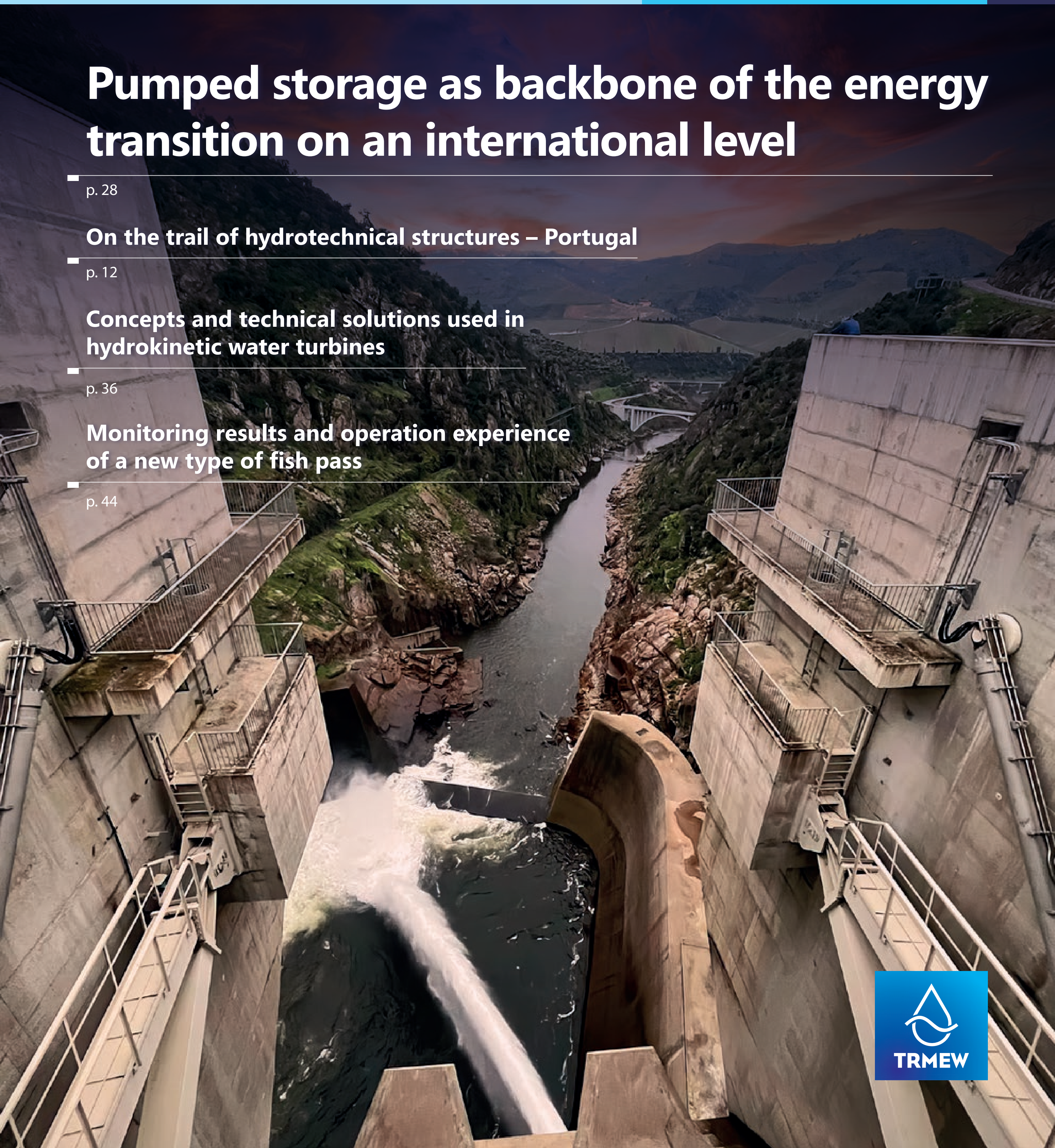
HYDROPOWER | WATER MANAGEMENT | ENVIRONMENTAL PROTECTION | INLAND NAVIGATION | ENERGY RECOVERY

# ENERGETYKA WODNA

1/2024 (49)
FREE COPY
ISSN 2299-0674





TRMEW

# AQUA OZE RENEWABLE ENERGY SOURCES

www.aqua-tech.info.pl

- ✓ invest in the future of our planet
- ✓ secure your future and earn money thanks to ecology
- ✓ be part of the AQUA-OZE ecosystem and support the global ecology
- ✓ be part of our planet... support renewable energy sources

www.aqua-tech.info.pl

# MODERN HYDROENGINEERING CONSTRUCTION

AQUA TECH

- ✓ modular small hydropower plants – design and construction
- ✓ movable weirs for riverbed retention
- ✓ anti-flood river level monitoring systems
- ✓ innovative solutions for hydrotechnics

find out more

AQUA-TECH Sp. z o.o.
Lipcowa 64
32-540 Trzebinia, Polska

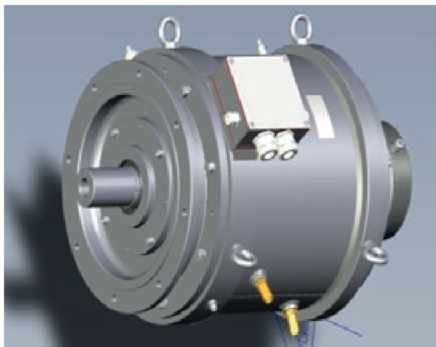
+48 530 133 269
+48 32 441 77 17

biuro@aqua-tech.info.pl

# AQUA GEN INNOVATIVE SOLUTIONS FOR HYDROPOWER PLANTS

www.aqua-tech.info..pl

- ✓ synchronous generators (PMSG) for SHPs
- ✓ SHP hydropower units for ultra low-head locations
- ✓ selection and SHP modernisation to the new technical guidelines



European Funds Smart Growth | Republic of Poland | NCBR Narodowe Centrum Badań i Rozwoju | European Union European Regional Development Fund

AQUA-Tech Sp. z o.o. is a beneficiary of the project POIR.01.02.00-00-0251 / 16 Development of a low-fall modular hydroelectric power plant with high energy efficiency and minimal environmental interference.

# From The Editorial Office

As the old saying goes: "you can never have too much of a good thing." This might have been true once, but its originator likely never dealt with an unregulated energy system impacted by unstable renewable energy sources (RES). Unfortunately, this saying did not hold true in the case of the events in the Polish power system during the recent long May weekend (the Polish national holidays from May 1st to May 3rd ). There was no joy for the power dispatch centre employees of the Polish Power Grid (Polskie Sieci Elektroenergetyczne S.A., PSE) and the cause of all the confusion were wind and photovoltaic farms producing too much energy for the current needs. These RES sources had to be shut down for nine consecutive days, and on May 1st, for example, PSE was forced to redispatch nearly 75% of the PV installed capacity that PSE can disconnect. Currently, the Polish power system is in a particularly difficult situation, due to the dynamic development of uncontrollable RES sources, which is not accompanied by the expansion of energy storage and flexible generation sources. It is worth mentioning that on May 1st, solar and wind energy accounted for just over 43% of daily energy production.

Meanwhile, in Portugal, in April this year, 91% of electricity came from RES and such dominance of renewable sources did not lead to the so-called overabundance problem. This raises the question of what is the key to the success of the Portuguese power system? The answer lies in storage hydropower plants and pumped-storage power plants, which are a crucial element stabilizing the Portuguese grid. The country began investing in large-scale energy storage nearly two decades ago and currently has a substantial energy buffer. Poland is only at the beginning of this path, with the symbolic starting point being the resumption of the Młoty PSH project, the first investment in a pumped-storage power plant in over forty years (counting from the commissioning of the Żarnowiec PSH). Therefore, it is all the more worthwhile to take an example from countries that have practically completed their energy transformation (carried out wisely). This was the goal of the study tour to Portugal organized by our editorial team at the end of January this year. A detailed report was provided by Ewelina Bogacka, Project office manager at the Instytut OZE, who acted as the group's guide.

Seeing the urgent need to build new PSHs in Poland, we have focused on the topic of energy storage in this issue. In addition to the study tour report, the role of PSHs in the energy transition, illustrated with selected examples from around the world, is discussed in articles by dr. Klaus Krueger, Senior Expert Plant Safety andEnergy Storage Solutions at Voith Hydro, as well as the author of this text together with Wioleta Smolarczyk, Business development coordinator at the Instytut OZE.

Other topics in this issue include a report on the current legislative situation in Brussels, which directly impacts the shape of the small hydropower sector in Europe in the coming years, authored by Dirk Hendricks, Secretary general of the European Renewable Energies Federation, as well as a review of concepts and technical solutions used in hydrokinetic water turbines, prepared by Artur Olszewski (Institute for Technology Optimisation), Witold Lorenz (Hydro-Vacuum S.A.), Przemysław Szulc (Wroclaw University of Science and Technology), and Adam Góralczyk (Institute of Fluid-Flow Machinery, Polish Academy of Sciences).

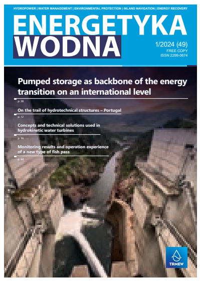
It is also worth mentioning an innovative solution in the area of water continuity restoration at transverse structures in rivers, implemented in recent years in Austria and Germany. Bernhard Mayrhofer, General manager of Fishcon, presented the new concept of a fish pass and summarized the operational experiences.

Enjoy your reading!

**Michał Kubecki**
Editor-in-Chief

# ENERGETYKA WODNA

International quarterly
NO 1/2024 (49) – estimated readership: 2 500 unique recipients
www.energetyka-wodna.pl


## NEWS



## PRACTICE



## LAW



## PROJECTS



## KNOWLEDGE



## ECOLOGY




**Editorial office:**
Michał Kubecki – Editor in Chief
Michał Lis – Managing Editor
Sandra Owieczka – Editorial Assistant
Julita Janszek – Editorial Assistant
redakcja@energetyka-wodna.pl
mobile: +48 518 304 194

**Subscription and advertising:**
Monika Grzybek
biuro@energetyka-wodna.pl

**DTP:**
Gustaw Nowak
grafika@energetyka-wodna.pl

**Printing house:**
Agencja Wydawnicza "ARGI"
ul. Żegiestowska 11
50-542 Wrocław

**Program council:**
Wojciech Majewski
Janusz Steller
Bogusław Puchowski
Ewa Malicka
Radosław Koropis
Robert Szlęzak
Andrzej Grześ
Małgorzata Stolarska
Michał Krzyszkowski

**Photo on cover:**
Spillway and plunge pool visible from the dam crest, PSH Foz Tua (Portugal)
Source: Agata Majerczyk

**Publisher:**
Polish Association for Small Hydropower Development (TRMEW)
ul. Królowej Jadwigi 1
86-300 Grudziądz
phone: +48 (56) 46 49 644
e-mail: biuro@trmew.pl
www.trmew.pl

TRMEW

Orders for institutional subscription adopts Kolporter Sp. z o.o. Sp.k. Information available at the hotline number 0 801 40 40 44 or on the website www.dp.kolporter.com.pl

It was published: 17.06.2024

# TRMEW news

**The first quarter of 2024 is already behind us. Time flows inexorably, just like water in rivers, our power plants are operating, but the prices for electricity are not satisfactory. How to address this?**

We are still waiting for the European Commission to approve the operational support regulations and modernization regulations, as well as the publication of the reference installation cost catalog. These regulations will enable many producers to make decisions about the possible modernization of their facilities. In discussions with the Ministry, TRMEW consistently emphasizes that the costs should concern "RES installations". There was also a meeting of our Association's representatives with the Energy Regulatory Office and the Ministry of Climate and Environment on this topic. The need to quickly address these issues was emphasized during these meetings. And what else?

We submitted comments on the draft amendment to the Construction Law. Our comments focused on expanding the catalog of projects that do not require a building permit but require notification, as mentioned in Article 29, paragraph 1 of the Construction Law, to include small hydropower plants (SHP) with a capacity not exceeding 50 kW (micro-installations) and shortening the time for issuing building permits for these hydropower plants.

In mid-April, we organized a training session on obtaining D and E energy qualifications; the meeting took place in Poznań. This year, we are planning another session in October, so those who could not attend now will have another opportunity to obtain the appropriate qualifications.

**Monika Grzybek**
Office manager
TRMEW



# Calendar

| | | |
|---|---|---|
| **17–18.06.2024**<br>Gdansk, Poland | **12th Edition of National Energy Summit OSE GDAŃSK 2024**<br>Organizer – European Business Center | https://osegdansk.pl |
| **19–21.06.2024**<br>Gdansk, Poland | **"Green Retention" Conference**<br>Organizer – Gdańskie Wody | https://zielonaretencja.pl/ |
| **8–10.08.2024**<br>Guangzhou, China | **The 9th World Battery&Energy Industry Expo**<br>Organizer – WBE | https://en.battery-expo.com |
| **9–10.03.2024**<br>Rzeszów, Poland | **IX Scientific Conference Energy Security Pillars and Development Perspective**<br>Organizer – Ignacy Lukasiewicz Institute for Energy Policy | https://www.instytutpe.pl/en/konferencja2024-en/ |

State Water Holding Polish Waters

# New approach to water management

**In the face of escalating climate change and civilizational challenges such as droughts, floods, and water pollution, water management emerges as a pivotal sector in ensuring human safety and environmental preservation. The State Water Holding Polish Waters (PGW WP) is poised to implement cutting-edge water maintenance practices during the planning and execution of conservation and investment projects. This heralds a novel eco-centric approach to water management by PGW WP.**

"A holistic approach to water management, encompassing eco-hydrology among other facets, not only aligns with the Water Framework Directive (WFD) but also contributes to the enhancement of water quality. In accordance with EU legislation, water is not a commodity but rather our heritage, which we are bound to safeguard", emphasized Joanna Kopczyńska, President of the State Water Holding Polish Waters.

"The linchpin to devising optimal solutions for flood and drought mitigation, as well as improving water quality, lies in harnessing the knowledge, experience, and expertise of water management professionals, scientists, and societal organizations", added Mateusz Balcerowicz, Deputy President of the State Water Holding Polish Waters for Flood and Drought Protection.

Success commences with meticulous planning, which is why PGW WP will incorporate publications delineating best practices for activities conducted on rivers, lakes, and water facilities during the planning stage of maintenance and investment tasks, including:

- Good Practices Catalog in River Maintenance and Hydrotechnical Investments (MGGP, April 2018),
- Good practices for river maintenance (Dobre praktyki utrzymania rzek, WWF Poland, August 2018),
- River renaturation — a handbook of best practices for the renaturation of surface waters (Renaturyzacja wód — podręcznik dobrych praktyk renaturyzacji wód powierzchniowych, Multiconsult, April 2020).

"In the face of challenges posed by climate change, it is imperative to undertake investments tailored to current and future needs. Adoption of best practices enables us to minimize the impact on the natural environment and introduce compensatory measures, which in some cases lead to the revitalization of previously degraded areas. A prime exemplar of a sustainable approach in water management are the tasks undertaken as part of the Flood Protection Project for the Oder and Vistula Basins. By bolstering flood safety for residents, we concurrently focus on relocating levees away from riverbeds, preserving natural river valleys, or creating small retention reservoirs and afforestation to enhance biodiversity", appended Mateusz Balcerowicz.

**Press Office**
State Water Holding Polish Waters

# Płock – dredging works at the Włocławek reservoir

**The State Water Holding Polish Waters has signed a contract for dredging works on the Vistula river in the vicinity of Płock. These works will improve the conditions of water flow during high water levels and ice flow during that periods, thereby enhancing the flood safety of Płock residents.**

The works will be conducted within the Vistula river channel, specifically in the Włocławek reservoir, an artificial water body created by damming the river in Włocławek. Ultimately, up to 1.5 million m³ of bottom material will be dredged. For Płock, such maintenance works represent a significant investment that will increase flood safety. The dredging of the Vistula river channel is planned at two locations:

- Radziwie/Płock at km 628+700 – 628 + 900 within the Włocławek reservoir area in the city of Płock,
- Reed barrier at km 637 + 350 – 637 + 600 within the Włocławek reservoir area near the town of Maszewo.

At each location, up to 5,000 m³ of bottom material will be removed as a result of dredging.

Further plans involve works at six additional locations, from which between 1 and 1.5 million m³ of excavation material will be selected. These undertakings will require an investment of PLN 20–30 million.

**Wojciech Kwinta**
inzynieria.com

# Over PLN 16 million for hydropower plant modernization

**An agreement has been signed for the modernization of a small hydropower plant in Rogów Opolski. The investor is the State Water Holding Polish Waters (PGW WP).**

The contractor will work in a design and build formula. The first stage is expected to last nine months, with the entire project scheduled to be completed within 26 months. The result will be greater efficiency of the hydropower plant while using the same amount of water, which, as reported, will significantly contribute to the reduction of air pollution and help in aligning with the implementation of EU climate and energy policy frameworks set for 2030. Additionally, the project implementation will also increase energy supply security by utilizing indigenous sources. The upgraded components of the small hydropower plant will be covered by an 8-year reliability guarantee from the contractor. The PLN 16.4 million investment is financed from PGW WP own funds.

**Łukasz Madej**
inzynieria.com

# Modernization of locks on the Oder Waterway

**The State Water Holding Polish Waters have completed the modernization of hydraulic structures in Januszkowice, Krapkowice, Krępa, Groszowice, and Dobrzeń on the Oder river. Thanks to the carried out works, water facilities, including locks and weirs, have gained improved functionality, translating into enhanced safety of facility use and inland navigation on the Oder Waterway. The investments were realized with the support of European Union funds.**

As part of the modernization works of the lock in Krapkowice, the existing lock chamber was rebuilt, and a new lock chamber with a length of 190 meters and a width of 12 meters, along with technical, mechanical, and hydraulic equipment meeting the requirements of European waterway standards, was also constructed. This lock is a concrete structure with a dock design. It consists of three gates equipped with hydraulically driven (automatically controlled) operational closures. These are steel gates allowing for the process of filling and emptying the lock. The executed works enable significant water and energy savings during locking operations. Additionally, new control rooms and outports were constructed, and the channel of the Sonia stream was partially relocated, with a syphon built on it. This project represents the largest investment in Krapkowice in a century.

As part of the modernization of the lock in Januszkowice, the small lock chamber was rebuilt by its demolition and the construction of a chamber with parameters of 190 meters in length and 12 meters in usable width in its place, as well as the reconstruction of the existing tugboat lock chamber. Within the lock area, the infrastructure and accompanying facilities were modernized, including the control room, outports, and the dividing dam. A new slipway for launching vessels with a mooring quay was built, along with communication routes. A new storage yard was also created, serving as a place for the transshipment of floating units.

The aim of the modernization of both locks — in Januszkowice and Krapkowice — is the development of inland waterway on the Oder and the improvement of low-emission environmentally friendly transportation systems. The executed works ensure the durability and reliability of the facilities, enabling safe and trouble-free inland navigation — for vessel crews and lock operators.

Together with the completed projects in Januszkowice and Krapkowice, the State Water Holding Polish Waters in Gliwice modernized three Oder weirs — in Krępa, Groszowice, and Dobrzeń. The works were carried out simultaneously at all three facilities and included a similar scope of works.

As part of the modernization, outdated and worn-out sector gates were rebuilt into flap gates, characterized by reliability and faultlessness. Importantly, controlling sector gates not only did not provide the waterway administrator — the State Water Holding Polish Waters in Gliwice — with certainty about their safe use but was also very time-consuming. Moreover, sector gates were highly susceptible to ice phenomena, which also entailed many risks, including for the workers of these facilities. In turn, flap gates ensure a constant water level, guaranteeing stable and safe conditions for Oder navigation. Although weirs themselves do not play significant flood protection functions, they should provide certainty about their reliability even in the event of flooding and high water levels, ensuring an appropriate pace of their laying and subsequent — setting up, thereby ensuring the safety of areas adjacent to the river.

**Press Office**
State Water Holding Polish Waters

# The State Water Holding Polish Waters – contract for key documents

**The State Water Holding Polish Waters has signed a contract for the development of new water maintenance plans for the entire country.**

Water maintenance plans are planning documents aimed at preparing a list of actions on inland surface waters, taking into account the needs related to flood protection and the necessity of achieving environmental objectives and water protection.

The documentation identifies sections where risks occur. It also includes, among other things, justification for the necessity of implementing specific actions, and if possible, a rough analysis of costs and benefits.

The current plans were adopted in 2016 through local legislation by the directors of the former regional water management boards (the State Water Holding Polish Waters have existed since January 1, 2018). The new plans will be adjusted to strategic and planning documents in the field of water management (such as the national program for the renaturation of surface waters, water management plans, plans to counteract the effects of drought) as well as current assessments of the uniform parts of surface waters.

The contract stipulates that within the next six months, 11 draft documents will be developed divided by water regions, and during the following nine months, a strategic environmental impact assessment will be conducted. The adoption of water maintenance plans by voivodes in the form of local legislation should take place no later than November 2025.

**Łukasz Madej**
inzynieria.com

# Orlen hydropower plant has been launched

**Orlen has launched a hydropower plant in Płock, powered by treated and purified wastewater from the main production facility. The unit will annually generate an amount of energy equivalent to the demand of about 400 households.**

A small-scale hydropower plant with a rated power of 160 kW, built on the premises of the Orlen water and sewage treatment plant in Płock, will produce approximately 800 MWh of electrical energy per year. The setup comprises a pipeline laid along the Vistula riverbank and hydro unit composed of a turbine and a generator positioned at the pipeline's terminus. The cost of the new hydropower plant reached PLN 3 million. The energy produced by it will be fed into the power grid, allowing the Orlen Group to generate additional revenue from sales, estimated at around PLN 0.5 million annually.

The water used in the refinery in Płock is drawn from the Vistula river. After use, it is first purified and treated to obtain parameters compliant with environmental standards. The treated wastewater is used for production purposes such as fire and utility water, and only the excess is discharged into the river.

Thanks to numerous modernizations, the Orlen plant has doubled its efficiency in water utilization for production processes. It has reduced the amount of discharged, treated wastewater from about 40 million m³ to 14 million m³, while the processed amount of oil has increased from about 8 million to over 16 million tons annually.

Among the new investments increasing the safety and efficiency of production processes are new filters for utility and fire water, a new collector, and a multi-chamber reactor for decarbonized water needed in production processes. Presently, the company is in the process of implementing an integrated management system for water and wastewater management, which will enable even more efficient water use and increase the safety of water and sewage networks.

The Orlen Group's Sustainable Development Strategy for the years 2024–2030 incorporates the "Blue Bridge" project, which involves treating wastewater from the sewage treatment plant operated by Płock water supply company to process water quality. Subsequently, it will be utilized within the refinery. This will reduce the intake of Vistula water used in production processes by about 25%.

