

Importance of hydropower reservoirs and dams in Europe to mitigate the energy crisis and to serve as a catalyst and enabler for the Green Deal

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ABSTRACT: Hydropower has a long tradition in Europe and contributed significantly during the last century to industrial development and welfare in most of the countries in Europe. The ambitious plan for an energy transition in Europe now seeks to achieve a low-carbon climate-resilient future in a safe and cost-effective way, serving as an example worldwide. The key role of electricity will be strongly reinforced in this energy transition. In many European countries, the phase out of nuclear and coal generation has started with a transition to new renewable sources comprising mainly of solar and wind for electricity generation. However, solar and wind are variable energy sources and difficult to align with demand. The IEA (2021) concludes that hydropower provides “unmatched” flexibility and storage services required for ensuring energy security and delivering more solar and wind power onto the grid. In the future, these services will be in much greater demand to achieve the energy transition in Europe, and worldwide. Hydropower has all the characteristics to serve as an excellent catalyst and enabler for a successful energy transition. The HYDROPOWER EUROPE Forum brought together some 650 relevant stakeholders representing all sectors (including design, construction, production, sectoral associations, environmental and social issues), who participated actively for 40 months (2018-2022) through an extensive program of review and consultation addressing needs of the whole hydropower sector targeting an energy system with high flexibility and renewable energy share. The follow-up ETIP HYDROPOWER project (2022-2025) consolidates the strong network of the HYDROPOWER EUROPE Forum into a sustainable association and helps to unify the voices of hydropower in Europe. ETIP HYDROPOWER will facilitate, enhance and disseminate the Research and Innovation Agenda (RIA) and the Strategic Industry Roadmap (SIR) (drafted under the HYDROPOWER EUROPE project) taking into consideration the future needs of the sector and the R&I targets and the emerging policy priorities. This will help to ensure that hydropower can play the vital role of an enabler in the transition to a clean and safe energy system and the achievement of climate neutrality by mid-century. Furthermore, besides unifying the voices of hydropower, ETIP HYDROPOWER will further align and coordinate the industry RIA and SIR strategies to provide consensus-based strategic advice to the SET Plan (European Strategic Energy Technology Plan) covering analysis of market opportunities and research and development funding needs, biodiversity protection and ecological continuity. Another goal is, in one with Europe and the latest EU climate and energy related policies, deepening the understanding of innovation barriers and the exploitation of research results.

1 INTRODUCTION

Global warming is the biggest known threat for the 21st century. The European Union is the first continent to fight against global warming by announcing the European Green Deal, courageously showing the way for other countries and continents. The EU aims to be the first carbon-neutral continent by 2050. To fulfil this objective, PV and wind power will replace oil and coal for electricity generation. But PV and wind are very volatile energies. For integrating this huge amount of variable renewable electricity into the grid, Europe must also lead the development and integration of the high storage and flexibility capacity of hydropower into the new energy system, efficiently and cost-effectively. To provide an effective contribution to this unprecedented new European Green Deal in a sustainable, efficient, and cost-effective manner, the hydropower sector needs to develop strongly through technical and environmental innovations.

The current energy crisis reveals the importance of an independent electricity supply with high availability. Here the existing hydropower reservoirs already play an important role in helping to overcome the critical situation in winter 2022/23 as well as the following winters without the risk of blackout. New multi-purpose storage schemes and pumped-storage powerplants will be vital in future for a safe, independent and renewable electricity supply besides other services such as flood and drought protection to mitigate climate change effects. Nevertheless, to tackle environmental, societal, technological and market challenges, the hydropower sector needs to find novel approaches to future development in accordance with environmental and social demand.

The Research and Innovation Agenda (RIA) and the Strategic Industry Roadmap (SIR), released by the HYDROPOWER EUROPE Forum and now implemented under the ETIP HYDROPOWER project (both funded by the EU Horizon 2020 and Horizon Europe research and innovation programs), are key contributions to the growing debate on the net zero economy and the European Green Deal under the challenge of a safe and independent energy supply. They will be highly relevant for discussions on finding the best solutions to provide the new energy system with flexibility and high availability.

