhesion and cohesion phenomena. The work of cohesion is related to the overcoming of covalent bonds or crystalline structures, i.e. actually breaking the internal cohesion of the material, but it is adhesion that interests us. Adhesion is a phenomenon involving joining of two surfaces of different bodies (phases). The process of their separation requires an expenditure of energy equal to the work named the work of adhesion.

Physical basis of the phenomenon

The value of the work of adhesion is a measure of the intermolecular attraction between two different substances, and is equal to the difference in the free energies of the force of adhesion of bonded substances. For example, in the case of fluid flow – in particular flow of water through a pipeline, pump or turbine, the value of this work is on average between approx. 150 mJ/m² and 250 mJ/m² in channels with a steel surface and below 100 mJ/m² in channels made of plastic. And it is on the basis of certain macroscopic quantities, determined experimentally, that one can programme the surface for a specific kind of interaction with the environment so that the energy expended on molecular interactions (or rather, overcoming them) is as low as possible. If one assumes a flow under regular conditions, the free energy of the water is approximately 70 mJ/m², then if we manage to create a channel with a surface energy of 70 mJ/m², adhesion will theoretically not occur. Such a hydrophobic surface can be obtained by applying BELZONA(1341) polymer composite coating to the metal. Considerable energy reserves found on the metal surface are converted (or actually "exchanged") in this coating process into adhesion, which, in this case, is beneficial and allows for just an appropriate degree of adhesion after the composite has solidified, at the same time the external surface of the coating has a free energy equal to that of water and therefore there is no interaction between the coating and water and thus no significant hydraulic loss in the flow. Such a loss means a reduction in the efficiency of pumps, turbines or hydraulic machines in general, while as far as pipelines are concerned, it affects the flow energy of the fluid. In both cases, more work has to be done (i.e. more energy is needed) to transport the same amount of fluid through bare metal channels when compared to composite-coated channels.

The cost of the electricity consumed by the centrifugal pump over its lifetime is many times greater than the purchase price of the pump. It is assumed that after a 10 years of operation, the decrease in efficiency of the pump can be around 8%, which is mainly influenced by the hydraulic losses already described in the article, as well as disturbances (turbulence) resulting from surface roughness increasing over time due to the operation. Earlier analysis of the causes of hydraulic losses clearly points to two properties that can be optimised, i.e. surface smoothing and the selection of a suitable surface material so that its surface tension is equal to or close to the value of the surface tension of water, which is 70 mN/m. This is confirmed by the experience of those who operate pumps with BELZONA(1341) coating over many years and the obtained laboratory tests results.

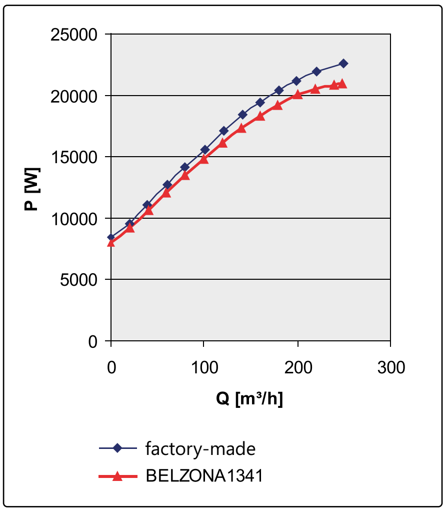


Fig. 1. Pel – Q – pump as manufactured and with BELZONA(1341) composite coating

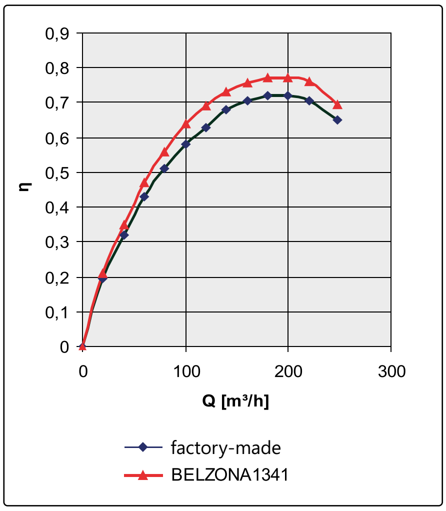


Fig. 2. η – Q – pump as manufactured and with BELZONA(1341) composite coating

Simulation of savings achieved after the application of BELZONA(1341) coating on example of a 90 kW centrifugal pump

Centrifugal pump performance after more than 10 years of operation (Photo 2):

- capacity 370 m³/h
- head H = 55 m
- rotational speed n = 1,450 rpm
- motor power 90 kW

The following parameters were measured (test stand at Leszczyńska Fabryka Pomp, 2013):

- suction pressure ps [kPa] and discharge pressure pt [kPa]
- flow Q [m³/h]
- power of current drawn at the motor P [kW]
- head H [m]
- efficiency η [%]

After the Belzona(1341) coating was applied, the parameters were measured again, and it was found that there was a 3.6 kW reduction in power consumption and the pump efficiency increased by 13%.

Financial calculations:

Reducing the electrical power demand by 4 kW results in a reduction in operating costs per year (8,000 h – operation) by:

(Energy cost [kW/h] x power [kW]) x (operating time [h] x efficiency gain [%]) = savings

(0.68 x 90) x (8,000 x 0.13) = PLN 63,648.00

Belzona(1341) coating costs – PLN 14,500

63,648.00 – 14,500.00 = PLN 49,148.00 savings per year

Laboratory tests

A detailed study of the changes in pump parameters was carried out at the Pump Laboratory of the Institute of Heat Engineering of the Warsaw University of Technology, comparing the characteristics of the pump with and without the BELZONA(1341) coating. A centrifugal pump with a capacity of Q = (180–210) m³/h was tested. The single-stage monoblock pump is driven by a 22 kW electric motor and achieves a nominal head in the range H = (28–26) m at constant speed n = 1,400 rpm. The cast iron pump impeller is equipped with axial thrust reducing vanes on the rear impeller disc. Comparative characteristics were recorded: head, power input and pump efficiency as a function of capacity. The tests were carried out on the pump in its original configuration and after coating the fluid-flow parts of the pump with BELZONA(1341) composite coating.

Pump with coating

The test results obtained for the centrifugal pump coated with BELZONA(1341), compared with the parameters of the factory configuration, show a decrease in power consumption (Figure 1) and a broad increase in pump efficiency around the optimum point by approximately 5 percent (Figure 2). Therefore, the application of a suitable coating to the pump can be regarded as an efficiency retrofit and contributes to a reduction in the energy consumption of the pump, which has been confirmed by numerous applications of this method in a real industry environment. A few years ago, a coating retrofit of 3 vertical pumps with different efficiency ratings was carried out at a Polish chemical plant. The aim was to reduce the energy consumption of the pumps. These pumps pump water continuously, so energy consumption accounts for a significant proportion of their operating costs. As part of the retrofitting, all components of the pumps, i.e. inlet funnel, impellers, guide vanes, reducing ferrules and discharge elbows, were coated with BELZONA(1341). The idea was to achieve the maximum effect of reducing hydraulic flow losses.

The results of the renovation

After the retrofitting, the pumps were installed at the same site, in the circulating water system, and were put back into regular operation. After a period of time, the performance of the pumps, such as capacity and energy consumption after pumping 1,000 m³ of water, was measured. Since the same parameters had been measured before, i.e. before the retrofitting, it was possible to make a very detailed comparison of the energy consumption required to pump a given volume of water by a pump without a coating and to compare that data to the parameters of same pump after the refurbishment, i.e. with a BELZONA(1341) coating. It was expected that the pumps would use less energy after retrofitting, and this is exactly what happened. The measurements in Figure 3 show a clear decrease in the energy consumed by the pump with coating compared to the pump without coating. This allows us

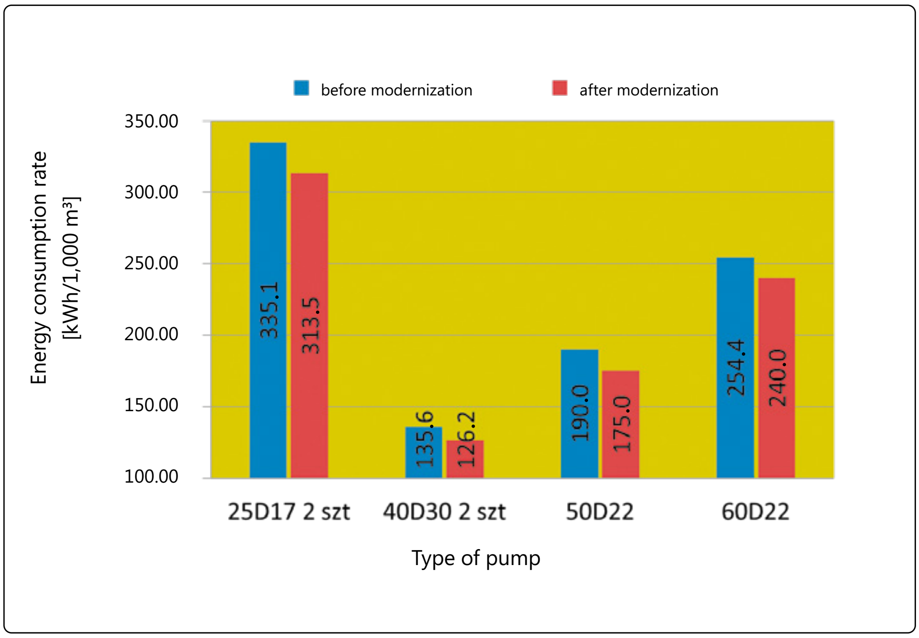


Fig. 3. Summary of energy consumption rate measurements for vertical pumps after pumping 1,000 m³ of circulating water.

Photo 4. 90 kW pump before and after coating with BELZONA(1341)

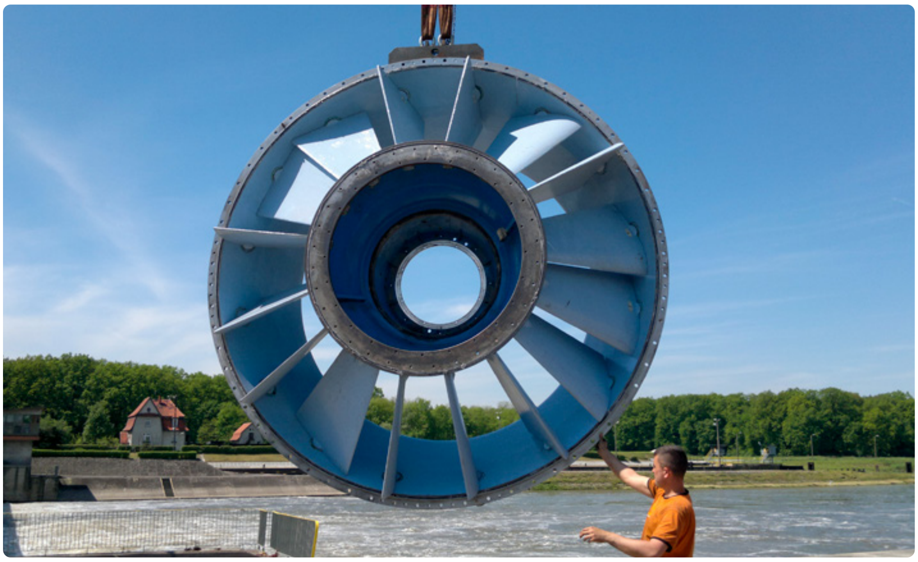


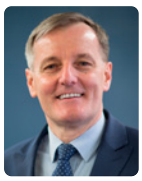
Photo 3. Kaplan turbine guide vane (on the Oder River) with BELZONA(1341) composite coating applied

to determine the so-called energy consumption rate, i.e. the kWh relating to the pumping of 1,000 m³ of water. For example, for a 50D22 pump (manufacturer's designation), the BELZONA(1341) coating reduces the pump's energy consumption by 15 kWh compared to the same pump without the coating. For this pump, the annual reduction in energy consumption of the BELZONA(1341) coated pump was 242,808 kWh! With the specific values of the measured electricity consumption before and after the pump retrofitting, one can easily calculate financial savings, i.e. the amount of money saved on electricity consumption (see frame at page 20).

Conclusions

The use of coatings in fluid-flow machines allows energy savings of 2 to 8% for new pumps (and more so for the used ones). In addition, by lowering the energy of the channel surfaces they become more resistant to corrosion – therefore it increases the life of components (rotors, vanes, guide vanes, etc.) of turbines and pumps, which, at present, with all the enormous struggles in terms of parts supply and galloping steel prices, increases the security of continuity and reliability of production and operation. In general, research results indicate that approximately 95% of machine failures are caused by inadequate properties of the surface layer of their components. The article shows that the condition of the layer determines the free energy of the surface, which has a significant impact on the energy consumption of the device. Furthermore, the impact of the aforementioned factors on the service life of machinery and equipment components operating in different environments must also be taken into account. It turns out that a polymer composite-modified layer of a metal surface improves its load capacity, ensures the continuity of deformations in contact with another component, inhibits corrosion processes and dampens vibrations, in a word – changes the operational quality of machine components. This makes it easy to refurbish parts by rebuilding and applying a new composite surface layer.

The refurbishment, according to research by the Fraunhofer Institute in Munich, reduces energy consumption by 79% compared with the energy required to make the same but new part, and also significantly reduces waiting times for the availability of a machine component. BELZONA(1341) polymer composites can be used to treat damaged shaft journals, fractured housings or bodies, and can also be used to restore surfaces worn by abrasion while increasing their strength.