GRAMWZIELONE.PL

**Editorial office**
gramwzielone.pl

Towarzystwo Elektrowni Wodnych

iha affiliate member

TRMEW

HYDRO FORUM

*Polish Hydropower Conference*

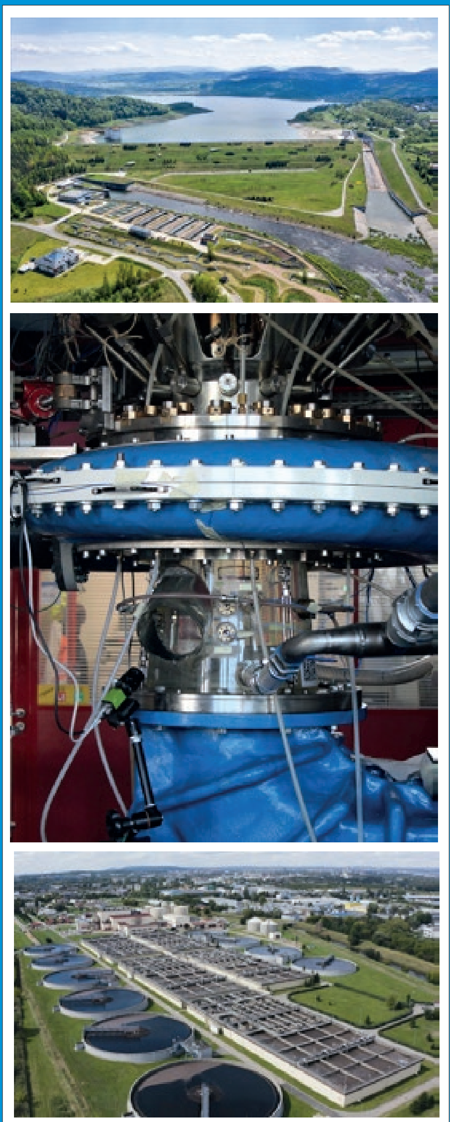
# HYDROFORUM 2024

Cracow / Świnna Poręba, 16-18 October 2024

Państwowe Gospodarstwo Wodne Wody Polskie

WODOCIĄGI Miasta Krakowa

LIFE NEXUS



## The programme includes:

- Legal-economic constraints and development strategy
- Projects - challenges and technological trends
- Climate and environmental trends
- HYDROFORUM Debate
- Hydraulic energy recovery in municipal water circuits
  - Life NEXUS project
- Operation and technology
  - practical experience and research results
- innovative units and small hydropower
- Study visit at the hydraulic energy recovery installations of Cracow Waterworks and at Swinna Poreba HPP

## Organisers

**Polish Hydropower Association**
tel.: +48 58 678 79 51, e-mail: biuro@tew.pl

**Polish Association dor Small Hydropower Development**
tel.: +48 56 464 96 44 , e-mail: biuro@trmew.pl

**Szewalski Institute of Fluid-Flow Machinery, Pol. Ac. Sci.**
tel.: +48 58 5225 139, e-mail: steller@imp.gda.pl

**Cracow University of Technology,**
**Faculty of Electrical and Computer Engineering**
tel.: +48 12 628 21 44, e-mail: iwona.goldasz@pk.edu.pl

## Partnership and patronage

- **PGW Wody Polskie / Regional Water Management Board in Cracow**
- **Polish Waterworks Commercial Chamber**
- **Cracow Waterworks**
- **Life NEXUS Project**

## Editorial collaboration and media patronage

WYDAWNICTWO IMP PAN

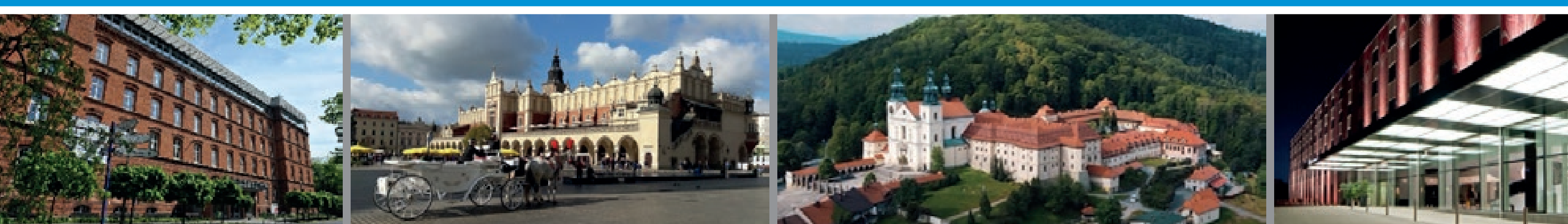
ENERGETYKA WODNA

zek

TVP 3 KRAKÓW

**You are invited to join the conference, collaboration a oraz sponsoringu.**

Further information alredy available from the Organisers' websites



# News from the Polish Committee for Large Dams

**On April 23rd of this year, the First Seminar of the Polish Committee of Large Dams titled "Operation of Polish large dams in the face of climate change — problems, experiences, challenges" took place. It was primarily aimed at managers and directors of hydrotechnical facilities of the State Water Holding Polish Waters and energy corporations. The aim of the seminar was to exchange opinions and experiences of hydro technicians in the use of hydrotechnical structures, especially large dams, of which there are 69 in Poland.**

Representatives of the Ministry of Infrastructure, the Chief Inspectorate of Environmental Protection, the State Water Holding Polish Waters, higher education institutions, PGE, Enea, and Tauron corporations, as well as individuals working in design offices and at the Technical Center for Dam Control of IMGW, participated in the seminar. Presentations related to the seminar's theme were delivered: "Activity of the Polish Committee of Large Dams" (Piotr Śliwiński), "Modern methodology for detection and monitoring of intensified filtration, including leaks and internal erosion in earth dams with examples of applications in Poland and worldwide" (Krzysztof Radzicki), "Mining damages in Silesia in the aspect of flood risk" (Andrzej Siudy), "Possibilities of updating the water management instructions for selected water reservoirs in the Warta basin in the context of changing climatic conditions and more efficient management of river water resources for economic and natural purposes" (Bogumił Nowak, Michał Wierzbicki, Anna Andrzejak).

After the break, a heated discussion took place involving seminar participants and invited guests, during which some of the problems related to the use of structures were addressed, such as formal procedures related to changing water permits and water management instructions, problems of cooperation with environmental organizations, or plans for the construction of new reservoirs and dams. The conclusions and summary of the seminar made by invited experts will serve as material for a possible future regulation regarding the technical conditions of using inland hydrotechnical structures. The Polish Committee of Large Dams plans to continue such meetings due to the very high interest of our community in this particular topic.

During the seminar, POLCOLD announced for the first time to the public the celebration of "Dam Day". This is an initiative of the European Club of the International Commission on Large Dams, aimed at disseminating knowledge about the role of dams in the economy, society, and the environment. Dam Day is celebrated every year in May and includes all initiatives raising social awareness about dams and their positive role in shaping water resources (floods and droughts), such as lectures, conferences, dam tours, or hydrotechnical picnics. The First POLCOLD Seminar has been included on the "Dam Day events list", and the following events were organised: a tour of the Dębe dam and power plant for postgraduate students of Warsaw University of Technology, the "Hydraulic engineering in Warsaw" conference at the Warsaw University of Technology on May 23, 2024, a technical excursion by SITWM — Besko, Klimkówka, Rożnów, Kańczuga, and an event at the Hydraulic engineering Campus in Kiczki Pierwsze.

**Piotr Śliwiński**
Chairman
Polish Committee of Large Dams POLCOLD

E24

The ecosystem
of the Ecological
Transition

NOVEMBER
5 — 8,
2024

RIMINI
EXPO CENTRE
Italy

ecomondo.com

# ECOMONDO

The green technology expo.

Organized by

ITALIAN EXHIBITION GROUP
Providing the future

In collaboration with

Ministry of Foreign Affairs and International Cooperation

ITA
ITALIAN TRADE AGENCY

madeinitaly.gov.it

Water Power & DAM CONSTRUCTION

# From the World

## 08.01.2024 Record-breaking investments unveiled by Statkraft in Norwegian hydropower and wind projects

European renewable energy generator Statkraft has announced plans to invest €6 billion in a comprehensive overhaul of its hydroelectric and wind power infrastructure — the largest investment program of its kind in hydro and wind power in Norway for decades.

Statkraft's focus on hydropower includes major upgrades to hydroelectric plants such as Mauranger, Aura, Alta, and Svean in Western, Central, and Northern Norway. However, the successful execution of these projects depends on factors such as a predictable regulatory framework, obtaining necessary concessions, power demand levels, and fostering a positive dialogue with local communities.

Additionally, Statkraft plans to invest up to two billion euros between 2024–2030 in the rehabilitation of dams and modernization of older power plants, ensuring continued cost-effective and regulated power production, as well as bolstering facilities against extreme weather, floods, and potential security threats.

## 15.01.2024 European organisations advocate for inclusion of hydropower in net-zero technologies

In a joint effort to highlight the pivotal role of hydropower in achieving the European Union's (EU) climate neutrality goals, Eurelectric, in collaboration with the EU Hydropower Alliance and vgbe energy e.V., issued a compelling letter urging legislators to include hydropower in the list of "strategic net-zero technologies" under the Net-Zero Industry Act.

The letter, titled "European Hydropower — A strategic net-zero technology", emphasizes the unique contributions of hydropower and its indispensability in achieving the EU's sustainability targets. As negotiations for the Net-Zero Industry Act reach their final stages, proponents argue that recognizing hydropower as a strategic player is essential for a sustainable and resilient EU power system. Hydropower, standing as the second-largest renewable energy source in the EU, annually generates 355 TWh of electricity. The letter highlights the unparalleled flexibility of hydropower, playing a crucial role in ensuring the secure and stable operation of the electricity grid. Pumped storage hydropower, constituting over 90% of available EU storage capacity, offers essential services for electricity storage, absorbing excess generation and avoiding curtailment.

As the EU aims to add 621 GW of new variable renewable electricity capacity within six years, the proponents argue that hydropower's flexibility and storage capabilities will become increasingly important in meeting these ambitious targets.

## 16.01.2024 Webuild successfully completes pad foundation for Rogun Dam, Tajikistan – set to become world's tallest dam

Webuild has achieved a significant milestone in the construction of the Rogun Dam in Tajikistan, set to be the world's tallest dam at 335 m — with the completion of the pad foundation. Situated on the Vakhsh River, approximately 90 km from the capital Dushanbe, Lot 2 of the Rogun Hydropower Plant is currently under construction by Webuild on behalf of OJSC Rogun HPP. This ambitious project, now 35% complete, involves tackling various technical, geological, climatic, and logistical challenges, demanding innovative solutions at a global level.

The dam, composed of rockfill with a clay material core (concrete pad in roller compacted concrete (RCC)), will boast a total volume of around 80 million m³, featuring a crest length of 800 m. Once finished, the Rogun Hydropower Plant is expected to have a total installed capacity of 3,600 MW, generated by six Francis Turbines, each with a capacity of 600 MW.

## 05.02.2024 Biden-Harris Administration allocates record funds for hydroelectric projects across 19 states

The Biden-Harris administration has unveiled its largest single investment in waterpower production in the US, allocating nearly $72 million to bolster hydropower facilities across the Nation as part of the Investing in America Agenda.

The US Department of Energy (DOE) revealed the selection of 46 hydroelectric projects spanning 19 states, set to receive up to $71.5 million in incentive payments. These funds, administered by the Grid Deployment Office and backed by the Bipartisan Infrastructure Law, mark the DOE's most substantial investment in hydropower facilities to date. The selected projects span across California, Colorado, Connecticut, Georgia, Idaho, Maine, Massachusetts, New Hampshire, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Rhode Island, Tennessee, Vermont, Virginia, Washington, and West Virginia.

Investments under the Hydroelectric Efficiency Improvement Incentives will bolster the U.S. hydropower fleet's continued operation and ensure a more reliable and resilient electric grid system. Facility owners or operators receiving the incentives will implement capital improvements to enhance efficiency by an average of 14%, with a statutory minimum of 3% per facility. These improvements include upgrades to facility turbines and generators, as well as enhancements to water conveyance structures.

# From the World

## 16.02.2024 Georgia's largest hydropower plant set for upgrade with EBRD and EU backing

The European Bank for Reconstruction and Development (EBRD) has announced it is providing a sovereign loan of €28 million to facilitate the modernization and rehabilitation of the Enguri hydropower plant, the largest electricity facility in Georgia. This initiative is complemented by a grant of €7.05 million from the European Union (EU).

The funding is slated to address critical issues concerning the structural integrity of the Enguri dam, alongside essential repairs to the underground tunnel and penstock. These measures aim to enhance the plant's operational reliability and ensure a more sustainable power generation and grid system. Moreover, the investment will be used to help minimize water leakages within the headrace tunnel while unlocking opportunities for additional renewable energy production. The allocated funds will also facilitate the construction of vital infrastructure, including roads for dam monitoring, improvements to electricity grid safety and reliability, and the establishment of a fish passage downstream of the Enguri dam.

## 12.03.2024 Dam Safety Society launched to address global concerns on water management

In a bid to enhance global efforts in water management and ensure the safety of crucial dam structures, the newly formed Dam Safety Society has been launched. The establishment of this institution aims to propagate the importance of dam safety and asset management worldwide.

Dams have increasingly become focal points in water management strategies globally, serving as vital reservoirs for economic stability and community well-being. With reservoir storage becoming increasingly crucial, particularly in the face of climate change, it's imperative that dams retain their operational integrity over multiple generations.

Recognizing the necessity for comprehensive dam safety measures, advanced countries have already implemented legislative and technological interventions. However, many developing nations are yet to establish similar frameworks, highlighting the need for a platform to bridge these knowledge and capability gaps. The society's mandate includes covering scientific, technological, and managerial aspects of dam safety, providing a platform for professionals to address unique challenges faced by existing dams. Unlike new projects, which benefit from standardized practices, dam safety requires a distinct approach, which the society aims to develop through shared knowledge and experiences.

In addition to fostering collaboration among professionals, the society plans to organize regular meetings focusing on various aspects of dam safety, including operation, maintenance, simulation, emergency responses, rehabilitation, and management. These gatherings will provide opportunities for knowledge exchange and the development of effective solutions to enhance dam safety practices globally.

## 12.03.2024 India's PM Narendra Modi lays foundation stone for 2,880 MW Dibang multipurpose hydroelectric project

Located near the village of Munli in the Lower Dibang Valley District, Arunachal Pradesh, the Dibang Multipurpose project will feature a 278 m-high dam, which upon completion will stand as India's tallest Concrete Gravity Dam. Utilizing advanced construction techniques such as Roller Compacted Concrete (RCC), the dam is also set to become the world's highest RCC dam.

The primary objective of the Dibang Dam is to harness clean and green energy, contributing significantly to the Northern Grid. Once operational, the project is estimated to generate 11.223 Million Units (MU) of hydropower annually. With a construction timeline spanning 108 months, the project is slated for commissioning in February 2032. The Dibang Multipurpose Project is not solely focused on power generation. It also prioritizes flood moderation as a crucial aspect of its design.

## 21.03.2024 Rye Development awarded $81 million by DOE for Lewis Ridge pumped storage project

Rye Development has announced it has been chosen by the US Department of Energy (DOE) to receive $81 million in funding for the Lewis Ridge Pumped Storage Project. This selection comes as part of the DOE's Clean Energy Demonstration Program on Current and Former Mine Land (CEML), funded under the Bipartisan Infrastructure Law.

The Lewis Ridge Project, slated to become one of the first pumped storage hydropower facilities constructed in the US in over three decades, is set to make history as the first such facility to be built on former mine land.

The project will convert former mine land in Bell County, Kentucky, into a closed-loop, 287 MW pumped storage hydropower facility, with the capacity to store electricity for up to eight hours and generate electricity to power 67,000 homes.

# On the trail of hydrotechnical structures – Portugal

**"We received permission to visit facilities in Portugal, so after the New Year, this is our travel destination", reads one of the first sentences of the December email I received from "Energetyka Wodna" as an introduction to the invitation for another study tour organized by the Editorial office as part of a training cycle covering European pumped storage hydropower (PSH).**

Source: Organiser's archive

Fig. 1. Study tour participants against the backdrop of the Baixo Sabor dam

I don't know where or how the Editorial office acquired such contacts, but the plan for the study tour to Portugal seemed very ambitious. It involved visiting two hydraulic structures, PSH Baixo Sabor and PSH Foz Tua, as well as workshops with representatives of the investor and technology suppliers, engineers, and practicing designers. During the four-day study tour, which took place at the end of January this year, we had the opportunity to delve into the intricacies of knowledge in both hydraulic engineering and the conditions of pumped-storage hydropower plants' operation in the Portuguese energy market. In light of the changes awaiting Poland, it was a very practical lesson for my team, which works on strategic projects for the country and Europe, our expert staff, and other participants of the tour representing the energy industry. The group consisted of 18 people, including engineers, designers, project managers, and representatives of energy companies.

## Purpose of the study tour

Historically, Portuguese PSH's facilities compensated electricity fluctuations in demand — proportionally higher daytime peaks and lower nighttime demand. Responding to the challenges related to renewable energy production, the role of hydropower plants has evolved, increasing the country's energy security in the decarbonization process. Initially, Portugal planned to phase out coal by 2030, but it managed this challenge much faster than the entire European Union, as the last coal-fired power plant was closed in 2021. Additionally, due to the conflict in Ukraine, Portugal plans to achieve the threshold of 80% renewable energy production by 2026. For comparison, Poland plans to reach this level only by 2035. Therefore, the goal of the study tour was to gain a deeper understanding of the Portuguese energy market and draw from its experiences to shape investment responses to Polish plans for changes in the energy sector. It can be argued that Poland will have to face the challenge without a plan for the planned changes. Today, we already know what specific problems will arise because by decommissioning coal-fired units, we will reduce 9 GW of capacity. Some of these values will be supplemented by new gas-fired units. We also observe significant growth in megawatts from renewable energy sources, but there is still no answer to what will balance them when the wind is not blowing and the sun is not shining. Polskie Sieci Elektroenergetyczne S.A. (Polish transmission system operator) continue to warn that after 2025, they will have trouble balancing the power system. The results of their analysis of the sufficiency of generation resources indicate that there will be 1,040 hours of imbalance in 2030, which is equivalent to two months a year when PSE will have trouble balancing the system.

Taking into account these scenarios, the study tour organizers carefully planned the agenda of meetings and workshops so that through direct interaction with practitioners and industry experts, participants could learn about innovative strategies and practices used in the Portuguese energy sector, especially in the context of using pumped-storage hydropower plants to compensate fluctuations in energy production as flexible and dispatchable generation sources. Additionally, through site visits, participants learned about the operation of PSH facilities, their management, and other practical aspects of their operation.

A parallel tangible goal, greatly facilitated by the study tour, was networking internationally and exchanging knowledge, which may contribute to more effective implementation of ongoing and future projects aimed at green energy storage facilities, intended to address the need for energy security.

## Visited facilities

Thursday, January 25th, was a day filled with inspiring visits to two key energy facilities — PSH Baixo Sabor and PSH Foz Tua. During the tours, we could directly observe how they function and what innovations Portuguese energy storage facilities utilize.

PSH Baixo Sabor is an impressive hydroelectric installation located on the Sabor river, a right tributary of the Douro river. Launched in 2016, this modern hydropower plant is another element of the

Source: Organiser's archive

Fig. 2. PSH Baixo Sabor, from left: view of the dam from the downstream side with the spillway, power plant building with discharge channels, participants of the study tour visiting the dam from the technical terrace level

region's energy infrastructure. Its total construction cost amounted to EUR 569 million. The main structural element of PSH Baixo Sabor is a gravity-arch concrete dam, reaching a height of 123 meters and a crest length of 505 meters. The power plant has an installed capacity of 144 MW, enabling the use of two reversible hydro units with Francis turbines. Thanks to advanced equipment, it is possible to efficiently convert the potential energy stored in the reservoir with an impressive capacity of 1,095 million m³. PSH Baixo Sabor not only serves as a source of electrical energy but also plays a significant role in water control in the region, ensuring the stability of electricity supply and regulating water flow in the Douro basin.

During the same day, participants had the opportunity to visit PSH Foz Tua, another significant hydroelectric facility, inaugurated in 2017. Located on the Tua river near its mouth to the Douro river, the upper reservoir with a capacity of 12 million m³ forms a double-curvature arch dam, reaching a height of 108 meters with a crest length of 275 meters. This structure not only allows for water retention but also generates a significant amount of electricity. The power plant has an installed capacity of 274 MW in turbine mode and 246 MW in pump mode, equipped with two Francis pump-turbines. With an annual energy generation of 305 GWh, PSH Foz Tua demonstrates considerable production potential. It is worth noting that this hydropower plant was built on the border of a UNESCO protected landscape region, emphasizing its importance both as a source of energy and in environmental conservation, thus becoming a green energy reservoir. PSH Foz Tua serves as an example of modern and sustainable energy infrastructure, contributing to meeting Portugal's energy needs in an environmentally friendly and efficient manner.

## The conducted meetings

Friday, January 26th, was dedicated to workshops organized at the headquarters of Engie, a leading energy company in Portugal focusing on the transformation of the energy sector, with emphasis on three main areas of activity: low-emission energy generation, transmission networks, and customer services. Given the speaker's expertise, the presentation focused on the Portuguese energy market and practical aspects of power plant operation in this market. During the workshops, we had the opportunity to get acquainted with Engie's facilities in the Douro basin, such as Baixo Sabor, Foz Tua, Feiticeiro, Miranda do Douro, Picote, and Bemposta. The most impressive experience of the day was the visit to the PSH management centre, where their systems

Source: Organiser's archive

Fig. 3. PSH Foz Tua, from left: briefing of study tour participants before visiting the facility, the Tua river valley with the dam, segment gate of the spillway, transformer station, workshops at Engie headquarters – presentation on the management system of hydropower plants

and work strategy were presented, including weather and market analysis, bidding on the next day's and current day's market, participation in the balancing market, real-time dispatching, and ancillary services. The facilities operated by Engie are equipped with hydro units manufactured and supplied by Andritz Hydro. Thanks to the presence of representatives from this company, Dieter Erke and Fabio Ferreira, we gained insight into the supplier's perspective. They shared their experiences, presenting reference projects, including the Gouvães PSH in Portugal.

Saturday, January 27th, was reserved for workshops organized by the COBA Group, which has been present in the global market since 1962, supporting clients with its expertise at actually every stage of the investment process. Specially for our study tour, a presentation was prepared covering the history and characteristics of pumped-storage hydropower plants in Portugal, the energy market, and examples of constructional and technical solutions used in these facilities. During this part of the study tour, we had the opportunity to get to know facilities such as Salomonde II and Alqueva II.

Salomonde I was built in 1953, with an installed capacity of 42 MW and an average annual energy production reaching 244 GWh. Equipped with two Francis turbines, the hydropower plant utilizes the water head of 126.36 meters.

Salomonde II is a significant investment realized between 2009 and 2016, which, through repowering, significantly increased the production potential of the originally built Salomonde I from 1953, one of the first hydropower plants of this type in Portugal. The rated capacity of the newly constructed power plant is 207 MW, with an investment value reaching EUR 200 million (as of 2010 prices).

As an underground power plant, Salomonde II, it's powerhouse features impressive dimensions, measuring 66 by 27 by 61.3 meters. Additionally, it has a cylindrical surge tank with a height of 50 meters and an inner diameter of 20 meters. The above-ground station is equipped with a transformer with a capacity of 250 MVA and a voltage of 400 kV, enabling effective connection to the national transmission network (RNT) via a 400 kV transmission line.

Alqueva I, commissioned in 2004, and Alqueva II, realized between 2009 and 2016, represent significant achievements in Portugal's energy sector. Alqueva I is characterized by an installed capacity of 256 MW and an average annual energy production of 461 GWh. Meanwhile, Alqueva II, equipped with two Francis turbines, features a capacity of 128 MW in turbine mode and 110 MW in pump mode, with an average annual energy production of 381 GWh. Both Alqueva power plants are not only important sources of energy for Portugal but also participate in the XFLEX HYDRO project. They utilize hydraulic short-circuiting, expanded operational range and intelligent controls in an innovative manner to enhance flexibility provided to the grid. This enhancement includes not only frequency services but also voltage support, which is crucial for grid stability. Through their involvement in this project, the Alqueva power plants play a significant role in developing innovative solutions in the energy sector, contributing to the improvement of efficiency and flexibility in the Portuguese energy system.

Discussions on the role of energy storage in decarbonizing the energy sector underscore the importance of innovative solutions and strategies that have already been implemented in Portugal, whose potential meets the needs faced by Poland. Energy storage facilities are a key element of the energy transformation, enabling the effective integration of an increasing amount of energy from renewable sources and minimizing greenhouse gas emissions. The information provided can help study tour participants better understand contemporary challenges and potential directions for the development of the energy sector, both at the national and international levels.

In addition to the substantive part, the organizers also planned other attractions for the participants, including integration and tourist activities. We had the opportunity to dine in truly excellent restaurants, which impressed us not only in taste but also in ambiance. On Sunday morning, we spent time with perhaps the best "Portonian" guide, who guided us through the city, telling us stories and answering our most imaginative and curious questions about this place.

### The energy market in Portugal

As mentioned earlier, Portugal sets high goals for the share of renewable energy sources in electricity production. In 2023, Portugal produced as much as 61 per cent of its energy from renewables, totaling 31.2 TWh, with wind power plants contributing nearly 25 per cent to the achieved production. Meanwhile, hydropower accounted for about 23 per cent.

