D8.2 Hydropower Policy Brief: The benefits of informing hydropower reservoir operations with climate and inflow forecasts

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D8.2 Hydropower Policy Brief: The benefits of informing hydropower reservoir operations with climate and inflow forecasts

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Abstract	This report presents the hydropower policy-brief: "The benefits of informing hydropower reservoir operations with climate and inflow forecasts". This policy brief summarizes the key results and recommendations from research carried out during the IMPREX project on four case studies representative of typical hydropower systems encountered in Europe. Based on strong collaborations with stakeholders and operational managers from European energy production companies, proof-of-concept demonstrators were developed to show the value of hydro-meteorological forecasts for the hydropower sector. Key messages and recommendations are presented in this policy brief.

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POLICY BRIEF

The benefits of informing hydropower reservoir operations with climate and inflow forecasts

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Background and challenges

The hydropower sector is sensitive to climate (rainfall, snowfall and melt, temperature), hydrologic conditions (river runoff variations) and river basin conditions (land use and occupation). Water and climate not only affect hydropower production capacity (i.e., electricity supply), but also energy consumption (e.g., electricity demand for heating or cooling).

The quantification of water resources availability and the anticipation of future climate conditions, considering the uncertainties associated with future scenarios, represent a challenge to the sector in both its daily operations and long-term strategic planning.

Daily operations include managing hydroelectricity production to effectively balance demand with supply, and avoid unstable prices and disruptions in the access to electricity. Long-term strategic planning ensures that adequate investments are considered to satisfy projected energy demands from population growth, increased electricity consumption, economic development and the global energy transition to renewables.

Hydropower strategic planning on medium- (weekly) to long- (monthly to seasonal) time scales, which are mostly driven by climate and hydrology at the local scale, needs to be aligned with daily and sub-daily decisions, which are mostly primarily driven by the energy market. Climate-oriented and market-oriented decisions have to cohabit in decision-making in hydropower reservoir operations.

Hydropower is the leading renewable energy resource globally. It is key to achieving the EU targets for reduction of greenhouse gas emissions and transition to a carbon-neutral electricity system. Expanding power generation from renewable energy sources has been a policy focus in Europe since the 2001 EU Sustainable Development Strategy (Commission Communication COM/2001/0264 final), followed by the 2020 climate and energy package, including the Renewable Energy Directive (DIRECTIVE 2009/28/EC of 23 April 2009), the 2030 climate and energy framework, reflecting EU commitments under the Paris Agreement, and the EU long-term decarbonisation scenarios up to 2050. Although the share of hydropower has remained largely constant over time (10-13%), while other renewable sources (e.g., bioenergy, wind and solar) grow rapidly, hydropower is predicted to remain an important source of renewable electricity generation in the total electricity mix.

A major characteristic of hydropower systems is their flexible and reliable production, which allows hydropower to be used for meeting base-load electricity requirements, as well as providing peak-load supply during peaks of high or unexpected demand. This is greatly due to the capacity of storing water in reservoirs, which translates into storing energy at one time for its use at a later time. This is an asset for daily operations but also to assist in building a climate-resilient energy system.

> *Hydropower reservoirs provide flexibility and reliability to energy systems, but challenges remain on how optimal operations can be improved given our current capacity to predict future climate and water conditions and the associated uncertainties. At long-term, there are challenges in determining the viability of major investments or dam operation procedures under changing climate conditions.*

Hydropower reservoir operations affect river flows, and hydropower water use can compete with other water users, such as agriculture and nature protection. The 2007 EU Directive on the assessment and management of flood risks (DIRECTIVE 2007/60/EC) acknowledges the cases of multi-purpose use of water bodies and calls attention to their impact on requirements for the achievement of the environmental objectives established under the EU Water Framework Directive on water policy (DIRECTIVE 2000/60/EC). While it is crucial for hydropower to deliver electricity when demands (and prices) are high, generating economic benefits, the sector must also take into account minimum environmental flows to maintain ecosystem services, downstream minimum flows during low flow and drought periods for other water uses, and flood risk regulations.