M.Eng. Roman Masek
Technical Director
BELSE

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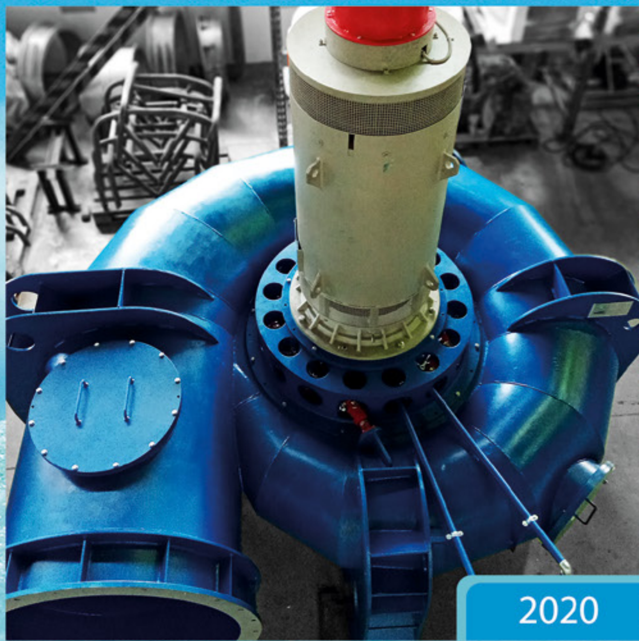
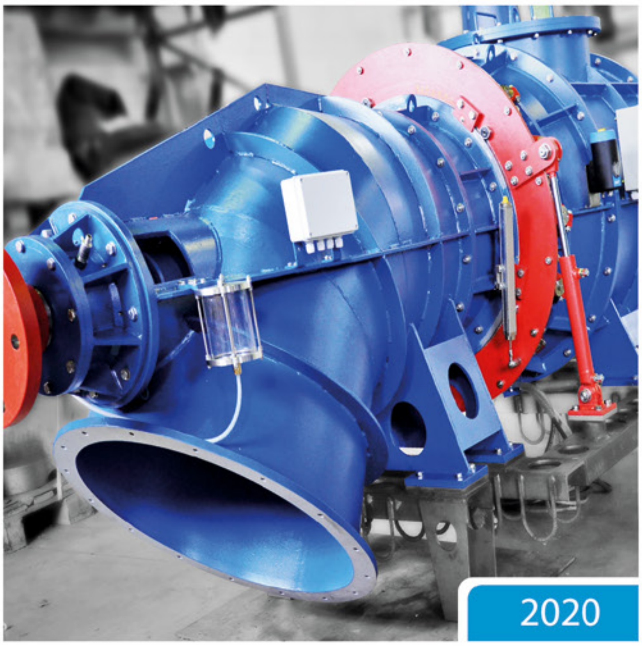


SHP San Secondo, Italy

1x92 kW (d=720mm, H=5.4m)



SHP Naviglio, Italy

1x84 kW (d=560mm, H=7.6m)

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The pump as a source of energy

A pump is a flow machine, which is mainly associated with the consumption of electricity. KSB company has been working for 45 years on the subject of pumps that operate as turbines that do not consume electricity, but produce it. The results of this work are already producing impressive results in many places.

Environmental and climate aspects, as well as the unstable geopolitical situation with its direct impact on the highly volatile prices of conventional energy sources, are leading to increased demand for alternative and renewable energy sources in all market segments. In Germany alone, it is estimated that there is a potential for the use of pumps as turbines (PAT) of around 100–250 MW of installed electrical capacity. Most of this potential is currently wasted, e.g. in water transport systems or industrial installations with throttle valves, although the use of PAT is technically very simple and extremely economical. By changing the direction of the water flow through the pump, the direction of rotation of the impeller is changed and a turbine is created (Fig.1). It is a simple and inexpensive way to produce or recover energy.

Applications

Pumps working as turbines (PAT) are useful in situations where there are differences in pressure and flow, such as liquid run-off from a height. With our pumps, generating and recovering energy is easy and inexpensive. Therefore, they can be used in situations where high investment costs make it uneconomical to generate energy using a conventional turbine.

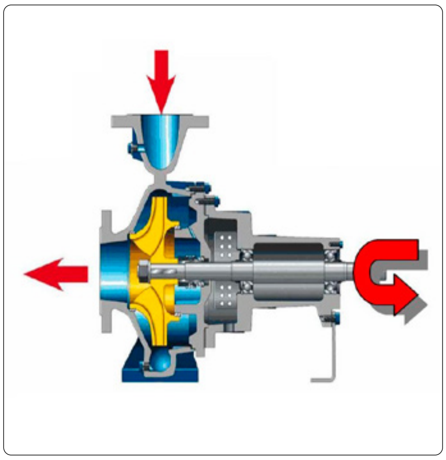

Fig. 1. Operation of the pump as a turbine (PAT)

The production program of KSB offers a wide range of pumps, that PAT systems are suitable for many applications:

- industrial plants (with different types of throttle devices),
- water transportation systems (outflow from water reservoirs),
- small hydropower systems,
- river dams,
- chemical and petrochemical processes (e.g., gas purification systems),
- bottom drains of storage reservoirs,
- oil delivery systems,
- reverse osmosis.

The energy generated can be supplied to the public electric grid (mains mode) or internal consumers (island mode). Additionally, a pump can be directly coupled to a turbine to reduce or replace the load on the drive unit.

Planning

Before installing a PAT system, it is necessary to carry out an analysis of the time distribution of the flow and the height of the liquid drop. With this data, the most efficient and economical PAT system can be designed in terms of size.

When planning the PAT system, the following principles should be observed:

- prepare the layout of the system with the KSB consultant (Fig.2),
- discuss the installation concept (electrical/electronic and mechanical systems),
- determine the electronic and mechanical integration of the PAT into the environment.

Products

KSB offers a wide range of pumps, but for turbine operation, we have carefully selected the ones that are best suited for these conditions. We chose the Multitec, Etanorm and Omega series because they allow energy recovery in installations with different hydraulic parameters and installation conditions. These pumps can individually recover energy from 0.5 kW to 750 kW, as shown in the nomogram in Figure 3.

Security

Care must be taken to ensure that the PAT system is always within the safe operating range. To be sure that this is the case, the selected pump type must be able to withstand the increased load level and all rotating parts must be made independent of the direction of rotation.

In the event of an emergency load shedding (e.g. mains failure in mains operation), the "turbine" will accelerate to run-up speed. It is therefore important to adequately protect the system against overspeed, e.g. by means of an emergency brake.

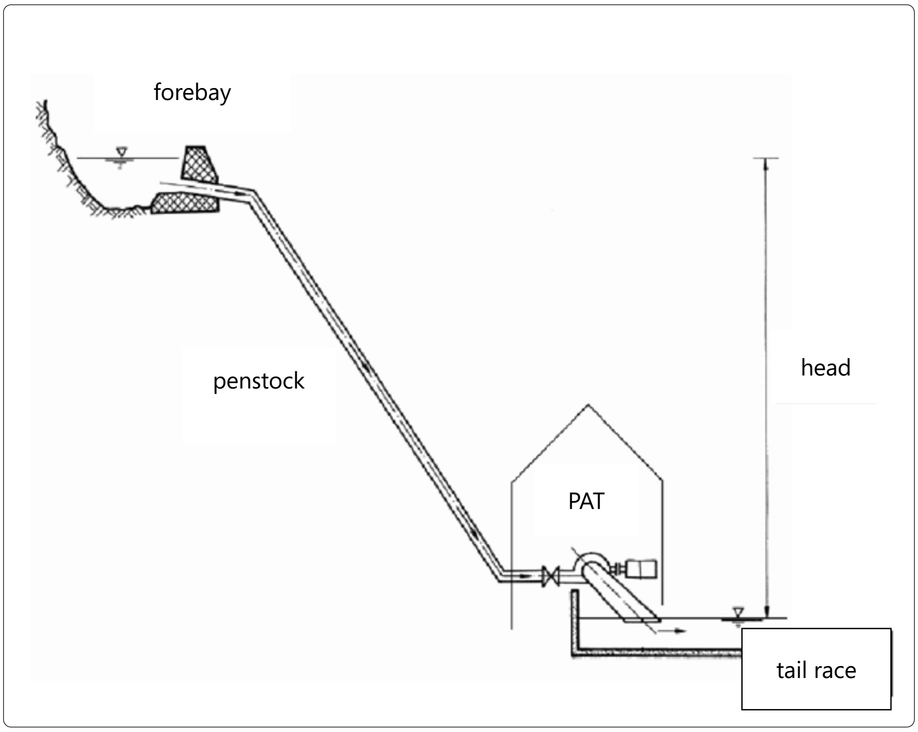

Fig. 2. Example diagram of PAT installation

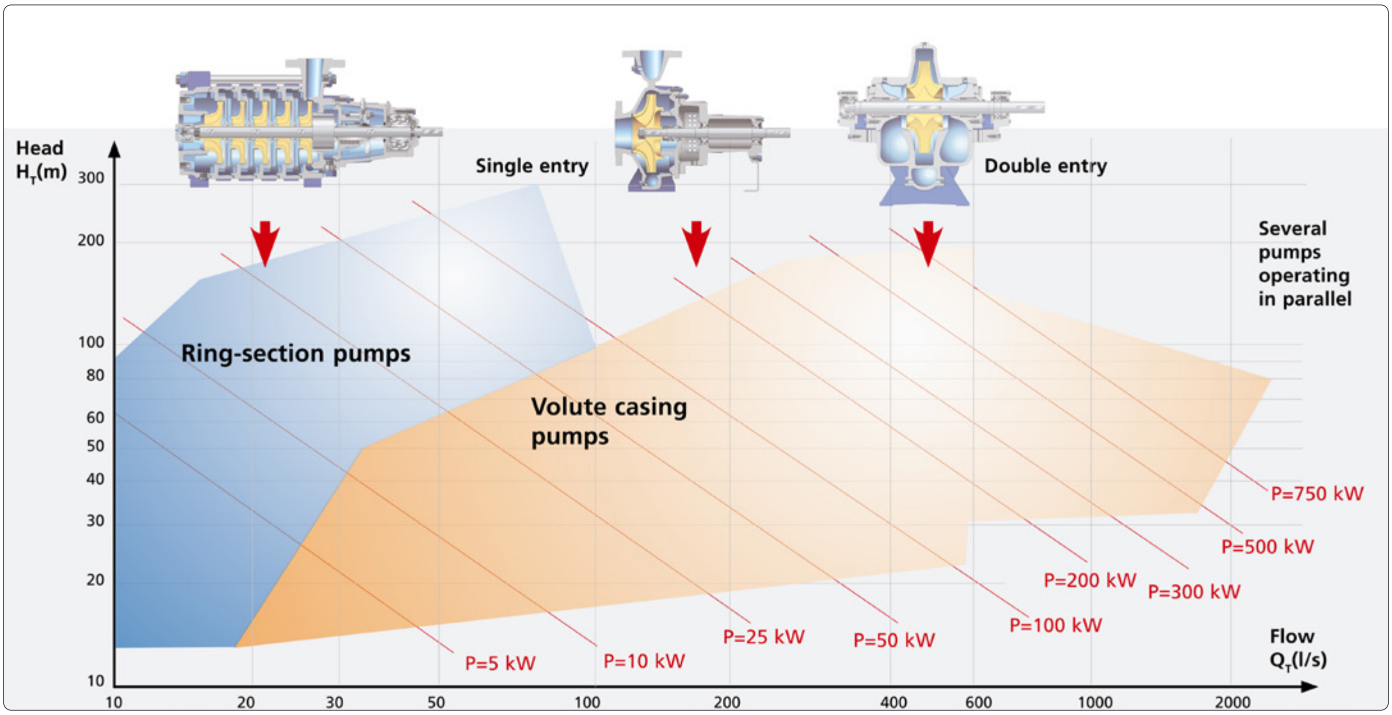

Fig. 3. Hydraulic parameters of the KSB's PAT

Another dangerous phenomenon that can occur in this type of installation is water hammer. This can occur as a result of sudden valve closure or an increase in turbine speed. When designing such an installation, the calculations used should be carried out and suitable components should be provided on the installation to eliminate this phenomenon.

Regulation of the PAT system

There are three ways to regulate pump as turbine systems to make the most efficient use of the changing hydraulic parameters of the system. Before choosing the appropriate method, however, it must be determined whether the PAT system will be connected to the external power grid or whether it will generate power for its own use (island mode). In mains mode, the power generated is fed into the external electricity grid and partly consumed for own use. In island mode, the generated power must be fully consumed by the connected appliances or stored.

The simplest and cheapest way to regulate a pump turbine is a throttle and water release system. In this case, the system must be designed for only one specific flow rate and one drop height. If these parameters change, it must be possible to change them by using throttling fittings and/or by-passes. This obviously means that some of the energy potential will be lost. On the other hand, such systems are technically uncomplicated, easy to control and, above all, very cheap. The constant speed is maintained via the existing power grid. Figure 4 shows a hydraulic diagram of such a system.

Another way to control PAT systems is to use components that allow the turbine speed to be varied to match changing hydraulic conditions. In this case, losses caused by system throttling are eliminated. Turbine speed variation can be achieved, for example, by using a frequency converter. Used in conjunction with standard three-phase motors, it provides a cost-effective solution for increasing system flexibility. It should be noted, however, that frequency converters cannot be used to supply the grid in island operation.

Another way of changing the speed of the turbine could be to use a variable ratio

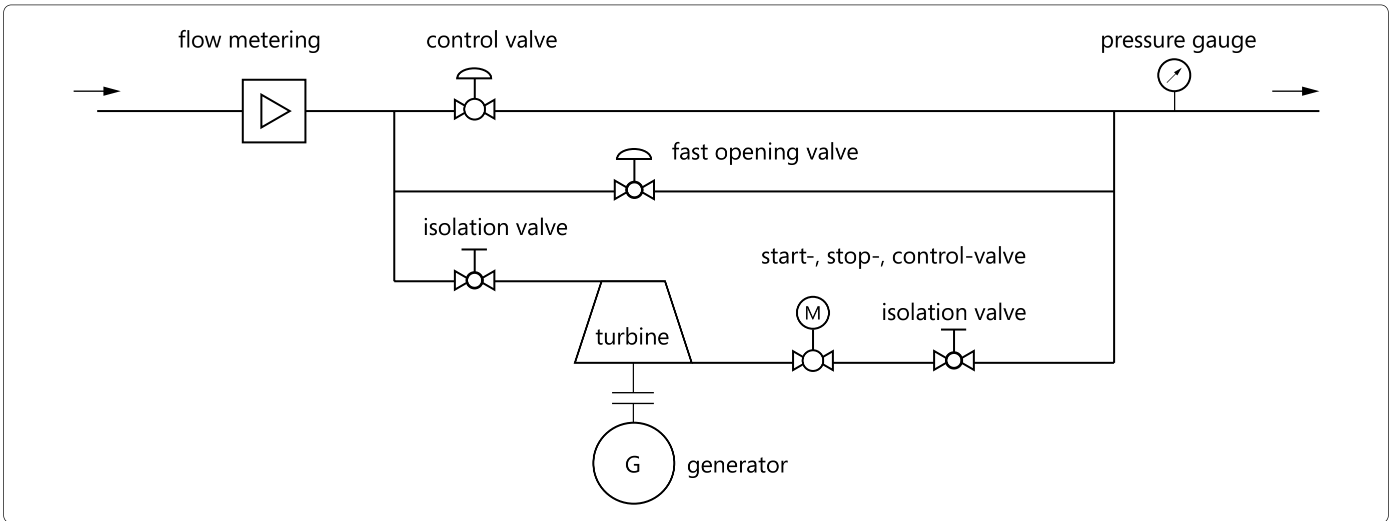

Fig. 4. Hydraulic diagram of a PAT system

Fig. 5. Pump turbines in parallel arrangement

gearbox. In this case, however, the efficiency of the system would need to be checked due to the lower efficiency of this type of device.

