2023

Flexible Hydropower

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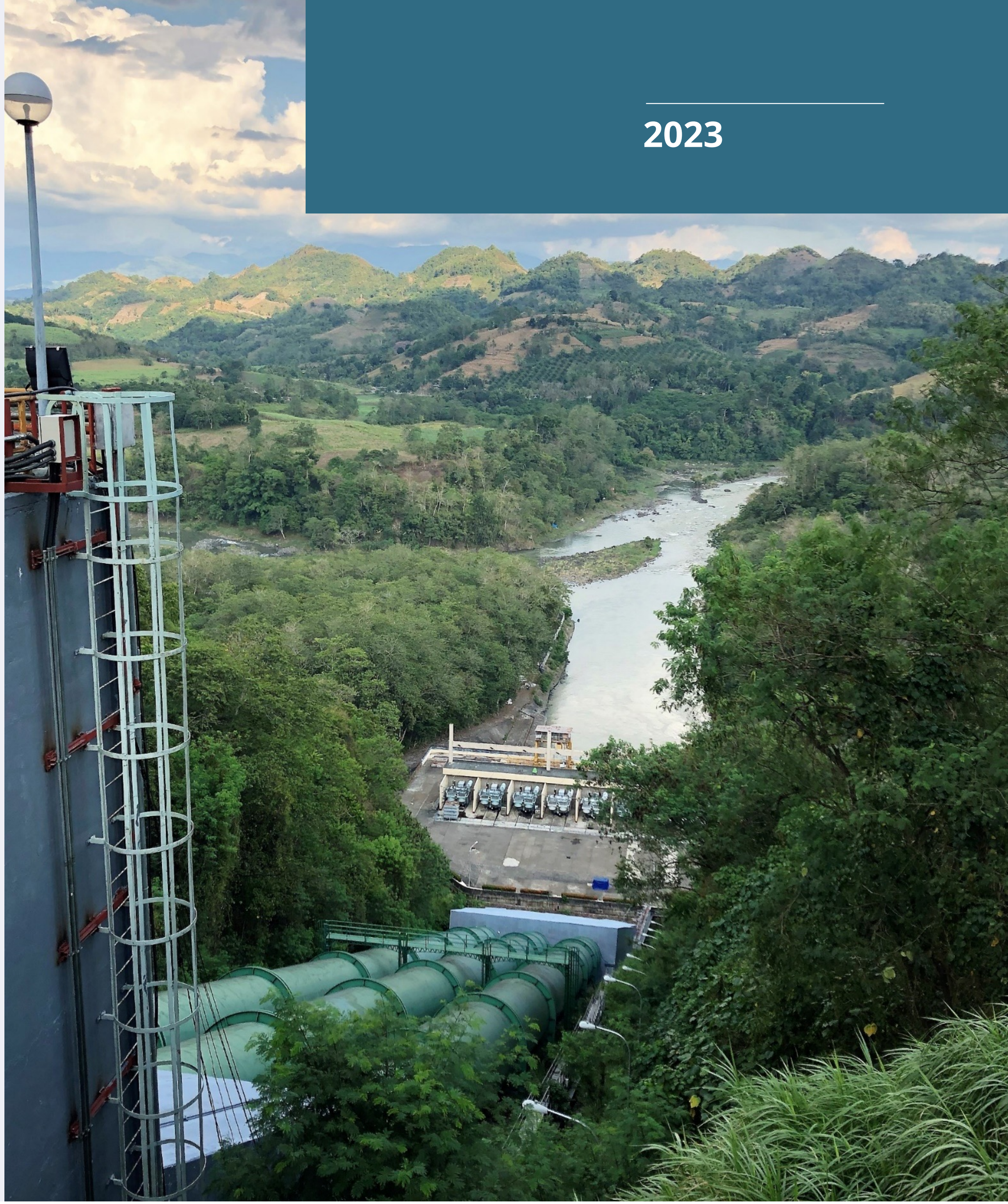


