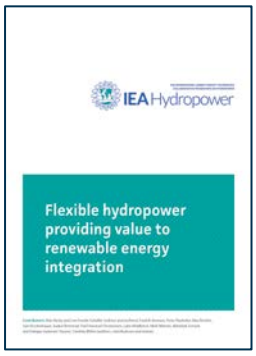
Flexible Hydropower Providing Value to Renewable Energy Integration



Achieving low-cost, reliable, and environmentally sustainable electricity is a key part of the global decarbonization challenge. Variable renewable energy (VRE), like wind and solar photo-voltaic (PV) energy, are increasingly important to expand energy access and enable clean energy electrification.

Variable power production from VRE needs to be balanced against consumption, and this can be accomplished through multiple measures, including energy storage, demand response and management, generation flexibility, flexible transmission technologies, and smart grid solutions.

What flexibility is needed?

Power system flexibility is defined as the ability to effectively cope with variations in the supply or demand of electricity. In systems with high shares of wind and solar energy, system flexibility becomes increasingly important to maintain system balance.

Flexibility type	Short-term			Medium-term	Long-term	
Time scale	**Sub-seconds to seconds**	**Seconds to minutes**	**Minutes to hours**	**Hours to days**	**Days to months**	**Months to years**
Issue	Ensure system stability	Short term frequency control	More fluctuations in the supply / demand balance	Determining operation schedule in hour- and day-ahead	Longer periods of VRE surplus or deficit	Seasonal and inter-annual availability of VRE
Relevance for system operation and planning	Dynamic stability: inertia response, voltage, and frequency	Primary and secondary frequency response	Balancing real time market (power)	Day ahead and intraday balancing of supply and demand (energy)	Scheduling adequacy (energy over longer durations)	Hydro-thermal coordination, adequacy, power system planning (energy over very long durations)

Contribution by Hydropower

Hydropower is the largest source of renewable energy in the electricity sector globally, representing 60 percent of total renewable generation in 2020. The technical potential for increased hydropower generation is large enough to meet substantial further deployment both in the medium (2030) and long term (2050). The International Energy Agency (IEA) expects hydropower generation to double by 2050. Hydropower is also by far the worlds' largest grid-connected storage technology. The International Hydropower Association expects that the current installed capacity of pumped storage hydropower of around 160 GW will increase to between 412 and 700 GW by 2050.

Reservoir, run-of-river, and pumped storage hydropower are already widely used for providing flexibility, energy storage and ancillary services in the electricity system and will play an even more important role in future systems with higher share of VRE. Hydropower can deliver important flexibility services to support the provision of secure, reliable energy supply, whilst underpinning the effective integration of cleaner energy technologies. Hydropower is also used to provide base load energy in many countries and regions that have both high (Norway, Costa Rica, Venezuela, Tajikistan, Quebec, British Columbia, and Tasmania) and lower shares of hydropower in their grid.

A good indication of the types of flexibility required can be obtained by the phases of VRE integration as proposed by the IEA.

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VRE Phase	System Description	Hydropower Contribution and Value
1	No relevant effects on system operation	No extra flexibility needed to be provided by hydropower. (many countries)
2	Additional flexibility needs can be met by minor adjustments to existing operations	Hydropower can provide the additional short-term flexibility needed related to small-scale rapid variation in power generation from VRE. (Brazil, China, India, Sweden, Texas)
3	VRE generation determines system operations to maintain stability	Quickly ramp and start at any time including switching between producing and consuming energy for pumped storage hydro. Flexibility from clean hydro provides technical and economic advantages, as well as reduced GHG emissions. (Italy, Germany, Portugal, Spain, UK, California)
4	Additional investment in flexibility resources is needed to balance the system, which is increasingly weather-driven	Hydropower can contribute to increased system value by providing the right capacity at the right times, rather than providing energy volume only. Pumped storage hydro and reservoir hydro have fewer competitors that supply medium- and long-term flexibility. (Ireland, Denmark, South Australia)
5	Structural surpluses of VRE generation from weeks to months may lead to curtailment	Hydropower can provide substantial amounts of capacity (power) driven short term flexibility, capacity plus energy-driven medium-term flexibility, and long-term power and energy flexibility.
6	Structural over- or under- supply over seasons to years validates needs for sector coupling	

What is the value of flexibility?

The value of flexibility to the power system and the users is difficult to quantify. In non-market systems, flexibility was built into the system with the value reflected in the energy cost. The move to market-based systems involved the introduction of prices for both energy and flexibility services. In both cases, the production schedules of flexible units are adjusted to ensure a supply / demand balance at the lowest cost. However, the value differs between locations and system status, with the fundamental challenge to ensure correct reward for services and products to provide the right operation and investment incentives, with the highest value when the power system is operated at the extremes.

Hydropower can increase production in periods with energy deficit and reduce VRE curtailment in periods with energy surplus by pumping or holding back hydropower generation. In market-based systems, this is part of the business model for pumped storage hydro plants, which buy the electricity at low price for pumping and sell it back while generating at higher prices, thereby providing valuable flexibility to the system.

Conclusions

Hydropower is unique in its ability to deliver a broad spectrum of flexibility services across all timescales

- Increasing VRE and decommissioning of fossil-based power production adds more uncertainty and variability to the power supply, increasing the need for flexibility
- Hydropower delivers a broad spectrum of flexibility services, from short-term inertia and frequency response to long-term seasonal storage, and can adapt to the needs in different systems
- Hydropower enables VRE expansion and address operational power grid challenges
- To value flexibility adequately, it is important to move beyond the levelized cost of energy as the metric and to consider the costs and benefits of all system services and to allow the lowest cost technologies deliver flexibility
- The value of flexibility services from hydropower will increase, as higher VRE levels increase system flexibility needs across all time scales
- Is hydropower adequately incentivised to provide highly reliable flexibility services, and are the remuneration mechanisms sufficient?

Hydropower can play a key role as a provider of clean energy and flexibility in a future low-carbon power system.