A high degree of system flexibility can be achieved by using several pump turbines in parallel. This type of control is particularly recommended for large flow variations. An example of this type of system is shown in Figure 5.

Installation options

The pump turbine can be connected to the generator/motor or other drive components in various ways. Installation options are shown in Figure 6.

The pump turbine does not have to be connected to the motor/generator by a coupling. It can also be driven by a fixed or variable ratio gearbox. The turbine can also be used to drive another machine directly, e.g. another pump. It is also very interesting to use a pump turbine to support a motor driving another machine. An example of such a solution is shown in Figure 7.

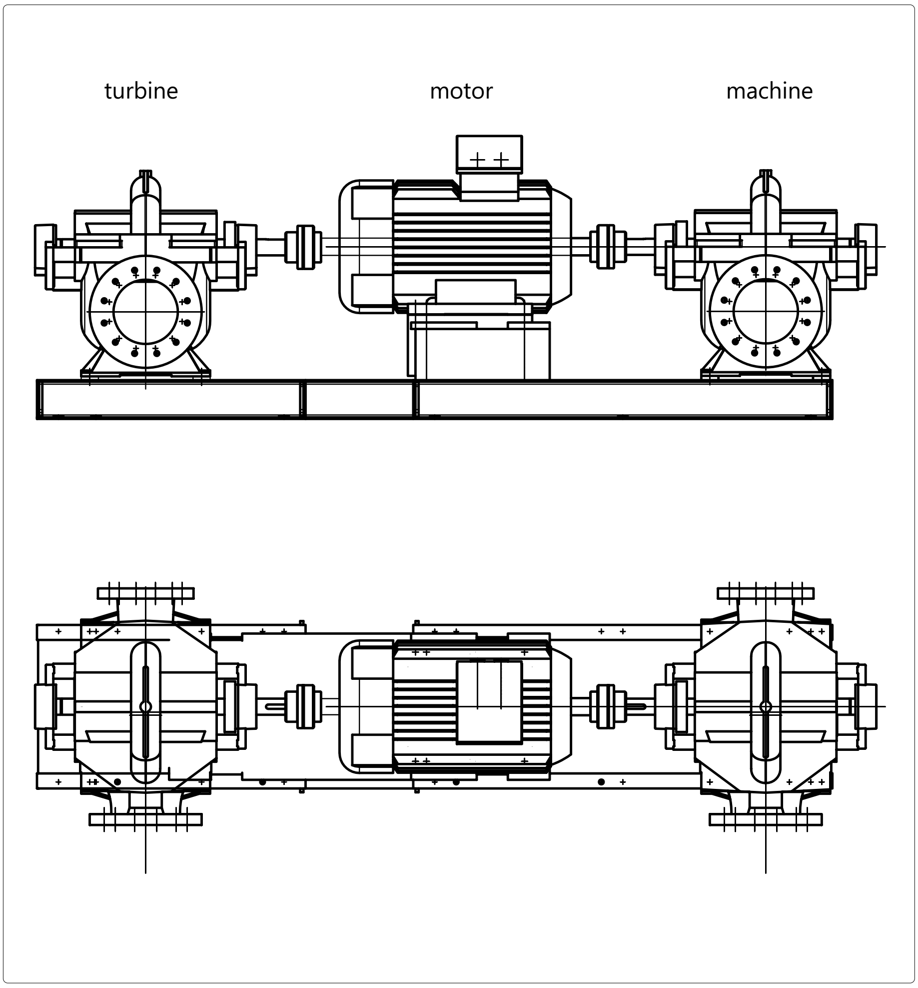

Fig. 7. Pump turbine to support the operation of the pump unit

Summary

The use of pumps as turbines is cost-effective due to the rapid return on investment. KSB pumps used as turbines are series products, and their price and availability are much more favourable than conventional turbines. The significantly shorter delivery time of the pumps means that the investment can be realised in a shorter period of time, and the relatively high efficiency of these machines ensures efficient energy extraction. Lower maintenance and upkeep costs are also important, as pumps are much cheaper to maintain than conventional turbines. A pump operating as a turbine is not a common solution at present, but the advantages of this type of system should mean that we will see more and more pump turbines in the future.

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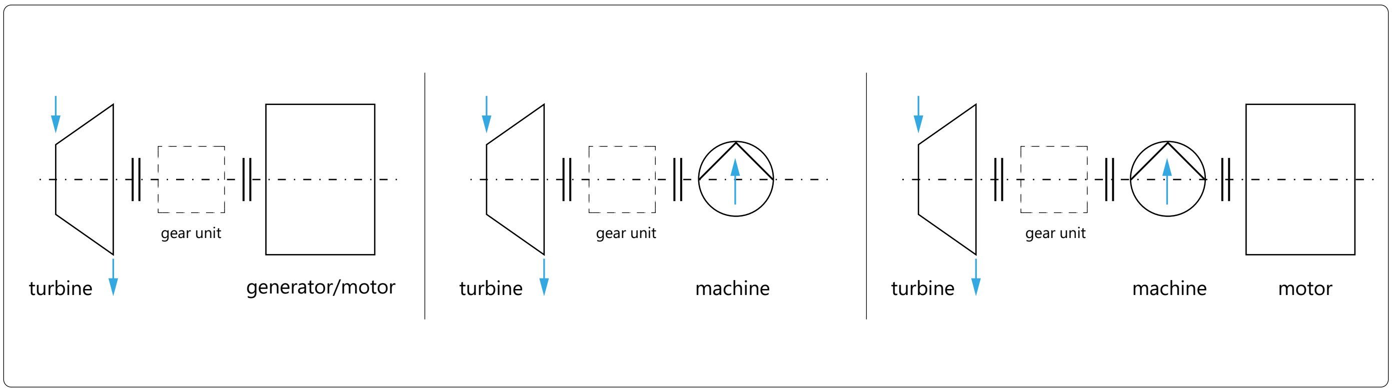

Fig. 6. Installation options

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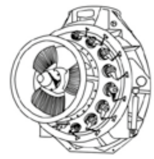

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ESG, DNSH – what is worth knowing?

ESG, DNSH – these acronyms appear more and more often in the area of environmental management, in many industries. The success of a business or investment may hinge on their level of expertise, particularly in regards to their comprehension of relevant regulations. The obligations that arise from their enactment, the measures that must be taken to comply with the directives, and the advantages that entrepreneurs derive from them are briefly enumerated in the subsequent paragraphs.

Source: Freepik

Although the topic of environmental, social, and governance issues has been discussed at trainings and conferences for some time now and in the industry media, it still raises many doubts. However, it is undisputed that non-financial reporting affects business; it has long been known that business is not indifferent to the environment in which it is run. This impact may vary, and it may also be measured in many areas. Until recently, information about the impact of business on the environment and activities in this area was an element of reports on corporate social responsibility (so-called CSR). When developing strategies, companies should consider social interests and environmental protection, as well as relationships with various stakeholder groups. However, often these reports contained only a descriptive approach, often including the so-called "greenwashing." This approach lacked measurably and the ability to assess their effectiveness, as well as linking activities in the supply chain.

The answer to the above problems and shortcomings is ESG. Environmental, social, and corporate governance concerns are increasingly becoming prevalent criteria for assessing the overall viability of a company's operational model and its long-term viability. Shareholders, as well as customers, are increasingly seeking and requesting thoughtful and forward-looking strategies and programs in all three domains. ESG criteria have become so important that they are the subject of regulations introduced by the European Union. ESG stands for Environment, Social, Governance. The above three criteria provide information on how the company operates in an environmentally and climate-friendly way, how carefully aspects such as occupational health and safety are respected, and what management and control processes should be implemented.

Is ESG only voluntary information for potential investors and customers? Well, no. As per the European CSRD Directive, companies are obligated to prepare non-financial reports under new, more stringent regulations starting from January 1, 2024. Who is responsible for reporting, and is there a planned implementation period? Key dates for specific types of enterprises are listed in the table.

Nonetheless, would it be worthwhile to implement ESG standards at present, given that the reporting obligation is solely applicable to our company from, for instance, 2027? Or does it not concern us at all? Of course! The non-financial reports also incorporate data from subcontractors or companies in the supply chain. Therefore, it is possible that our firm's failure to adhere to environmental, social, and governance norms will result in the loss of orders or the chance to collaborate with businesses that are required to submit non-financial documentation.

As mentioned above, each letter of the ESG abbreviation corresponds to one of the three criteria. But what areas are covered by these criteria? What steps should be taken to meet the requirements of a given criterion? The letter "E" in short is responsible for the broadly understood environment, including the area related to climate change. Issues related to carbon emissions and carbon footprint, vulnerability to climate change (adaptation and mitigation actions), water management (including stormwater management and water retention), biodiversity, waste, packaging and renewable energy should be reported under this criterion. The letter "S" stands for social issues, such as employee rights, occupational health and safety, employee development, diversity and equal opportunities, approach to customers, supply chain standards, and impact on the local community. The letter 'G' corresponds to corporate governance. These are issues related to company management, approach to various stakeholder groups, a set of systems and procedures ensuring compliance with the law, remuneration of managerial staff, and corruption prevention procedures.

In addition to the obligation to report non-financially, implementing an ESG strategy may also bring a number of other benefits:

- ESG aspects may affect the company's profits and its market position, especially in the long term;
- non-financial reports are other sources of knowledge about the company that facilitate decision-making for managers, clients, potential employees, investors and financial institutions;

- the non-financial and financial areas remain inextricably linked – and if this is the case, a responsible and safe company should also consider ESG factors in its risk assessment.

It's important to emphasize that financial institutions are particularly relevant to the long-term sustainability plan. Not only are they subject to regulations regarding ESG as a company, but they are also obliged to pay special attention to information from other companies in this area. As the global objective is to redirect capital flows towards sustainable activities, non-financial factors will increasingly determine whether an enterprise receives financing and, if it does, whether it receives it on more or less preferential terms.

At this point here we can move smoothly to the EU taxonomy. This is another term that appears when discussing topics related to non-financial reporting. What is a taxonomy? The term "taxonomy" is commonly used to refer to one of the provisions of EU legislation, specifically Regulation (EU) 2020/852 of the European Parliament and Council dated 18 June 2020, which establishes a framework to facilitate sustainable investment. This regulation is intended to prevent the financing of investments that are harmful to the natural environment and deepen climate change. The essence of 'green financing' is precisely the assessment of planned activities and projects with the six objectives of the taxonomy. The taxonomy lists four criteria that must be met in order for an activity to be considered environmentally sustainable. An investment or activity can be considered "green" and environmentally sustainable if:

- makes a significant contribution to the achievement of at least one of the six environmental objectives;
- does not cause serious harm to any other environmental objectives;
- is carried out in accordance with minimum guarantees;
- meets the technical qualification criteria.

The environmental objectives listed in the above-mentioned regulation are as follows:

- mitigating climate change,
- adaptation to climate change,
- sustainable use and protection of water and marine resources,
- transition to a circular economy,
- pollution prevention and control,
- protection and restoration of biodiversity and ecosystems.

The above-mentioned environmental objectives require proof that the planned action or investment does not result in significant harm (DNSH – not result in significant harm) An activity is considered to cause serious harm to climate change mitigation if it leads to significant greenhouse gas emissions and will therefore be incompatible with the first environmental objective. An activity is considered to cause serious harm if it increases the adverse effects of current and expected future climatic conditions on the activity or on people, nature, or assets. It is unacceptable if the activity in question harms the good status

Source: Own study

Company type		Fiscal year	Reporting year
Companies 500+	Subject to the NFRD and meeting one of two criteria: • EUR 20 million on the balance sheet or; • EUR 40 million in revenues.	**2024**	**2025**
Companies 250+	Not subject to NFRD, meeting one of two criteria: • EUR 20 million on the balance sheet or; • EUR 40 million in revenues.	**2025**	**2026**
SMEs	Listed on a stock exchange that meets two of the three criteria: • >10 employees, • balance sheet PLN 350 thousand EUR or; • turnover 700 thousand EUR. and Credit Institutions	**2026**	**2027**

Tabel 1. Schedule for implementing the reporting obligation

or good ecological potential of water bodies, including surface waters and groundwater, or the good environmental status of marine waters. For the fourth objective, an activity is deemed to cause significant harm to the circular economy, including waste prevention and recycling, if it results in a significant inefficiency in the utilization of materials or the direct or indirect utilization of natural resources, or a significant increase in the generation, incineration, or disposal of waste, or if the long-term storage of waste is likely to cause significant and lasting harm to the environment. Pollution prevention and control non-compliance may arise in the event that these activities result in significant inefficiencies in the utilization of materials or the direct or indirect utilization of natural resources, or a significant rise in the generation, incineration, or disposal of waste, or if the long-term storage of waste is likely to cause significant and lasting environmental harm. Activities that significantly harm the health and resilience of ecosystems or harm the conservation status of habitats and species, including those of EU significance, will be incompatible with the sixth and final objective.

Legal acts dedicated to taxonomies specify the branches and sectors of the economy for which compliance with environmental objectives should be analyzed. These industries are:

- forestry (e.g. afforestation, forest protection),
- activities in the field of environmental protection and restoration (e.g. reclamation of wetlands),
- industrial processing (e.g. production of renewable energy technologies, chlorine production),
- energy (e.g. production, transmission and distribution of electricity and heat),
- water supply, sewage and waste management and remediation (e.g. modernization of water intake, treatment and supply systems, composting of bio-waste),
- transport (e.g. rail transport of goods, low-emission airport infrastructure),
- construction and activities related to the real estate market (e.g. construction of new buildings, renovation of existing buildings, installation, maintenance and repair of equipment increasing energy efficiency),
- information and communication (e.g. data-based solutions for reducing greenhouse gas emissions),
- professional, scientific and technical activities (e.g. aid for market research, development and innovation).

The use of classification to evaluate the "greenness" of activities may offer us the chance to secure financing for our upcoming endeavors, at a reduced rate. In the area of broadly understood water management, a DNSH assessment may be needed to obtain funding for the construction of retention facilities, renewable energy sources, or infrastructure for rainwater management.

To systematize the assessment of activities or planned investments, the following steps can be taken:

1. Description of the activity, including the progress of work on the project.
2. Indication of the environmental goal(s) that the given project is part of.
3. Analysis of the compliance of a given project in terms of the indicated environmental goal, identification of risk areas, indication of possible corrective actions (catalog of actions for individual types of investments).
4. DNSH analysis (in relation to other purposes).
5. Summary and assessment of the "greenness" of the investment.