Source: Organiser's archive

Fig. 4. From left: lunch break at Quinta da Terrincha restaurant, guided tour of Porto city center, panoramic view of Porto from Ponte Luís I bridge

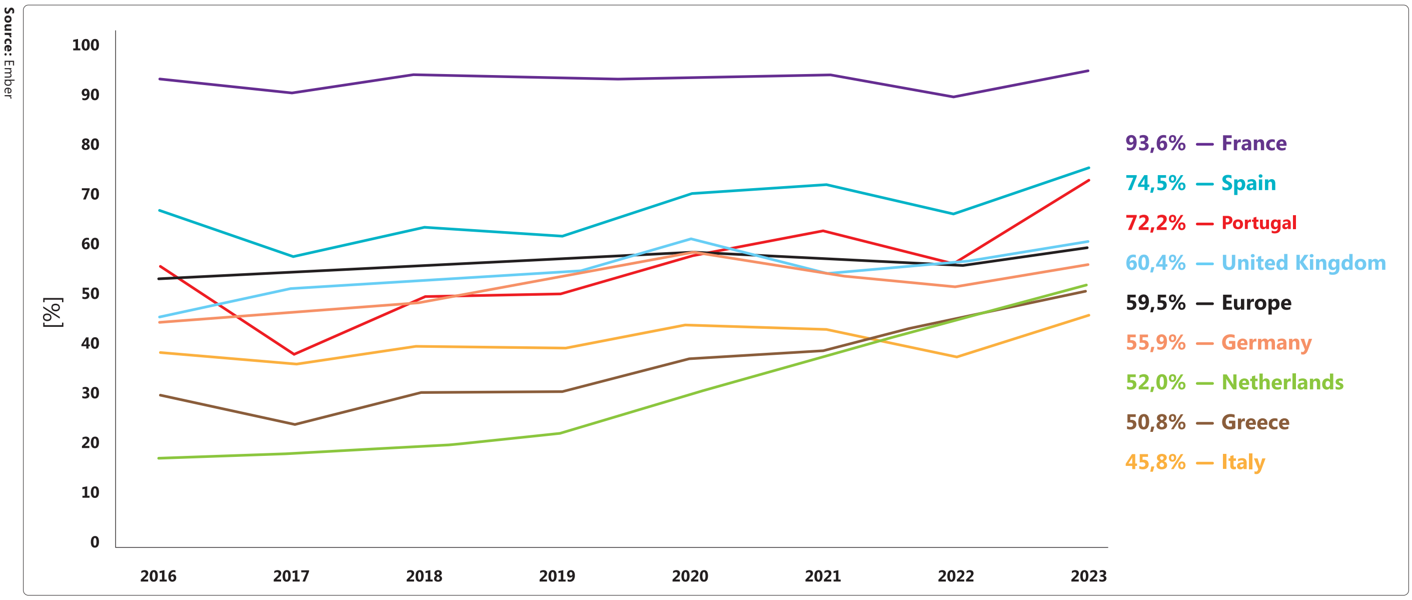



Fig. 5. Share of RES in electricity generation in selected European countries

As seen in the graph, Portugal ranks among the top three in Europe in terms of generation from renewable energy sources. The 2023 results represent the highest value in the history of the Portuguese system. On an annual basis, there was a 70 per cent increase in hydroelectric production, considering the exceptionally dry year of 2022.

Hydropower plants play a fundamental role in managing electrical grids as they provide the only rapid redundancy for other forms of renewable energy, such as wind or solar, which are unpredictable due to meteorological reasons. Currently, there are 42 hydroelectric power plants (with a capacity exceeding 10 MW) operating in Portugal, with a total installed capacity of almost 6 GW. On average, they produce 13 thousand GWh of electricity annually. However, these values will continue to grow as Portugal undertakes further hydroelectric projects. The project known as Complexo do Tâmega involves the construction of three power plants — Gouvães, Daivões, and Alto Tâmega. These are pumped-storage hydroelectric power plants located in the Tâmega river valley, a tributary of the Douro river, in the northern region of Portugal, near Porto. All three facilities are already operational.

Together, these three power plants will have an installed capacity of 1,158 MW, representing a 6% increase in the country's total installed electrical capacity. The project is owned by the Spanish company Iberdrola and is valued at EUR 1.5 billion. The complex will be able to produce 1,766 GWh of energy annually.

## Main conclusions

The most significant outcomes of the January study tour organized by "Energetyka Wodna" Editorial office were not only the opportunity to gain engineering knowledge through the example of the discussed facilities, but importantly, the chance for direct contact with experts and industry practitioners in the energy sector in Portugal. They have successfully implemented energy market reforms in their country. As a team manager involved in implementing project solutions in the energy industry and providing advisory services in this field, this was the greatest value we could acquire. The extensive portfolio of the participants will certainly be applicable in our professional work.

As a participant in another study tour organized by "Energetyka Wodna", I am deeply impressed by the professionalism and dedication of the Editorial office, which ensured the smooth running of the meeting agenda and our comfort in every situation, even behind the scenes during the tour.

**M. Eng. Ewelina Bogacka**
Project manager
Project office manager
Instytut OZE sp. z o.o.

# Intelligent Asset Management Platform for Hydropower (iAMP-Hydro)

**In the pursuit of enhancing the efficiency and sustainability of hydropower operations, iAMP-Hydro emerges as a groundbreaking initiative, fostering collaboration between academia and industry. Spearheaded by a consortium of distinguished researchers and practitioners, this project endeavours to revolutionize the management of hydro assets across Europe. Through a comprehensive approach that integrates cutting-edge technology, data analytics, and interdisciplinary expertise, iAMP-Hydro holds the potential to reshape the future of hydropower management.**

iAMP-Hydro represents a concerted effort aimed at developing digital solutions to address the evolving needs of the EU hydropower sector. With a significant portion of hydro generation assets slated for potential upgrades by 2030, the project's objectives align closely with the imperatives of energy sustainability and digital transformation. By harnessing the collective capabilities of its diverse partners, iAMP-Hydro seeks to unlock new pathways for optimizing asset performance, minimizing environmental impact, and fostering socio-economic development in the communities served by hydropower facilities.

At its core, iAMP-Hydro aims to revolutionize hydropower management through the development of an intelligent Asset Management Platform (iAMP), comprising two foundational layers: the intelligent Data Management Layer (iDML) and the intelligent Data-driven Optimization Layer (iDOL). By leveraging cutting-edge technologies such as machine learning and deep learning, iAMP-Hydro seeks to empower operators with predictive maintenance models, ecological status monitoring tools, and advanced weather and flow forecasting capabilities, thereby enhancing operational efficiency and resilience.

## Key Objectives

The core objectives of iAMP-Hydro revolve around the creation of an intelligent Asset Management Platform (iAMP) designed to enhance operational efficiency, flexibility, and sustainability within the hydropower domain. The platform encompasses three pivotal digital solutions:

a) condition Monitoring and Predictive Maintenance Modelling: Leveraging IoT sensors and advanced analytics, iAMP-Hydro enables real-time monitoring and predictive maintenance of electromechanical equipment. By harnessing data on vibration, temperature, acoustic signals, and electrical parameters, the platform empowers operators to pre-emptively address potential issues, thereby minimizing downtime and optimizing asset performance. Through the integration of machine learning algorithms, iAMP-Hydro continuously refines its predictive capabilities, adapting to changing operating conditions and maximizing the lifespan of critical components,

b) ecological Status Monitoring and Water Management: Recognizing the intricate interplay between hydro operations and environmental sustainability, iAMP-Hydro incorporates tools for monitoring ecological parameters and managing water resources. By leveraging remote sensing technologies, geographic information systems (GIS), and hydrological modelling techniques, the platform enables operators to assess the ecological health of water bodies, identify potential risks to biodiversity, and implement proactive measures for habitat conservation and water quality management. Through the integration of stakeholder engagement mechanisms, iAMP-Hydro facilitates collaborative decision-making processes, ensuring that environmental considerations are effectively integrated into operational planning and management strategies,

c) improved Weather and Flow Forecasting: Drawing on operational data from hydropower plants and external sources, iAMP-Hydro facilitates advanced forecasting of weather patterns and flow dynamics. By integrating meteorological data, hydrological models, and machine learning algorithms, the platform enables operators to generate accurate predictions of reservoir inflow, outflow, and water balance dynamics. Through the development of customized forecasting tools tailored to the unique characteristics of each hydropower facility, iAMP-Hydro empowers operators to optimize reservoir operations, manage flood risk, and enhance energy production efficiency. By providing decision support tools that incorporate uncertainty analysis and scenario planning capabilities, iAMP-Hydro enables operators to make informed decisions in the face of evolving weather patterns and hydrological conditions, thereby improving operational resilience and minimizing risk.

The key objectives of iAMP-Hydro are encapsulated within four core data services


Fig. 1. General outline of the system validation in operating hydropower plants

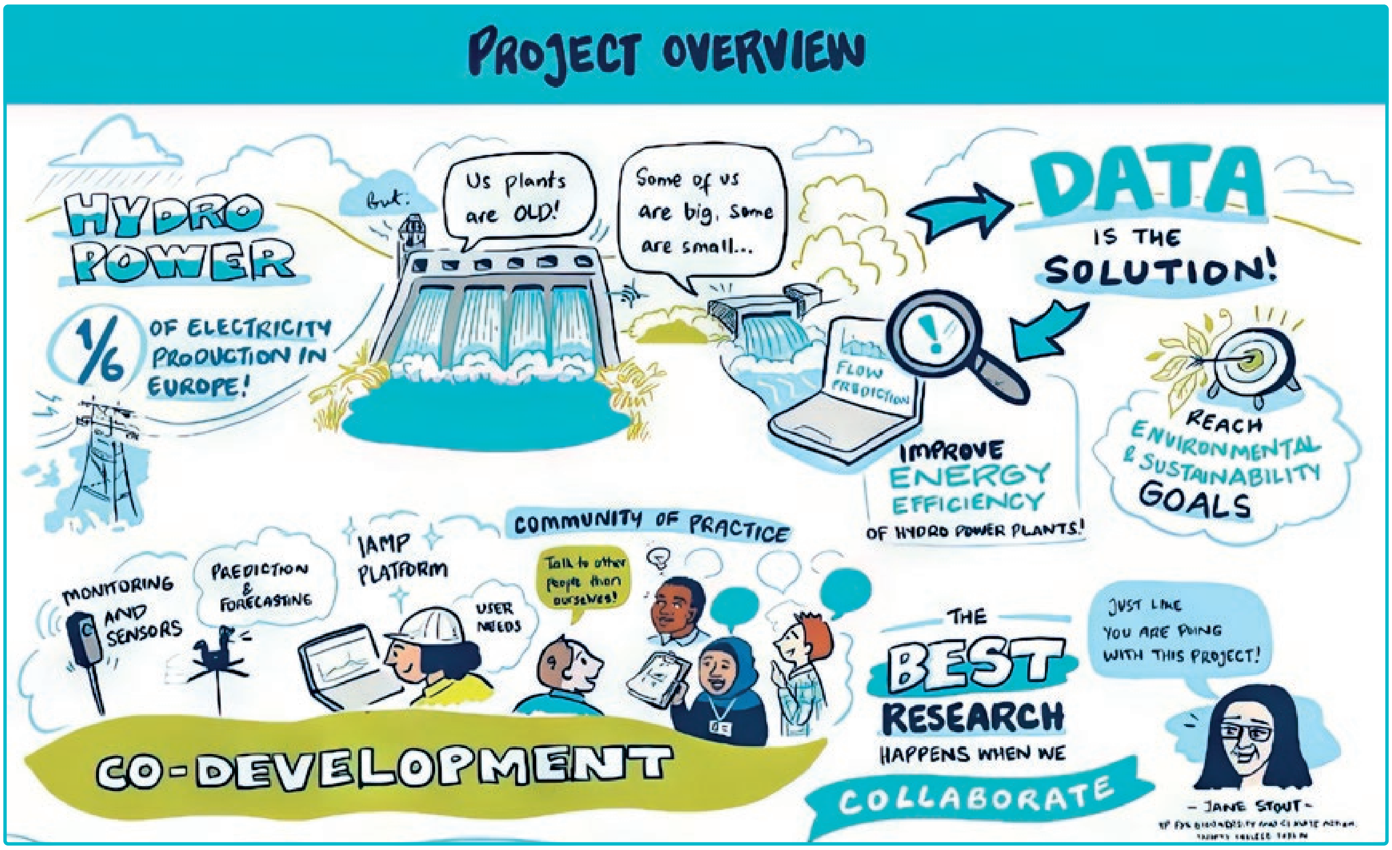



**Fig. 2.** General outline of the IAMP-Hydro project

bundles, each designed to unlock new opportunities for data-driven collaboration and innovation:

a) Data Collection Services Bundle: Facilitating the seamless ingestion, curation, mapping, and sharing of hydro-related data assets, this bundle forms the foundation upon which iAMP-Hydro's intelligence is built,
b) Data Security Services Bundle: Ensuring the confidentiality, integrity, and availability of data assets within the iAMP-Hydro platform, this bundle plays a critical role in safeguarding sensitive information and mitigating cybersecurity risks,
c) Data Sharing Services Bundle: Central to the iAMP-Hydro platform, this bundle facilitates the establishment and monitoring of intelligent data contracts over a distributed ledger technology (DLT)-enabled infrastructure, enabling secure and transparent data sharing among stakeholders,
d) Data Analytics Bundle: Empowering stakeholders with advanced analytics capabilities, this bundle enables the exploration, design, and execution of analytics workflows, generating new insights and knowledge across a range of domains, including predictive maintenance, operational optimization, and environmental impact assessment.

### iAMP-Hydro Validation Sites

The iAMP-Hydro project aims to validate its technologies at five existing hydropower plants, each offering diverse conditions for testing. These plants vary in power output, climate, water flow regimes, and equipment types. For instance, Berchules, located in a dry tropical climate, is a run-of-river plant with a horizontal Francis turbine. Makrochori, situated in Greece, is a dam-toe plant with three Kaplan turbines. These differences will thoroughly test the robustness of the iAMP platform.

Baseline conditions will be established at each site, and key performance indicators (KPIs) relevant to project results will be defined. Implementation plans for digital solutions will be executed to gather data from the plants, aiding in technology co-development and forming case studies to evaluate the iAMP platform's potential impacts on plant flexibility, predictability, sustainability, and profitability.

### Collaborative Framework

At its core, iAMP-Hydro embodies a collaborative ethos, bringing together a diverse array of stakeholders spanning academia, industry, and research institutions. Through strategic partnerships and knowledge exchange, the project aims to leverage collective expertise and foster innovation in the field of hydropower management. By promoting interdisciplinary collaboration and fostering a culture of open innovation, iAMP-Hydro seeks to accelerate the development and adoption of digital solutions that enhance the resilience, sustainability, and performance of hydropower assets. Through initiatives such as joint research projects, technology transfer programs, and capacity-building activities, iAMP-Hydro aims to create a vibrant ecosystem of innovation that drives continuous improvement in hydropower management practices.

### Value Proposition

By leveraging the insights generated through advanced analytics and optimization algorithms, iAMP-Hydro aims to create tangible value for stakeholders across the hydropower value chain. From facilitating innovative operational scheduling and management strategies to optimizing asset performance and minimizing environmental impact, iAMP-Hydro offers a myriad of benefits, including improved power output, enhanced energy price stability, and socio-economic sustainability.

**Dr Israel Enema Ohiemi**
Dept. of Civil, Structural
and Environmental Engineering
Trinity College Dublin

Graphics come from the archive of **iAMP-Hydro** project.

# Utilisation of BELZONA polymer composites in industry

**Technological progress and competitiveness have made it necessary to improve the durability and reliability of machinery and equipment operated in different branches of the industry. The improvement in durability is related to the increase in the requirements placed on materials in terms of mechanical properties, fatigue and thermal resistance or physical and chemical properties related to the corrosive endurance. The durability of a material largely depends on the condition of its surface (more precisely, the surface layer). The physical and chemical state of this layer can be very different from the properties of the native material, making a number of machine's utilisation opportunities determined only by the state of their surface.**

In order to increase the service life, as well as to enable the regeneration of machine parts and equipment, special layers with predetermined repeatably reproduced properties are placed on their surfaces. Surface modification techniques also include technologies for regenerating these surfaces with BELZONA polymer composites. Application of these composites is possible in temperature range from 5°C to 35°C, and in some cases even from –5°C to 150°C. The main advantage, compared to the application of layers by high-energy techniques (such as hardfacing, metallizing and others), is that the composites can be applied under normal conditions, at ambient temperature.

BELZONA polymer composites are designed to achieve optimum resistance to factors acting directly at the composite layer. Composites designed for use in highly corrosive environments are built from components that are resistant to the corrosive medium in question. On the other hand, when a machine component is exposed to severe erosion (abrasion), they can be coated with composites reinforced with $Al_2O_3$ particles, such as BELZONA(1811) and (1812) (photo 1).

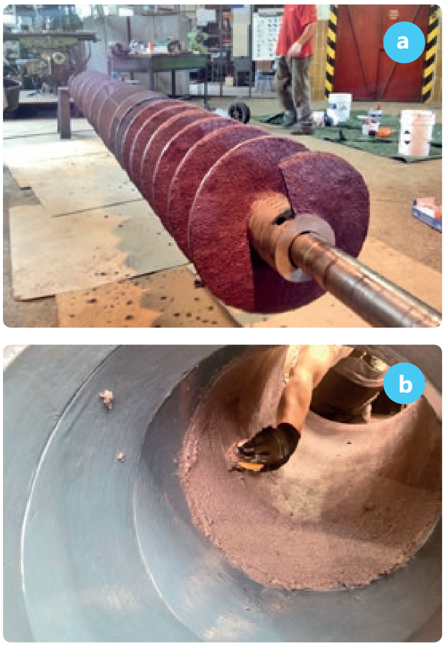



**Photo 1.** Abrasion protection with BELZONA(1811) and (1812) composites: a) screw feeder, b) dust duct elbow

## Surface repairs of machine components

When another reinforcing material is added to the polymer matrix, it is possible to obtain completely new, much better properties of the composite compared to those of its individual components. In this way, the most popular composite used in the refurbishment and modernization of machine parts, i.e. BELZONA(1111) composite, was produced. This composite was strengthened by filling its matrix with particles of alloyed steel with added silicon. These particles surrounded by a polymer matrix form a dispersion-reinforced composite. BELZONA(1111) has mechanical properties unparalleled among other polymeric materials, i.e. it behaves under load in a way similar to steel, showing elasticity (limited creep) and excellent fatigue strength. BELZONA(1111) composite can be used for repairs and surface modifications of many machine components, such as shafts, bearing housings, or large-size bearings (photo 2).

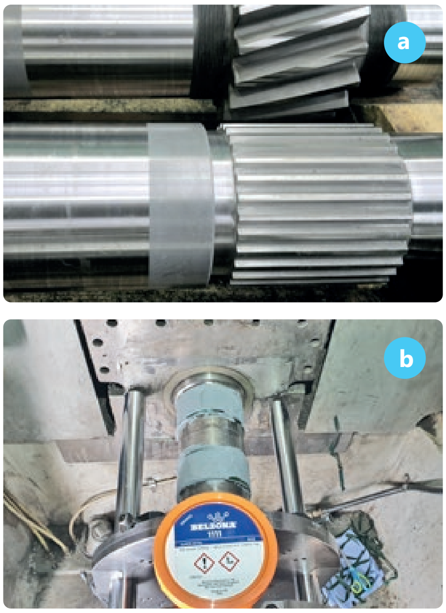



**Photo 2.** Refurbishment using BELZONA(1111) composite: a) shaft journal, b) roller bearing housing

The increase in the seating strength of the bushing presented in photo 3, compared to the same seating, but made with the use of a classical method with significant metal-to-metal contact area, resulted from the elimination of inconsistencies in the shape of the bushing in relation to the socket, errors in alignment, and the improvement of the contact surface of the parts to be seated. It is through the use of semi-fluid composite BELZONA(1321) or, for larger clearances, BELZONA(1111), that metal surfaces were "swapped" for composite ones, thus improving the strength of the seating. Structural strengthening technology using composite materials is also possible due to the excellent adhesion of BELZONA materials to applied surfaces.

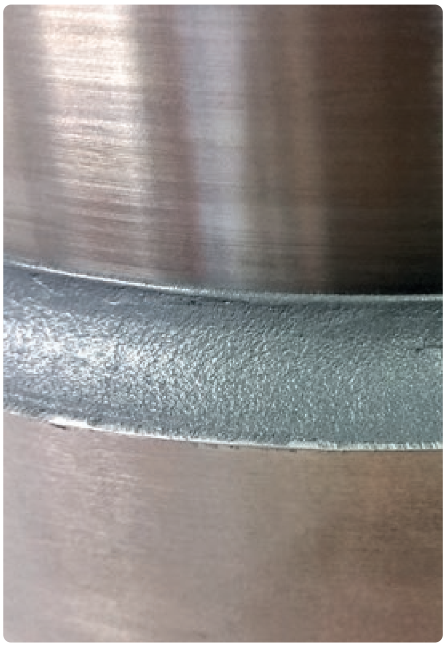


**Photo 3.** Strengthening of the structure using the technique of "cold" bonding with BELZONA(1321) composite

## "Cold" bonding technology

The adhesion of BELZONA composites to materials such as concrete, stone, plastics and rubber exceeds the strength of the substrate material. This property has been used for a whole range of "cold" bonding techniques for different materials. Using this technology, it is possible to join metal to metal elements (e.g. steel to aluminum), as well as metal elements to polymeric material, such as steel pipe to PVC one. A good example of such utilisation is also

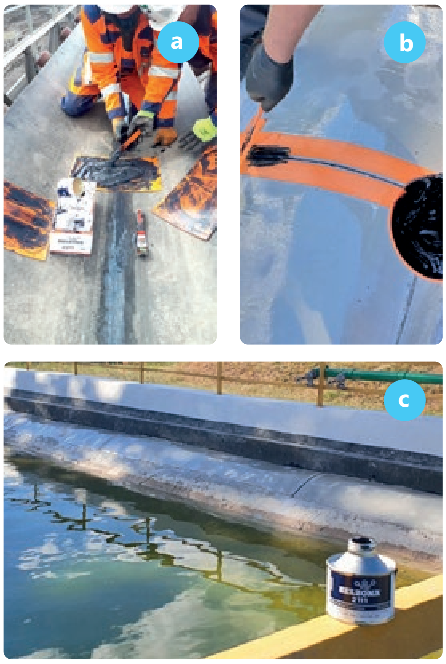


**Photo 4.** a) Repairs of damage to rubber and plastic elements, b) and c) sealing of expansion joints of fire prevention water tank

**Photo 6.** BELZONA(1341) composite coating in a rotodynamic pump

the technology for repairing and bonding of torn conveyor belts. By performing bonding with BELZONA(2131) composite, it is possible to achieve nearly 78% of the nominal strength of the continuous belt at the joint area. Meanwhile, using BELZONA(2211) or (2311) composite, it is possible to make a quick and effective repair of damage to many rubber or other elastic components (photo 4).

The aforementioned technologies for repairing conveyor belts improve the durability and reliability of their operation, in which one more technology, the BELZONA Grip System, fits in. The application of a layer of composite, externally reinforced with corundum, on the surface of the conveyor belt drive drum increases its coefficient of friction many times over. As a result, there will be no slippage during the start-up of the conveyor belt, regardless of weather conditions. Moreover, after the application of this technology, the belt pretension may be reduced by about 2–3 times, which will consequently relieve the load on the bearings on which the drum is seated, as well as the belt itself.

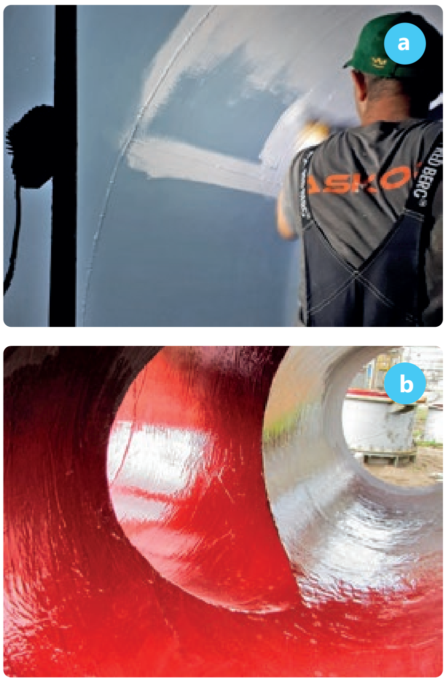


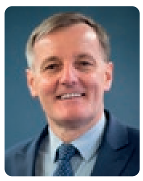
**Photo 5.** corrosion protection with BELZONA composite coatings: a) chemical storage tank, b) acidic fume outlet duct

## Corrosion protection

Excellent adhesion and good mechanical properties are also very important factors when it comes to corrosion protection, as only those outer layers of composite will protect the surface well against corrosion — so it is important that our composites adhere well to the substrate (no subsurface corrosion) and are impermeable (high resistance to microcracking and other mechanical damage during exposure to a corrosive environment). A whole group of composites used for classical corrosion protection have such properties. There are many such examples in industry, where the application of a thin layer of composite coating effectively protects surfaces from corrosion, as well as from erosion caused by aggressive chemical liquids (photo 5).

A special type of coating that also protects against corrosion is BELZONA(1341) composite coating. Applied to the inner surfaces of pump components, it significantly reduces the flow-related hydraulic losses in the device. Smooth and hydrophobic surface structure (photo 6) allows to improve the efficiency of the pump by several percent when compared with the uncoated device of the same kind.

Improved durability due to corrosion/erosion protection and due to improved mechanical seating of parts in contact with each other, as well as reduced energy consumption, are the main advantages of using BELZONA polymer composites for refurbishing and upgrading parts of machinery, equipment and facilities operated in different branches of industry. What makes it even more incredible is the fact that the mass share of the composite layer often does not exceed a mere 1% (BELZONA layer thicknesses – 0.2 to 6 mm) of total mass of the refurbished elements, and yet it is often the one that radically changes their durability!