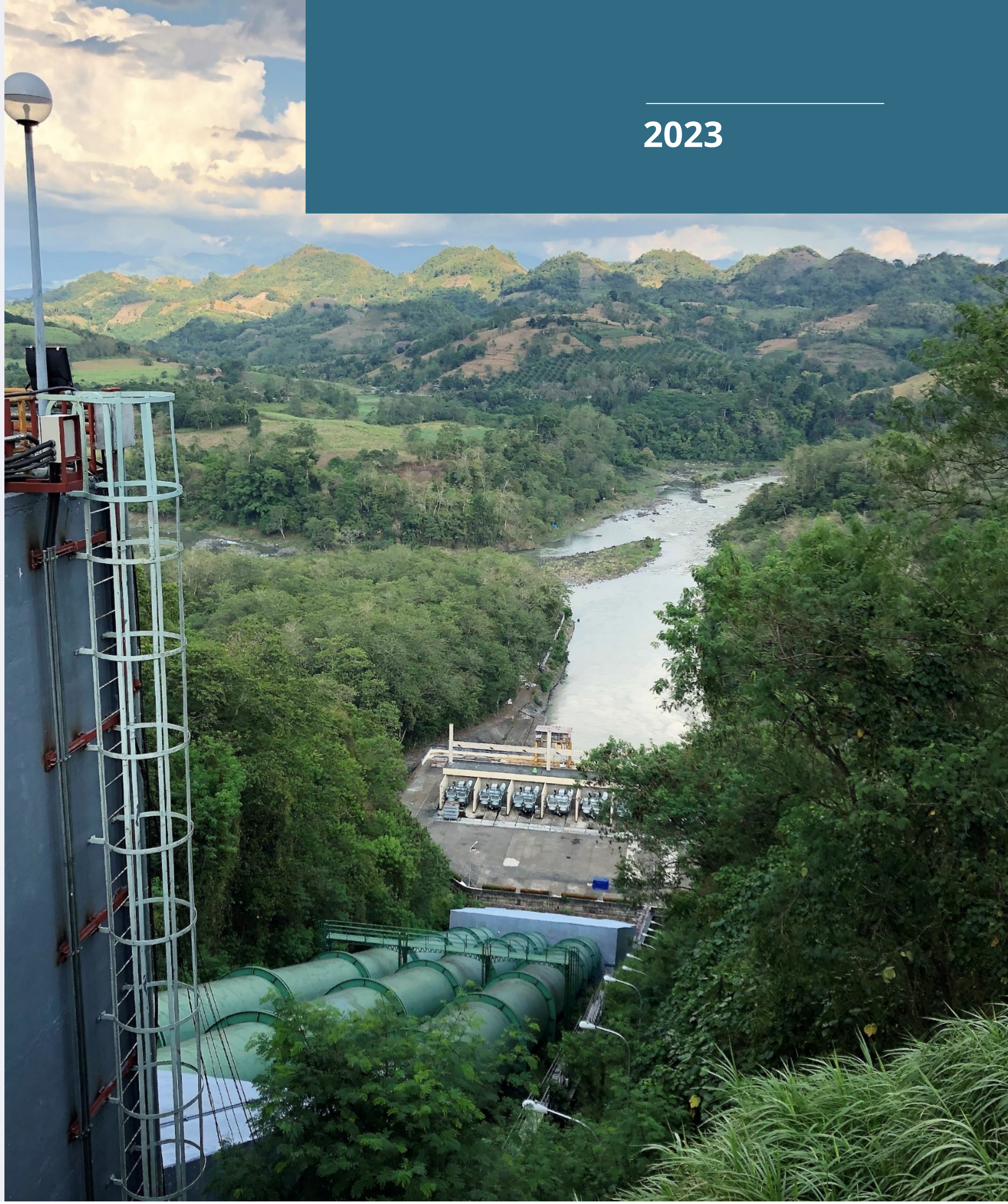
CONTEXT

In the current context of the poly-crisis, investing in renewables is a multiplier solution that simultaneously addresses affordability, energy access, energy security and resilience from climate shocks

