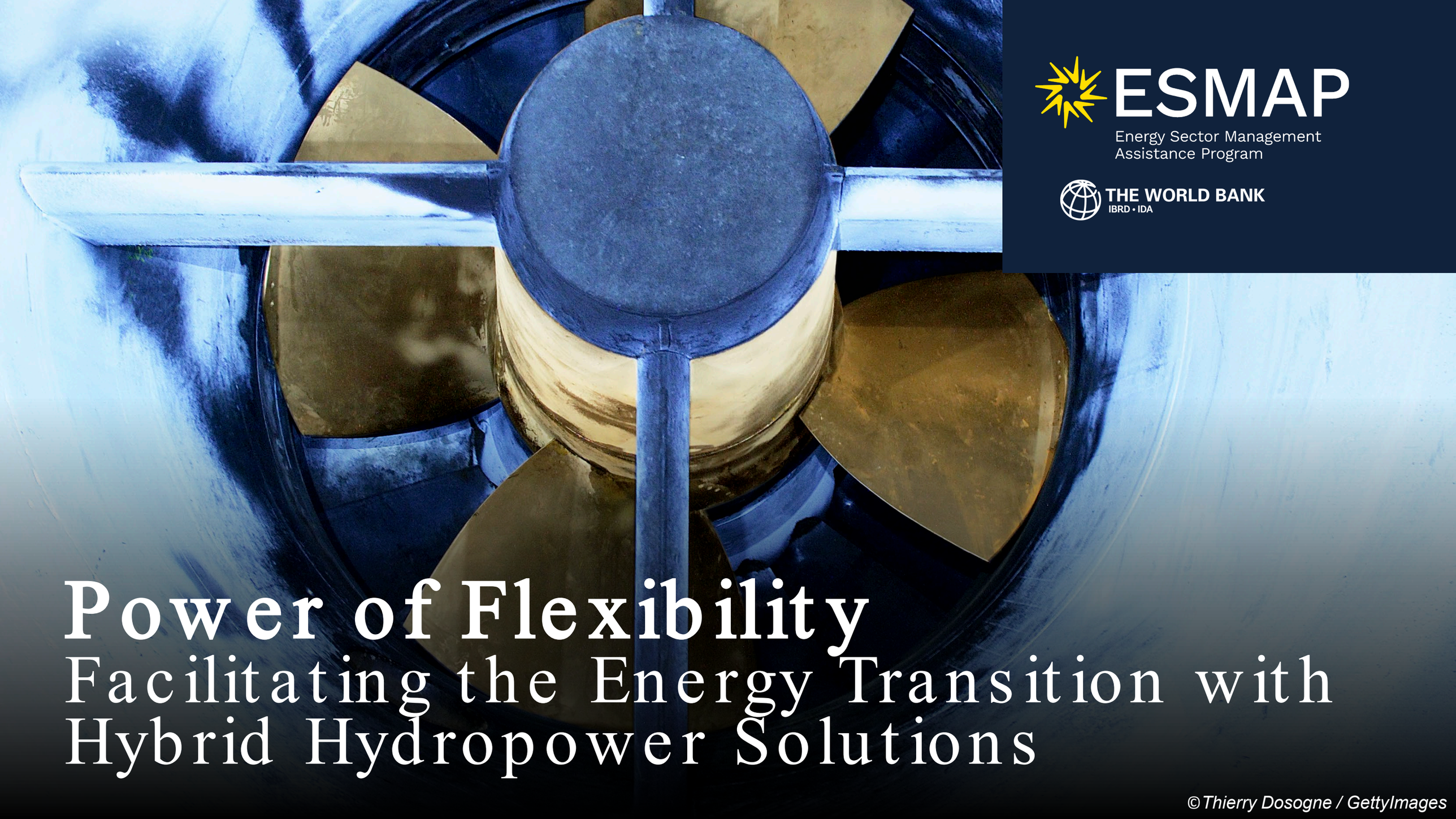

ESMAP
Energy Sector Management Assistance Program

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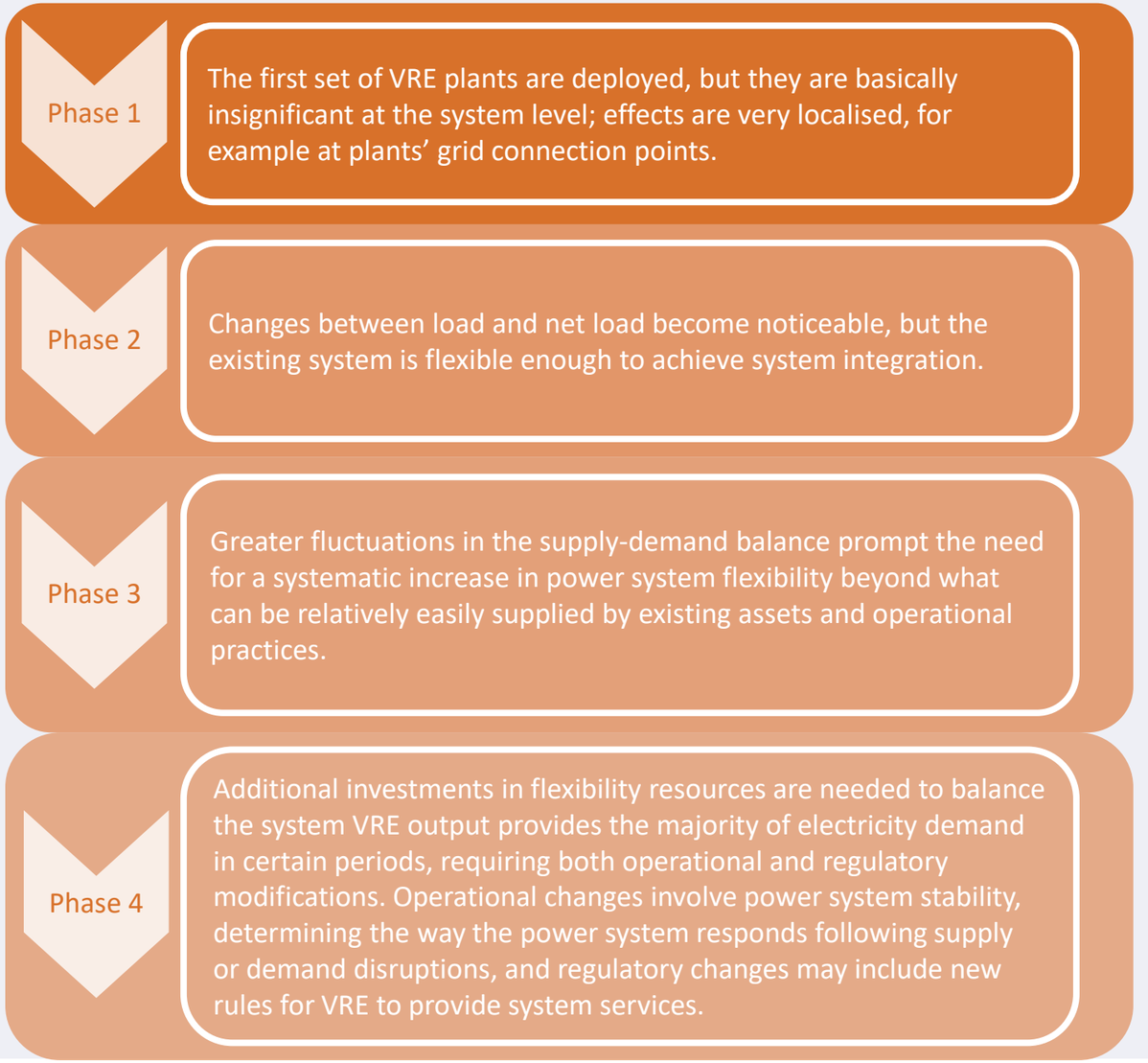
Power of Flexibility
Facilitating the Energy Transition with Hybrid Hydropower Solutions

Transforming the power system

Variable renewable energy (VRE) generation is expected to have an increased share—reaching 25 percent in 2028—due to increased affordability of wind and solar, according to IEA.

While increasing VRE shares is a vital step on the path toward global power mix transformation, it will have implications for power systems given the challenge it poses to maintaining power system balance. Keeping up with this rapid transition requires exploring solutions that support and enhance power system flexibility, in turn reducing the strain on systems.

Scaling up and sustaining high shares of variable renewable energy (VRE) call for hydropower hybrids that not only generate electricity, but also provide energy services to increase resilience and reliability of power systems.