For example, compliance with the taxonomy objectives will occur for projects related to construction (in terms of new facilities) if:

- The business has implemented physical and non-physical solutions ("adaptation solutions") that mitigate the key identified climate-related physical risks that are relevant to the business.
- The assessment of climate risk and exposure is proportional to the scale of the activity and the expected duration of its operation.
- Climate projections and impact assessment are based on best practices and available guidelines, and incorporate state-of-the-art science in exposure and hazard analysis.
- The implemented adaptation solutions do not have a negative impact on adaptation activities on the level of resilience to climate-related physical risks of other people, nature, cultural heritage, goods and other types of economic activities, and are consistent with local, sectoral, regional or national strategies and adaptation plans.

To summarize, the subject matter pertaining to environmental, social, and corporate governance strategies, non-financial reporting, and EU taxonomy ought to be of interest to all entrepreneurs. This may be of key importance for the possibility of business development in a changing reality, where environmental, social and management issues take on a specific importance.

mgr inż. Monika Kłosowicz
Consultant for environmental protection and sustainable development Antea
Antea Polska SA

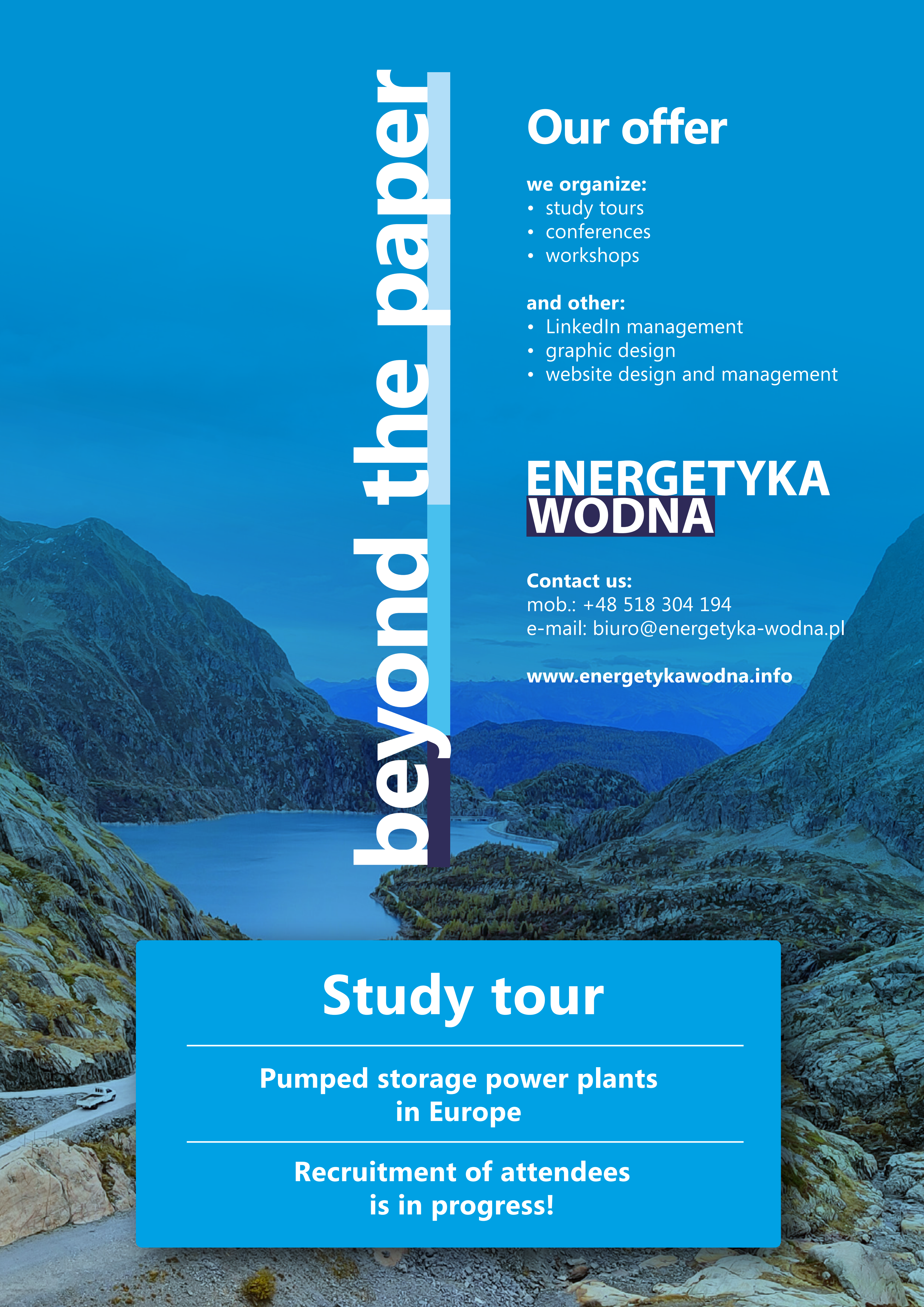
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Photo 1. View of Maków Mazowiecki SHP

Pioneering microgrid with a SHP in Maków Mazowiecki

Last autumn a new small hydropower plant in Maków Mazowiecki was commissioned. Connected to a microgrid, the facility creates a unique system in Poland for direct supply of public sector facilities with energy produced by harnessing the local hydropower potential. Let's take a closer look at the details of this project.

Situated on the left bank of the Orzyc river, Maków Mazowiecki's new SHP is a visually attractive and highly functional showcase of a modern approach to hydropower facilities. Notably, it is juxtaposed with a protected historic landmark — the powerhouse building of the old SHP, once operated on the opposite bank of the river. The project, implemented using the design & build formula, represents a return to a past method of river water management.

Hydrotechnical project scope

Commissioned by the Maków Mazowiecki authorities, the investment project comprised the construction of a new weir (to replace a structure that had been unfit for its purpose for decades) and the construction of a power plant together with a vertical slot fishway, as well as the development of the area around the facility.

The modern weir now dams the waters using a multi-layer composite rubber dam filled with water, hydraulically controlled and installed in the main span (17 m wide). The water is injected into the shell via process pipelines grouted into the weir slab. In the event of a power failure in the control system, an emergency mechanism is available to lower the weir. In addition, the weir's second span includes a wooden gate, which can be used for repair work or during the passage of floodwaters. The last, shortest span of the weir was used to install a flushing gate. Above the weir runs another landmark of the site – a wooden footbridge supported by three reinforced concrete walls and a pylon connected to the footbridge by steel cables.

The SHP building is situated near the weir itself and comprises two levels. The

Photo 2. Weir on the Orzyc river before and after the project

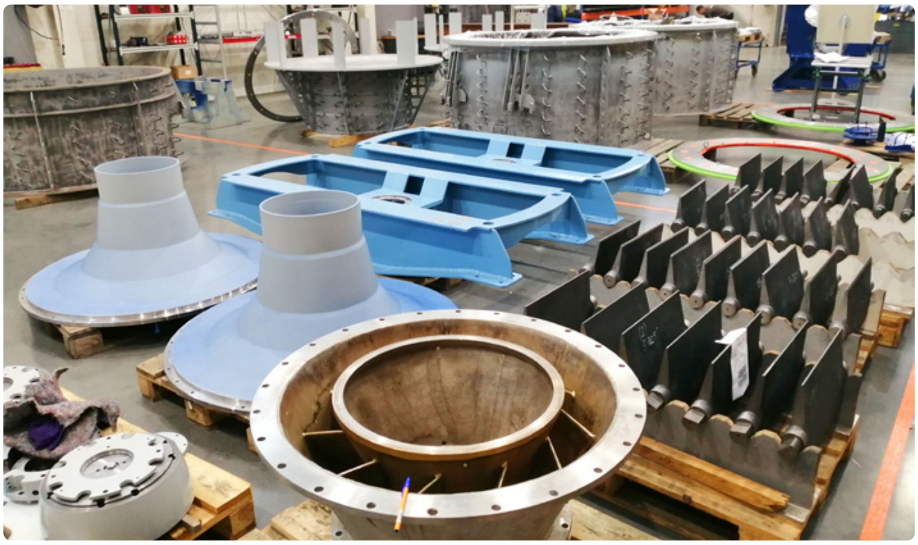


Photo 3. Kaplan turbine components on the assembly stand

first contains the control room, where the control and power cabinets as well as power evacuation system are located. The second, lower, level is the main powerhouse, where the hydro units are installed. The reinforced concrete body of the building, including the pitched roof, is varied by striking glazing with aluminium joinery. Water for the power station is taken in via a reinforced concrete channel, whose geometry has been designed to facilitate the cleaning of the trash rack. Moreover, the facility also features Poland's first automatic horizontal trash rack cleaner.

The SHP's construction process was multi-stage and took the existing infrastructure into account. A mere description of the work in each stage would be long enough to warrant a separate article, so we will use photos to illustrate the scale of the project, from concept to SHP commissioning.

Advanced Plant Automation

The powerplant houses the key technological elements – spiral inflow chambers with complex geometry, steel suction pipes and hydropower units. The Maków Mazowiecki facility utilises twin Kaplan vertical-axis turbines juxtaposed with asynchronous generators, each with a rated output of 55 kW and a maximum flow rate of 4 m³/s.

The runners and wicket gates are fully controllable, allowing the entire system to be carefully optimised according to the current hydrological conditions. The hydropower units can operate independently. The turbine controllers work in tandem with high-speed electro-hydraulic systems, enabling rapid power changes and synchronisation of the additional turbine with the grid, if the demand at any given time exceeds the maximum output of the operating turbine in the given hydrological conditions. In AUTO mode, i.e. unmanned operation, once the relevant conditions are met (safeguards, water level, grid parameters, temperatures), the hydropower unit oper-

Photo 4. Interior of the SHP with two hydro units and control platform

Ryszard Mazur,

Enerko Energy Project Manager

The Maków Mazowiecki project was an interesting construction challenge for us in many aspects. One of them was to protect the historic SHP building during the works while the stilling basin of the new weir was being constructed. The foundation of the existing building was completely uncovered in the course of the works, hence the construction process required the foundations of the old hydropower plant to be shored up so that the planned activities could be carried out safely.

Construction work carried out near and in water requires special preparation, including protection against the intrusion of river water into the work area (sealed retaining walls called Larssen sheet piling, among other things, are used for this purpose). There was an additional difficulty in this case because a bypass of the combined sewer, which collects waste from the left bank of the city (and which conflicted with the planned works), had to be made before the works could even begin. As part of the project, a new section of the sewerage system was built along the weir, following a route parallel to its previous course. It connects the existing manholes located on both sides of the riverbed. The overall effect of our work is a delightful sight indeed. I do not think it an exaggeration to say that this is one of the nicest newly built SHPs in Poland. Additionally, the facility's surroundings have been designed in such a way as to be an attractive recreational area for the town's residents while also fulfilling an educational role in the field of RES.

Photo 5. The course of the investment in Maków Mazowiecki – from the concept, through the individual stages of construction work, to the final result

ates on the microgrid in cooperation with a so-called "power guard", preventing energy flowing outside the microgrid into the national power grid.

A dedicated control system enables the intuitive operation of the SHP facility and the rubber dam. Completing the generation system is an automatically controlled trash rack cleaner, working in tandem with a flushing channel and a flushing gate. The cleaning system enables efficient, maintenance-free cleaning of the power plant trash rack and channelling debris carried downstream to the tailwater by opening the gate. The facility operator has remote access to a SCADA system to monitor the current status of all equipment and create graphs, reports and summaries of microgrid operation.

Sebastian Wites, Chief Automation Officer at IOZE hydro

During the project, it was decided that all the electricity generated would be used to supply public sector facilities operated by the city council. The microgrid features a grid analyser installed at a point, where the power plant connects to the electricity grid, which feeds information to the control system about the current power consumption of these facilities. Depending on the hydrological conditions and the factors specified in the water permit, the hydropower units regulate their output in such a way as to keep the power level at the connection point close to 0.0 kW.

Considering the high dynamics of power demand changes in the buildings connected to the microgrid (in both directions) and the high inertia of the machinery (it takes time to adjust the hydraulic systems to set the proper water flow through the turbine and therefore the power at the generator terminals), this task was rather complicated. However, the result exceeded all expectations — in a positive sense. Preliminary results after the first months of the system's operation indicate that the power generated by the SHP covers approximately 82% of the energy needs of the grid-connected buildings.

Photo 6. Horizontal trash rack cleaner supporting the operation of the facility

Smart energy management

A high-tech and highly automated SHP with associated infrastructure is not all there is to say about the project's innovative nature. The control system's designer revealed some more details for this article [see the box].

Due to the solution's scalability, it is planned to further optimise the developed control system and integrate further electricity consumers into the RES microgrid. The expansion of the microgrid is aimed at maximizing the self-consumption of the energy generated and the even greater contribution of SHP to meeting energy demand.

Inspiration for others

If this does not resonate well enough from the above, then it must be stressed what a nationally unique development we are dealing with in Maków Mazowiecki. Indeed, the investment project undertaken by the city authorities is an example of cost-effectiveness in pursuit of sustainability, which addresses the challenges of the energy transition. An own generation source and distribution network to supply one's own energy consumers is the most profitable solution, preferable even to selling electricity to the grid or operating as part of a energy cluster. The local government has become an active participant and, at the same time, a role model for other organizations in terms of energy security, economic impact and educational values.

The general contractor for the investment project was Enerko Energy. The technological solutions tailored to the needs of the SHP and microgrid users were designed and supplied by IOZE hydro.

Photos come from the archive of **IOZE hydro**.

Wioleta Smolarczyk
IOZE hydro

Photo: World Hydropower Congress – commemorative photo of participants at the closing ceremony **Source:** IHA

Bali Statement on Powering Sustainable Growth

The Bali Statement on Powering Sustainable Growth calls for sustainable hydropower to be the backbone of national strategies to build thriving, low-carbon economies bolstered by clean, renewable energy.

As the world's largest source of renewable energy generation and storage, hydropower has underpinned industrial development in many of the world's most advanced economies, while also strengthening water management. Most of the untapped hydropower potential that remains today is located in developing regions, as highlighted by the International Renewable Energy Agency (IRENA) in its 2023 report on The Changing Role of Hydropower. The development of this vast potential can drive sustainable economic development and support the massive deployment of wind and solar that is needed to deliver the clean energy transition. Planning for sustainable development should be grounded in a holistic system-wide understanding, drawing upon the most optimal combination of renewable energy sources to underpin economic development and societal transitioning. Sustainable hydropower and pumped storage provide a low-carbon complement to variable renewable technologies, but development is being held back by a lack of appropriate policy and market frameworks. As a result many countries that have developed variable renewables at pace without also investing in a reliable source of storage are now struggling to maintain electricity stability and therefore sustainable growth. This is the ignored crisis within the crisis. The global hydropower community has rearmed its commitment to the sustainable development of projects through its adoption of the San José Declaration on Sustainable Hydropower and uptake of the Hydropower Sustainability Standard. But this commitment is not enough. The market alone struggles to reward reliability, flexibility and balance. It is up to governments to ensure that policy and regulatory frameworks match the ambition of global climate goals, and for multilateral banks to provide the innovative financial mechanisms that are needed to spur new development. This can only be achieved by acknowledging, enabling and incentivising sustainable hydropower development to play its full role in economic transformation.