2 STATUS OF HYDROPOWER DEVELOPMENT IN EUROPE

Hydropower has a long history in Europe and in the first half of the last century contributed significantly to industrial development and welfare in most of the countries of Europe. Hydropower in Europe, and indeed worldwide, has many advantages such as:

- Renewable energy without direct emission of CO₂, excellent energy gain or pay back factor
- Excellent efficiency, production can be easily adapted to the demand (flexible peak energy)
- In-country independent energy creating jobs and financial resources in remote areas (taxes and concession fees)
- Strong contribution to flood and drought protection with potential for recreational and tourism activities
- Facilitation of navigation for the large rivers in Europe.

Today within Europe, including Turkey, almost 650 TWh are generated in an average hydrological year, which equates to about 65% of the economically feasible hydropower potential (Figure 1). For a few years, the yearly production of hydropower has stabilized near 650 TWh and the total installed capacity near 230 GW. It should be noted, however, that the yearly hydropower production is also influenced by the hydrological situation each year.

Figure 2 shows the situation for hydropower use and untapped potential in different countries within the Europe region. It can be noticed that in many countries there is still considerable potential for development. In Figure 2, the highlighted countries have developed less than 50% of the economical feasible potential, assuming that the market conditions would allow for it. For 14 countries the share of hydro in the overall electricity generation is between 25% and 50%, for three countries between 50% and 90% and for another two countries higher than 90%. This demonstrates that in more than half of the countries in Europe (as shown in Figure 2) hydropower

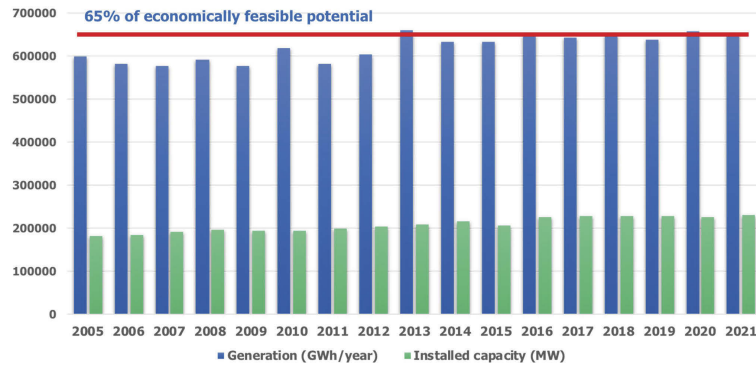


Figure 1. Evolution of yearly production and installed capacity of hydropower in Europe since 2005 (according to Hydropower & Dams World Atlas 2022).

represents an important share in the electricity generation, which is important for the success of a safe energy transition.

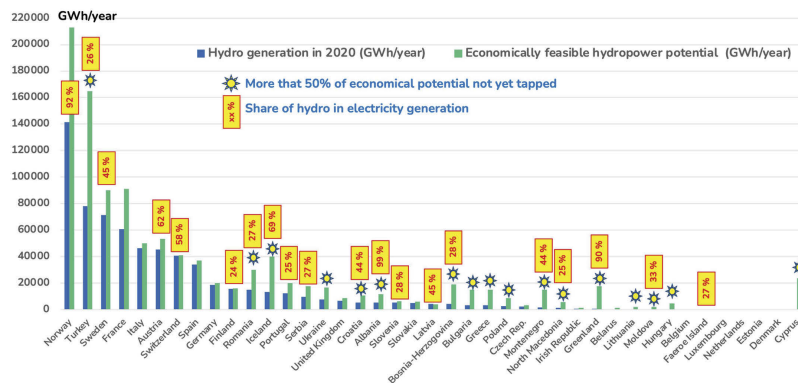


Figure 2. Generation and extension potential of hydropower in countries within the European region (according to Hydropower & Dams World Atlas 2021). The countries having developed less than 50% of their economical feasible potential (assuming market conditions have a demand for it) are highlighted. The share of hydro in the electricity generation is indicated for the countries with a share of more than 25%.