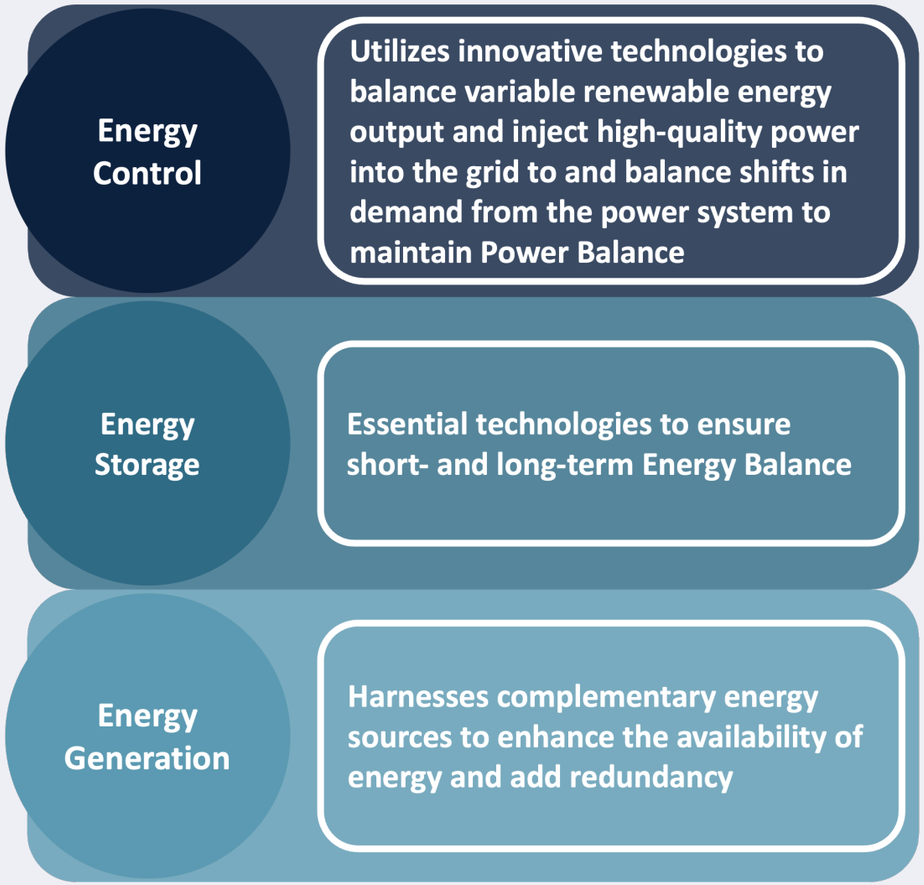


Source: IEA 2017, 2020.

Why Hydropower Hybrids

Hydropower hybrids utilize water as the primary energy source, combined with one or more renewable energy sources, energy storage, and an overarching operations and control system.

This enables hydropower hybrids to leverage the distinctive strengths of each technology to provide **energy services** to enhance **power system flexibility** and **energy security**.