The renewable energy share need to reach well over 30% of total energy consumption by 2030 to be on track with the net-zero energy emissions by 2050

- Solar PV is the fastest growing technology
- Followed by wind

Both are VRE energy sources and increase the need for dispatchable renewable energy sources such as hydropower



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DIFFERENTATION

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FLEXIBLE OPERATION

POWER SYSTEM FLEXIBILITY

HYDROPOWER CAPABILITIES

POWER SYSTEM FLEXIBILITY

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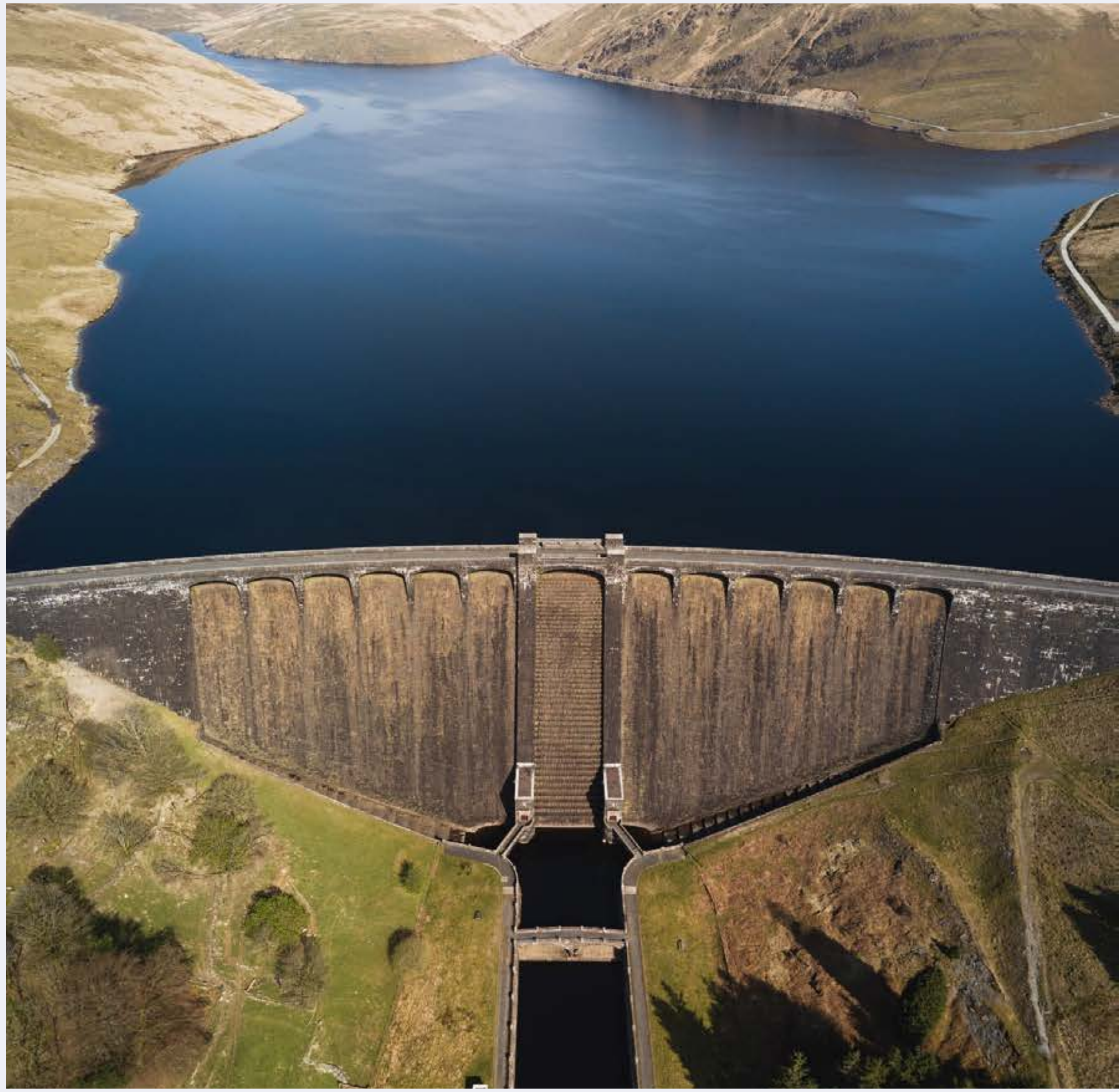
Power system flexibility is the ability to balance variations in the supply or demand of electricity. In other words, to balance total load and generation at any time.