Nevertheless, relatively little investment has been undertaken over the last 15 years, as can be seen in Figure 3 which shows the installed capacity under construction. In 2012, a quite significant increase in the construction of new power plants reaching almost 10,000 MW can be seen. This may be attributed to the Fukushima catastrophe leading many countries to redefine their energy strategy towards renewable sources such as hydropower alongside the planned phasing out of nuclear energy. Since 2015, however, construction activity has been decreasing to some 3000 MW with an activity above 5000 MW in 2019.

The low investment level around 2021 can be attributed to the fact that electricity prices on the European spot market were very low due the following reasons:

- Production capacity in Europe was too high (especially via conventional thermal generators using coal)
- Cost of CO₂ certificates were very low
- The market was distorted due to the high subsidies provided for renewable energy sources such as solar and wind

Thus, under such market conditions hydropower generation was strongly penalized. However, the actual energy crisis reveals the important and vital role of hydropower – storage and pumped-storage - to help ensure a safe supply of electricity in the coming winters in Europe. Due to the energy crisis, the attractiveness of the extension and upgrading of existing hydropower plants, with the purpose of making them more flexible through the refurbishment of equipment and

increasing storage where possible, together with the construction of new pumped-storage power plants, has increased again strongly in countries with high storage potential. Furthermore, in many countries a significant amount of untapped hydropower potential still exists. However, in view of environmental and socio-economical constraints, the partial use of this remaining potential is extremely challenging and can be reached only through innovative and sustainable solutions for new hydropower plants.

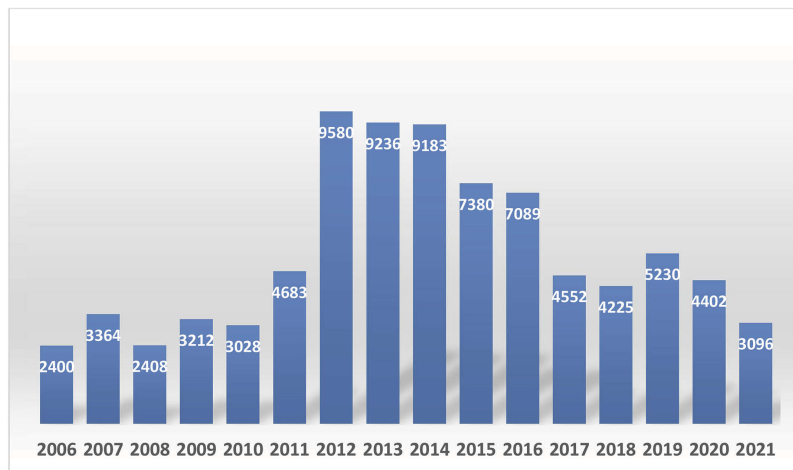


Figure 3. Installed capacity in MW under construction since 2006 (according to Hydropower & Dams World Atlas 2022 without Turkey).

3 OUTCOMES OF THE HYDROPOWER EUROPE FORUM: RESEARCH AND INNOVATION AGENDA – STRATEGIC INDUSTRY ROADMAP

The HYDROPOWER EUROPE Forum (<https://hydropower-europe.eu>) was supported by the EC under the Horizon 2020 programme LC-SC3-CC-4-2018 with the goals of developing a Forum through which an extensive programme of consultation could be undertaken to support the development of a Research and Innovation Agenda and a Strategic Industry Roadmap which would facilitate launching a series of innovations in the hydropower sector, targeting an energy system with high flexibility and renewable share.