Objectives

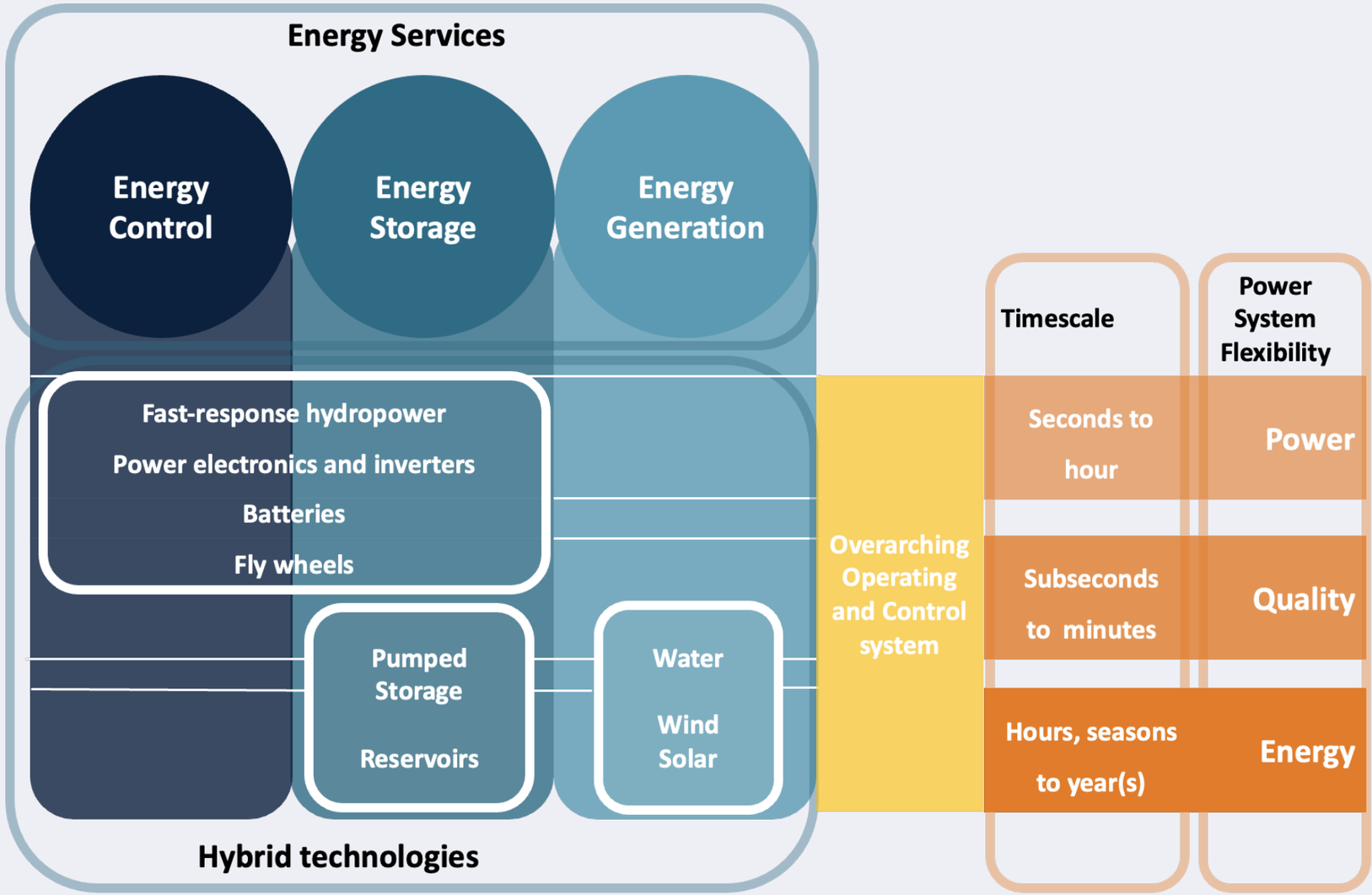
- **Stable short- and long-term power supply**
- **Energy services tailored to boost flexibility, resilience and reliability**
- **Improve the performance energy services from existing hydropower plants**

Integrating technologies

Hydropower hybrids integrate technologies under an overarching operation and control system