**M.Eng. Roman Masek**
Technical Director
Belse Sp. z o.o.

Photos come from the archives of **Belse Sp. z o.o.**

# Opportunities offered by PEN@HYDROPOWER COST Action for the development of the European hydropower community

**The Pan — European Network for Sustainable Hydropower (PEN@HYDROPOWER) CA21104 is a COST Action funded during 2022–2026 by the most experienced agency at European level in financing networking projects. PEN@ Hydropower is an interdisciplinary network of researchers, engineers, scholars, and other stakeholders, such as representatives from industry, policy and civil society, to facilitate close collaboration among European research groups through projects supporting sustainable hydropower.**

New requirements in terms of operation and maintenance of hydropower plants as well as co-generation of electricity with other renewable energy sources (RES) need substantial future research. Therefore, the main aim and objective of the PEN@ HYDROPOWER is to establish and implement an effective and collaborative network in the field of sustainable hydropower sector for reaching the goal of Clean Energy Transition (CET) till 2050.

### Research objectives and building capacity

The research coordination objectives of the PEN@HYDROPOWER are following:

- evaluation and highlighting of the new role for hydropower (HP) and pumped hydro storage (PHS) within power sector, considering the flexibility and energy storage needs of the future electricity systems,
- establishment of a scientific framework for HP producers/investors to improve the performance and competitiveness of existing and new HP and PHS plants within the European electricity system, including technological innovations, environmental constraints and digitalization,
- build a collaboration platform of scientists and stakeholders to develop a holistic assessment and new approaches to support sustainable development and adaptation of the EU hydropower potential, considering the resilient infrastructure needs, the environmental and societal conditions, and the climate change forecasts for the coming decades,
- mapping the current EU legislative and market framework, the CET scenarios, and identification of policy gaps and barriers to achieving the optimum balance between hydropower production and the environmental impacts to evaluate and promote the new role of hydropower in the changing energy and market needs,
- development of a holistic scientific strategy based on consideration of digitalization, climate change adaptation, a balance between production, industrial demands (WEF nexus), and environmental impacts of increased flexibility. Understanding of social acceptance, controversies, and policy improvement needs.

The capacity building objectives of the PEN@HYDROPOWER are following:

- increasing the existing technical network by including additional disciplines, such as social, environmental and computer sciences through stakeholder outreach activities,
- bringing Early Career Investigators (ECI) into leadership positions while aiming for gender balance via a mentoring program,
- fostering career development of ECIs through joint PhD programs, knowledge transfer and Training Schools, with different disciplinary perspectives on sustainable HP and cross-disciplinary collaboration,
- awareness creation for the importance of HP in the energy mix with focus on policymakers (in particular Europe) and industry via targeted dissemination activities.

### COST Action activities

In PEN@HYDROPOWER, the core of the COST Action activities is carried out at the Working Group (WG) level. WGs perform the tasks to fulfill the objectives of the network's project plan, as described in their Memorandum of Understanding. As a result, five WGs operate within PEN@HYDROPOWER covering the following topics:

- WG1: Hydropower Role in Flexible Energy Synergies focus mainly on the conditions for the use of hydropower within flexible systems. Attention will be paid to the assumptions and trends of electricity accumulation for various water sources and conditions, innovative systems and monitoring options.
- WG2: Technological Evolution Through Innovation & Digitalisation pays attention to the technological evolution requirements for innovative solutions to tackle the foreseen ambitious scenarios. Additionally, digitalization aspects are considered. They will pave the way toward increasing hydropower competitiveness and enhancing grid flexibility, stability, safety, and resilience. Multidisciplinary approaches (mechanical and electrical engineering, ICT, environmental engineering, trading) will achieve these goals, combining massive sensor deployment, AI and big data processing, building forecast models, and digital twins.
- WG3: Sustainable hydropower and its adaptation to climate change supports cross-disciplinary collaboration to facilitate sustainable development in the hydropower sector which considers economic-, environmental- and societal needs in a changing climate. To enhance the sustainability and resilience of hydropower systems, a holistic systems analysis approach is needed, requiring transdisciplinary collaboration that accounts for technical, environmental, and social challenges. Finally, climate change projections have to be incorporated into the analysis in order to mitigate potential impacts of climate change.
- WG4: Clean Energy Transition and policy measures focuses on understanding and identification of major trends, restructuring the power sector in the following decades. Within the process, cross sector couplings is identified and novel hydropower role is evaluated. Evaluation is conducted based on EU frameworks and directives, CET and trends.
- WG5: Holistic assessment and stakeholder interaction addresses an urgent need for holistic assessment of hydropower using much improved stakeholders interaction was identified. By holistic the Action means realizing of all aspects of hydropower, not only technical (e.g.,


**Source:** Author's archive

**Fig.** Commemorative photo of the participants of the first coaching school, held May 9–12, 2023 in Timișoara, Romania

lifetime extension) or environmental (e.g. biodiversity, local climate change), but also societal (reception by residents) and financial (e.g., return of investment and reasonable profitability). Policy suggestions based on PEN@Hydropower best practices and future scenarios as well as stakeholders outreach and engagement.

PEN@HYDROPOWER contributes to establishing a fruitful network based on joint activities and social interactions to promote stronger knowledge creation and sharing within the industry, end-users, and academic communities belonging to the European hydropower and broader energy sectors. In particular, to support the creation of new and novel ideas we enforce during the WG meetings, an inclusion and exchange among the PhD students of the participating research groups, so ideas can better be transferred. PEN@HYDROPOWER is an excellent framework for individuals at every stage of their career to discover exciting opportunities, meet new connections, and broaden personal research horizons.

## Summary activities of PEN@HYDROPOWER

PEN@HYDROPOWER organized the following type of actions covering the hot topics in the hydropower field:

- meetings, working group meetings, workshop and conferences,
- short-term scientific missions (STSM) allow researchers involved in PEN@HYDROPOWER to visit an institution or laboratory in any country in the world. Their aim is to foster collaboration and share new techniques and research infrastructure that may not be available in a participant's home institution or laboratory. STSMs provide a good opportunity for both young and experienced researchers looking for mentoring and lifelong learning. Five STSM actions took place throughout the 1st Grant Period (GP1),
- training schools (TS) offer intensive training on Sustainable Hydropower topic. These schools offer researchers from any career stage, lifelong learning opportunities. TSs program incorporates theoretical and practical knowledge in the field of hydropower. Several TSs are planned to be organized by PEN@HYDROPOWER within different European areas (Eastern, Western, Southern, Northern) during each grant period. The first training school (TS1) within PEN@HYDROPOWER was organized with 26 participants between May 9–12, 2023 in Timișoara, Romania. The next two training schools will be organized between May 7–10, 2024 in Thessaloniki, Greece and September 3–6, 2024 in Porto, Portugal,
- conference grants are aimed by PEN@HYDROPOWER participants and in particular at young researchers from Inclusiveness Target Countries. They help individuals attend beneficial international conferences that are not organized by PEN@HYDROPOWER or other COST Actions,
- communication and dissemination are for sharing scientific results of vital importance in strengthening science and research. This actions to share results with researchers, policy makers, the private sector and civil society such as NGOs are especially targeted because of the value and impact that communication and dissemination activities can have on the community.

Today, the Management Committee (MC) of PEN@Hydropower includes representatives of 34 countries. The MC has the role of coordinating and supervising the implementation of the COST Action. More than 200 applicants from 38 countries around the world are involved in the activities carried out by the 5 WGs. We invite you and your colleagues to join the PEN@HYDROPOWER community to build the future of hydropower together.

## Acknowledgements

This publication is based upon work from COST Action "Pan European Network for Sustainable Hydropower" (PEN@Hydropower) CA21104 supported by COST (European Cooperation in Science and Technology).

**Sebastian Muntean**
Romanian Academy – Timisoara Branch

**Ewa Malicka**
Polish Association for Small Hydropower Development TRMEW


Source: Philipp Habring / MZS

# The new EU legislative period – issues and new opportunities for hydropower

**The actual legislative situation in Brussels, driven among other things by the initiative of the European Green Deal, is affecting many sectors of the community's economy, including hydropower. It requires the active participation of industry representatives in the development of further legislation in order to protect the current position of this energy sector. However they create opportunities for the adoption of positive solutions as well. This article summarizes both past achievements and upcoming challenges from the perspective of the European Renewable Energy Federation (EREF).**

The current European legislative period (2019 to 2024) has been defined by the European Green Deal presented by the President of the Commission, Ursula von der Leyen, in November 2019. This Green Deal should set the course for a modern, resource-efficient and competitive economy that achieves net-zero greenhouse gas emissions by 2050, decouples growth from resource use and makes this transition fair and inclusive for all.

In recent months, The EU institutions finalised their negotiations on new and revised EU legislative procedures provided for under the European Green Deal under high pressure until the end of February 2024 so that the European Parliament can formally adopt them by the end of its session in April 2024.

## Legislative battle for hydropower

Despite facing strong opposition to small-scale hydropower, the political work of national and European associations has led to successes in favour of hydropower, which will now form the basis for the coming years. Of particular significance is the establishment of the legal principle of overriding public interest for renewable energies, including hydropower. In addition, the EU institutions have been instructed to integrate this legal principle into existing and new European nature conservation legislation.

The new legislative period will see the revision of the Water Framework Directive. After more than 20 years, this presents an opportunity for the sector to adapt restrictive legal passages to the fact that hydropower and the good ecological status of a river can go hand in hand. Small hydropower plants create habitats for rare and valuable aquatic plants and birds as well as for fish, enrich the waters with oxygen and clean the rivers of all kinds of floating debris. The same applies to the finalisation of the definition of free-flowing rivers. It should be emphasised here that, at this stage of the negotiations, there is a broad consensus not to demolish any existing hydropower plants. In conjunction with the national implementation of the new EU regulation on nature restoration, only barriers that are no longer needed for energy production, shipping, water supply or flood protection should be removed. In this context, EREF continues advocating for detailed case-by-case assessments of barriers in order to secure the future potential for small hydropower.

## New electricity market design

Even though the agenda for the new EU legislative period is still being discussed, indications suggest that the debate on a new design for the electricity market will continue.

The new agreement on market design from December 2023 emphasises the extension of the service life of power plants (repowering) and the promotion of flexibility as key issues for the hydropower sector. However, there is still a lack of business models on flexibility from which hydropower owners could potentially benefit. Furthermore, the distinction between storage and run-of-river power plants ignores the continuum of flexibility performance of hydropower plants. A possible solution could be drawn from the United States, where flexibility is assessed through the MW-mile tariff. This approach ensures that the remuneration is proportional to the length of the load curve in order to support flexibility sources compared to generation with a flat load curve.

A Bavarian study on hydropower plants generating less than 1 MW concludes that run-of-river power plants have a potential modulation capacity of 800 MW. For France, initial estimates suggest a modulation potential of 300 MW over a two-hour period for hydropower plants under 10 MW, which is equivalent to the output of thousands of batteries. Moreover, other hydropower services such as black start, congestion management and voltage regulation within distribution grids should be remunerated. Hydropower plants contribute to the stability of distribution grids, thus facilitating the increased production of green electricity from variable renewable sources, especially from photovoltaic systems.

### Accelerated decarbonisation needed

The need to accelerate the decarbonisation of the European economy has become increasingly evident, particularly in light of the breach of the 1.5°C limit in the last twelve months and the escalating frequency of climate-related disasters. EREF therefore advocates for the resolute and full implementation of the European Green Deal and a clear and ambitious policy path for the next decade from 2030 to 2040 as a priority for the new EU legislature. With regard to the recently set target to reduce European greenhouse gas emissions by 90% by 2040, EREF urges the newly elected EU decision-makers to establish correspondingly high targets for a renewable energy expansion for 2040. At the same time, EREF calls for the expansion of hydropower to be included as an explicit item on the new EU agenda and for the development of a dedicated action programme to advance this objective.

### RED implementation

At national level, the implementation of the Renewable Energy Directive (RED) is pending. According to the RED, the decision to include hydropower in the national acceleration areas for renewables lies with the Member States. In addition, it should be ensured that national governments adhere to the proposed accelerated authorisation procedures for hydropower projects.

With the support of its members, EREF will inform the newly elected decision-makers in the European Parliament and the European Commission about the benefits and opportunities of hydropower and continue to advocate for its expansion.

**Dirk Hendricks**
Secretary General
European Renewable Energies Federation (EREF)

## Industry catalog



Fig. 1. View of the SHP Pilzno with the weir and the accompanying fish ladder for aquatic fauna

# Repowering of the SHP Pilzno

**The small hydropower plant (SHP) Pilzno has recently undergone repowering. The task set for the designer and the supplier of technology was all the more challenging as the facility is relatively "young" and has been characterised by a high technical standard from the beginning. So let's take a look at how its modernisation has been undertaken and what the results are.**

As an introduction, it is worth outlining the historical background of the construction of the hydropower plant. The SHP, picturesquely located on the edge of the Carpathian Foothills, was built at the same time as the accompanying rubber dam, i.e. in 2000. It is located on the right bank of the Wisłoka river. A river damming with a span of approx. 100 m (the rubber dam alone measures more than 70 m in length) was constructed south-east of Pilzno in connection with the reclamation of the aggregate post-mining area. The flooding of the area between Strzegocice and Mokrzec led to the creation of a water reservoir of over 140 ha. The investment landscape is complemented by an impressive over 400-metre fish ladder for aquatic fauna, completed in 2021, in the form of a bypass channel consisting of 45 stone pools[1] .

## Impulse for action

Among the modernised facilities that we have so far had the opportunity to talk about in "Energetyka Wodna" magazine, the SHP Pilzno stands out in several respects, both technically and in terms of optimising the business side of the project. The investment is an example of good practice. The decisive driver for the owner to replace the generation system with the accompanying infrastructure was the ending support for the production of green energy. A necessary condition to be met in order to participate in the new scheme was the implementation of a completely new RES installation to the extent consistent with the statutory definition and interpretation of the Energy Regulatory Office (URE).

A separate issue that was taken into account was the degree of wear and tear of the equipment currently in operation and the overall efficiency of the system, which left room for optimisation (especially as the facility was affected by flooding in 2010). In the course of the conceptual analyses, it was established that the modernisation would enable annual production to be significantly higher than that recorded to date.

The business model developed in the initial stage, together with financial analyses, formed the basis for the investor's decision to launch the project. Equally helpful was the multi-variant technical concept, which allowed different configurations to be traced and the most optimal solution to be recommended in terms of cost and technical-economic efficiency.

## Technological and functional puzzle

The project involved the dismantling of the existing hydro units and the construction in their place of three highly efficient gen-

Fig. 2. Transport of the turbine runner

[1] https://wislokabezbarier.com/mokrzec-rzeka-wisloka/

Fig. 3. Installation of the Kaplan turbine case

**Sebastian Wites,** Chief Automation Officer at IOZE hydro

*Thanks to the use of synchronous generators with permanent magnets (produced on special order), which cooperate with the turbines without the use of a gearbox, we have not only achieved a higher efficiency of the entire system, but also a noticeable improvement in the operating culture of the equipment. It is now extremely quiet inside the machine room, even when operating at full power.*

*Moreover, when designing our control and automation systems, we pay particular attention to their usability. We are keen to ensure that the SCADA application is ergonomic, as simple and intuitive to use as possible, while at the same time providing maximum data on the operation of the equipment and its condition. The basic assumption in its development is to achieve the most efficient operation of the generation system. It is how hydro units operate and in what combinations that is the result of a number of factors: hydrological, technological and functional. The control system's task is to make use of the maximum of the current resources on which it operates.*

*It is worth emphasising that the change in technology at the SHP Pilzno to a system of three independent RES installations is a very interesting practical procedure which, in the case in question, translates into concrete, highly satisfactory electricity production performance, sold at the highest available price. This is because, among other things, it is possible to automatically maintain the set water level for the indicated RES installation whose operation is most economically advantageous at a given time. The machines can operate independently of each other, in adjustment to factors resulting from the support scheme in which the system is registered and current energy prices. The SHP is also prepared to provide system services in addition to generation only. The control system can cooperate with an energy trading company by directly and automatically adapting the facility's operation to the current energy sales conditions.*

*What is important from the perspective of the use of the installation — as part of our services, we provide remote supervision over the correct operation of hydro units, and in the event of incidents — if possible — we remotely remove their causes. Our service technicians are also available if any work is needed in the facility.*

erating systems, representing separate RES installations with individual power connections for each. This, of course, involved obtaining separate connection conditions and concluding separate connection agreements, and later distribution agreements, resulting from the planned form of electricity sales. The investment has been submitted to both the RES auction and the FIT/FIP support scheme. Finally, two of the newly completed generating systems qualified for the sale of energy at the guaranteed price obtained in the auction, and one generates energy that is sold under the FIP scheme. Both forms of support will last for the statutory period of 15 years, which significantly affects the profitability of the project.

In addition, the control system implemented for the facility makes it possible to manage the operation of individual new RES installations both independently and interdependently. In practice, this means that when available flows are too low, the facility operator may decide which generating system is currently operating in the most cost-effective manner. Ultimately, the new SCADA solution will allow this to happen automatically.

What is still worth mentioning in terms of the technical scope of the project is the construction work carried out in the facility. The installation of the new hydro units required the reconstruction of the concrete surfaces of the inflow chambers, as well as the suction pipes and the ceiling of the building. It was also necessary to install additional guides to allow the safe and precise placement of the approx. 7-tonne turbines and a similar weight of generators. The scope of the facility's structure correction was designed and constructed to suit the needs of the operation of the equipment.

### New operating culture of the facility

The three new RES generating systems are equipped with classic vertical Kaplan turbines with an installed capacity of 300 kW each, working together with synchronous generators excited by permanent magnets. This is an innovative solution in terms of SHP standards, as up to now the use of generators of this type was associated with the need to support the operation of the plant with inverters. The turbine controller system implemented in the facility allows stable operation with an efficiency of up to

Fig. 4. Model of the SHP developed at the conceptual stage

Fig. 5. From top: turbine cases awaiting installation, turbine chambers

Fig. 6. View of the interior of control cabinets

97%. There is no need for reactive power compensation in this case. Additional information, among other things, in this respect is presented in the box.

### Turbine production from the inside

The new quality in the SHP facility is reflected not only in the method of its control, but equally in the technology of the installed equipment. We can find a few words on this subject in the statement of the turbine design engineer.

## Andrzej Kuszak,

Mechanical Design Engineer
at IOZE hydro

*IOZE hydro turbines have the advantage over the so-called old generation turbines that their shape is the result of highly advanced CFD simulations. We conducted the simulations in collaboration with world-class specialists in computational fluid mechanics and flow machines. Thanks to this, the hydromechanical efficiency of our turbines is much higher than that of dismantled hydro units and allows for increased electricity production yields at the same available flow. Additionally, in the case of the investment in question, the renovation of the suction part of the system led to the elimination of flow disturbances that previously reduced the efficiency of the hydro units. Another issue is the elimination of waste of available flow thanks to the turbines designed and constructed by us, to which we pay special attention.*

*It is worth mentioning that the mechanical solutions used in the systems installed in the SHP Pilzno are definitely more environmentally friendly than the old installation. There are fewer components requiring lubrication, so there is minimal risk of leakage. The components used are produced in such a way that they generate the smallest possible carbon footprint (we even use a special calculator to calculate the carbon footprint). In addition, we try to optimise these structures on our own so that the consumption of* *materials is as low as possible and so that as little waste as possible is generated during production. The intensive work of our technologists focuses on planning the production of turbines in accordance with the 6Rs principles (Rethink — Refuse — Reduce — Re-use — Recycle — Repair). Our products not only generate clean energy, but their production is also focused on environmental friendliness.*

**Fig. 7.** Interior of the facility after repowering

**Summary**

The investment we discussed here is an expression of a flexible approach to the challenges faced by the owners of SHPs to maintain the highest possible profitability in the operation of their facilities under evolving market conditions. The cooperation of the investor with IOZE hydro's consultancy and design team in the case of the SHP Pilzno was based on the assumption of comprehensiveness of services and resulted in the resumption of operation of the modernised facility from January 2024 and the first energy produced since then (nearly 2,000 MWh).

As shown above, in the case of the installation in question, despite the relatively good technical condition of the power plant, it was worth repowering and ensuring a profitable period of its operation. It should be stressed at this point that investments implemented by IOZE hydro are practically never limited to the mere supply of technology. This is due to the deep awareness that hydropower projects are so complex that even seemingly insignificant formal oversights, e.g. in the case of the procedure at the Energy Regulatory Office, may make it impossible to implement the assumptions that affect profitability. The cooperation of investors with an experienced team helps to avoid many pitfalls.

In addition to the supply of technology, the owner of the SHP Pilzno received full support in the administrative process, during procedures related to obtaining certificates from the Energy Regulatory Office, as well as in obtaining funding for the project through intermediation in discussions, preparation of the necessary analyses and fulfilment of formalities with the bank. The construction design was also prepared by engineers who create and optimise hydropower plants on a daily basis. As a result of the efforts of the Investor and the consultancy and design team, the guaranteed energy sales price obtained for the individual installations is almost three times higher than would have been possible for the same facility if the modernisation had not been carried out. Every successfully completed project begins with the belief that it will bring real, measurable benefits to the investor. IOZE hydro ensures that the basis for such a belief has strong professional justification.

Finally, for the sake of accuracy, it should be emphasised that in the case of the SHP Pilzno, the legislation and official interpretations of the Energy Regulatory Office in force at the time of the procedure were used. The aforementioned procedure of replacing all the equipment of an existing SHP installation with new equipment, which is herein referred to as repowering/modernisation, was treated by the Energy Regulatory Office in the same way as the construction of a new RES installation, and thus made it possible to obtain 15 years of support under the FIT/FIP scheme. The current situation is no longer so simple and unfortunately not all power plants will be able to undergo a similar process, but for some facilities the possibilities discussed above are still available. We stress that each case should be treated individually, with a precise approach to formal and legal issues and the planning of the entire process in order to guarantee the achievement of the desired business objective. This paper presents one example of good practice in the optimal use of hydropower potential as well as formal opportunities to intensify the benefits of hydropower activities — in line with the slogan "Turn water into profits".

**Wioleta Smolarczyk**
Business development coordinator
IOZE hydro

Photos and graphics are from the archives of **IOZE hydro.**

# Pumped storage as backbone of the energy transition on an international level

**Dynamic changes in the structure of national energy mixes worldwide, resulting in an increased share of unstable energy sources such as wind and solar power plants, have caused energy system operators to face unprecedented challenges in balancing the grid. Currently, the only effective solution to this problem is pumped-storage power plants. This article reviews selected case studies involving investments in these large-scale energy storage facilities.**

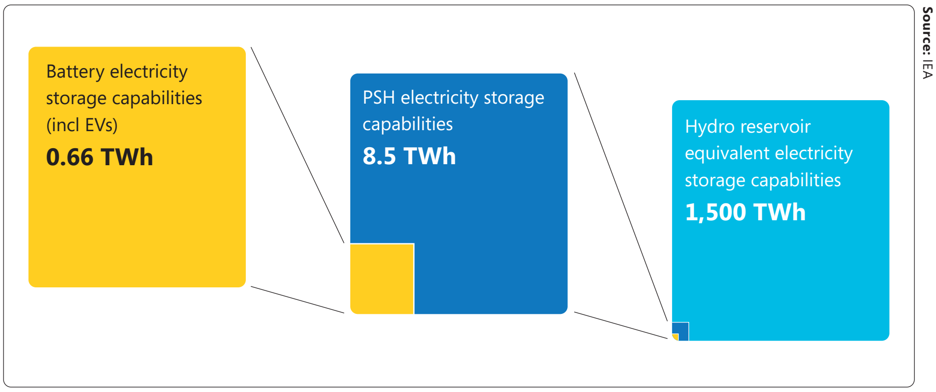



**Fig. 1.** Worldwide installed storage capacity in the electricity and mobility sectors

Hydropower is the world's largest renewable energy source, accounting for 15% of global electricity generation [1]. This makes hydropower's contribution greater than that of nuclear power and greater than that of all other renewables combined, including wind, solar PV, bioenergy and geothermal. It is the forgotten giant and the backbone of low-carbon electricity, providing almost half of the world's green electricity today [2]. Hydropower should therefore play an important role in the energy transition because it is a proven, mature, predictable and competitively priced technology. In addition to low $CO_2$ emissions, the technology is extremely efficient and has an extremely long plant service life. As a flexible and grid stabilizing energy source, hydropower enables the integration of wind and solar power.

## Long-term proven energy storage technology

Pumped storage technology is currently the only long-term, technically proven and cost-effective way of storing temporarily energy on a large scale and making it available at short notice. However, traditional storage power plants also make an important contribution to electricity storage, as the natural water inflow is only converted into electricity when needed. Fig. 1 illustrates the storage capacities installed worldwide using hydropower and compares these with the battery storage capacity installed worldwide [2]. On the left, the total installed battery storage capacity worldwide for 2021 is shown, i.e. stationary battery storage including also all batteries in electric vehicles: this amounts to less than 1 TWh worldwide. For comparison: the annual energy demand in the form of electricity in Germany is approx. 500 TWh, i.e. all the batteries in the world could cover the electricity demand in Germany for just half a day. The total storage capacity of pumped storage is shown in the middle, which is 13 times greater than the battery capacity. If you also compare these two figures with the classic water storage power plants, a completely different picture emerges, as their storage capacity amounts to 1,500 TWh and is therefore 2,200 times greater than all chemical battery storage facilities combined.