> *There are technical, economic and environmental challenges related to the operation of multipurpose hydropower reservoirs. Changes in hydropower operation affect other water uses and, reversely, operations from other uses affect hydropower production. This raises the challenge of evaluating the benefits of a joint optimal operation, supported by tailored forecast information on future climate and water conditions.*

The optimization of hydropower production is a water allocation problem. It relies on making the best decision between using water today (i.e., releasing water through the turbines to produce electricity and deliver it to the power grid) or storing water to be used tomorrow, when, based on projected demand and future value of water, electricity prices and demand are expected to be higher. Climate variability and change affect water availability and the future value of water. Consequently, it also affects the decisions to be taken.

> *Although hydropower is largely considered a mature sector in terms of innovation, progress remains to be made in terms of enhancing in-house capacity to integrate state-of-the-art European climate services in daily operations and planning. To better inform decisions and operations, climate and hydro-meteorological information on future water inflows to reservoirs can be used. Challenges remain on quantifying the economic value of using this information efficiently in hydropower operations.*

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Relevance of informing hydropower operations with climate and inflow forecasts

- The research project IMPREX explored the use of climate and inflow forecasts to inform hydropower reservoir operations. It focused on forecasts for several days to months ahead, and on projections of water availability under climate change.
- Based on strong collaborations with stakeholders and operational managers from European energy companies, it addressed the challenges of matching available forecast information with local hydrological-energy contexts and needs.
- Proof-of-concept demonstrators were developed in four case study areas in France, Italy, Spain and Sweden. They assessed the operational value of forecasts at short to seasonal time scales, and the impacts of climate predictions on the adaptability of reservoir operation rules.
- Altogether, the IMPREX case studies provide a strong body of evidence on the economic benefits of hydro-meteorological predictions and climate services to the hydropower sector in Europe.

Key Messages:

- There is evidence of the link between the quality of inflow forecasts and their economic value to hydropower reservoir operations. In general, more accurate forecasts bring additional benefits to the hydropower sector in terms of increased hydropower production and revenues. The quantification of these benefits depends however on how climate-driven decisions interact with price-driven decisions in the hydropower system.
- Hydropower systems that are already dimensioned to capture the seasonal hydro-climatic variability of the inflows in their operations are less impacted by imperfect climate predictions. The room for improving hydropower benefits with better forecasts and hydroclimatic-informed operations is small in terms of yearly percentages of total electricity production (on average, up to around 3% per year). However, it corresponds to potential extra gains of thousands or millions of euros per year that can be used to invest in the sector and in integrated water management in complex river basin water systems.
- When there are competitive water uses, the main source of improved benefit for the hydropower sector may not be associated with the use of a particular forecasting system, but rather with the fact that the additional forecast information enables an improved operation that benefits all water uses.
- Under climate change scenarios, particular attention should be paid to transition periods of projected changes in hydrological regimes. The higher variability of projected hydro-climatic conditions will make the optimal operations of hydropower reservoirs more challenging. It tends to amplify the potential value of forecast information.

Recommendations

IMPREX addressed the challenges of quantitatively measuring the economic value of hydro-meteorological predictions to the hydropower sector. The following recommendations can be derived from the work carried out:

- The increased availability of climate services prompts questions about how these services can meet the sector's needs and expectations, and be incorporated in current hydropower practices. Given the presence of multiple time dynamics in hydropower systems, tailoring information to the required level of scale and detail is crucial to move from the stage of having predictions available to having predictions fully integrated in decision-making and economically impactful.
- Benefits are expected from including better hydro-meteorological forecasts in the chain of forecasting and reservoir management systems. It is therefore important to continue increasing the understanding of climate-water-energy systems and their interdependencies and responses to extreme events. The continued exploration of weather, climate and water services' capability of anticipating extreme events over different temporal scales is to be encouraged and fostered: when hydropower systems are at critical states (e.g., reservoir water levels too low or too high), knowledge of future conditions facilitates interactions between water users.
- Multi-sectoral co-benefit analysis can shed light on how consumptive water uses can also benefit from better-informed hydropower operations. There is therefore a potential for win-win situations, and open opportunities to promote further integrated water management frameworks. Multi-sectoral contexts can also foster commitments to align policies and practices among sectors by taking into account interlinkages and trade-offs on short-term operations and long-term strategic planning.
- Research and operations move at a different pace. However, the involvement of hydropower operational forecasters and service developers in joint research and innovation projects has proven to be effective: this can be an asset to optimize the efforts needed to adapt hydropower operations to state-of-the-art forecast products made available by service providers.

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