POWER SYSTEM EVOLUTION

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The power system in most countries and regions are evolving in an unprecedented rate of change towards low carbon or emission free system.

In power systems with high shares of VRE sources, system flexibility is becoming increasingly important to maintain system balance due to the variability and uncertainty in these resources (IEA, 2017, 2018).

Phase	Description
1	At initial stage of VRE deployment with no relevant effects in system operation
2	Additional flexibility needs can be met by minor adjustments in existing operations
3	VRE generation determines system operations in order to maintain stability
4	Additional investments in flexibility resources are needed to balance the system
5	Structural surpluses of VRE generation from weeks to months may lead to curtailment
6	Structural over- or under-supply over seasons to years validates the need for sector coupling

Source: IEA (2018)

CHALLENGES IN POWER SYSTEM BALANCING

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The need for balancing occurs at different time frames, ranging from sub-seconds to seasonal and annual balancing needs.

Challenges in power system balancing can also be seen in the light of capability to deliver grid stability as:

ENERGY BALANCE

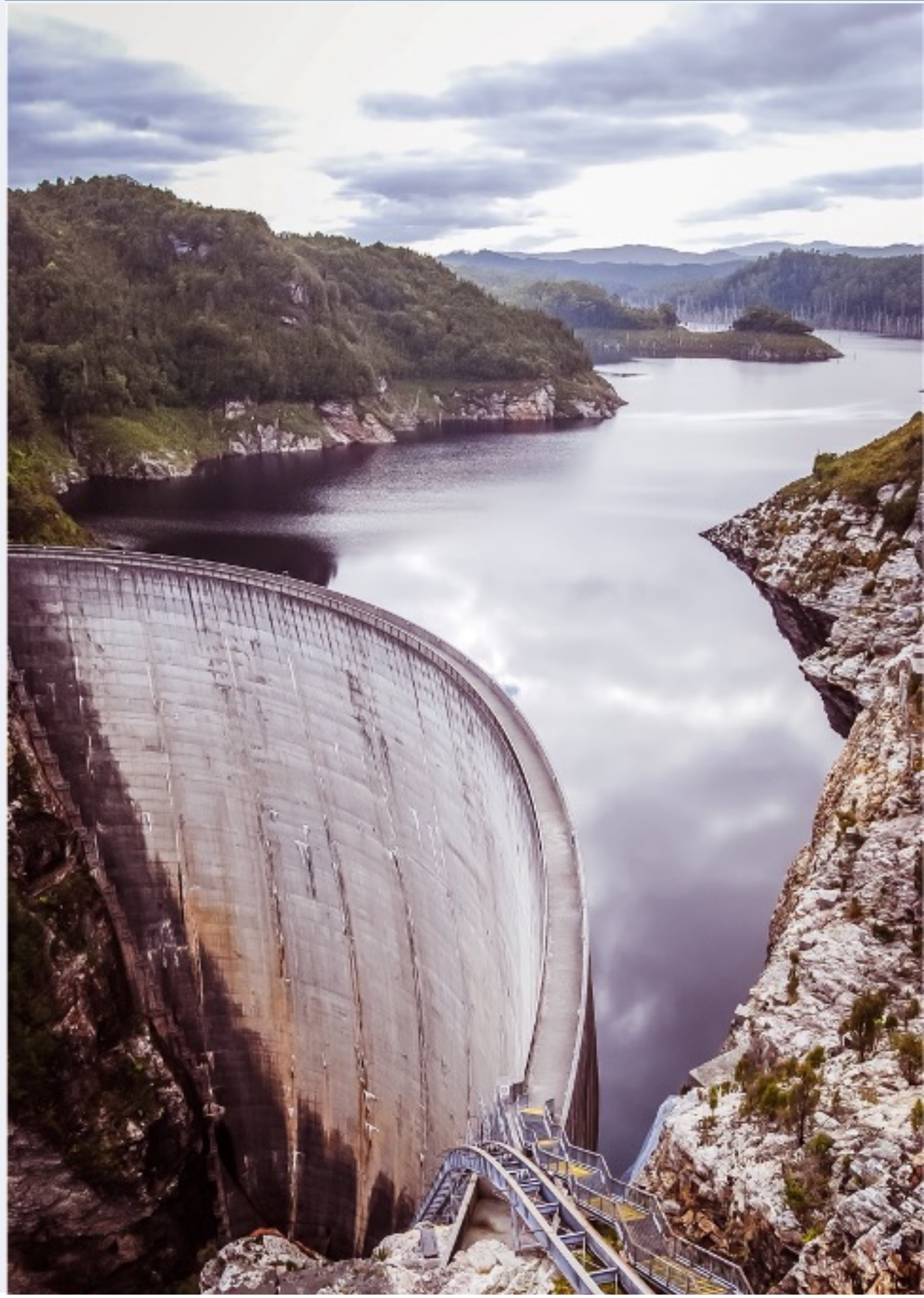
POWER BALANCE

FREQUENCY

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)

Source: IEA (2018)

HYDROPOWER CAPABILITIES



Hydropower has the unique capability to deliver power and energy when the power system requires it to maintain balance and quality in the short, medium, and long term.

- **Unit (MW)**
- **Plant power output (MW)**
- **Operating range (MW)**
- **Ramp rate (MW/s)**
- **Energy generation (GWh)**
- **Energy storage (GWh)**

FLEXIBLE OPERATION

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Hydropower is an essential foundation for the energy transition because this entails a significant increase in the demand for providing base load and flexible energy generation.

Hydropower Capability	Power system flexibility		
	Power	Energy	Frequency
Unit			
Plant			
Operating range			
Ramp rate			
Energy generation			
Energy storage			
Time scale	*Seconds to one hour*	*Medium to long term*	*Seconds to minutes*