In its "Hydropower Special Report", the International Energy Agency (IEA) emphasized the following facts in addition to this comparison [2]:

1. existing and new storage power plants and pumped storage are the most affordable sources of flexibility in the electricity sector today.
2. hydropower is the only very low-carbon electricity generation technology available that is capable of storing large quantities of electricity on a seasonal basis.
3. these capabilities will be essential for the cost-efficient and safe operation of intermittent renewable energy sources dominated power systems of the future.

Many countries have already recognized this great potential. The leader in terms of existing pumped storage capacity within the EU is Italy with 7.2 GW. Outside Europe, however, China, Japan and the USA top the list with many times the Italian capacity [3]. In Germany, extensive measures to expand or modernize hydropower plants and pumped storage in particular have yet to be implemented.

A pumped storage power plant stores electricity in the form of potential energy. The basic principle of energy conversion is shown in Fig. 2. In pump mode (charging), electrical energy is taken from the electrical grid to feed a motor that mechanically drives a pump. The water is pumped from the lower basin into the upper basin. In the turbine mode (discharging), the water simply flows downhill via gravity and drives a turbine. The turbine then drives mechanically the generator rotor and the electri-

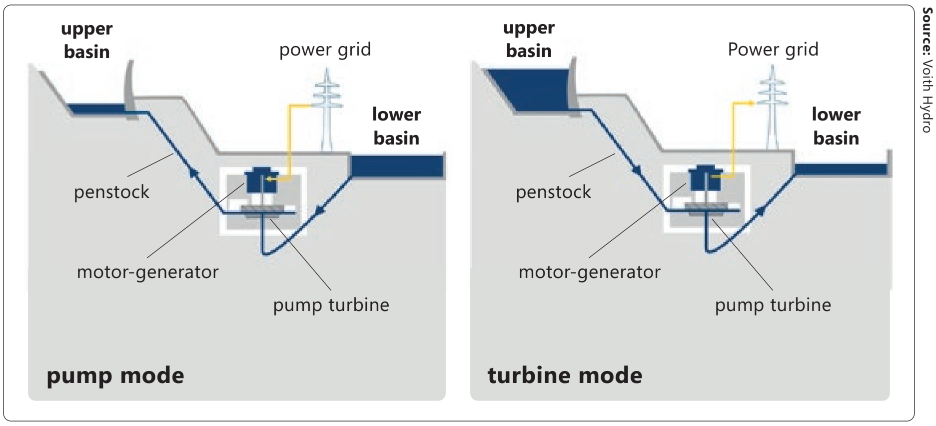



**Fig. 2.** Functional principle of a pumped storage system

cal energy returns from the generator stator to the electrical grid (for more details please refer to [4]).

### Global challenges in the electrical grid – from Germany to Down Under

Electricity systems with a high proportion of RES (Renewable Energy Sources) are confronted with new situations and require additional flexibility. Fig. 3 shows the load profile in the month of January in Germany and the PV and wind feed-in into the transmission grid of the transmission system operator (TSO) in 2019. Five years later, the situation regarding the need for flexibility due to the expansion of RES and weather events is even more dramatic and grid operators in Germany have to "master" mainly 4 different situations:

1: RES feed-in exceeds load demand for hundreds of hours per year,
2: very steep positive and negative load gradients must be controlled,
3: low feed-in from wind and PV over days and weeks ("dark doldrums"),
4: forecast errors for wind and PV due to unexpected special weather conditions.

Another example of such challenges is illustrated in Fig. 4. It shows the current situation in the state of South Australia for a representative week in November with a significant feed-in of wind and solar power. The state of South Australia has shut down some years ago all its own coal-fired power plants and at the same time increased continuously and rapidly the share of RES. The consequence was that enough capacity of gas-fired plants had to be built up in parallel.

In Fig. 4 the PV feed-in is shown in yellow and the wind feed-in in green color. The different shades of orange represent gas-fired power plants that must run continuously and in parallel with the volatile renewables, even if wind and PV could completely cover the load demand. In these cases, excess energy is exported to neighboring states, sometimes for negative electricity prices. The main reason for this is to maintain a minimum of critical rotating mechanical inertia in the event of grid or generation outages. Another reason for gas-fired power plants to operate in this way is that they have to compensate for the volatility of wind and PV 24 hours a day, 365 days a year in order to ensure consumption and frequency stability at all times. Very steep load gradients and other extreme situations in which there was no wind and no PV feed-in can also be seen in the middle of the load curve (analogous problem shown in Fig. 3).

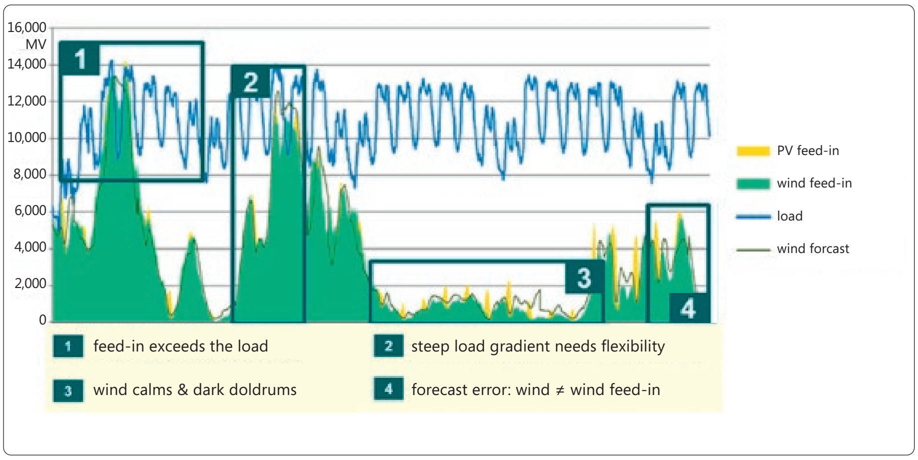
This figure also illustrates why Australia has decided to invest in seasonal pumped-storage power plants rather than solely in chemical batteries. Several pumped-storage power plants are currently under construction, including the "Snowy 2.0" project. The small white rectangle depicts the contribution of the large Tesla battery in Hornsdale with a capacity of 100 MW and a maximum storage capacity of 129 MWh. The future contribution of the Snowy 2.0 pumped-storage power plant, with a maximum power of 2.2 GW and a storage capacity of 350 GWh, is illustrated by the large rectangle in grey color, representing the total storage capacity. The storage capacity of Snowy 2.0 is 2,500 times greater than the Tesla battery, allowing it to store electricity for a week without sun and wind, rather than just for an hour. It should be noted that this area can also be imagined as a mirror image downwards on the negative y-axis in pumping mode. This is because Snowy 2.0 will provide a total flexibility range from – 2.2 to + 2.2 GW. With this flexibility and the rotational inertia of the six reversible hydro units, it is possible to shut down many gas power plants in the region to lower electricity costs for consumers and reduce $CO_2$ emissions.

### Addressing the challenges – Decarbonization activities in China and India

Other countries are facing similar challenges and are also tackling them with determination. Fig. 5 describes the electricity mix in China in 2020. The annual electricity consumption in China is approx. 6,800 TWh (Europe: 3,300 TWh, Poland: 170 TWh). Since 2019, the country's decarbonization activities have been progressing steadily despite increasing electricity demand. After all, under the Paris Climate Agreement, China has committed to peaking its greenhouse gas emissions by 2030. The installed capacity of PV and wind was 21% of the total installed generation capacity in 2019, but less than 9% of the electricity generated. One reason for this discrepancy was the curtailment of RES — up to 25% — due to a lack of bulk energy storage systems and grid transmission capacity.

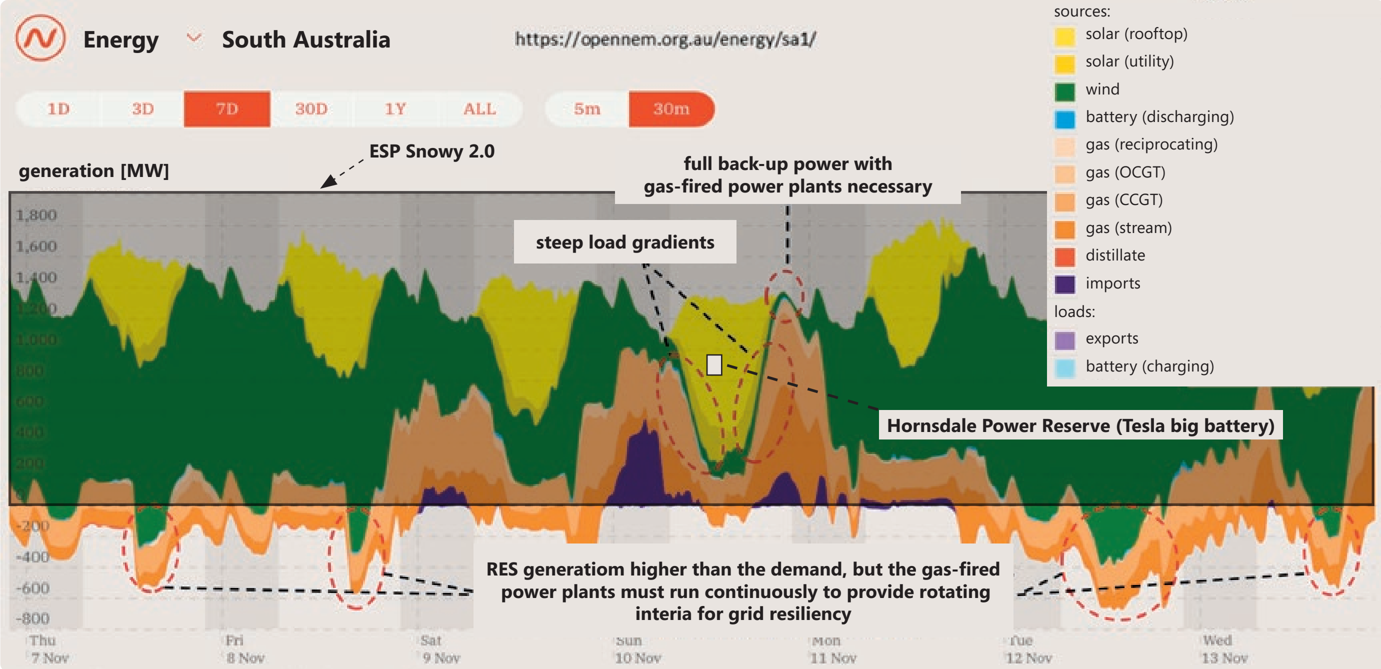
In addition to the massive expansion of RES, the decarbonization efforts also include the further expansion of nuclear power plants. In 2023 53 GW of nuclear power plants were in operation and approx. 22 GW under construction. Another crucial element of the decarbonization activities is the very strong expansion of the pumped storage fleet shown in Fig. 6. The expansion plan for pumped storage envisages a fourfold increase from 30 GW in 2019 to 120 GW in 2030. And this plan is not just a declaration of intent, but a done deal: 10 pumped storage projects alone were awarded on the market in 2023, with a further 12 new projects to follow in 2024. The new pumped storage fleet will reduce in future significantly the past RES curtailments and will ensure the base-load operation of the increased nuclear power plant fleet. These activities are accompanied by a corresponding expansion of the high-voltage transmission grid.

For over 20 years, the Chinese energy industry has clearly defined who builds the pumped storage facilities and who oper-




Source: Vattenfall

Fig. 3. Load profile, wind and PV feed-in in January 2017 in MW




**Source:** Matthew Stocks, Australian National University, World Hydropower Congress, Sep 2021

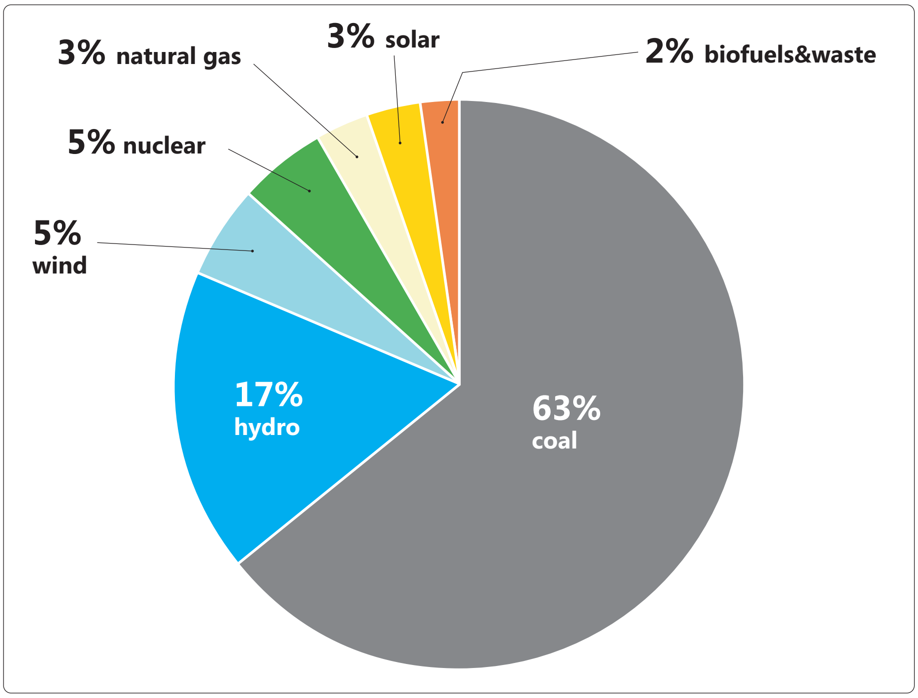
**Fig. 4.** Weekly load profile with RES feed-in and gas-fired power plants in South Australia, storage contribution of pumped hydro Snowy 2.0 and compared with the Li-ion battery

ates them from then on: these are the two big TSOs, State Grid (SGCC) and China Southern Power Grid (CSPG). The refinancing and remuneration of the power plants is also clear and characterized by two components: In addition to remuneration for the amount of energy supplied during turbine operation, there are also capacity payments that cover important services such as frequency and voltage regulation, and black start capability [5].

In the north-east and north-west of China, existing and new pumped storage plants are taking over the integration of volatile RES. This includes smoothing the intermittent load profile, voltage regulation and the provision of rotating masses for grid stability. In the rest of China, pumped storage plants often take over peak load shaving and grid frequency control. This avoids fossil-fueled peak load power plants and smog in and around urban centers.

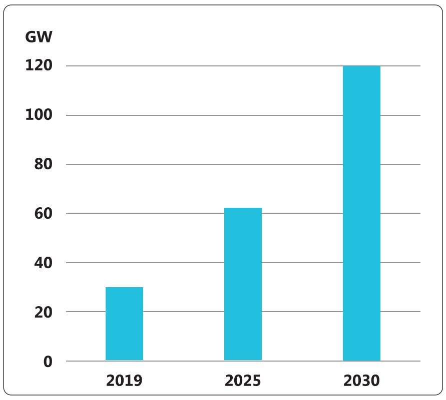
Similar to China, the expansion of solar, wind and hydropower is just as strong in India. The installed capacity of wind and PV parks is expected to almost triple by 2030: from 150 GW in 2023 to 450 GW in 2030. In order to stabilize the Indian grid during this tremendous expansion of RES, the pumped storage fleet must be expanded according to Fig. 7. At the end of 2022, 23 pumped storage projects with a total capacity of 25.6 gigawatts were in the project pipeline across the country. In addition, the expansion of decentralized and mainly grid-serving 5h battery storage systems are also planned to smooth out volatility and temporarily store renewable energy. These measures will be accompanied by further grid reinforcement in the medium and high-voltage range.

One lighthouse pumped storage project in India, which is under construction is a hybrid project where the pumping energy is mainly provided by the wind and PV farms in the immediate vicinity of the pumped storage plant (see Fig. 8). This hybrid project that combines a 1.2 GW of pumped storage power plant PSH with 2 GW of solar farm and 400 MW of wind towers and forms one electricity balancing area with a common switchyard. The main purpose of this facility is to convert the very volatile generation of the wind and solar farms into dispatchable electricity production. The second purpose is to do this with a very low $CO_2$ carbon footprint. The main $CO_2$ footprint contribution is the construction phase. During operation the $CO_2$ footprint is almost zero. The pumping energy is supplied by the collocated wind and PV park. Short time exceptions are necessary when starting the 240 MW or 120 MW pumps utilizing the grid connection since both the wind park




**Source:** world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx

**Fig. 5.** Electricity mix in China in 2020




Source: China – Policy and Market Frameworks Working Group, Pumped Storage Hydropower International Forum, CSHE, CREEI, September 2021

**Fig. 6.** Forecast for the development of pump hydro in China until 2030

and the solar park do not provide any rotating mechanical inertia.

It was also interesting that this project was awarded through a competitive auction in 2020 by the Indian government. The auction details are also interesting [6]:

- for the renewable energy supplied during off-peak hours, the pre-specified tariff is 4.00 USD cents per kWh,
- for the pumped hydro storage plant a weighted average tariff of 5.61 USD cents per kWh and a quoted peak tariff of 8.50 USD cents per kWh was offered. 900 MW out of 1,200 MW were secured capacity with this tariff,
- six hours daily for peak tariff are foreseen during the peak demand windows: 5:30 – 9:30 am and 5:30 pm – 12:30 am, on a day-ahead and on-demand basis,
- these tariffs are granted over a 25-year period of time, which is very important for the investment security.

## Increasing the flexibility and grid resiliency in Lithuania

One European example is the expansion of the Kruonis pumped hydro power plants in Lithuania. As illustrated in Fig. 9, only 4 out of 8 units were built. The first reversible pumped storage unit with fixed speed began operating in 1992, while the fourth one began operating in 1998. The current capacity is 900 MW with 4 units in operation. The individual unit capacity is 225 MW in generator mode and 200 MW in pump mode. The full upper reservoir can provide today 12 full load hours in turbine mode. The head variations are from 95 m to 115 m.

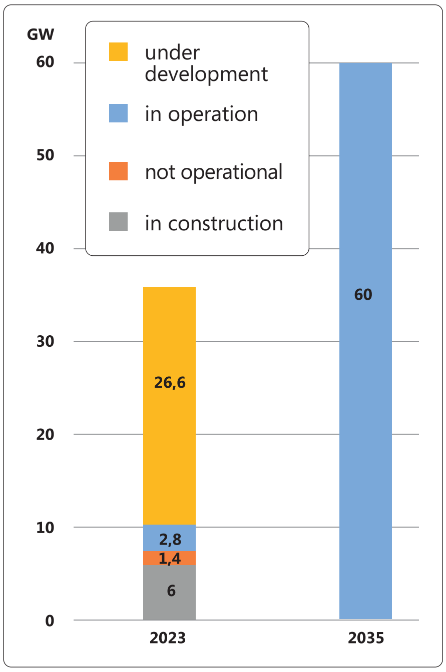
In 2023 Voith Hydro was awarded the engineering and manufacturing of a fifth new unit, which will be quite unique in the world. This will be a variable-speed unit using a 110 MW / 130 MVA converter connected to the stator of the motor-generator (see Fig. 10). This converter feeds directly the stator of synchronous designed machine with 12 pairs of salient poles. Some new challenges had to be taken up. The first challenge is the spatial integration of the largest converter in the world for a hydro power unit in an existing powerhouse. The result and sizing of the chamber for the converter station can be seen in Fig. 11.

The second challenge is the head variation from 95 m to 115 m, but this is no problem for a variable-speed unit. Special and new features of this solution are:

- utilization of a Modular Multilevel Converter (short MMC) with a very high averaged efficiency. The supplier is Hitachi Energy, who bought some years ago the ABB branch for HVDC lines including the converters (HVDC: high-voltage DC lines),
- with this full converter solution, a direct start of the pump in water is possible and leads further to very fast load changes in pump and turbine mode. For instance, no blow down system is necessary for dewatering the runner for a pump start,
- the anticipated power control range in pump mode is from 50 MW at low head conditions up to 110 MW (full load), which will offer a significantly higher flexibility for the grid load dispatcher,
- the synchronous machine is running always with cos phi = 1 since the converter is controlling the reactive power on the grid side,
- the converter can also control the reactive power for the grid, even if the power unit is in stand still conditions.

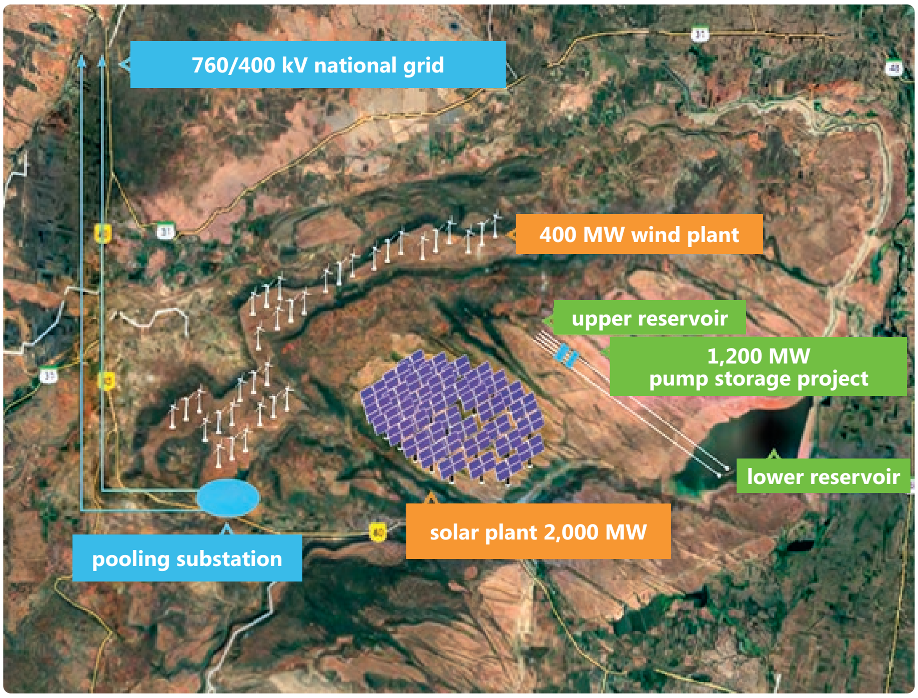
## What Germany could achieve from a pumped storage fleet expansion?

Anyone who thinks that these international findings and recommendations for action regarding flexibility increase and decarbonization cannot be transferred to countries like Germany, please refer to a scientific study published in 2014 by RWTH Aachen University in cooperation with Voith Hydro [7, 8]. Under the leadership




Source: india.mongabay.com/2023/03/new-pumped-hydro-norms

**Fig. 7.** Planned expansion of the pumped hydro storage fleet in India




Source: https://www.hydroreview.com/hydro-industry-news/pumped-storage-hydro/contract-awarded-for-1200-mw-pinnapuram-integrated-renewable-energy-pumped-storage-project-in-india/

**Fig. 8.** Pinnapuram Integrated Renewable Energy Pumped Storage Project

Source: Ignitis

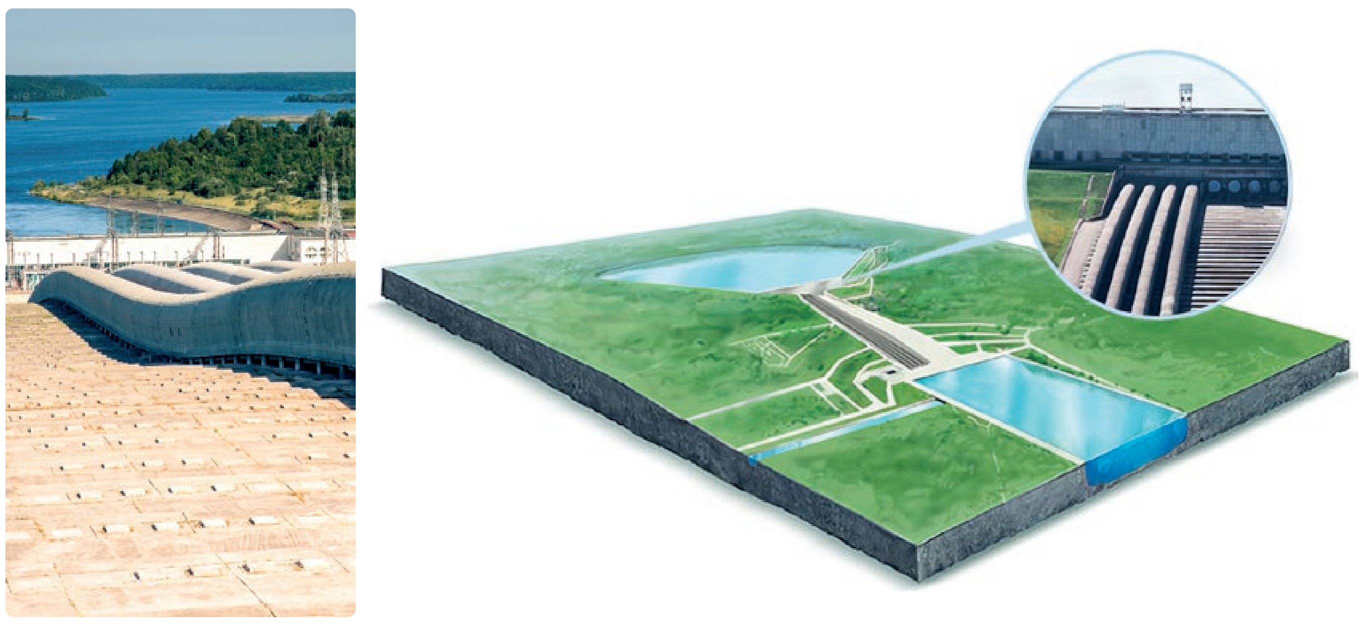


Fig. 9. Kruonis pumped hydro plant

of Prof. Dr. Ing. Albert Moser, who heads the renowned Institute for Electrical Systems and Grids, Digitization and Energy Economics at RWTH Aachen University, the addition of 8 GW of pumped storage by 2030 with a share of 60% RES and a scenario with 16 GW by 2040 with 80% RES in Germany were examined. The main findings are still valid:

- 15 GW of pumped storage (7 GW existing + 8 GW new construction) can replace up to 13 GW of thermal power plants,
- 23 GW of pumped storage (7 GW existing + 16 GW new construction) can replace up to 16.6 GW of thermal power plants.