> *"The industrial revolution was powered by water; water, wind and sun together will power the sustainable growth of the future".*

This Statement puts forward recommendations for accelerating the development of sustainable hydropower alongside other renewables. It is based on a wide-ranging consultation with governments, the private sector, international financial institutions and civil society organisations.

Prioritising development that is sustainable

Hydropower can make a vital contribution to delivering on UN Sustainable Development Goals. Its unique capability to provide large-scale long-duration energy storage coupled with a range of multipurpose benefits can support the advancement of several UN Sustainable Development Goals:

- ensure availability and sustainable management of water and sanitation for all,
- ensure access to affordable, reliable, sustainable and modern energy for all,
- build resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation,
- take urgent action to combat climate change and its impacts,
- strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

As with any major infrastructure development, when not developed responsibly hydropower can have negative impacts on communities and ecosystems. The San José Declaration on Sustainable Hydropower recognises that all types of river- and water-based infrastructure should deliver net positive benefits to project-affected communities and the wider environment to merit their construction and continued operation. The Hydropower Sustainability Standard, which is governed by a multi-stakeholder council and assessed independently, provides an international reference for good and best practice in hydropower sustainability.

10 ways hydropower enables sustainable growth

According to UN figures and projections, more than 2 billion people worldwide today do not have access to safely managed drinking water, while around 660 million people will still lack access to electricity by 2030. Hydropower projects, when sited, planned and executed in accordance with international good practice in sustainability, offer benefits to sustainable industrial development that extend far beyond electricity production alone:

- **long-lasting, low-carbon electricity generation** – once a hydropower facility is built, it can provide energy for many decades, and does not need to burn fuel in order to operate. Hydropower generally has lifecycle greenhouse gas emissions similar to or lower than other renewable options,
- **management of water resources** – nearly 40% of hydropower dams globally provide multiple non-energy services. This includes freshwater management through flood and drought mitigation, drinking water supply, irrigation and waterway navigation; services that are increasingly vital in a climate-constrained world,
- **grid balance through flexibility, dispatchability, frequency regulation and storage** – hydropower, especially pumped storage, is the only proven large-scale renewable technology that can provide the services needed to ensure electric system stability and resilience in the low-carbon grids of the future,
- **synergy with other renewables** – by acting as a 'water battery', hydropower is a natural complement to variable renewables like wind and solar. It can store excess energy from wind and solar, and release it quickly when the wind doesn't blow or the sun doesn't shine. Hydropower reservoirs also pro-

vide opportunities for developing hybrid systems, such as the integration of floating PV,

- **decarbonisation of hard-to-abate industries** – industry consumes more energy than any other sector. Powering heavy industries with renewables instead of fossil fuels can accelerate sustainable development by decoupling emissions from industrialisation,
- **climate mitigation and resilience** – hydropower's provision of flexible storage, low-carbon electricity generation and multipurpose benefits (including flood and drought control) will be crucial in adapting to a warmer world marked with increasingly frequent extreme weather events. At the same time, new technological advancements in the operating ranges of hydropower facilities will help to minimise the impact of weather patterns on their performance and reliability,
- **affordability** – across its lifespan, hydropower provides one of the lowest-cost electricity generation options among all major fossil fuel and renewable energy sources. The technology has provided a backbone of affordable energy for countries that have invested historically in its development,
- **sustainability** – sustainable hydropower practices have been refined over many years through
- constructive dialogue between industry, communities, indigenous people, governments, NGOs and financial institutions. This process has resulted in the Hydropower Sustainability Standard, an internationally recognised certification scheme that provides a framework to ensure projects are developed sustainably,
- **green job creation** – the hydropower sector already employs more than 2 million people worldwide (IRENA). Incorporating hydropower into sustainable growth strategies will spur further social and economic development through the creation of new career opportunities,
- **economic development in local/rural communities** – hydropower potential is often sited in remote locations. The development of new capacity and the supportive infrastructure required to integrate it into grids widens rural electrification and enables rural economic growth.

Recommendations for decision-makers

At the current rate of hydropower development, industrial growth in developing regions will rely on the continued production of fossil fuels, and global climate targets will not be met. Governments and financial institutions must work together with the hydropower sector to accelerate progress through four key actions:

1. **plan for future energy needs** – with increasing use of variable renewables like wind and solar power, decision-makers must work together across boundaries where necessary, to identify the most optimal overall mix of low-carbon renewable energy technologies to enable sustainable development,
2. **incentivise sustainable hydropower development through financial and market mechanisms** – to meet the objectives of the Paris Agreement and the UN Sustainable Development Goals, the IEA estimates that investment in hydropower needs to double to US $100 billion a year, while the fleet of existing assets must be retained and enhanced. This cannot be achieved unless hydropower is on a level playing field with other renewables. Decision-makers should implement appropriate market frameworks to incentivise and de-risk new hydropower investment and modernisation activities in order to meet climate targets, including remuneration for the non-energy services provided by hydropower projects,
3. **accelerate the development of renewables through transparent and efficient permitting and licensing processes** – hydropower planning and approval processes typically take more than five years before new projects and substantive modernisation activities can even begin construction, and in many cases much longer. Meanwhile, the default option is often to fall back on fossil fuels. The massive deployment of renewables needed to meet global climate goals through sustainable development should be accelerated by improving the efficiency of these processes wherever possible without compromising sustainability,
4. **incorporate hydropower sustainability practices into government regulation and financial sector obligations** – accelerating development does not mean cutting corners. Application of best sustainability practices, built and governed through multi-stakeholder consensus such as the Hydropower Sustainability Standard, should be either integrated into regulatory frameworks or referred to as a preferred tool to maximise the benefits of projects and mitigate any negative impacts.

Transforming recommendations into actions

The Bali Statement on Powering Sustainable Growth was officially issued on 2 November 2023 at the conclusion of the World Hydropower Congress. As the Secretariat to the World Hydropower Congress, the International Hydropower Association (IHA) commits to advancing the recommendations of the Bali Statement through its work programmes and global advocacy, in collaboration with its members and partners. This will include the development of refined policy and market framework recommendations as appropriate for different national and regional contexts. Organisations and persons with an interest in sustainable hydropower are encouraged to engage in IHA's work programme and advocacy work to support the delivery of this Statement's recommendations. Find out more or get it touch at hydropower.org.

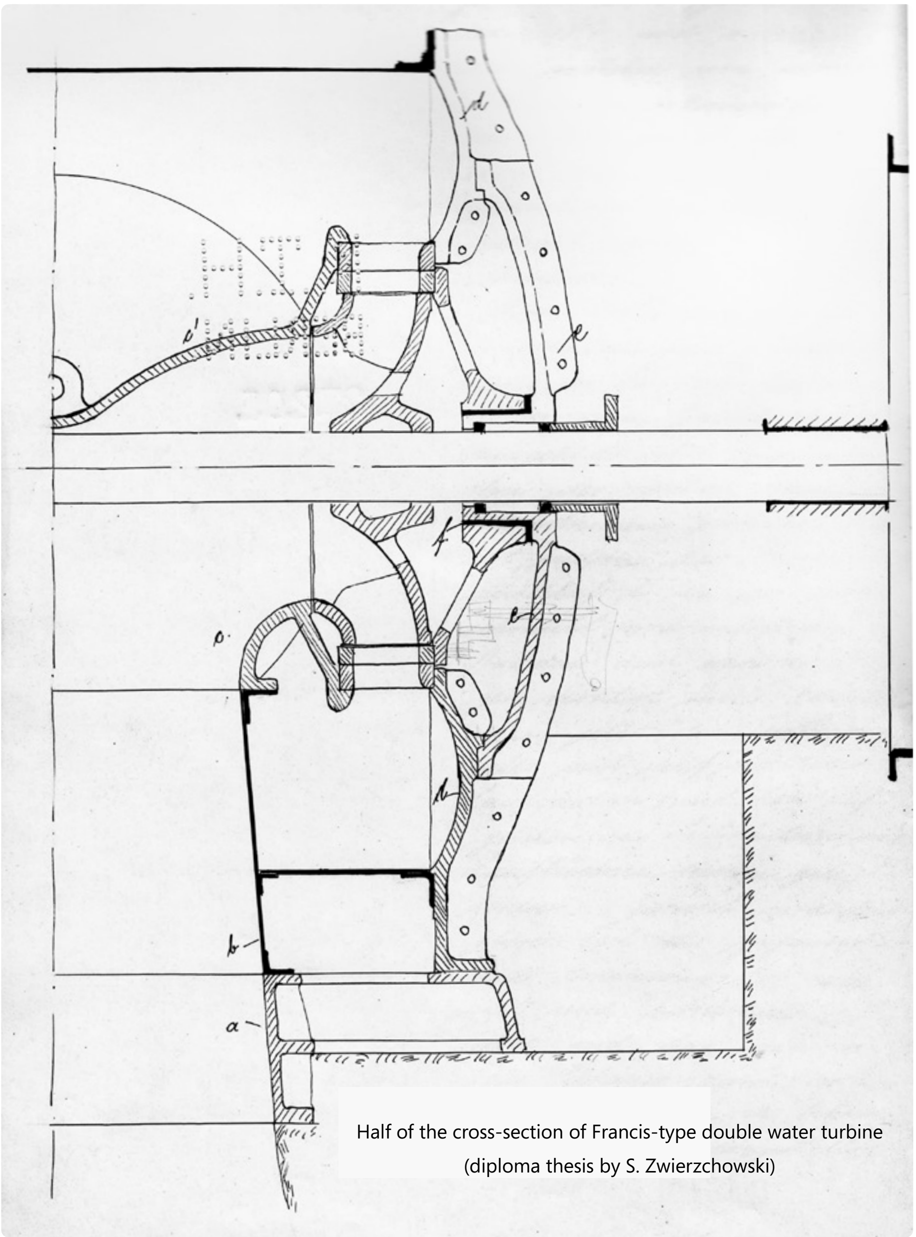
International Hydropower Association

Professor Stanisław Jan Zwierzchowski – precursor of the design of modern water turbines

In the history of technology development, you can find the names of many outstanding Poles: scientists, researchers and engineers. Unfortunately, most of them are completely forgotten. One of them was a world-famous designer of water turbines at the beginning of the 20th century – prof. S. Zwierzchowski. It is worth recalling the figure of such an outstanding precursor of Polish water-power engineering.

Stanisław Jan Zwierzchowski was born on April 27, 1880 in Śrem (then under Prussian rule), where he graduated from German secondary school. In the years 1900–1905 he studied at the Technical University of Berlin-Charlottenburg. He obtained a mechanical engineering diploma there, designing the Francis turbine as his diploma thesis (Fig. 1). After a short industrial practice in a factory H. Cegielski in Poznań, he left for the USA. There he started working as a designer in one of the largest water turbine factories, Allis Chalmers, first in Milwaukee, and then in its branch in Montreal, Canada.

It can be assumed that the decision to leave across the ocean for the young, twenty-five-year-old engineer was influenced in particular by the fact that despite his interests in the field of water turbines, which were clearly visible already during his studies – see the topic of his diploma thesis, he could not find a field for himself in Poland, where there was no water turbine construction industry or even prospects for its creation. On the other hand, European factories were still stuck in design concepts that would soon become history [1].



Source: The diploma thesis of S. J. Zwierzchowski (1905)

Fig. 1. Francis-type double water turbine – discharge $Q = 3\ m^3/s$, head $H = 30$ m, power $P = 900$ HP

Comprehensive engineering, scientific and teaching activities in the USA

In 1907, after two years of work in industry, Stanisław Zwierzchowski was appointed to work at the University of Michigan in Ann Arbour, where he became the organizer of the first studies in the USA in the field of water engines and other hydromechanical machines. He was first a lecturer there, and from 1909 an associate professor, and in 1912 – seven years after graduating, he was the first in the United States to become a full professor of hydromechanical machines. He gave lectures on the theory and design of water turbines, compressors, piston and centrifugal pumps [2], [3].

Prof. S. Zwierzchowski soon became an outstanding authority in the field of water turbines, and his deep knowledge and teaching abilities attracted not only students, but also many engineers from other countries to Ann Arbour. He did not give up his construction activity. In a short time he achieved many successes in turbine design and was also a highly paid expert and advisor to leading water turbine manufacturers in the USA.

The main area of prof. S. Zwierzchowski activity was the development of the design of Francis type turbine runners. The result of theoretical and experimental research carried out in the years 1909–1914 was the design and construction of low-head Francis water turbines with diagonal-axial flow runners, with very high specific speeds and high efficiencies (approx. 93%), as well as much higher discharge and power – by several dozen percent than those previously achieved [2], [3]. In this way, he refuted the then common belief that the design of turbines, especially those with low heads, had reached its final limits. This brought him worldwide fame. He also worked on Kaplan and Pelton turbines.

In 1913, the professor became an American citizen and adopted the shortened spelling of his surname – Zowski. His design achievements, numerous publications [3], [4] and the academic textbook "Water Turbines" were published and cited in the literature under this name. The paper "Some Recent Tests of High-Power and High-Speed Water Turbines" (1914) became a basic study due to its detailed presentation of all the characteristic curves (efficiency hills) and results obtained with the author's new runners and their comparison with the results achieved by other leading turbine designers [5].

Results obtained by prof. Zwierzchowski-Zowski stimulated other designers to make further attempts to increase the speed of turbines on the path chosen by him, which, among others, led to the creation of propeller turbines with runner blades adjustable during operation, i.e. Kaplan turbines (1913). It is characteristic that V. Kaplan himself initially tried to increase the specific speed of Zwierzchowski's runners by following the above-mentioned route [1].

Social and political activity in the USA

At the turn of 1916/1917, prof. S. Zwierzchowski was a member of the Survey Committee, headed by Col. E. M. House, advisor to President T. W. Wilson, preparing materials for the future peace conference. After the end of the war, he accompanied President Wilson at the Paris Peace Conference (1918), as an expert on Polish affairs, in establishing Poland's western borders.

In addition to his scientific work, the Professor was active in social activities in Polish organizations. He was a co-founder of the Pennsylvania Crafts Institute and the main shareholder of the radical Kuryer Polski in Milwaukee (1907–1920) [2], [3].

He remained a professor at Ann Arbor State University until the end of the academic year 1921/22, although he had already accepted the offer of a professorship at the Warsaw University of Technology.