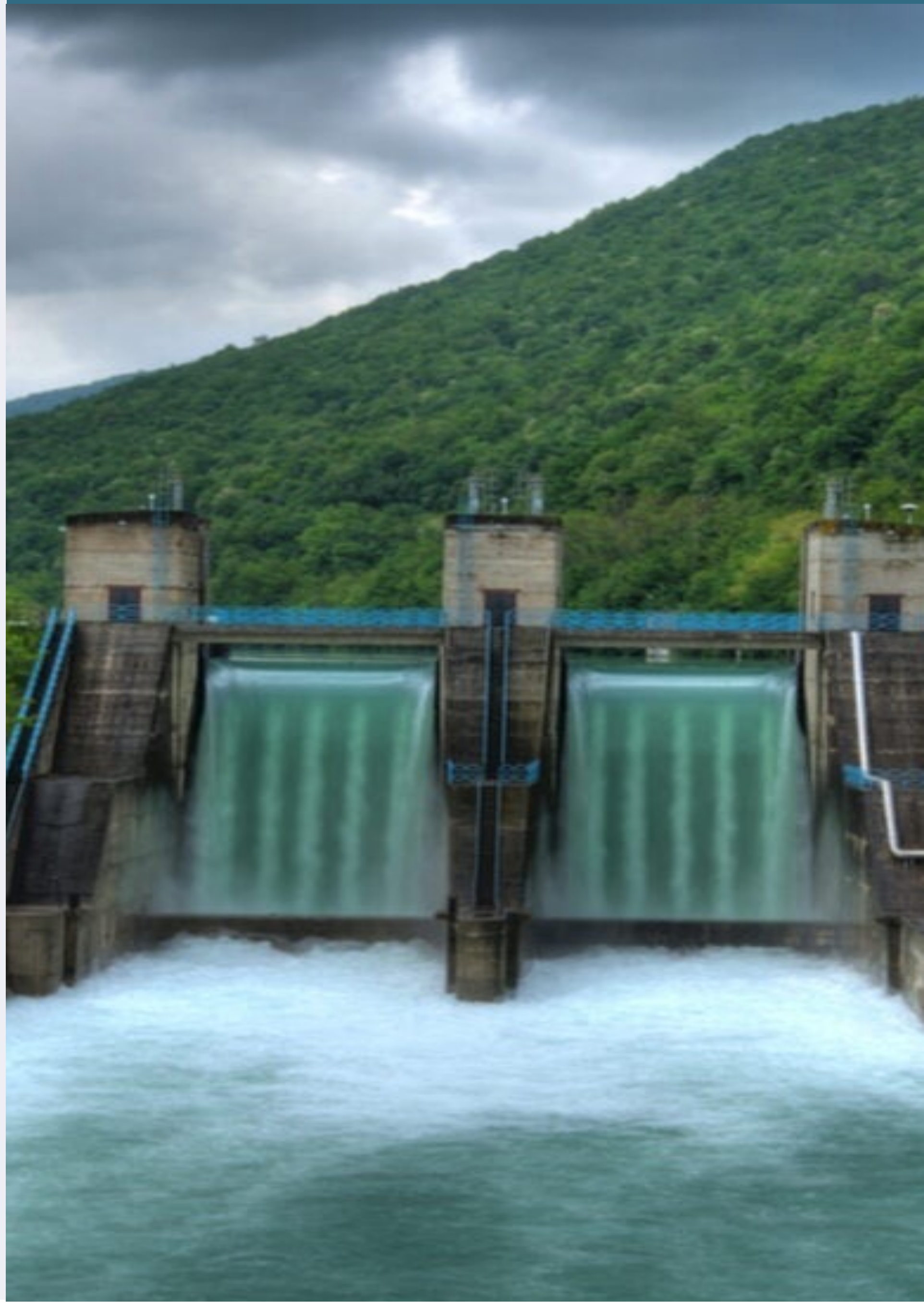
Source; World Bank, ESMAP HDF

ENHANCE CAPABILITIES

The design of a hydropower plant is also evolving from focusing on energy generation to enhancing capabilities to meet power system flexibility requirements.

A hydropower plant cannot deliver everything on its own and it is necessary to carefully select and optimize to enhance these capabilities.

This increases the value of solutions that efficiently balance the variability, and enhances the resilience and reliability of power systems.



EVOLUTION OF HYDROPOWER?