Fig. 12 shows the typical load profile for one week for the 2030 scenario (top without pumped storage use and bottom with the existing 7 GW of pumped hydro fleet together with an assumed expansion of 8 GW). The share of RES plus must-run power plants is marked in grey, the share of thermal power plants is marked in yellow, and the curtailment of RES is marked in red. In this scenario, 10 GW are assumed as must-run power plant output for the stabilization of the transmission grid (rotating inertia provided by thermal power plants). This representation was chosen to give an impression of the volatile use of the thermal power plant fleet that would be necessary if neither energy imports/exports were possible nor pumped storage available. Without the use of pumped storage, excess production from RES regularly occurs which cannot be compensated even if the fossil-fuel electricity generation is almost completely shut off. In this situation, the pumped storage fleet receives the excess generation from RES and returns it to the grid several hours later. This avoids curtailing wind and PV, creating a win-win situation for the pumped storage fleet and RES.

A pumped storage fleet with an installed capacity of 15 GW (7GW at present + 8 GW expansion) prevents curtailment of 6 TWh of RES per year. This seems to be not much avoidance of curtailment, but 6 TWh corresponds to the yearly production of 900 on-shore wind towers with 2.5 MW each. The wind tower equipment above ground (i.e. without the civil foundations) costs more than €1 million per MW. 6 TWh of annual curtailment of wind means that somebody spends more than €2.2 billion as CAPEX for 900 wind towers with 2.5 MW each, which would then be built just to stand still the whole year.

Fig. 12 illustrates another win-win situation between pumped storage fleet and the thermal power plants because the consistent use of the energy storage as short-term storage levels off the capacity curve of the fossil-fuel power plants, as well as reducing their peak load. This in turn leads to the following advantages for the thermal power plants:

- the number of start-up/shut-down processes is reduced, as are the load gradients. This reduces wear and tear of high-load components such as the steam generator and steam turbine including the connecting steam pipes,
- this also significantly reduces start-up and shut-down costs. The macro-eco-

Source: Voith Hydro

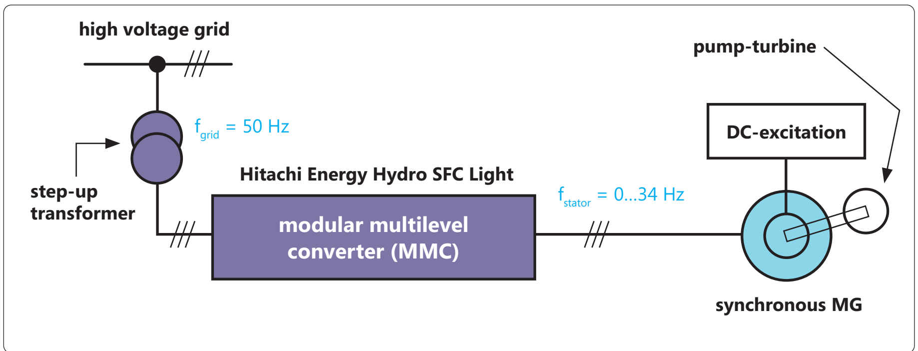



Fig. 10. Simplified single line for the converter and synchronous motor-generator

Source: Voith Hydro

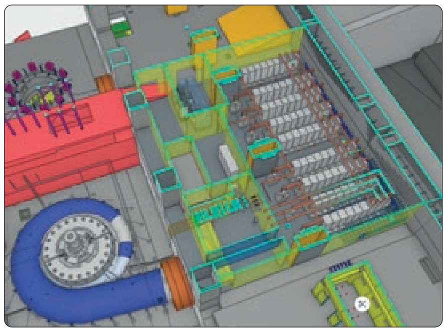


Fig. 11. Converter hall of the new power unit in the Kruonis pumped hydro plant

Source: Voith Hydro

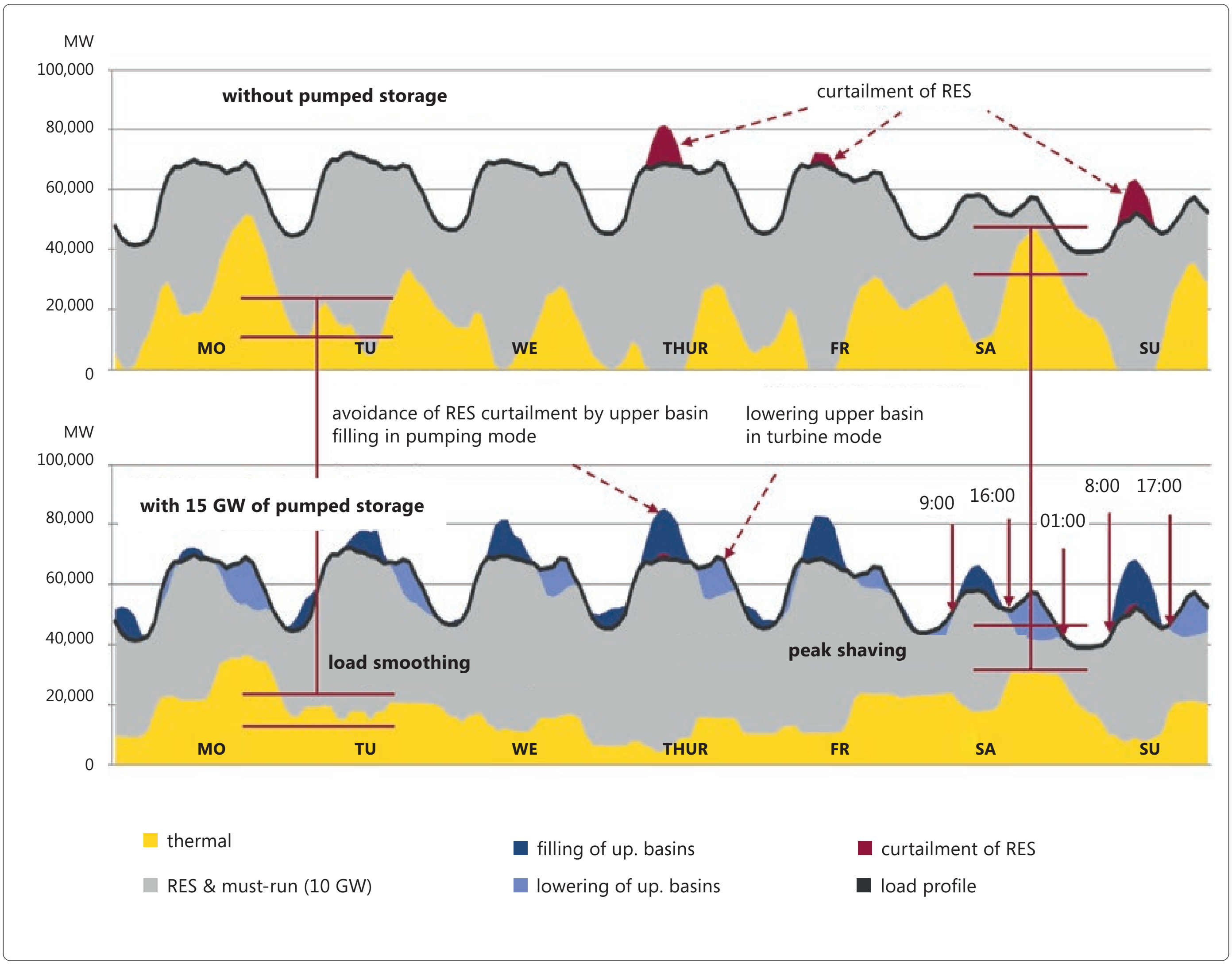



**Fig. 12.** Typical week load profile in 2030 in Germany with a 60% share of RES [7, 8]

nomical analysis of the study considers theses costs for the thermal power plants as well as their load-dependent efficiency,

- in addition, the active pumped storage fleet reduces the yellow areas, i.e. the use of hydro storage reduces the consumption of gas and/or coal. The real fossil fuel consumption reduction is significantly larger than shown in Fig. 12 because the start-up and shut-down losses incurred by the thermal power plants are not taken into account in the yellow areas.

The main lessons learnt are: The expansion of RES and an expansion of the pumped storage fleet can reduce the capacity reserve of thermal power plants and reduce the curtailment of valuable renewable energy (wind and PV). In contrast, a RES expansion without significant energy storage cannot reduce this capacity reserve and significant proportions of renewable generation would have to be curtailed. In addition, the aforementioned study stated back in 2014 that an expansion of pumped storage power plants can significantly reduce dependence on gas imports. Even though the research was conducted ten years ago, its findings are more relevant than ever. Hydropower — and pumped storage in particular — provide important answers to current challenges.

**Dr. Klaus Krueger**
Senior Expert Plant Safety and Energy Storage Solutions

Voith Hydro Holding GmbH & Co. KG, Germany

**References:**

1. IHA, World Hydropower Outlook, 2023, https://www.hydropower.org/publications/2023-world-hydropower-outlook
2. IEA Hydropower Special Market Report Analysis and forecast to 2030, 2021, https://www.iea.org/reports/ hydropower-special-market-report
3. European Commission, Hydropower and Pumped Hydropower Storage in the European Union, 2023
4. Krueger, K.: Pumped Hydroelectric Storage. In K. Brun, T. Allison, and R. Dennis: Thermal, Mechanical, and Hybrid Chemical Energy Storage, New York, NY: Elsevier, ISBN 978-0-12-819892-6, 2020.
5. China Policy and Market Frameworks Working Group September 2021 world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx https://pumped-storage-forum.hydropower.org
6. PV magazine India 2020, https://www.pv-magazine-india.com/2020/01/31/seci-concludes-worlds-largest-renewable-plus-storage-based-assured-supply-tender-at-rs-4-04-kwh-fixed-for-25-years
7. Moser, A., Rotering N., Schäfer, A.: Unterstützung der Energiewende in Deutschland durch einen Pumpspeicherausbau — Potentiale zur Verbesserung der Wirtschaftlichkeit und der Versorgungssicherheit (im Auftrag der Voith Hydro). IAEW RWTH, Aachen, 4. April 2014, online: www.wasserkraft.info
8. Krueger, K. und Rotering N.: Successful energy transition in Germany by pumped storage expansion (original German paper title: Energiewende erfolgreich gestalten durch Pumpspeicherausbau), VGB PowerTech, p. 37–44, 9/2014 and Wasserkraft und Energie, p. 23–36, 2/2015.

# Footsteps to follow in PSH

**The question of adapting the Polish Power System to the challenges posed by the energy transition happening before our eyes does not involve reinventing the wheel. We can use pumped storage hydropower (PSH) solutions that are available, proven and currently being developed by many countries in Europe and worldwide. The key is to intensify political efforts, among other things, to create a legal, administrative and business environment that is truly friendly to such projects.**

Large-scale hydropower projects take years to prepare, as well as their construction and operation (here we are talking about decades). They have a much broader time horizon than other RES technologies. Naturally, they also involve a higher financial risk, which in turn requires specific policy instruments, incentives, and a long-term political vision and perspective. In addition, a significant challenge is to estimate all the benefits, which is necessary to open up discussions and negotiations between the various stakeholder groups and to bridge the gap between economic viability and non-financial benefits.[1] Unfortunately, the inaction of our decision-makers has resulted in a multiple-decade hiatus in the construction of large-scale hydropower plants that could provide the system stability that is now so badly needed. Let us put the current situation into a metaphor. We have a patient — the Polish Power System; we have a diagnosis — the loss of stability linked to storage inefficiencies and we have a cure — large-scale energy storage provided by PSH. However, we are delaying the administration of this cure. The disease is progressing. How long will the patient last? Numerous forecasts are being made about this. What is certain, however, is that by 2050, the patient must be pretty healthy, as they will have to do very well in a zero-carbon reality built primarily on unstable renewable energy sources. Let's have a look at a few countries that have been quicker than Poland in starting to "treat the patient" and have understood that they need the significant storage capacity provided by PSH.

### Australia

First, let's travel to the remote Australia. The order is not accidental for a simple reason — the similarity of the energy mix to our own. Unlike in Poland, however, several new pumped storage projects are at an advanced preparation stage or are currently being built. Since 2015, Australia has seen a significant shift towards investment in renewable energy generation, driven mainly by reduced technology costs rather than legislative or policy changes. Australia's National Electricity Market (NEM) has experienced a renewables investment boom, with 135 renewable energy projects, mainly solar and wind, with a total capacity of 16 GW and a value of more than $26.5 billion between 2016 and 2021. These investments have resulted in a decline in the market share of coal-generated power. The share of renewable energy has increased from less than 10% in 2000 (mainly hydropower) to almost 36% by the end of 2022. Over the past eight years, Australia has seen an increase in renewable energy investment triggered by various factors such as government incentives, rising electricity prices and cost reductions in renewable technologies.[2] By 2040, most of Australia's coal power plants will be decommissioned, and almost 85% of the country will be powered by renewable energy.[3] With the Australian Energy Market Operator (AEMO) forecasting that at least 45 GW/620 GWh of energy storage capacity in all forms will be needed to transition the country's energy system from fossil fuels to renewables (the latest estimate is 46 GW/640 GWh[4]), former Prime Minister Malcolm Turnbull has pointed to pumped storage projects as the ideal technology for energy storage.[5]

So what is being done to achieve these ambitious targets? A lot. We have every reason to envy Australia's determination and holistic approach to making the power system more flexible. There are 12 PSH projects currently under development with a total capacity of over 15 GW/>560 GWh. The Kidston power station (using pits left over from gold mining) and Snowy 2.0 are under construction. Two more sites (Oven Mountain and the expansion of the existing Shoalhaven Pumped Hydro Scheme) have secured all necessary permits, so work will start soon on these. Feasibility studies have been drawn up for several projects (Capricornia Energy Hub, Pioneer-Burdekin, Flavian, Mt Rawdon, Big T, Central West, Cethana), and the Borumba project already has an investment decision (a contractor for the design work is scheduled to be selected by the end of March 2024[6]).

The Australian Energy Market Operator has published an Integrated System Plan for the National Electricity Market since 2018, which is revised every 2 years. The 2024 version is currently under consultation.[7] The study is a comprehensive roadmap for the country's energy transition. AEMO's message is clear and consistent: urgent action is needed to deliver benefits to consumers as Australia's energy industry moves away from its traditional reliance on coal-fired generation. There is no hesitation here on energy transition.

### Scotland/UK

In one blink of an eye, we are in Scotland at the solid base of the UK electricity system. Scotland has the highest mountains in the UK and the largest inland lakes. This, combined with high rainfall, makes water use for electricity generation viable in this region. Currently, Scotland produces around 85% of the UK's energy from water. There are 78 large dams and 54 medium/large hydropower stations, along with over 300 km of tunnels. There are plans for over 5 GW of new pumped storage capacity.[8]

---

[1] Quaranta E., Hydropower and pumped storage in the European Union: insights from CETO, Hydropower 4/2023, 40–44

[2] Evans Ch., Renaissance of the hydropower industry in Australia, Executive General Manager Development, Queensland Hydro

[3] https://pumpedhydro.com.au/education/pumped-storage-hydropower-in-australia/

[4] Draft 2024 Integrated System Plan For the National Electricity Market. A roadmap for the energy transition, AEMO Australian Energy Market Opertator

[5] https://www.pv-magazine-australia.com/2022/03/24/turnbull-pointsto-pumped-hydro-as-ultimate-storage-solution/

[6] https://infrastructurepipeline.org/project/borumba-dam-pumped-storage-hydro

[7] Draft 2024 Integrated System Plan For the National Electricity Market. A roadmap for the energy transition, AEMO Australian Energy Market Opertator

[8] https://www.hydropower-dams.com/hydro-2023/scotlands-hydropower-heritage/

Britain's National Grid ESO said last year in its Future Energy Scenarios that it expects an additional 10 GWh of storage capacity to be needed by 2030, rising to around 40 GWh by 2050.[9] There are currently only four long-term PSH schemes in operation in the UK.

Accordingly, in 2021 the Scottish Government granted planning permission for the following PSH schemes: the 450 MW Red John to be built near Inverness, Eishken on the Isle of Lewis (300 MW), which will use seawater, Coire Glas in Lochaber in the Highlands with up to 1,500 MW, Balliemeanoch (1,500 MW), Corrievarkie (600 MW), Glenmuckloch in the Dumfries & Galloway region. In 2023, the Scottish Government approved the expansion of another existing facility — Cruachan in Argyll. An underground PSH will be built adjacent to the one already in operation.[10] Six of the planned projects are expected to more than double the UK's pumped storage capacity to 7.7 GW, create almost 15,000 jobs and generate up to £5.8 bn for the UK economy by 2035, according to a new report by Scottish Renewables and BiGGAR Economics.[11, 12]

The plan for the construction of new PSH schemes is to reach 15 GW of installed capacity in these facilities by 2050. Compared to the current 2.8 GW, this will be a dramatic increase. As outlined above, pumped storage hydropower has a unique opportunity to deliver socio-economic benefits as a well-established and proven technology that plays a key role in meeting the UK Government's ambition for net zero emissions while ensuring consumer energy security.

[9] https://www.bbc.com/news/uk-scotland-highlands-islands-57510870

[10] https://www.power-technology.com/projects/cruachan-power-station-expansion-scotland/?cf-view

[11] https://www.scottishrenewables.com/news/1295-six-pumped-storage-hydro-projects-to-create-up-to-14800-uk-jobs-new-report-finds

[12] The Economic Impact of Pumped Storage Hydro A report to Scottish Renewables, May 2023, BIGGAR Economics

## Czechia

The final example is the Czech Republic, which is much closer to Poland. There are currently 4 PSH schemes operating with a total installed capacity of ~1.2 GW. In March, representatives of the ministries of the environment and agriculture presented the six best possible locations for new pumped storage hydropower plants in the country, which will double the current production and storage capacity. These are existing hydroelectric dams where the planned investments will not significantly conflict with nature and landscape conservation objectives. The basis for selecting the sites was a study carried out in 2010 by one of the ministries. These are Orlík, Slapy, Pastviny, Libochovany, Vinice and Slezská Harta. This list is open as further pre-investment studies will be carried out.[13]

Czechia is setting an example for Central European countries, including Poland, of how pumped storage hydropower can be approached strategically. Above all, it demonstrates that ensuring the stability of the power system is a priority and requires special efforts.

[13] https://www.cire.pl/artykuly/serwis-informacyjny-cire-24/czesi-zamierzaja-postawic-szesc-nowych-elektrowni--szczytowo-pompowych

## Conclusions important for Poland

The growth rate of installed PSH capacity globally is 0.9% between 2019 and 2020, and 3.3% between 2020 and 2021.[14, 15] The future will belong to countries pursuing advanced, multifaceted efforts, such as Australia, Scotland/UK, Czechia and many others. Poland cannot afford to remain on the sidelines of global change because of its heavily guarded approach. Our indolence so far is costing us a lot. For example, this March alone, there were six cases of non-market redispatching of generation units in the Polish Power System, i.e. the disconnection of RES installations with a total capacity of several hundred to several thousand MW over several hours, due to an oversupply of generation in the system and the need to restore regulatory capacity.[16] This is a telling, measurable symptom of the weakness of our system. A system that, to be cured, needs courageous action stemming first and foremost from a forward-looking approach, strong political will and a deep conviction in the benefits of pumped storage hydropower growth.

[14] Hydropower Status Report 2021, IHA

[15] Hydropower Status Report 2022, IHA

[16] https://www.pse.pl/komunikaty-osp

**Michał Kubecki**
CEO
Instytut OZE
+ 48 505 176 479
michal.kubecki@ioze.pl

**Wioleta Smolarczyk**
Business development coordinator
Instytut OZE

**www.hydro.ioze.pl**

OZE instytut

# Concepts and technical solutions used in hydrokinetic water turbines

**Hydroelectric water turbines are the foundation for the energetic use of the natural resources contained in watercourses. The excellence of these designs is reflected in the ratio of shaft power to hydraulic power. The best of them can reach up to 93% efficiency, and have a favourable characteristic shape, which enables them to operate over a wide load range under various hydrological conditions. This is achieved, among other things, by utilising the accumulated knowledge and experience of the designers to date. In addition, the high efficiency value is accompanied by the use of control methods, such as variable positioning of the guide vanes and/or the rotor and variable speed control, which has a global effect on the flatness of the operating characteristics.**

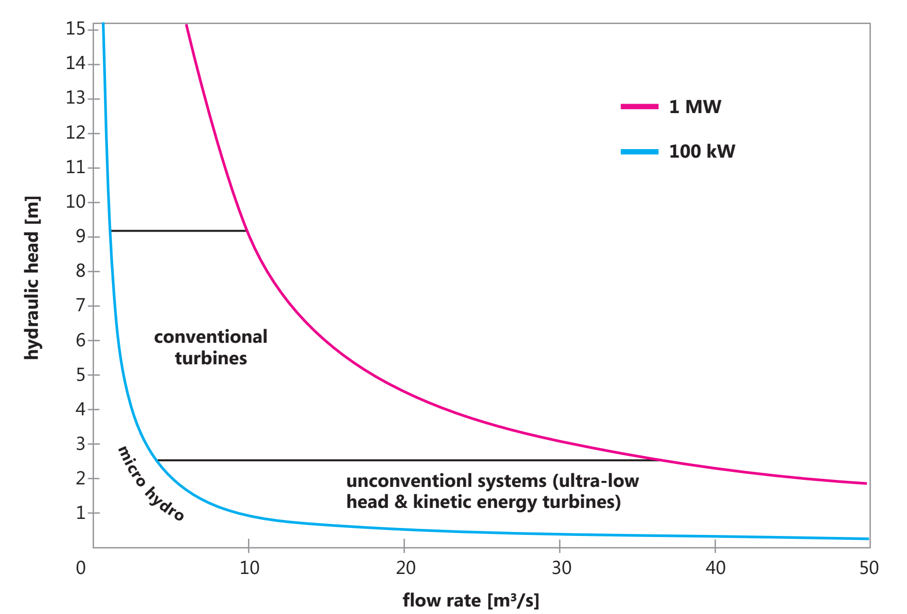



**Fig. 1.** General classification of hydropower technologies [1]

The general division of water turbines is defined with reference to the value of the dynamic or kinematic speed discriminator. In the case of high falls (practically not found in Poland), Pelton action turbines are used, and in other applications turbines are used: Francis (upstream and midstream, reversible turbines) and Kaplan (low-fall, downstream and midstream). Most of these machines are designed and manufactured as units and are therefore relatively expensive. Fig. 1 shows the use of water turbines [1]. In addition to the traditional turbine designs used to exploit the generally available hydropower potential, there is a range — ultra-low gradient and large gullets — that is currently of interest to scientists and engineers. The energy use of low-drop water stages in turbines is still a design challenge today. Rising electricity prices and the consequent need to improve the energy efficiency of various industrial processes is making the area of micro and even picoturbines economically important. These are machines with dual functionality. The first has the ability to operate on high gradients with a very small gullet and is used to recuperate hydraulic energy in pressurised installations. In quite a number of cases, pumps (of various designs) operating in turbine motion — PAT — are used here [3, 4]. The second type is the non-drop machines, which recover the kinetic energy of flowing rivers and are an interesting solution for distributed energy concepts, especially when their operation in hydrofarms is considered. These turbines are anglicised as hydrokinetic, although the names proposed by one of the Professors at the Hydroforum 2023 conference: rotokinetic and rotodynamic seem worth considering as Polish equivalents.