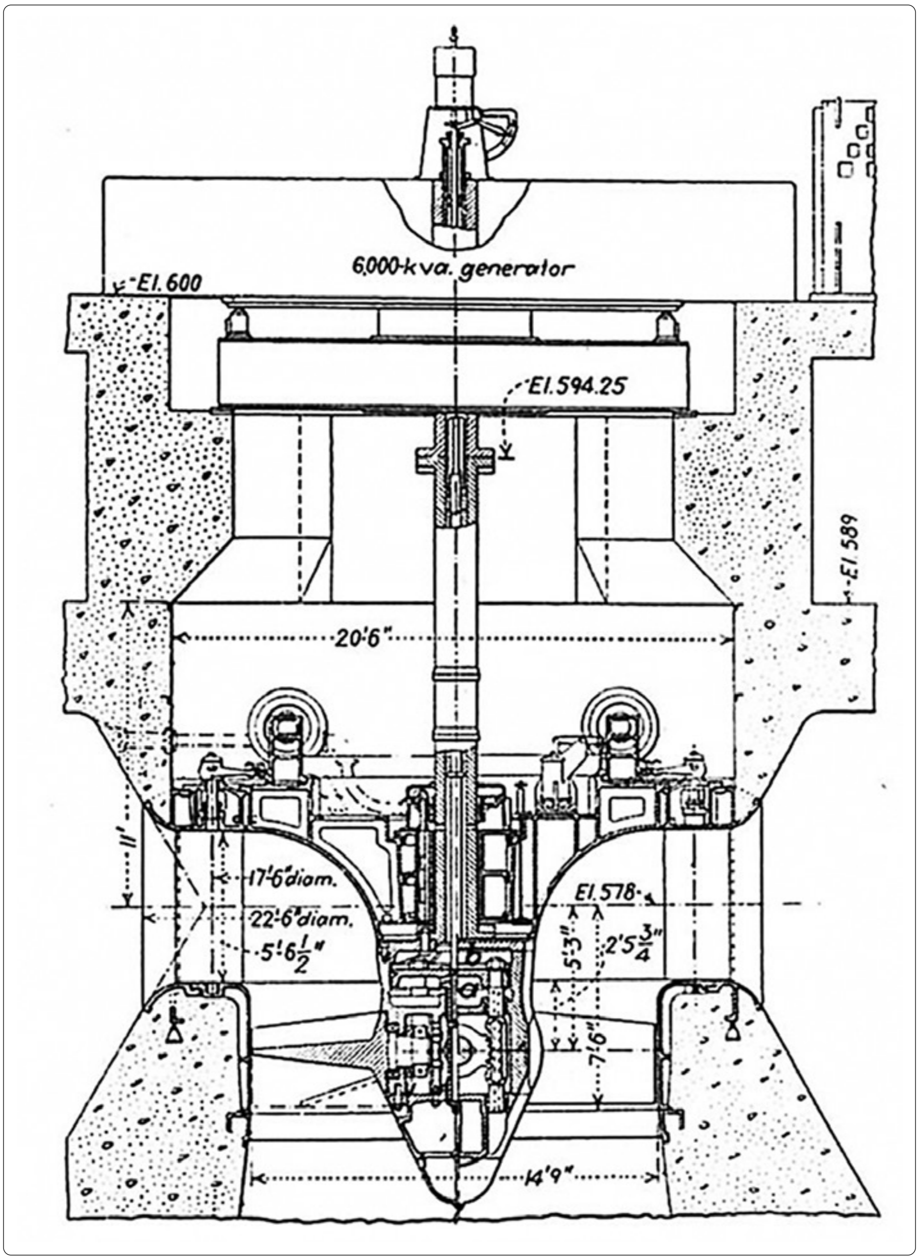
Coming to Poland and teaching activities

In mid-1922, prof. S. Zwierzchowski and his family came to Warsaw, but retained American citizenship. He lived in a house he built at ul. Filtrowa 13. Appointed full professor, he began lecturing and on October 1, 1922, took over the management of the Department of Water Engines and Pumps established for him, first putting the main emphasis on didactics (Fig. 2).

The Department's staff initially consisted of two assistants. Scientific work was very difficult because the Department did not have a laboratory. It was only in the 1930s that the Professor founded a small laboratory intended for scientific

Source: Author's archive

Fig. 2. Professor S. J. Zwierzchowski during his activities in Poland



Source: Zwierzchowski S., Turbines with adjustable runner blades, Przegląd Mechaniczny, 1937, vol. 3, no. 11

Fig. 3. Water turbine with self-adjustable runner blades designed by R. V. Terry (1932, USA, Mermet on the Kenawha River); water pressure above the piston (b) equal to the pressure in the supply spiral, water pressure under the piston (a) equal to the pressure in the suction pipe

Source: Zwierzchowski S., On the selection of the most appropriate type of water turbines for plants with slopes in the Vilnius region, Przegląd Elektrotechniczny, 1936, No. 9.

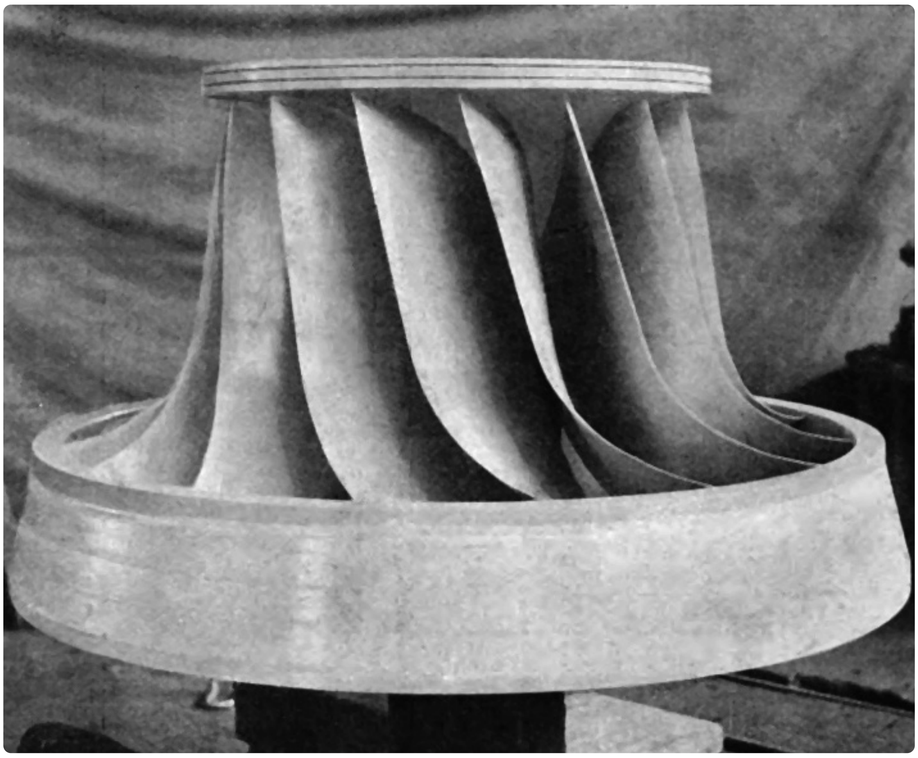


Fig. 4. Designed by prof. S. Zwierzchowski, the runner of the Francis water turbine built in interwar Poland [4]

research on water turbines and pumps. There were also shows for students. To conduct this work and develop scripts, Prof. Zwierzchowski employed one, and later two, assistants, whom he paid from his own funds.

Scientific, research and social activities in Poland

Scientific research conducted in Poland, both theoretical and experimental on models, first concerned Kaplan water turbines and then propeller turbines with self-adjustable runner blades. It was undertaken in connection with preparations made for the construction of such turbines in Poland for water power plants in the Vilnius region [6]. In the extensive article "Turbines with adjustable runner blades" (Przegląd Mechaniczny, 1937, vol. 3, no. 11), he described in detail the construction of such a turbine (Fig. 3) and included a number of its characteristic curves. These works were interrupted by the outbreak of World War II.

While working in Poland, he financed most of his scientific and construction works himself. He published several publications [4], in Przegląd Mechaniczny, Przegląd Techniczny and Przegląd Elektrotechniczny (Fig.4), and published four academic handbooks in the field of water turbines and pumps. Professor Stanisław Zwierzchowski headed his Department until the outbreak of the war, giving lectures on water pumps and turbines to third-year students of the Faculty of Mechanical Engineering of Warsaw University of Technology. In the years 1933–1935 he was the Dean of this Faculty. From 1923 he was a member of the Academy of Technical Sciences and from 1932 he was a member of its management board. In 1930 he joined the Warsaw Scientific Society, where from 1931 he served as deputy secretary of the Faculty of Technical Sciences. At the same time, he maintained active contacts with the Polish community in the USA, among others: editing in the years 1923–1928 Kurier Polski – the oldest Polish periodical [2], [3].

The sudden end of the Professor's activity and its significance

The German attack on Poland caught prof. S. Zwierzchowski in Warsaw. As an American citizen, he took advantage of the opportunity to leave Poland and on September 9, 1939, during the several-hour ceasefire during the siege of Warsaw in order to evacuate citizens and foreign missions, he left with his family for the USA. The outbreak of the war and the news coming from Poland were a huge shock for the Professor, which undoubtedly shortened his life. He died on January 11, 1940 of a heart attack in Charleston, South Carolina and was buried there.

Professor Stanisław Zwierzchowski was one of those professors who, being outstanding specialists in their fields, endowed with strong personalities, exerted a great influence on students and on domestic and foreign technical and industrial environments. Achievements of prof. Zwierzchowski were groundbreaking for the development of low-head Francis water turbines with high power and led to a significant reduction in the costs of electricity generation as well as made the Professor's name famous on a global scale. This notoriety is also the result of his talents as a great teacher. Many of his former students became well-known in the engineering and hydraulic machinery industry. One of the testimonies may be his biography in two languages, emphasizing the above-mentioned facts and the image on the title page, published in issue 1/1964 of the international scientific journal La Houille Blanche [5].

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Faculty of Power and Aeronautical Engineering
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Literature:

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Photo: Krichim dam and hydropower reservoir in Bulgaria

Hydropower and Pumped Hydropower Storage in the European Union: insight from the CETO

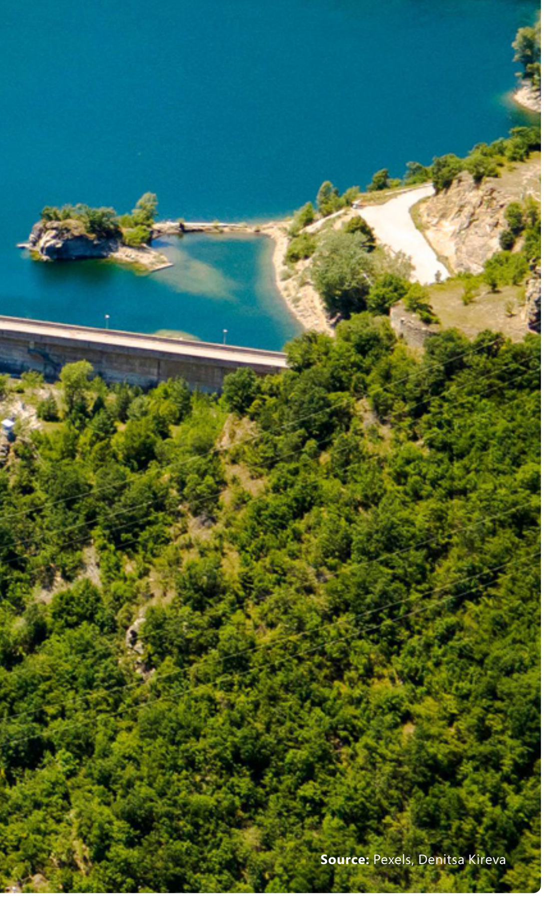
Hydropower is a complex sector that needs to be managed holistically, as it can have multiple benefits and impacts, especially when large reservoirs are built. New sustainable developments in the EU are possible, and this development will support the leadership of the European hydropower sector globally.

To address the complexity and multi-faced character of the transition towards a climate neutral European union (EU), the European Commission has set up the Clean Energy Technology Observatory (CETO). CETO monitors the EU research and innovation activities on clean energy technologies, providing a repository of techno- and socio-economic data on the most relevant technologies and their integration in the energy system. CETO targets in particular the status and outlook for innovative solutions and the sustainable market uptake of both mature and emerging technologies. Hydropower is a complex sector within the Water-Energy-Food-Ecosystem (WEFE) nexus and is a key technology to support the integration of volatile renewable energy sources, providing energy storage, grid stability and flexibility. Water and hydropower reservoirs can provide multiple services, but can also generate impacts. Therefore, sustainable hydropower needs to achieve a good balance between impacts and benefits and the targets of different policies. These points are deeply discussed in the CETO report (Quaranta et al., 2023), and some major insights are discussed in this article.

State of the art and complexity of hydropower

Hydropower is currently the largest low-carbon and renewable electricity technology, with 1,397 GW of global installed capacity and 4,408 TWh of electricity generation in 2022. Worldwide, pumped hydropower storage (PHS) currently provides regulation, spinning reserve, and approximately 96% of utility scale energy storage. In the European Union (EU), the hydropower installed capacity in 2022 was 152 GW, and generated 374 TWh (including energy generation from PHS), which is the highest share from renewable energy sources, slightly below wind energy. Currently, the EU hosts 46 GW of PHS's turbine capacity, which is a quarter of the global installed capacity (45 GW in China).