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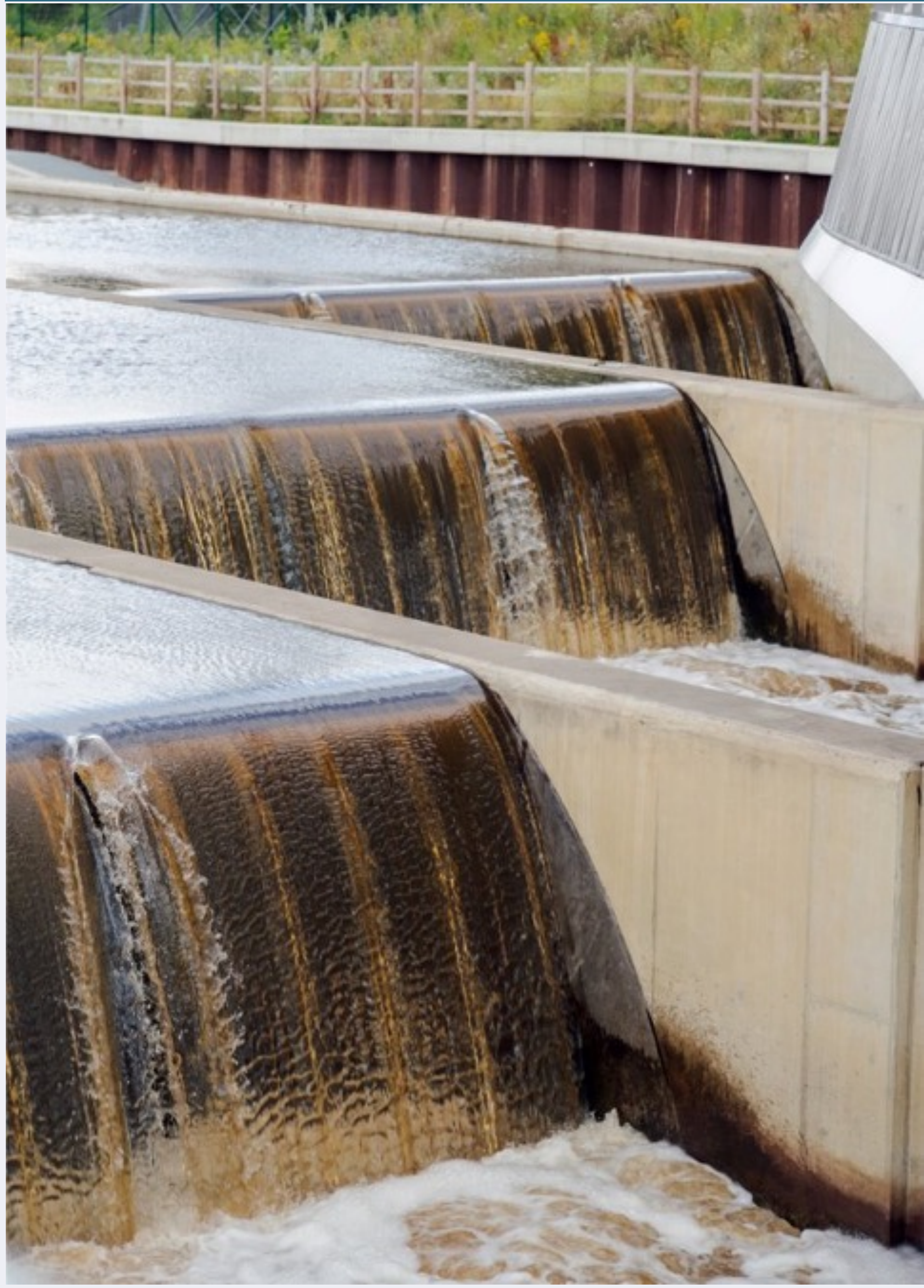

Maximize the value and benefits of infrastructure developement

Enhanced capabilities, operational synergies, value, climate adaptation and mitigation, and societal, environmental and economic benefits

HYDRO HYBRIDS

Use hydropower to enable dispatchable VRE?

Can VRE enhance the climate resilience of hydropower?

SUSTAINABLE DEVELOPMENT

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Sustainable infrastructure projects balance the utilization of available resources with the natural limitations of site conditions while mitigating the unavoidable adverse impacts and contributing to improving the living standards of those affected.

How to balance the need

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Water resource management	Agriculture	Aquaculture	Environment ecological	Recreational and cultural interests
Balance increased variability in hydrology Flood attenuation and control	Enhance reliability of Irrigation systems	Mitigate impact on river systems Enable fisheries	Careful identification of potential impact and how to mitigate and improve condition s	To sustain existing livelihoods or enable new

Source; World Bank, ESMAP HDF