The outcomes of the HYDROPOWER EUROPE Forum show the pathway to the vision for hydropower in Europe defined through wide consultation following four directions:

- Increasing hydropower production through the implementation of new environmentally friendly, multipurpose hydropower schemes and by using hidden potential in existing infrastructures
- Increasing the flexibility of generation from existing hydropower plants by adaptation and optimization of infrastructure and equipment combined with innovative solutions for the mitigation of environmental impacts
- Increasing storage by the heightening of existing dams and the construction of new reservoirs, which have to ensure not only flexible energy supply, but which also support food and water supply and thus contribute to the WEF NEXUS and achievement of the SDGs of the United Nations
- Strengthening the contribution of flexibility from pumped-storage power plants by developing and building innovative arrangements in combination with existing water infrastructure.

This vision was underlined by the Research and Innovation Agenda (RIA) and the Strategic Industry Roadmap (SIR), which also provide an inspiring example for hydropower development worldwide which is of high importance to the hydropower sector in Europe, which is already playing a major role in the worldwide market today. Eighteen research themes comprising some 80 topics were identified (RIA) as well as 11 strategic directions including some

40 detailed actions (SIR) ranging from regulation framework to social acceptance and innovative environmental strategies.

Besides the RIA and SIR (HPE, 2021b,c), the outcomes of the HYDROPOWER EUROPE Forum can be summarized as follows:

- A state-of-the-art report on Hydropower Technologies has been produced (HPE, 2021a).
- The HYDROPOWER EUROPE Forum has been launched, which includes a global network covering the whole sector of Hydropower, comprising some 650 participants in 2022.
- An extensive programme of consultation has been undertaken, comprising workshops, regional workshops and many online events to support the development and prioritisation of recommendations for the industry.
- A complex systems analysis of the European hydropower sector has been undertaken allowing priorities to be compared against findings from the wide consultation programme (HPE, 2020).
- A series of roundtables, discussions and dissemination events, including consultation with NGOs, has been implemented to better understand issues and priorities and to help raise awareness of how hydropower in Europe can support the clean energy transition (HPE, 2021d).
- The steps needed for a sustainable voice for hydropower in Europe, including a focus on facilitating R&I priorities, have been considered and an implementation plan proposed.

4 ETIP HYDROPOWER - UNIFYING THE VOICES OF HYDROPOWER

A European Technology and Innovation Platform (ETIP) is a community whose primary purpose is to define R&I priorities for its sector. The secondary purpose is to overcome barriers to the deployment of R&I outcomes: e.g., industrial strategy, market opportunities, exploitation of research results, international cooperation, education, environmental and social impacts. There is a need for a unified industry to be represented and recognized at a European level. The HYDROPOWER EUROPE Forum provided a first opportunity to gather some 650 stakeholders representing all the sectors of the value chain. Under the ETIP HYDROPOWER project (<https://etip-hydropower.eu>), the hydropower forum will continue to grow and offers an ideal opportunity to help unify the voices of hydropower in Europe (Fry et al., 2023).

ETIP HYDROPOWER will further detail the already developed industrial strategies as well as analysis of market opportunities and research and development funding needs, by a deepening of the understanding of innovation barriers and exploitation of research results, which are in line with the Recovery Plan for Europe and the latest EU climate and energy related policies.

The ETIP HYDROPOWER has the mission to:

- represent a consolidated and strong network of representatives from industry, academia, research centers, civil society and sectorial associations of the hydropower sector
- enhance and disseminate the Research and Innovation Agenda (RIA) and the Strategic Industry Roadmap (SIR) taking into consideration the future needs of the sector and R&I targets and emerging policy priorities
- align and coordinate the industry RIA and SIR strategies to provide consensus-based strategic advice to the European Commission and the SET Plan (European Strategic Energy Technology Plan) covering analysis of market opportunities and research and development funding needs, biodiversity protection and ecological continuity
- deepen the understanding of innovation barriers and the exploitation of research results in line with the latest EU climate and energy related policies

The ETIP HYDROPOWER aims to be a recognised interlocutor for the European Commission, Member States and Associated Countries about the hydropower sector specific R&I needs. ETIP Hydropower foresees working relationships with the relevant national/regional/EU-level platforms to ensure synergies between EU, national and regional activities.