Hydropower is a well-established technology. Hydropower equipment does not use rare and critical materials, differently from wind and solar devices and batteries. Water (including hydropower) reservoirs provide additional services, e.g., water storage for irrigation and fire-fighting, flood control and drought mitigation, and navigation. The Energy Return on Investment (EROI) is the highest one amongst the renewable energy technologies (Fig. 1). Hydropower is a dispatchable technology, ensuring flexibility and stability services to the grid. Pumped hydropower storage (PHS) is a mature technology, hence its technological and market position is more advanced than that of other energy storage technologies (e.g., batteries, thermal and chemical storage). PHS and water reservoirs can store water&energy (at the daily, monthly and seasonal scale, depending on the installed capacity) more cost-effectively than any other option, and can put and adsorb energy available in seconds or few minutes. IRENA's and World Bank's analyses identified hydropower as currently one of the least expensive forms of renewable electricity generation (when looking at the LCOE over the lifespan). However, large hydropower systems also can cause some adverse impacts. When developed in freshwa-

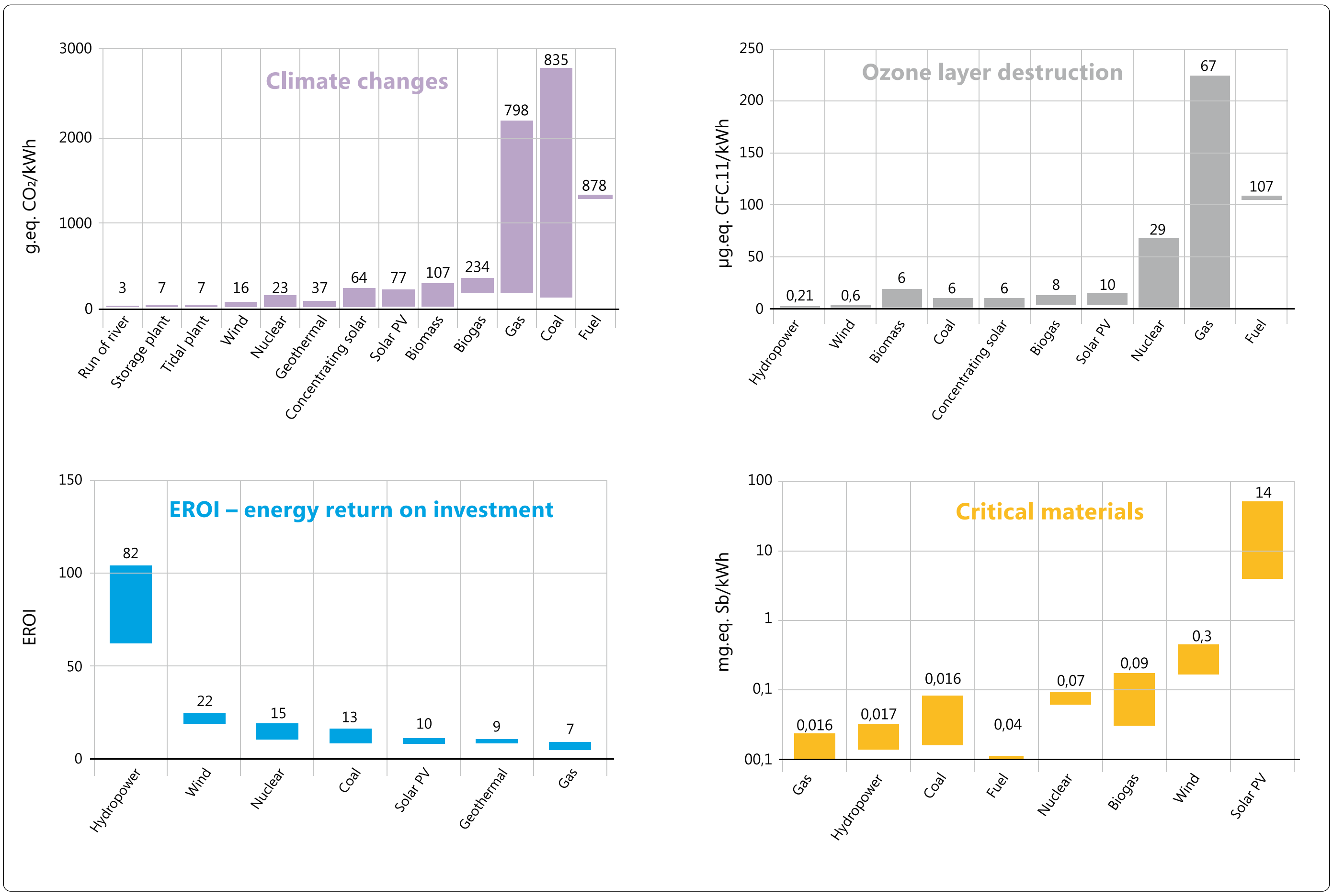

Source: Pexels, Denitsa Kireva

ter systems, hydropower is responsible for several impacts (or in the case of multipurpose installations, co-responsible): new barriers and diversion canals obstruct the natural river flow, causing ecological, hydrological and morphological alterations. Barriers in rivers alter sediment transport and hinder fish migration, but, on the other hand, hydropower trash racks act as a plastic sink, contributing to reduce the amount of plastic discharged into the oceans. Large reservoirs can emit methane and carbon due to the organic matter decomposition under conditions favourable to methane production (anoxic conditions, large areas of low water depth) and generate evaporation. The construction of big civil works requires a large amount of concrete and sand. Therefore, strict standards and associated legislation were put in place, especially in the EU, to protect ecosystems and the environment, meaning that new hydropower development has to fulfil high sustainability requirements (note that in the EU, less than 10% of barriers in rivers are equipped with hydropower).

Within the policy-context, new barriers and dams in freshwater systems (not only for hydropower generation) are perceived as a source of impact in the Water Framework Directive (Directive 2000/60/EC), which is aimed at the preservation or recovery of the "good ecological status" of the aquatic environment. On the other hand, hydropower is a renewable and clean energy source. Its flexible operation and storage capacity allow to integrate the volatile energy production of wind and solar power plants, ensuring flexibility, grid stability and ancillary services. Therefore, hydropower plays a key role in the long-term decarbonisation scenarios (i.e., the Sustainable Development Scenario and the Net-Zero Emissions Scenario by 2050) and in the renewable energy targets set in the Renewable Energy Directive (Directive 2009/28/EC, REPowerEU). Therefore, sustainable hydropower needs to achieve a good balance between clean electricity generation and impacts (and benefits) on the environment and on the society.

Sustainable hydropower potential in the EU

Recent projections carried out at the European Commission estimated that hydropower generation could increase by up to 30 TWh/y in 2030, reaching 430 TWh/y in 2050. Since the average production in the last decade was 360 TWh/y, additional 70 TWh/y are approximately needed to reach the 430 TWh/y in 2050. This potential should be deployed in a sustainable way, and, therefore, con-



Source: Strategic industry roadmap extended executive summary brochure, ETIP Hydropower Europe, December 2021

Fig. 1. Impact indicators from ETIP Hydropower Europe (EU project): average values and the bars represent the max. and min. values

tinuous R&D activities are ongoing to develop novel technologies and more sustainable solutions. Table 1 summarizes different hydropower strategies and the associated potentials, assessed in scientific studies[1] for the EU, focusing on:

1) low-impacting technologies and strategies for traditional hydropower generation, i.e., strategies aimed at increasing energy generation with minimal impact on the environment and that do not require additional barriers,
2) additional storage capacity that does not involve new reservoirs in freshwater systems.

Traditional hydropower

The additional hydropower need of +70 TWh in the projection can be partially filled by low-impacting technologies and strategies, which could provide between 40 and 45 TWh/y (Tab. 1). The modernization of the existing hydropower fleet is an attractive opportunity to increase efficiency, sustainability and resilience (the average age of the EU fleet is almost 45 years). Quaranta et al., (2021) estimated that the annual electricity generation from the existing hydropower fleet could be increased by approximately 8% (~30 TWh/y), implementing hydropower digitalisation and modern electro-mechanical equipment. Additional strategies to increase generation from the modernisation of aged plants include dam heightening (much more useful to increase storage capacity) and new waterways to increase the peak installed capacity. Developing hydropower in existing infrastructures, e.g., in water distribution networks (aqueducts), in existing low head barriers (e.g. in water mills) and in wastewater treatment plants has been the aim of numerous research and experimental activities, especially for local purposes and self-consumption. This is due to the considerable lower impacts compared to conventional reservoir hydropower, and the untapped potential in the EU. There also exists a hidden potential in hydraulic infrastructures in the private water intensive industry, such as mining or energy production (using cooling waters). Hydrokinetic turbines exhibit a low potential, but could represent an interesting strategy when installed at the hydropower plant tailrace, rather than in freshwater and free-flowing rivers. However, the available technical potential associated to these technologies is limited to approximately 14 TWh/y at EU scale.

Source: Hydropower and pumped hydropower storage in the European Union, Status report on technology development, trends, value chains and markets, 2023

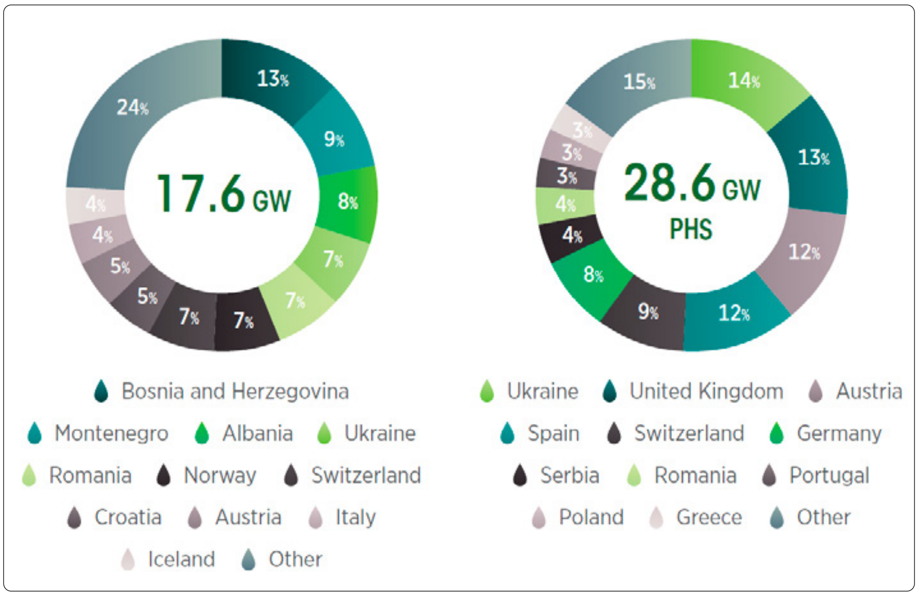
Hydropower technology/strategy	Potential	Reference	Units
Hydropower plant modernization	30–40	Quaranta et al., (2021)	TWh/y
Existing historic barriers not mill-related	5.2	Punys et al., (2019)	TWh/y
Hydropower in pressurized water and wastewater systems	3.1	Quaranta et al., (2022)	TWh/y
Water wheels in existing mills	1.6 (up to 3 TWh/y using turbines)	Quaranta et al., (2022)	TWh/y
Rainfall on building roofs	0.5	Quaranta et al., (2022)	TWh/y
Hydrokinetic turbines in rivers	0.17–1.2	Quaranta et al., (2022)	TWh/y
Hydrokinetic turbines in the tailrace of hydropower plants	1.4	Quaranta and Muntean (2023)	TWh/y
Pressurized conduits for irrigation and industrial flows	<0.1	Mitrovic et al., (2021)	TWh/y
Floating PV (evaporation reduction)	<0.1	Quaranta et al., (2021), 10% of reservoir surface coverage	TWh/y
Closed loop hydropower	25	Stocks et al., (2021)	TWh
Spatio-temporal coordination of reservoirs	140	Worman et al., (2022), demand reduction over 3–5 years	TWh
Reservoir interconnection	0.14	Gimeno-Gutierrez and Lacal--Arantegu (2015), max distance of 5 km	TWh
Sea water PHS	t.b.d.	Kougias et al., (2019)	
PHS in mines	some TWh	Weber et al., (2024)	
Heat recovery from generators	2.9	Quaranta and Muntean (2023)	TWh/y
Floating PV on hydropower reservoirs	139	Kakoulaki et al., (2022), covering 10% of 1,608 km2 of EU reservoirs' surface, associated to 49 GW of hydropower installed capacity and 94 TWh/y of hydropower generation.	TWh/y
Floating PV on hydropower reservoirs	729	Lee et al., (2020), Europe, 14% of reservoir surface coverage	GWp

Tab. 1. Potential of different hydropower strategies (in EU when not specified) and theoretical energy storage. See the full report for the full list of references

Water and energy storage

The closed loop Pumped-Hydropower-Storage (PHS) potential in the EU is 330 TWh, among which 25 TWh are the cheapest sites and 67 TWh refer to the most expensive sites, but new PHS may generate environmental impacts and may not be feasible under environmental constraints. A less-impacting strategy to develop new PHS may consist of interconnecting existing reservoirs, whose energy storage potential was quantified in 140 GWh in EU by connecting reservoirs which are closer than 5 km. A real technical opportunity for PHS is expanding the operating range. By introducing smart sensors, variable speed turbines with increased efficiency and system optimization to new or existing PHS,

[1] Most of the assessments were carried out in the Exploratory Research project SustHydro coordinated by Emanuele Quaranta at the European Commission.



Source: IRENA

Fig. 2. Hydropower project pipeline in Europe, 2022–2037

the overall PHS utilization can increase. Countries with redundant PHS potential could look for increasing their potential market share by selling their services to neighbouring countries. Opening up cross-border markets for balancing capacities could also serve as an important incentive to increase the use of the existing PHS's capacity. Underwater or sea-water PHS, low-head energy storage and underground PHS using abandoned mines may offer a relevant potential, and some assessments are in progress. Energy could also be stored using existing lakes or small depressions, or retention basins on a terrain in sustainable urban drainage systems.

Hybridisation

Hydropower also exhibits high hybridization potential with other energy technologies. For example, run-of-river plants can produce hydrogen when energy prices fall to zero. Batteries can ensure energy storage for several hours, whilst hydropower can store and release energy for days and weeks, including seasonal transfer, and, therefore, batteries and hydropower can be integrated together, reducing the stresses on hydropower turbines (e.g. stop and start cycles) for short-term (e.g. seconds, minutes) balancing services. Photovoltaics could be installed on dam's surfaces or on reservoirs' surfaces. Floating PV on EU hydropower reservoirs could provide 139 TWh/y, but have some limitations, e.g., should be limited to reservoirs which do not suffer icing in winter or large water level variations. Waste-heat can be extracted from the cooling system of the generator. Tidal and wave power technologies implement similar freshwater hydropower technologies, thus ocean energy can be a suitable place for hydropower market expansion. See the full report for additional information on hydropower sustainability and key sustainability indicators in the EU. Figure 2 depicts the Hydropower project pipeline in Europe.

Economic added value of hydropower

Employment in hydropower industry spans various value chain elements as project design, manufacturing, project construction and O&M. The sector employment generally includes engineers, geologists, ecologists, economists, technicians, and skilled workers. It also provides employment to scientists, as well as a wide range of scientists working in corporate and academic R&D activities. IRENA estimates that every 1 MW of community-owned hydropower installed generates ten full-time equivalent jobs in every year of its operation. This is significantly more than any other generation technology. Globally in 2021, approximately 2.36 million people worked directly in the hydropower sector. In 2021 there were 2227 employed people in the manufacturing, 108,494 in the construction and 1,169 in the R&D in the EU (hydropower sector).