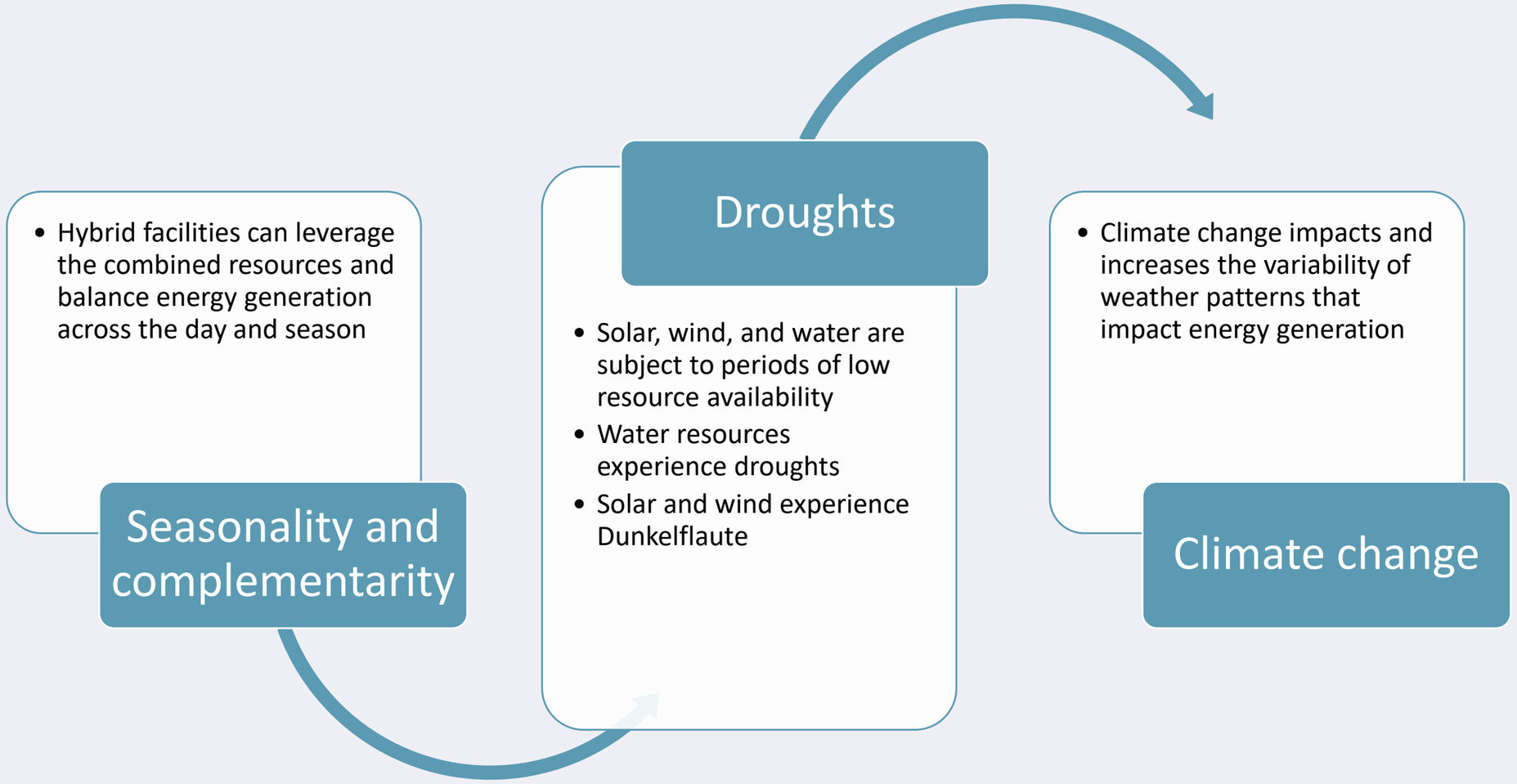
This enables the hydropower hybrid to deliver multiple energy services and support power system indicators over a range of temporal resolutions.

Energy services could present incentives for deployment in regions characterized by weak or underdeveloped grid systems or high VRE shares—considering a hybrid can provide readily dispatchable high-quality power to the grid, besides balancing load changes originating at the grid.



Securing Energy Generation

Energy generation is secured by utilizing multiple technologies allow harnessing the complementarities and seasonality of renewable energy sources.



Harnessing Benefits

A strong focus on integrated infrastructure planning and management can yield benefits beyond improving power systems. This applies, but is not limited, to the following elements for both hybrid hydropower facilities and virtual hybrid hydropower facilities

Strengthening energy security	**Creating multiple revenue streams from the same infrastructure.**	**VRE turned into dispatchable energy.**	**Reduced cost of project preparation activities.**	**A shared organization.**
Hydropower hybrid solutions can help address how energy security can be boosted to support economic development and improve quality of life (Banna et al. 2023).	A hybrid facility can boost revenue from energy generation relative to stand-alone plants.	Hydropower hybrids can use VRE to store more energy, by either pumping water to a higher-elevation reservoir or conserving it for later use and dispatching the energy when the opportunity calls for it.	It is possible to conduct joint site investigations, surveys, geological and geotechnical surveys, feasibility studies, and assessments for site selection and associated infrastructure.	Operational expenses in all project phases can be reduced relative to those in stand-alone projects if they all share project implementation, execution, and operation and maintenance.

Harnessing Benefits

Hybrid hydropower facilities located on the same land and utilizing the same grid connection point may bring additional benefits:

Power transmission costs are reduced

Hydropower hybrid with a single injection point requires lower capacity, when peak power output is less than the combined peaks of the stand-alone plants, or excess generation is shifted to storage.

Power systems are supported by supplying high-quality power at the same connection point.

Hybrid hydropower facilities are an excellent alternative to explore for countries and small island states that require greater energy access.