In more detail, ETIP HYDROPOWER will answer the following questions:

- Which research and innovations projects are the most important in order that hydropower can fulfil the role of an enabler and catalyst in the energy transition?
- Which strategic actions have to be taken when, in order that hydropower can fulfil the role of an enabler and catalyst in the energy transition?
- How public awareness can be increased for hydropower in the transition to a clean energy system focusing towards a zero-emissions target?
- How hydropower projects can be carried out to create win-win situations with other renewables and other services contributing to the Water-Energy-Food Nexus and the achievement of the Sustainable Development Goals of the United Nations?
- What form of sustainable associate organisation representing the hydropower sector is required to ensure the vital role of hydropower in the energy transition?

ETIP HYDROPOWER will address these questions and challenges with working groups identified and launched based on consultation with the hydropower sector willing to participate with the sustainable associate organization beyond the ETIP lifetime. Potential working groups may cover a wide range of topics including, for example, the fields of economy, environment, equipment, structures, pumped storage hydropower (PSH), small hydro, digitalization, communication, market rules, legal frameworks etc. depending upon the specific need of the sector. Working groups will also include Civil Society Organisations for the identification of potential social impacts of hydropower.

This structure allows for robust outreach approaches and societal engagement actions to be implemented across the EU and associated countries. The outcome of the working groups will be position papers on specific themes prepared by joint workshops, thematic conferences, webinar series, regular exchanges and wide consultation. The activities of ETIP HYDROPOWER, involving an external scientific board and the above-mentioned working groups, is structured according 5 work packages as shown in Figure 4 below.

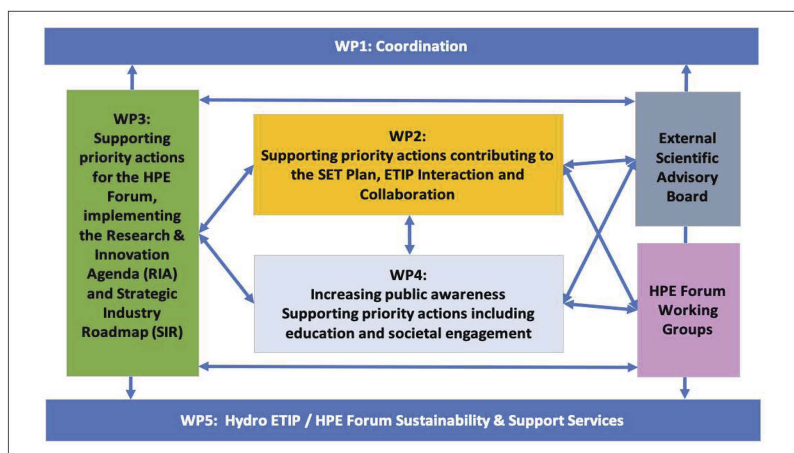


Figure 4. Structure and work packages of the ETIP HYDROPOWER project.

Figure 5 provides a generic representation of the mission and activities of ETIP HYDROPOWER at a strategic level within the hydropower sector. As illustrated by the anchor symbol the ETIP HYDROPOWER can unify and magnify the voice of hydropower to key stakeholders such as the European Commission and other EU institutions. It does not replace existing initiatives; rather it links them, allowing for presentation of key issues with one voice when appropriate. The job of the ETIP HYDROPOWER is to manage the linking and unified messaging process (arrows in brown in Figure 5). Existing initiatives continue with their own programmes and communications as before as shown in Figure 5 (blue dotted arrows).

The ETIP Hydropower project runs for three years from September 2022 to August 2025 and aims to be a facilitator for unifying the voices of the hydropower sector and to be a recognised interlocutor for the European Commission, Member States and Associated Countries regarding the hydropower sector specific deployment and R&I needs. The purpose

of the ETIP HYDROPOWER project is also to prepare for a transition into a sustainable, self-funded organization i.e. association which lasts after the duration of the project.