Focusing on the EU, hydropower contribution to the EU annual gross domestic product (GDP) is approx. EUR 25 billion considering electricity generation, but if the multi-services associated to hydropower are considered, this value may increase up to EUR 45 billion. A substantial share of tax value goes directly to local and regional budgets and helps to foster regional development. Approximately EUR 3 billion additionally come from the Gross Value Added, including trade of turbines. Water and hydropower reservoirs can also be used in the context of flood control. Most of the European river systems are heavily impacted by multiple pressures along the river corridor and/or feature significantly altered conditions in inundation areas. To cope with natural hazard of floods on river corridors, the European Parliament released the Floods Directive (Directive 2007/60/EC) in 2007 for managing river systems. Given the severity of floods in Europe (325 major floods in Europe between 1998 and 2004, and more than 200 since 2000), the European Floods Directive addresses the risk analysis and provides operative tasks for the member states. The storage capacity of reservoirs can mitigate floods and impacts of long drought periods. Figure 3 shows an example of water reservoir. Gøtske and Victoria (2021) estimated that the annual inflow for high (mid)-emission scenarios is going to decrease by 31% (20%) in Southern countries and to increase by 21% (14%) in Northern countries, and more frequent and prolonged droughts in Mediterranean countries are expected. Therefore, an increased seasonality of hydropower operation is required, and this implies an optimal use of the reservoir throughout the year in several regions of Europe.

However, a major challenge of multi-purpose reservoirs is sharing water, costs and benefits amongst competing users, and to define user priorities. Multi-purpose water reservoirs can provide water for irrigation and drinking use, support flood and drought risk management, river navigation and recreation, in addition to hydropower. The EU owns several multipurpose reservoirs. Almost 4,500 large dams (higher than 15 m, or above 5 m and with volume above 3 mm³) are in the EU according to the ICOLD 2023 register of dams. Approx. 50% of reservoirs store water for hydropower generation (both as single- and multi-purpose reservoirs). In order to solve conflicts associated to the water use in these reservoirs, for example, EDF (Electricité de France) and the WWC (World Water Council) have agreed in 2012 to cooperate, and launched a program to work on a SHARE concept framework for multi-purpose hydropower reservoirs. The purpose is to maximise the benefits of the multi-purpose use of hydropower reservoirs by considering the principles of 1) shared resource, 2) shared rights and risks, 3) shared costs and benefits. It is essential to allocate water with a greater flexibility and adaptability among users during the whole lifetime of the reservoir. It is also essential to consider the short-term and the long-term effects that hydropower can generate on the environment and on our society, both at the local scale and at the regional/national scale.

International connections

Some non-EU countries, but located in the hearth of the EU area, play an important role in the hydropower sector. Norway and Switzerland are lead consulting companies for larger hydropower projects worldwide (including specialized equipment), and host a large part of the hydropower reservoirs in Europe. They also play a key role in European research projects, R&D and scientific publication, along with the U.K.

The hydropower share on the national energy mix is about 95% in Norway. Norway has almost half of Europe's reservoir (storage) energy capacity, that will help enormously to integrate renewable energy in North-West Europe. In Switzerland, the hydropower share on the national energy mix is 57%. Switzerland is highly dependent on electricity imports from the EU in winter, that usually roughly compensates with exports in spring and summer by activating its hydropower resources. However, given the vastness of the European electricity market, Swiss generation capacities play a minor role for meeting European demand. Switzerland thus yields little to no structural power stemming from electricity trade balances with the EU, but a key role in scientific and consultancy services. Albania is fully dependent on hydropower due to its natural conditions, and its hydropower share on the national energy mix is almost 100% (70% of the area is mountainous). However, 50% of the domestic electricity demand is imported. Although it is a non-EU country, Albania has included in the National Renewable Energy Plan for 2015–2020 entries from the Renewable Energy Directive, which is in force in the EU. Some provisions arising from both the Water Framework Directive and the Birds and Habitats Directive will be implemented.

Conclusions

Hydropower can be considered an important sector, especially to maintain a competitive EU in the world, and its benefits should not only be looked from the installed capacity point of view (some additional benefits are: export capacity, services provided by reservoirs, employment, flexibility). Hydropower catalyses an optimal integration of volatile energy sources (e.g. wind and photovoltaics) into the electric grid, and supports the achievement of the renewable energy targets. The multiple services of hydropower reservoirs in the EU can provide additional benefits and mitigate the effects of climate change. Europe is home to more than half of hydro equipment manufacturers and large operators of hydropower. As global hydropower market expands due to increase in global installed hydropower capacity, European operators and manufacturers are an important source of jobs. The export capacity of EU's hydropower companies and their innovative characteristics, associated to a lead position in terms of scientific publications, make the EU's hydropower sector a world leader.

Being at the centre of the Water Energy Food Ecosystem nexus, several obstacles and challenges exist. The first major barrier is the effort to simultaneously pursue renewable energy, climate and environmental goals. The most suitable sites in the EU have been already exploited or are protected by environmental legislation (e.g., protected areas, natural parks), so that new large plants would be installed in less favourable sites, increasing costs, especially for the implementation of environmental mitigation measures. Hydropower development is also affected by climate changes (water availability, seasonality, extremes), but hydropower reservoirs can help to mitigate climate change effects (flood control, drought mitigation). Hydropower projects have longer pre-development, construction and operational timelines than other renewable energy technologies, hence have higher financial risk, requiring specific policy instruments and incentives as well as a longer-term policy perspective and vision. Another major challenge is putting a value for all benefits, that is necessary to allow discussions and negotiations between different water users and externalities, and to bridge the gap between financial and economic viability. The challenge is to find ways of framing long-term strategies, securing long-term finance sources, and shielding them as effectively as possible from short-term constraints. These challenges should serve as a catalyst for a more comprehensive dialog among stakeholders (e.g. industry, academy, associations, citizens and governmental institutions). The development of hydropower, as well as of all the other renewable energy technologies, have to objectively consider benefits and impacts on the short and long-term, in order to mitigate possible conflicts among different targets (e.g. energy and environmental targets) and stakeholders, depletion of resources (e.g. water, minerals and materials) and ensure a sustainable growth within the WEFE nexus.

Official full report

Quaranta, E., Georgakaki, A., Letout, S., Kuokkanen, A., Mountraki, A., Grabowska, M., Gea Bermudez, J. and Tattini, J., *Clean Energy Technology Observatory: Hydropower and Pumped Hydropower Storage in the European Union – 2023 Status Report on Technology Development, Trends, Value Chains and Markets*, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/841176, JRC134918.

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Emanuele Quaranta
Scientific officer

Joint Research Centre, Italy
European Commission

Photo 1. Examples of low flows, from left: Budkowiczanka river – Krzywa Góra, 17.02.2021, Vistula – Warsaw, 27.05.2020

Source: from left: Mateusz Krupa, helipoland.com

When the river is running out of water

What is a low flow, how is it determined, why is it so important in hydrology and water management, and what is its significance for the environment? We answer the most essential questions.

There is no single precise definition of a groundwater recession flow. It is a conventional term that refers to specific hydrological conditions in a river. Low flow is most often defined as a time when water resources in rivers fall below a certain, designated limiting level. This is almost always a result of less than usual rainfall supply to rivers. However, there may be more factors, such as climate (sunshine, wind, air temperature), relief, geological structure, soil type, nature of vegetation, or hydrographic system. Such a multifaceted nature of a low water event makes it very difficult to predict its timing and course.

Low flow, as a hydrological phenomenon, is very often associated in Poland with the existence of hydrological drought – the third stage of drought development after atmospheric and soil drought. It is manifested by reduced flow in rivers. This is because, in the absence of rainwater recharge, rivers drain and lower groundwater levels. In this way, they also contribute to the development of hydrogeological drought.

How do you know if it is already?

There are very many methods and criteria for determining groundwater recession flow. In IMGW-PIB, the most frequently used method is the one based on analyses of annual minimum flows (NQ). The data collected from many years allow to determine the characteristic flows of the 2nd stage, such as:

- WNQ – high low flow (maximum NQ value),
- SNQ – mean low flow (arithmetic mean from NQ),
- ZNQ – ordinary low flow (median of NQ)
- NNQ – lowest low flow (minimum value of NQ).

These form the basis for determining threshold values. A flow that has not reached the SNQ (multi-year mean low flow) is considered a low flow and, if it remains at the following level for a contractually defined number of days, is the basis for issuing a hydrological drought warning. Low flow are characterised by a number of parameters, the determination of which required the development of an appropriate methodology. The most significant measures relevant for analysing and describing lows include:

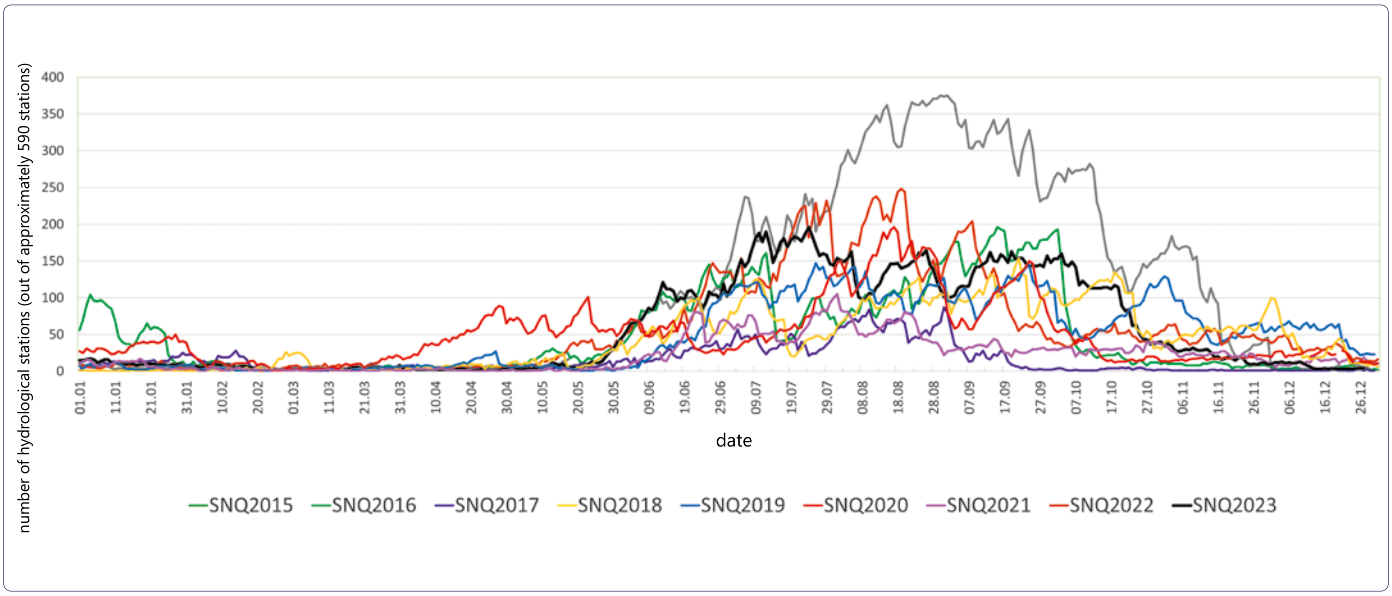
- volume of low flow (thousand m^3),
- minimum low-flow rate (m^3·s-1),
- duration of low water event (days)
- starting and ending date.

The average low flow (m^3·s-1) is also a noteworthy parameter.

In the literature or media reports, it is also common to hear of deep and shallow low flow. These terms are used to describe the intensity of the phenomenon. A deep low indicates a greater scarcity of water. A low flow in terms of extent can be a local, regional, national, or even continental phenomenon.

Seasonality of low flow

The regime (course of hydrological phenomena during the year) of the majority of Polish rivers predisposes them to low flow in summer and summer-autumn. Increasingly, the low flow extremes fall in summer, even though this season is characterised by the highest rainfall. Why does this happen? In addition to the rainfall total itself, the temporal distribution and intensity of the rainfall play a not insignificant role in this case. The summer season



Source: Author's archive

Fig. 1. Summary of the number of hydrological stations below SNQ (multi-year average low flow) from 2015 to 2023

is dominated by thunderstorms – heavy and torrential rainfall. These are quickly transformed into surface and subsurface run-off and rapidly enter watercourses to form smaller or larger surges and then leave the catchment area. High air temperatures and sunshine are also important. River and groundwater resources do not recover, and intensive evapotranspiration (evaporation from the ground and plants) and vegetation growth (vegetation) further reduce the amount of available water.

The occurrence of low flows on rivers is also possible during the cold months, especially when temperatures fall below 0°C, and in mountainous areas. Most often, winter low flow are not associated with a lack of water, but with water storage in the form of snow and ice. In addition, the frozen ground effectively restricts the infiltration and infiltration of water into deeper parts of the soil. As a result of river drainage, groundwater resources are depleted, and as a result, a hydrological low develops, as in the summer half season. In the case of severe frost, ice phenomena may also develop. Low flow events of this origin are less frequent in Poland and usually end when the snow melts. Nevertheless, both autumn and winter lows are extremely important for hydrologists.

The last few years in Poland have been characterised by warm and rainy winters, with the result that winter low flow – except in high mountain areas – have hardly been recorded. This change in precipitation structure is not conducive to improving retention, as rainfall in winter is not as effective in replenishing underground water 'stores' as the melting snow cover in spring. This is one of the reasons why farmers often already face a lack of moisture in the soil in spring and, from May onwards, river flows rapidly drop to values indicative of hydrological drought. In turn, the most intense lows in recent years fall in August – this was also the case in 2015, when we recorded one of the most severe low flow in Poland. Flows below the SNQ were observed at more than half of the stations, and about 15% of hydrological stations set records for low water levels (Fig. 1).

The importance of low flow

As mentioned earlier, a low flow event is a period when water resources are registered below a certain limit, i.e. there are water deficits. Any shortage or, in an extreme situation, lack of water, has adverse consequences for the economy and the environment, which is why hydrologists also carry out measurements of river flow at low water levels.

Knowledge of the course and other parameters of base flow effective management of water resources. This knowledge is used to design more efficient retention reservoirs that collect water during periods of excess and allow the use of stored resources during low flow. Winter low flow are crucial for the energy industry. When water levels are too low and ice phenomena are additionally present, power stations may have limited water abstraction capacity and thus a reduced ability to produce energy. The formation of ice at low water levels impedes the march of ice, contributing to ice jams and consequent flooding or waterlogging. Such conditions also pose a challenge for icebreakers, which can only operate when the water depth in the river channel or reservoir is adequate. Prolonged periods of low water also cause changes in aquatic and water-dependent ecosystems. Small reservoirs dry up, wetlands disappear and water quality deteriorates. This affects the structure of the flora and fauna in the area – some species disappear and new ones appear.

Low flow prevention

As a result of climate change, lows and droughts are having an increasingly strong impact on human life. Activities carried out by IMGW-PIB are extremely important in this aspect. Forecasts and warnings against hydrological droughts constitute essential information allowing to limit losses related to this threat. The scale of the phenomenon is evidenced by the fact that every year IMGW-PIB issues several hundred of such warnings, and the average low flow from many years may not be achieved at over half of telemetric hydrological stations of the National Hydrological and Meteorological Service.

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