## Development of hydrokinetic turbines

Hydrokinetic turbines (English: hydrokinetic turbine, water current turbine, ultra-low-head hydro turbines, zero head hydro turbine, free flow/stream turbine, in-stream hydro turbine) are classified as action hydro machines. They convert the kinetic energy of the current into electrical energy. Although the use of rivers in this form has accompanied the development of civilisation for at least 40 centuries (the Code of the Laws of Babylonia, 20th century BC, contains a paragraph on the penalties to be imposed on the perpetrators of water-wheel theft), the form of operation of these machines changed in the previous century from thrust to profile flow. Fig. 2, presents a Polish accent in this area, in the form of a painting by Bernardo Bellotto Canaletto from 1770, which depicts the 'View of Warsaw from the Praga' with a floating water mill located, in the middle foreground [2]. The machine shown, called a “bździel”, was most likely built as a water wheel system driving a mechanical process such as grinding, rolling or hammering. The system shown may have been used for food production. It was certainly not the oldest facility of this type on the Vistula, as the 1286 foundation document of the city of Sandomierz also mentions the operation of a floating mill [5]. Although facilities of this type were common in Europe from medieval times until around the 18th century, by the end of the 19th century they had become a rare feature of the landscape. This was a result of the development of more efficient (and much more productive) forms of human energy generation.

The development of hydromechanics in the 19th and 20th centuries, including the understanding of the flotation process, opened another chapter in the development of hydropower machines using the energy of the river current. Fig. 3, shows a prototype of a non-flume hydroelectric power plant designed in 1939, by K.F. Kostin. This was a turbine with a rotor diameter of 1.5 m, which was housed in a diffuser-shaped metal casing. There was a metal mesh at the turbine inlet to protect the hydropower plant from debris. The shaft bearings were made of textolite and were lubricated by water. The turbine assembly

Fig. 2. Painting 'View of Warsaw from Praga' with a water mill in the middle plan by Bernardo Bellotto Canaletto, 1770 [2]

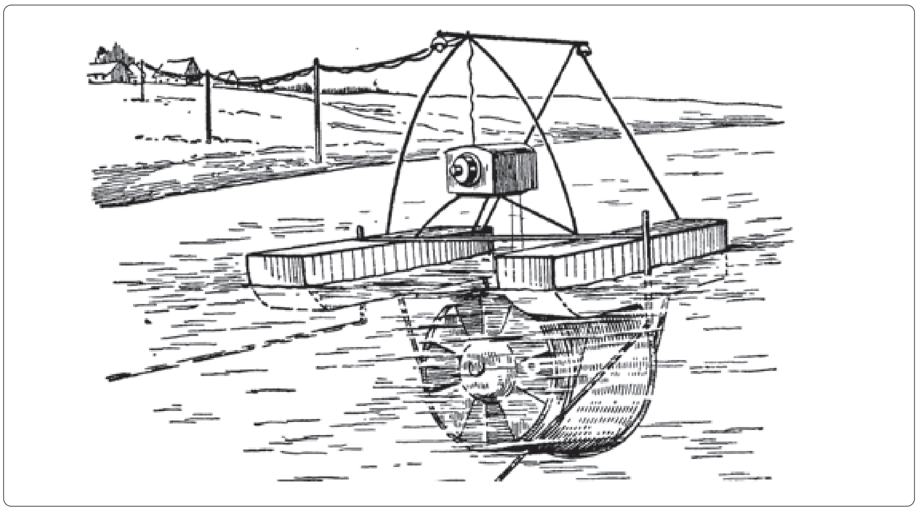


Fig. 3. Prototype of a hydrokinetic hydroelectric power station, 1939 [6]

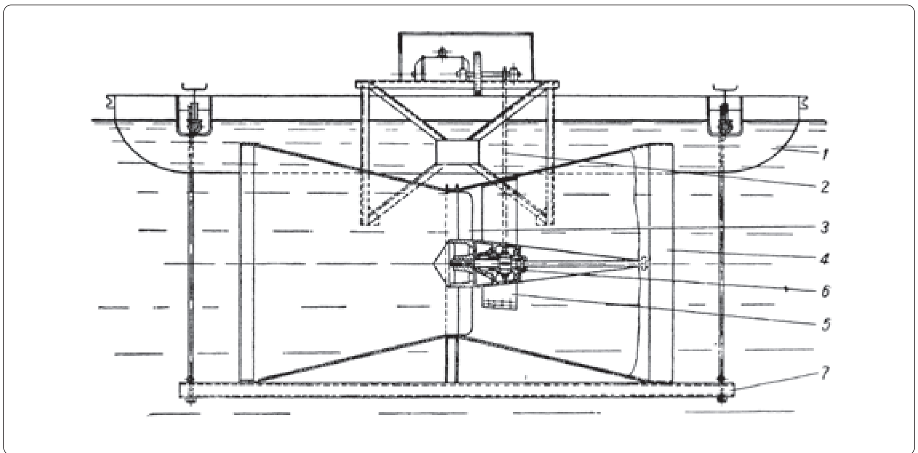



Fig. 4. Concept of a productive, floating hydropower plant, 1945 [6]

was mounted on two rigidly connected metal floats. The turbine was coupled to an electric generator with a shaft speed of n = 1,000 rpm using a Gall chain. The total weight of the machine was approximately 1,300 kg. In addition, in 1945, S. P. Klykovsky [6] developed a design for a low-power floating hydroelectric power plant with a propeller turbine for factory production (Fig. 4).

In the Western literature, the authorship of the use of current energy to produce electricity or irrigation is attributed to Peter Garman [7], who developed the hydrokinetic turbine [8]. In 1978, the Intermediate Technology Development Group (ITDG) designed the Garman turbine for water pumping and irrigation. Fig. 5 shows an incomplete approximate timeline for the development of hydrokinetic turbines [6].

In the early 1980s, the US Department of Energy built a 15 kW water motor operating in the current [9]. In 1986, the companies: Nova Energy Systems and ITDG designed a turbine in the Darrieus straight-bladed system, developing 0.5 kW at a current of 1 m/s. Scientific work on the use of currents for power generation

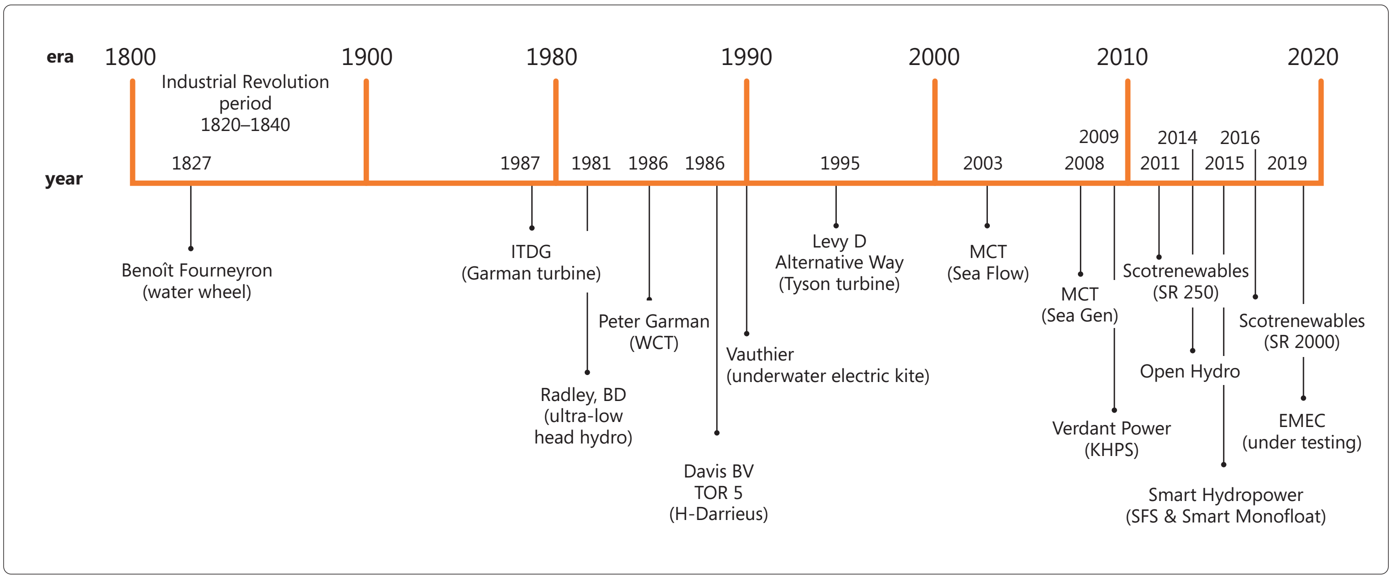



**Fig. 5.** Approximate development timetable for hydrokinetic systems [6]

and irrigation has been carried out in several countries such as Canada [10] and Australia [11]. Darrieus straight-bladed turbines of 5 kW and 15 kW have been used in Canada and Africa, respectively. In Australia, Alternative Way developed the Tyson horizontal turbine with a generator submerged underwater [8]. After 2000, hydrokinetic turbine designs were developed in Europe by companies such as Guinard Energies Nouvelles from France, Smart Hydro Power from Germany, and AquaLibre and Powerfluxx from Austria. Since 2017, in Poland, companies such as Inex Green and the Institute for Technology Optimisation (Instytut Optymalizacji Technologii Sp. z o.o.) have taken an interest in the technology and developed their own prototypes. The designs presented represent only a fraction of the hydrokinetic turbine solutions that have emerged.

## Development possibilities and contemporary design solutions

Hydrokinetic turbines are water engines that use the kinetic energy of flowing water through its appropriately shaped hydraulic elements to produce electrical or mechanical energy. They are placed in rivers, artificial channels with a usable current and in areas of strong tides and ocean currents. A characteristic feature of hydrokinetic turbines, and at the same time an unquestionable advantage, is that energy production is realised with minimal or no gradient. The division of hydrokinetic turbines according to various criteria is schematically shown in Fig. 6. The basic division of the aforementioned hydrokinetic machines is based on the orientation of the rotor axis in relation to the direction of the incoming water. There are two main types: axial-flow and transverse-flow rotor turbines, which are divided into individual subtypes.

Regardless of the design solution, there are three main ways to install hydrokinetic turbines in an aquatic environment, as illustrated in Fig. 7. The first involves mounting the device on pontoons, boats or other floating platforms. The second is characterised by the entire support structure including the hydropower unit being submerged, usually seated or anchored on the bottom or shore. The third, on the other hand, is that the turbine is sus-

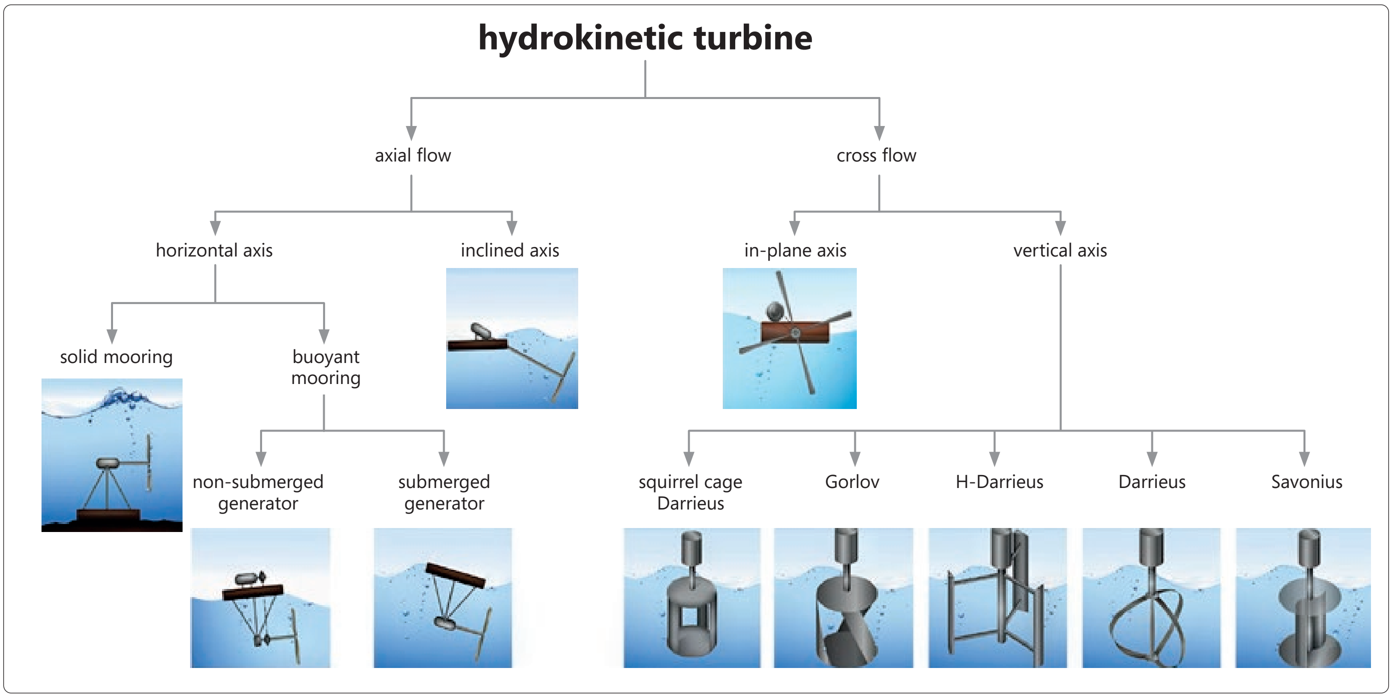



**Fig. 6.** Division of hydrokinetic turbines [10]

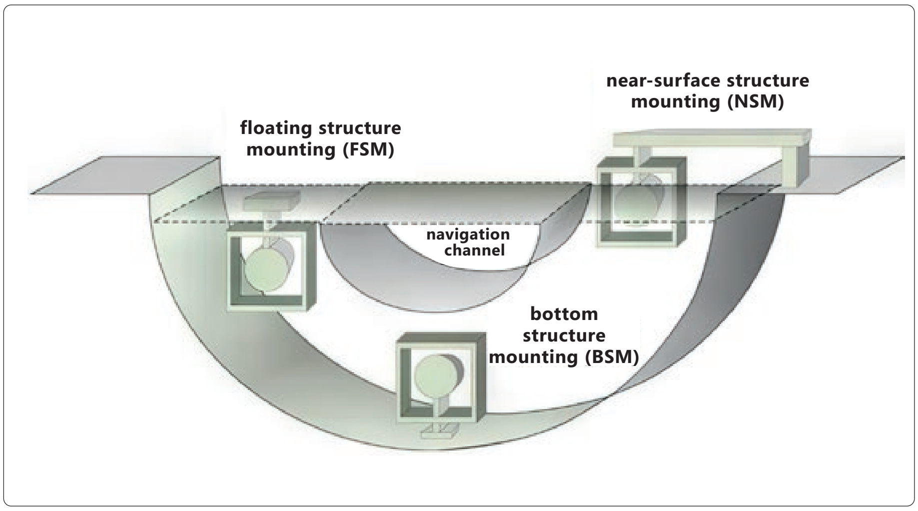



Fig. 7. Ways of installing hydrokinetic turbines [13]

pended from a dedicated crane structure that is installed on the riverbank. When considering axial flow turbines, for example, a propeller rotor is used whose axis of rotation is aligned parallel or oblique to the inflow velocity vector. These cases are illustrated in Fig. 8. The oblique positioning of the shaft's axis of rotation is used in small turbines mounted on boats, pontoons or other structures floating mainly in rivers or canals. Horizontal-axis turbines have a wider range of applications. In addition to rivers and canals, they are used to produce energy from tides and currents.

In cross-flow turbines, the direction of water flow is perpendicular to the rotor axis, of which there are several most common variants. The first of these is the impeller by French designer Georges Darrieus and is divided into three geometric variants — Fig. 9 [12]. The curved-blade rotor (Curved-Darrieus, ribbon rotor) was patented in 1931 and is practically not used in hydrokinetic turbines. The other variants, the squirrel cage rotor (SC-Darrieus) and the H-type (H-Darrieus), are simple designs widely used in hydrokinetic engines. Their disadvantage is that they have virtually zero starting torque, necessitating additional systems to give run-up/run-down to the turbine rotating assembly, and large torque pulsations are noted during operation.

Another type is the transverse flow rotor — the Gorlov rotor (Fig. 10 a), invented

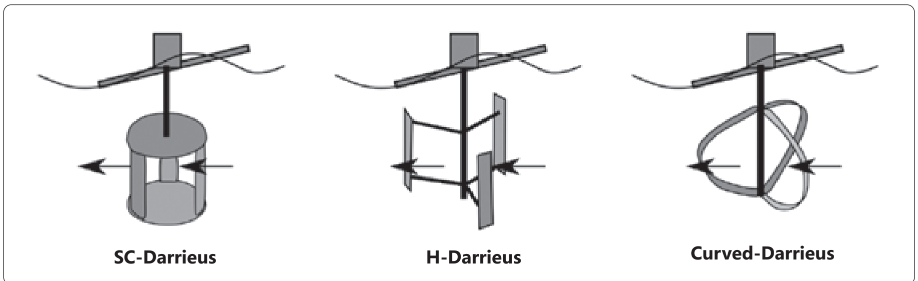



Fig. 9. Darrieus rotor variants [12]

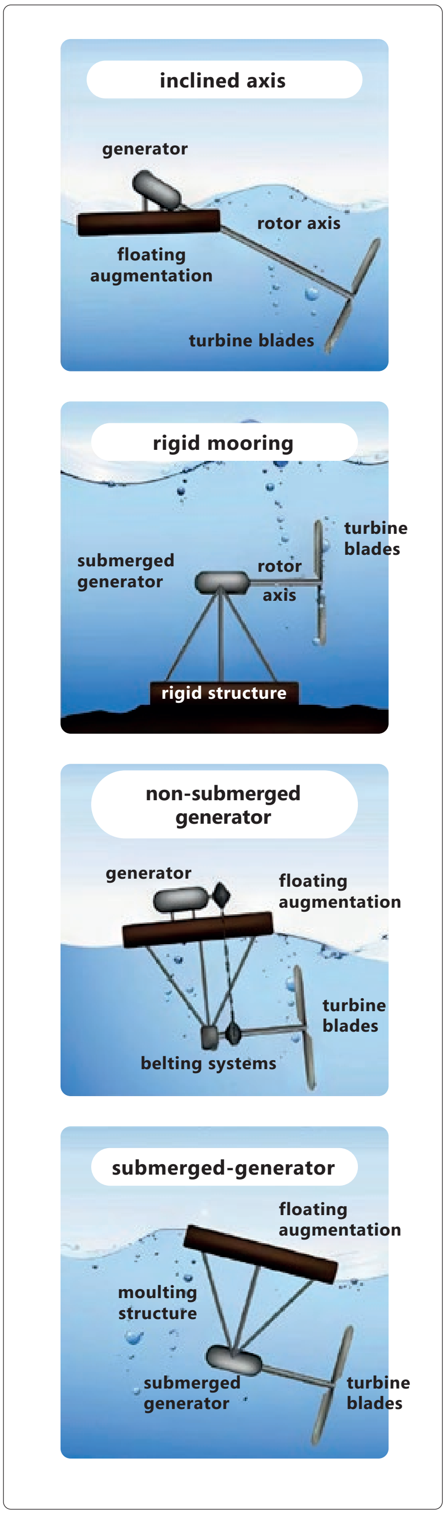



Fig. 8. Division of axial flow hydrokinetic turbines [12]

by Alexander M. Gorlov of Northeastern University. Its design is very similar to the H-Darrieus rotor with the difference that its blades are not rectilinear, but are set obliquely with an additional spiral shape. This results in lower torque pulsations during operation and lower vibrations and stresses in the turbine structure.

Another type is the Savonius rotor, which was first described by S. J. Savonius around 1920. It is characterised by the lowest energy efficiency and does not need a starting system; however, it has large torque fluctuations during operation. An interesting solution is the Tyson turbine rotor proposed by Alternative Way [12], which is shown in Fig. 10 c.

Developments in hydrokinetic turbine design, aimed at increasing the recovered power at a given rotor diameter and current velocity, have led to the need for fluid acceleration elements in the rotor area. For this purpose, various booster-fluid elements are used, including: channels, shrouds (orifices), vanes, (wind) lenses, nozzles, concentrators or diffusers. Fig. 11 shows the breakdown of booster elements.

Among other things, diffusers, which are commonly used in propeller rotor turbines with axial flow, can fulfil the functions of a booster element. Their use induces negative pressure and thus increases the flow velocity in the area of the rotor in operation. The use of a diffuser increases the control capability of the turbine, which is realised by changing the speed of the rotating assembly. The shape of the diffusers used depends, among other things, on the type of turbine, as shown in Fig. 12.

The use of a diffuser in a turbine flow system has the following key advantages:

- increases the power output of a device with a specific rotor size,
- allows a smaller rotor to achieve the desired power output,
- increases the rotor speed at which maximum efficiency is achieved, enabling the use of cheaper gearboxes and generators,
- reduces the tip loss (turbine axial) of the rotor, increasing efficiency,
- allows the Betz-Zukowski limit to be exceeded,
- allows the application of higher power turbines in shallower rivers.

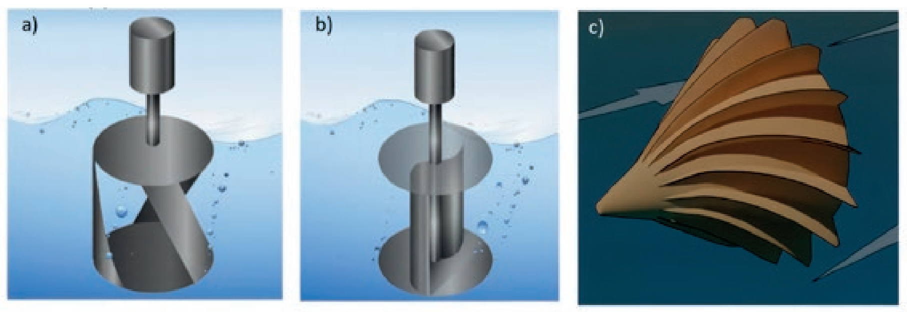



Fig. 10. Rotors of hydrokinetic turbines: a) Gorlov, b) Savonius, c) Tyson [12, 15]

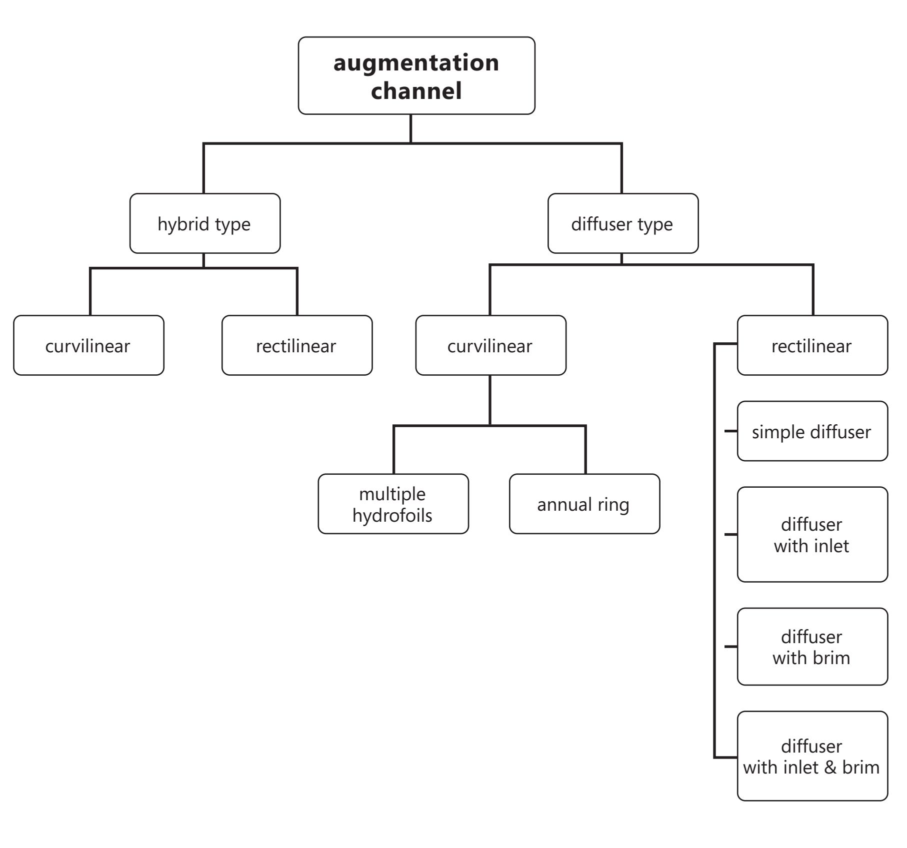



Fig. 11. Division of components supporting the operation of hydrokinetic turbines [6]

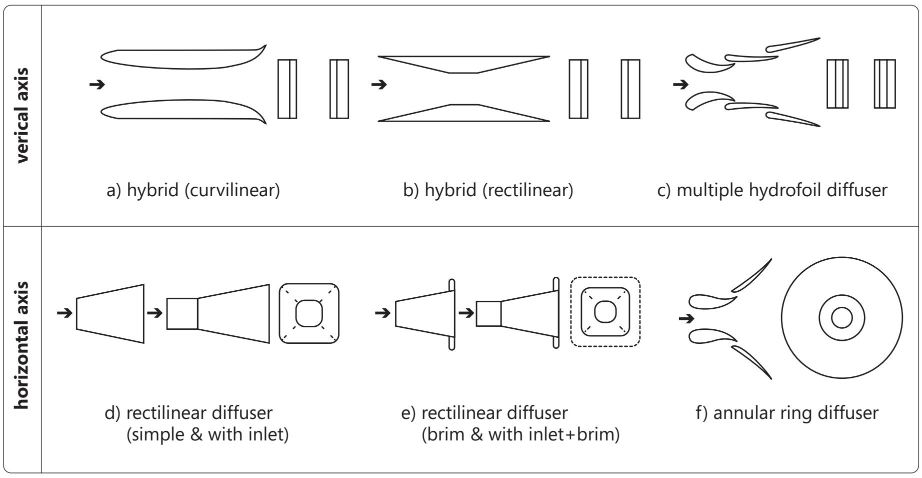



Fig. 12. Shapes of hydrokinetic turbine diffusers in use [6]

## Characteristics of hydrokinetic turbines and technical limitations of hydrokinetic turbines

The basic parameter that determines the performance of hydrokinetic turbines is the energy utilisation factor cp, also known as the power factor. The cp coefficient defines the ratio of the power on the turbine shaft to the power of the water flowing through the rotor working field:

(1)

$$C_P = \frac{P_T}{\frac{1}{2}\rho V^3 S}$$

where:
$P_T$ – power at the turbine shaft,
ρ – density of water,
S – working area of the turbine.