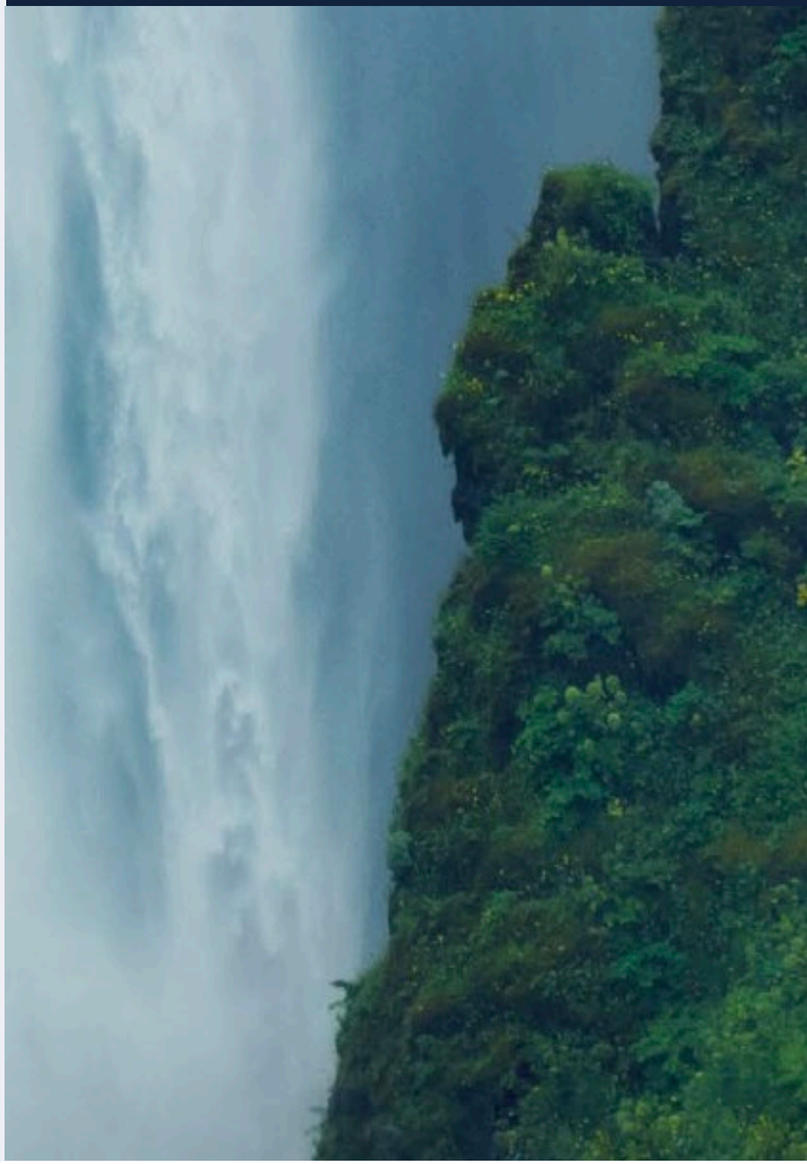
A site's fullest potential is utilized sustainably

Land use becomes more effective, lowering impacts on biodiversity and ecosystems, leaving more nature either untouched or available for other uses.

Economies of scale are achieved

Through cost minimization via shared use of infrastructure, project preparation activities, and organizational resources across the project life cycle, including development, implementation, operation, and maintenance.

Exploring Challenges



Integrating multiple technologies adds complexity, and must be managed effectively across its life span.

Unlocking the full potential of hydropower hybrids requires harnessing multiple integrated renewable resources under **an overarching operation and control system.**

Power system models and study software are keystones of operation and planning studies. It is necessary to examine gaps in modeling hybrid generation using software that simulates power systems.

Complexity must be managed effectively across its life span. As the technologies involved in a project grow, it becomes increasingly challenging to prioritize and harmonize resource utilization, efficiently deliver services

Hydropower hybrids may concurrently mitigate ecological impacts—to deliver societal benefits—and deliver energy services.