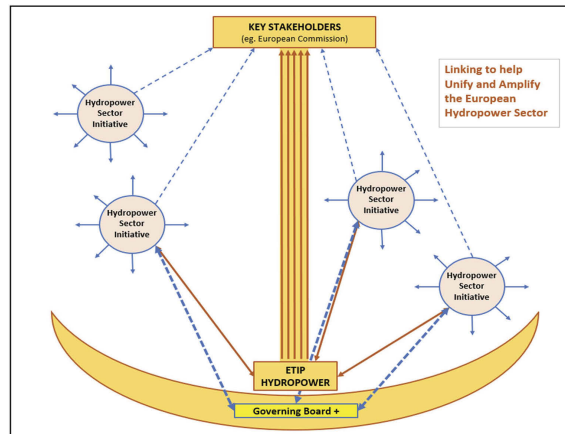


Figure 5. Generic representation of the mission and activities of ETIP HYDROPOWER at a strategic level within the hydropower sector.

With regards to *advocacy* in order to help unify and magnify the voice of hydropower, this association would have 3 main axes:

1) *Towards the decision makers:*

- Being the main contact point for all hydropower related activities as an EU association for the EU decision makers.
- Focused on lobbying, communication with stakeholders, increasing visibility of the hydropower sector, ensuring the inclusion of the voices of the hydropower sector, providing inputs for future energy policy, quantifying the added value brought by hydropower, highlighting the positive services hydropower provides to the environment.
- The technical expertise would be drawn from national hydropower entities.

2) *Towards the funding organisms:*

- Providing a clear research priorities list for the national and also the EU-level funding organisms by identifying and collecting the priorities from the association members.
- Increasing the funding amounts available for Hydropower research in national and European funding programmes. National research priorities or funding activities would be done through national hydropower entities.

3) *Between the stakeholders:*

The association would provide a network between all the relevant hydropower stakeholders in order to hear early in the process from new technologies, projects or activities related to the European and global hydropower sector.

In view of *collaborative R&I* this association may have three main types of research collaboration:

- **Small projects programme:** As part of the annual membership fee, each member pays a contribution into the small projects fund. This fund is used to directly contract ‘small projects’ addressing issues of priority to the forum members. Small projects are expected to cost in the €10-50K budget range.
- **Co-funding projects programme:** These projects would be significantly larger and more costly than those proposed under the small projects programme. Forum members will be invited to express interest and potential financial support for collaborative working on projects on this list. Where there is sufficient support and pledged finance, then:(i) a project specification will be developed in detail. (ii) a project budget will be developed in detail. (iii) a collaborative research agreement established. (iv) the project tendered for contract, proposals evaluated, tender selected and project implemented.
- **Collaborative bidding programme:** Where existing funded programmes of research (for example, EC Horizon Europe and other programmes) show opportunities for relevant

hydro industry research, these will be presented to the forum members with the opportunity to collaborate on a joint proposal submission. The costs associated with development of such submissions would be borne by individual members; the HPE Forum role here is to raise awareness with members and facilitate initial proposal team building.

5 CONCLUSIONS

ETIP HYDROPOWER will help to ensure that hydropower can play the vital role of a catalyst and enabler in the transition to a clean and safe energy system in Europe. Hydropower has proven to be a reliable supplier in the energy crisis. Its important contribution to secure storage with the lowest indirect CO₂ emissions amongst the renewable energies will become even more important in the energy transition towards the achievement of climate neutrality by mid-century. ETIP HYDROPOWER will help to unify the voices of hydropower in Europe and worldwide, to increase public awareness on its catalyst and enabler abilities as well as motivate innovative collaborative research towards environmentally compatible solutions. Besides electricity supply, hydropower can offer other services which are important to help mitigate climate change effects, like water supply, contribution to flood and drought protection with potential for recreational and tourism activities and facilitating navigation on the large rivers.

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