An equally important parameter that determines the applicability of a turbine is the speed ratio (λ or TSR), defined as the ratio of the line velocity at the outer diameter of the rotor to the fluid velocity in front of the turbine:

(2)

$$\lambda = TSR = \frac{\Omega R}{V} = \frac{\pi n D}{V}$$

where:
Ω – rotor angular velocity,
D – diameter of the turbine,
R – turbine radius,
n – rotational speed,
V – water inflow velocity.

Fig. 13 shows the ranges of the speed factor and energy utilisation for the different types of generating equipment with no booster (rotor alone) [16]. It should be pointed out that machines using fluid thrust as their operating mechanism do not exceed power coefficients of $C_p$ = 0.3÷0.35. Their speed coefficients are small. Turbines whose operation is based on circulating flow around a hydrodynamic profile are characterised by much higher $c_p$ values of even $C_p$ = 0.5 and large TSR coefficients. It is worth noting that each design is limited by the Betz-Zukowski limit of $C_p$ = 0.593 (unassisted systems).

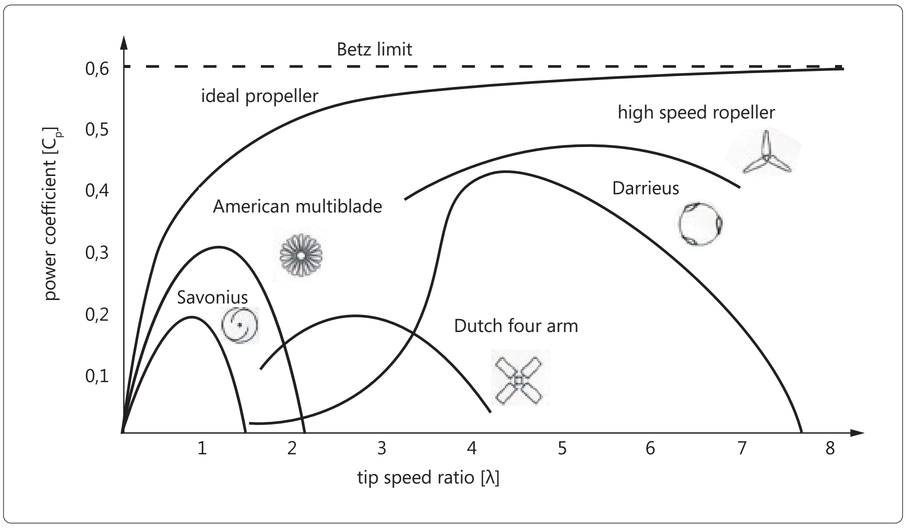



**Fig. 13.** Plot of the power factor as a function of the speed factor of hydrokinetic turbines [14]

It is also important to note that drag-force turbines, despite their small $C_p$ power coefficients, are an application complement to boost-based machines. The latter will be limited in terms of application, e.g. by the depth of the river, and an increase in power is only possible through the use of diffusers. For the first type of turbines, in the case of a horizontal axis of rotation, the power will only depend on the length of the rotor.

## Summary

Modern hydrokinetic turbines are relatively new designs, despite the cognitive, research and application work already carried out. Their advantages depend on the design of the rotor and the longitudinal axis of the position of the rotating assembly in relation to the flowing river current. They are machines: with low rotor speeds, friendly to the biological life of the river, interfering minimally with its structure and producing clean energy. Although the concept of hydrokinetic turbines is not new, these machines have not fully reached technical maturity. Various design solutions are being sought to maximise the use of the available potential. At present, hydrokinetic turbines, mainly for inland applications, are produced worldwide, also in commercial form, with a wide variety of designs, which the authors will attempt to explain in the next article. The increase in electricity prices, the need to increase the share of renewable energy in the exploitable energy potential and, ultimately, the desire to do away with fossil fuels altogether, mean that the cost-effectiveness of building hydrokinetic turbines is currently increasing and may become extremely attractive in the future.

**Artur Olszewski**
Institute for Technology Optimisation
(Instytut Optymalizacji Technologii Sp. z o.o.)

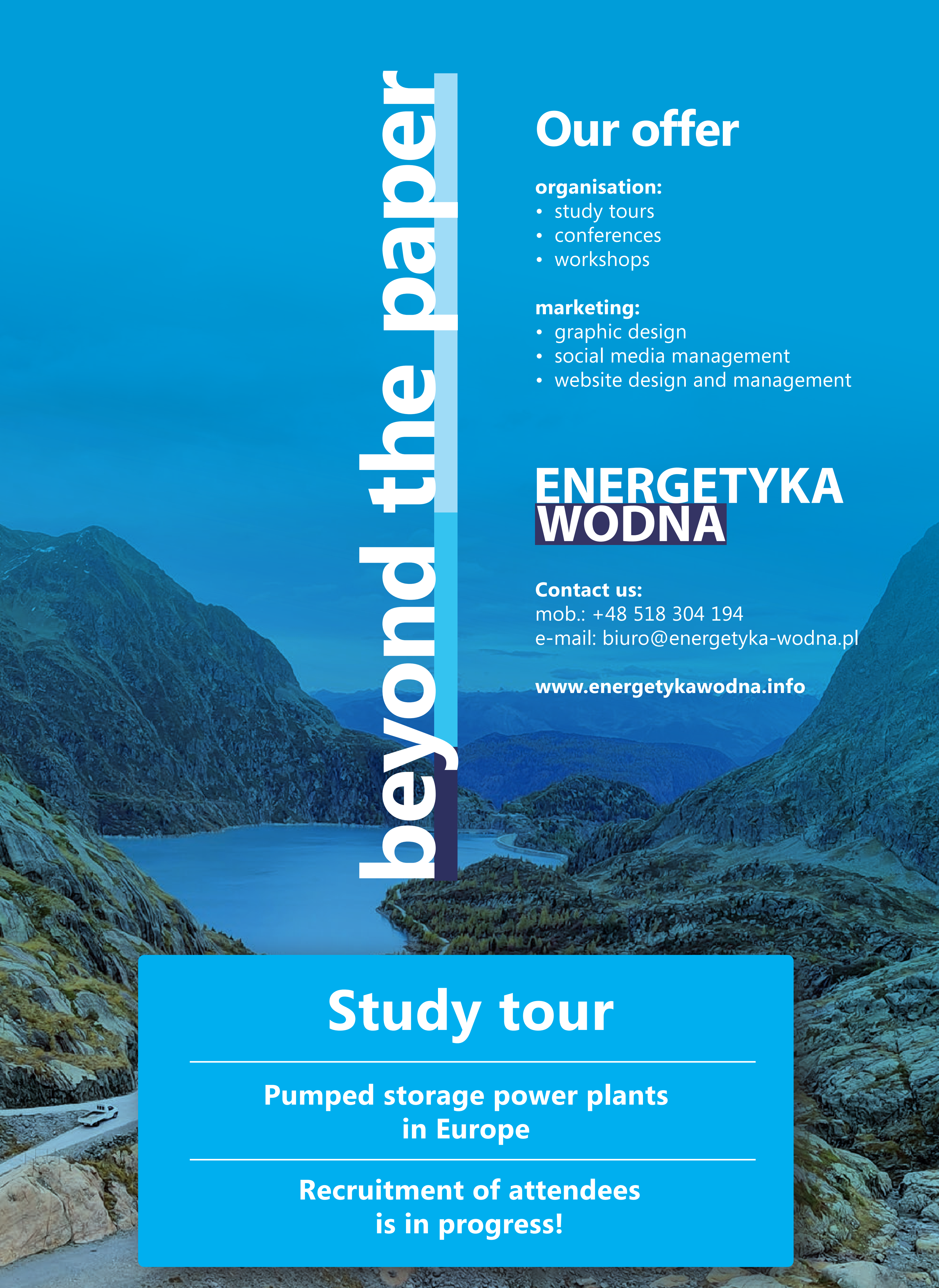
**Witold Lorenz**
Hydro-Vacuum S.A.

**Przemysław Szulc**
Wroclaw University of Science and Technology

**Adam Góralczyk**
IMP PAN

**References:**

1. US Department of Energy, Energy Efficiency and Renewable Energy; Wind and Hydropower Technologies, Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants, Tech. Rep. DOE — ID-11263; January 2006.
2. Vue de Varsovie prise de Prague, le peintre s'y est peint avec son fils, Zamek Królweski w Warszawie.
3. Lorenz W., Janczak M., Konstrukcje miniturbin THV i ich przewagi nad pompami w ruchu turbinowym PAT, Kierunek Pompy, 2/2023
4. 4. Janczak M., Lorenz W., Miniturbiny THV do odzysku energii w układach pompowych i regulacji parametrów sieci, Energetyka Wodna 3/2023.
5. T. Lalik, Sandomierz w świetle źródeł pisanych, w: Sandomierz: badania 1969–1973.
6. Кажинский Б.Б., Свободнопоточные гидроэлектростанции малой мощности, Массовая радиобиблиотека (МРБ), 1950
7. Garman P., Water current turbines. A field worker's guide, 1986.
8. Ibrahim W.I., Mohamed M.R., Ismail R.M.T.R., Leung P.K., Xing W.W., Hydrokinetic energy harnessing technologies: A review, Energy Reports, 2021.
9. R R.L., H B.D, Definition of Cost Effective River Turbine Designs US Dep Energy, 1981
10. Davis, B., 1989. Vertical axis hydro turbines for off grid installations. In: Int. Conf. Hydropower Niagara Falls. New York, United States.
11. Levy D. Power, from natural flow at zero static head, Int. Power Gener., 18 1995.
12. Kumar A., Saini R. P., "Performance parameters of Savonius type hydrokinetic turbine — A Review", Renewable and Sustainable Energy Reviews, Volume 64, October 2016, Pages 289–310.
13. Tamb A. R., Pontoon, an alternative flexibale cheap mounting option for the renewable decentralized river current turbine power service, 2014.
14. Gharib-Yosry A., Blanco-Marigorta E., Fernández-Jiménez A., Espina-Valdés R., Álvarez -Álvarez E., Wind-Water Experimental Analysis of Small SC — Darrieus Turbine: An Approach for Energy Production in Urban Systems, 2021, MDPI, Switzerland.
15. https://en.wikipedia.org/wiki/Tyson_turbine. Stan na dzień 22.12.2023.
16. Khan J., A generic performance curve for tidal and hydrokinetic devices, The Journal of Ocean Technology, Vol. 13, No. 2, 2018.


beyond the paper
Our offer
organisation:
• study tours
• conferences
• workshops
marketing:
• graphic design
• social media management
• website design and management
ENERGETYKA WODNA
Contact us:
mob.: +48 518 304 194
e-mail: biuro@energetyka-wodna.pl
www.energetykawodna.info
Study tour
Pumped storage power plants in Europe
Recruitment of attendees is in progress!

# First monitoring results and operation experience of a new type of fish pass

**Various types of fish passes are used to restore water continuity at transverse structures in rivers. The Fishcon lock represents a new technical solution for restoring water continuity especially for location with limited space. The technology has been examined in the last five years at three reference sites in Austria with great success.**

The Fishcon lock, also known as 2-chamber organism bypass, is a further development of a fish lock. The technology is based on a patented hydraulic connection of two lock chambers that operate in opposite directions. This mode of operation enables fish to continuously swim into the lock chambers from both sides and prevents intermittent operation, which occurs at conventional fish locks and fish lifts with one chamber. This leads to an increase in effectiveness and, in addition to the upstream migration of fish, it also enables fish to migrate downstream at the same time if there is an appropriate water connection.

### Function of the Fishcon lock

The two chambers of the Fishcon lock are realized with slide gates to the upstream water and downstream water. In operation always a chamber of the fish lock is opened to the upstream water and the other chamber is opened to the downstream side, so that fish and other organisms can swim in the chambers from both directions. After a defined time, all four slide gates change their position. Organisms that have entered the chambers before can now migrate further upstream and downstream. To guide the organisms, an attraction flow runs from the upper water through a connecting pipe into the downstream water. In the connecting pipe there is either a throttle or small turbine to limit the discharge rate of the attraction flow.

Due to the energy dissipation outside the fish migration area behind some self-cleaning fine screens and the adjustable attraction flow, there is no high turbulence in the chambers and optimal flow velocities for fish migration can be achieved. A fixed rough sole structure without any steps and if needed an illumination of the chambers further support the migration at the Fishcon lock. The system has several advantages compared to other types of fish passes in terms of space requirement, usage by changing water levels, water demand, operational safety and costs when overcoming medium height differences.

As part of a research project carried out jointly with the University of Natural Resources and Life Sciences Vienna, two reference systems were built in Upper Austria in 2018/2019 and the function was then analyzed through comprehensive monitoring studies. In 2022/2023 further projects with the Fishcon lock were implemented in Austria, Germany and Switzerland. Also, at these sites biological functional tests already started and the migration of a large number of fish could be documented. At the moment three Fishcon locks are fully tested with great results, two systems at the river Alm and one at the river Aschacharm.

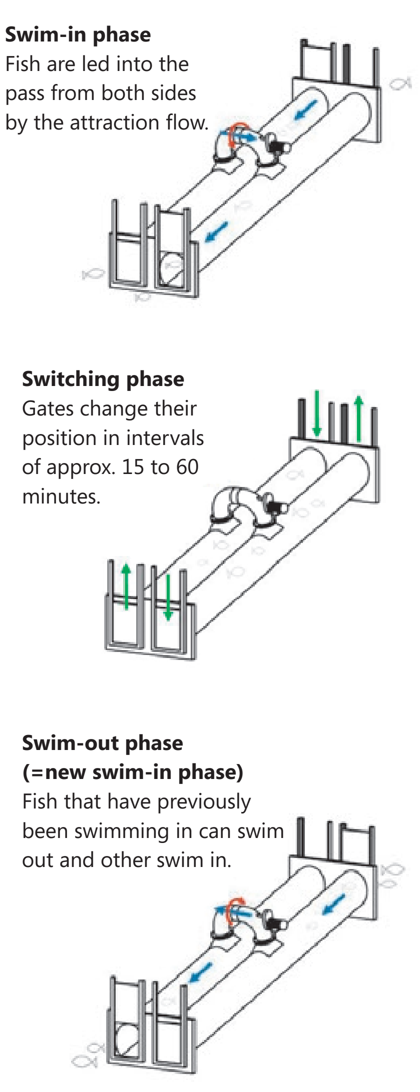



Fig. 1. Function of the Fishcon lock with a small turbine for using the attraction flow

Fig. 2. From the left: Fishcon lock from inside with a fine screen made out of bars (normally the chambers are always full filled with water) and fine screen made out of a metal sheet with holes (the picture is made outside the chambers by removed connection pipe bend)

### Positive experiences from the trout region

The first Fishcon lock was installed at the river Alm. The lock-system with a chamber diameter of 900 mm and a length of 6 m was installed at the "Lippenannerl" diversion power plant next to a new hydroelectric screw turbine in the end of 2018. The fish bypass overcomes a height difference of approximately 2 m and is operated with an attraction flow of 100 l/s, which represents a water saving of over 50% compared to the originally planned vertical slot pass. The body of water with

**Fig. 3.** Fishcon lock Lippenannerl at the river Alm next to the residual flow hydroelectric screw turbine

**Fig. 4:** Fishcon lock Schwarzmühl at the river Alm next to the residual flow power plant

an mean water flow of 11.1 m³/s is a trout region with the main fish species brown trout 50 cm.

In spring and autumn 2019, a video monitoring was carried out by the University of Natural Resources and Life Sciences Vienna to check the biological function of the Fishcon lock for fish at the site. A total of 683 fish ascents and 305 fish descents were detected in the study period of 104 days despite a very poor fish population of around 10 kg/ha in the river. The largest fish migrated was a brown trout with a length of 420 mm. At the electrical fishing for determining the fish population no bigger fish could be catch. The migration of all fish species identified during fishing and monitoring (brown trout, rainbow trout, brook trout, lake trout, grayling, bullhead) could be demonstrated. Based on the monitoring results, the Fishcon lock Lippenannerl was assessed as fully functional with best grade according to the Austrian guideline. In addition, a prepared report confirms the function of the of the Fishcon lock Lippenannerl according to the German DWA-M 509 and BWK method standard.

In 2023 a another Fishcon lock with very similar design parameter was installed at the same river in Upper Austria approximately 10 km downstream of the Fishcon lock Lippenannerl at the weir "Schwarmühle". The hight difference at this spot is with around 3.8 m almost twice as high. After installing the Fishcon lock next to the new built residual flow hydro power plant at the weir of the diversion power plant, big parts of the Fishcon lock were buried with gravel for optical and safety reasons. The monitoring results were very similar to the Fishcon lock Lippenannerl. Again, all species of the river used the new fish pass for their migration and the Fishcon lock got the best possible rating according Austrian valuation standards. The big number of bullheads, which used the Fishcon lock for their ascents indicates, that bottom-dwelling fish species can use the system without any problems.

## Many fish migrated in the barbel region

In 2019 the first Fishcon lock in the barbel region was installed at the river Aschacharm in Upper Austria with a mean flow if 2 m³/s. The size of the chambers was identical with the both installations at the river Alm. For cost reduction, the Fishcon lock was placed behind a not used gate in the weir "Leumühle" and the connection to the downstream water was realized by using an existing approximately 100 m long channel. Although many parameters of this channel, like flow velocity, water depth and placement related to the power plant, were not optimal, a big number of fish used the Fishcon lock for their migration.

To determine this upstream fish migration, a fish trap monitoring was implemented from autumn 2019 until the end of June 2020, with the investigation period of 145 days. The migration of a total of over 5,300 fish from 27 native species could be documented. This also includes the migration of schools of fish, bottom-dwelling fish species and weak-swimming fish species. The largest fish that passed through the Fishcon lock on the Aschacharm was an eel measuring 700 mm. The migration of a pike measuring 601 mm and a zander measuring 610 mm were also documented. No bigger fish could be determined in this river at the electrical fishing.

Due to the very positive results, the Fishcon lock Leumühle was assessed

**Fig. 5.** Fishcon lock Leumühle at the river Aschacharm placed in the existing weir

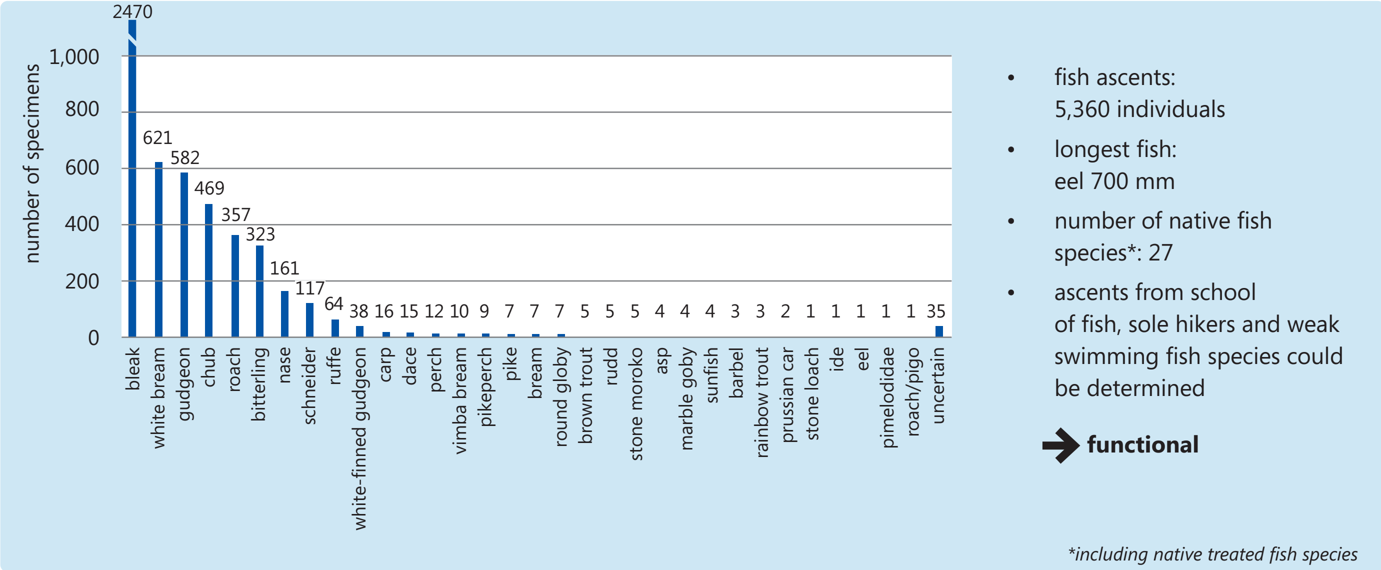



**Fig. 6.** Fish ascents at the Fishcon lock Leumühle at the river Aschacharm

as functional according to the Austrian guidelines and German standards. The biggest fish in general, which used the Fishcon lock for its migration was an huchen with a length of 87 cm at the river Mattig in Upper Austria. In total already over 30 species used the Fishcon lock for their upstream migration and no harm, age or size selectivity could be documented.

## Several years of operation

The first Fishcon lock installation at the river Alm is in operation since the beginning of 2019 and the Fishcon lock on the Aschacharm since mid-2019. Both systems were regularly checked and their function monitored. The around 10 years of summarized operation time shows that the slide gates operate very reliable. In average there is only every two years a slide gate blocked with flotsam. These malfunctions can be detected by the control system and rectified within a few minutes. The fine screens of both systems clean themselves automatically due to the changing flow. During the checks, only a few pen-sized pieces of wood were found between the bars at the facility. These did not affect the functionality at any time due to a very generous design. The operation of the systems shows that the illumination has to be cleaned of algae at longer intervals. With the very clear water of the Alm, cleaning has not yet been necessary until now; for the reference system on the Aschacharm, cleaning the illumination once a year is recommended. Exceptional situations such as flooding, ice and snow could not limit the functionality of both systems. The sole substrate before, in and after the chamber has hardly changed so far, resulting in a continuous sole connection. The technical function of both systems shows that very low-maintenance and reliable operation is possible with the Fishcon lock.

In addition to the Fishcon lock, the function of the turbine, which enables energetic use of the guiding flow at the Fishcon lock, was also examined. A research project was carried out together with University of Technology Graz in 2019/2020 to design the turbine concept, optimize the rotor geometry using CFD simulations, then determine the efficiency under real conditions. Despite the alternating flow through the rotor, an efficiency of approximately 65% (shaft power to hydraulic power) was measured and a total efficiency of 50% (electrically energy output to hydraulic energy) is realistic. Due to the low additional costs and the high full-load hours, the turbine can be operated economically at many locations. Currently long-term studies are being carried out.

**Fig. 7.** Huchen with 87 cm, which used the Fishcon lock for the ascent

## Further projects and cooperations are planed

Due to the positive test results, further projects with the new fish pass have already been implemented or are currently being planned mainly in Austria and Germany. Together with the first cooperations partners WWS Wasserkraft (USA and Japan), Whooshh (Sweden) and Troll Systems (Norway) the company FISHCON tries to introduce the technology to new markets. New cooperations with regional partner companies are considered to reach interested stakeholders in further countries.

**Bernhard Mayrhofer**
General manager and head of development
FISHCON GmbH
phone: +43 650 940 1368
e-mail: office@fishcon.at
**www.fishcon.at**

Graphics and photos come from the archive of **Fishcon** company.