Development of resilient hybrid facilities requires further innovation and research to build methodologies and analytical tools

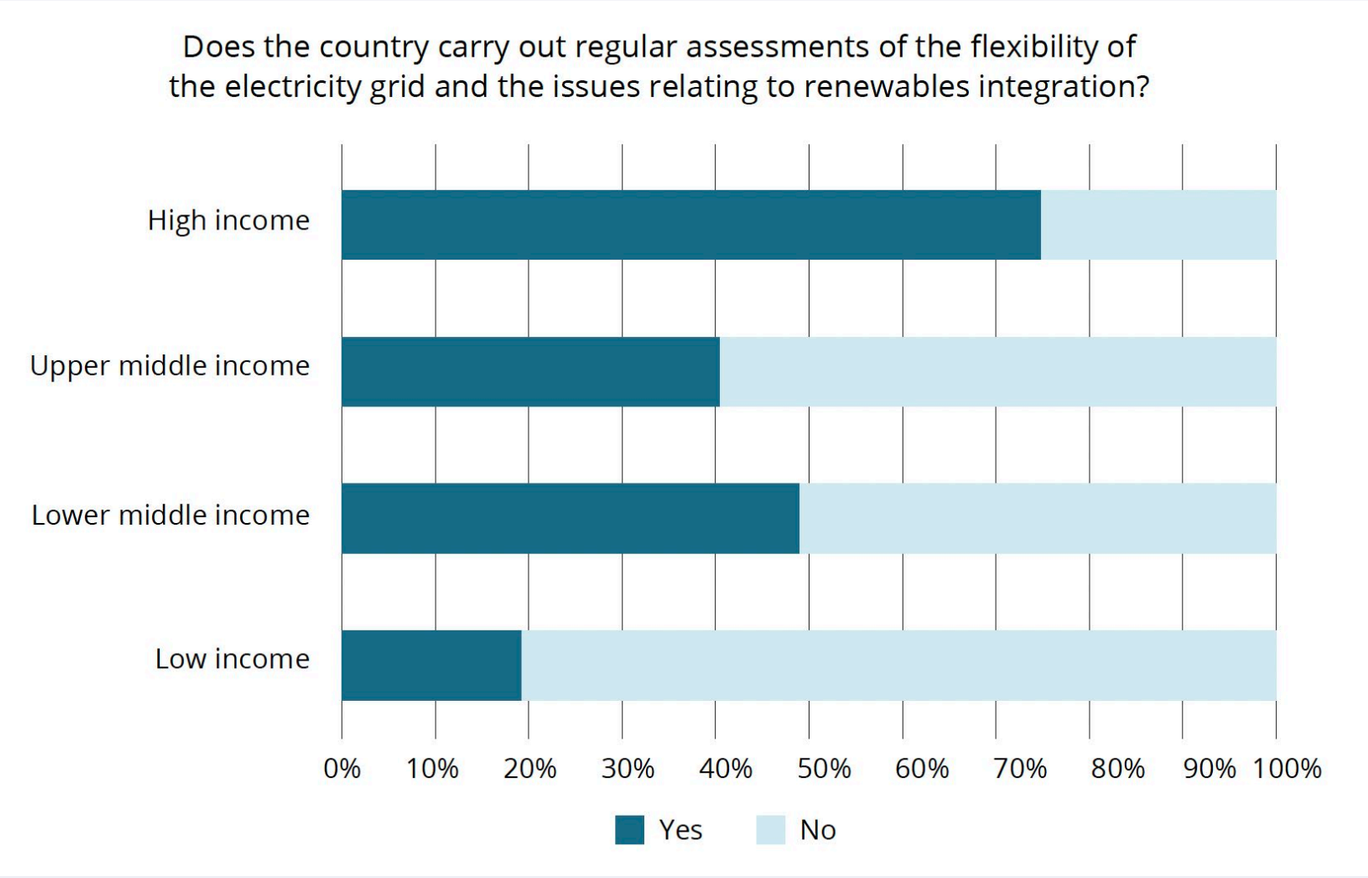
Fostering Energy Services

Enhancing bankability and scaling up investments of hybrid hydropower projects require supporting energy services through market design

Remuneration can have two important roles: (1) ensuring efficient resource utilization for energy balance, and (2) making visible the importance and value of energy services for maintaining power system balance.

The European and Indian market incentives share certain common aspects: they both acknowledge VRE's impact on power systems and work to develop legislation, regulations, and markets for energy services to incentivize the energy transition, and ensure energy security and affordability.

Development of resilient hybrid facilities requires further innovation and research to meet future flexibility demands.



Source: ESMAP https://rise.esmap.org/scoring-system

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THANK YOU.

Elin Hallgrimsdottir and Bente Brunes