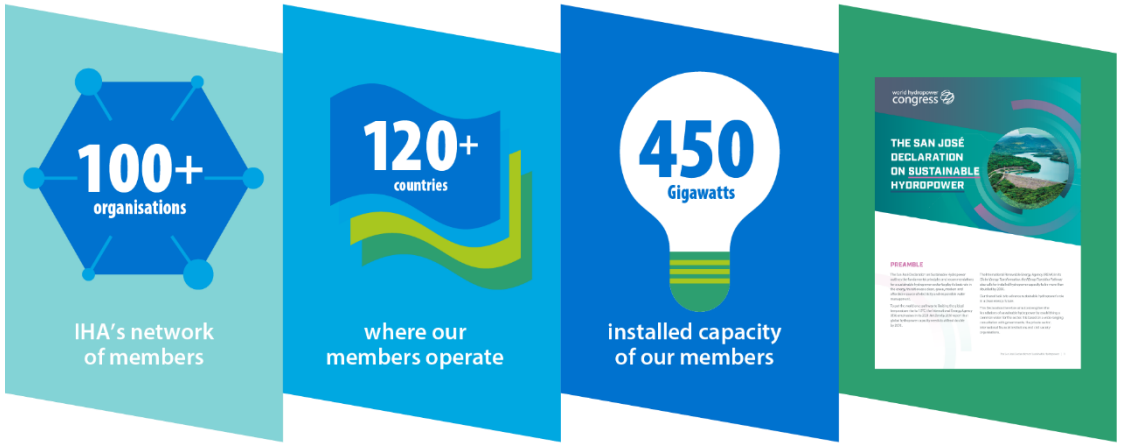
iha
international hydropower association

Flexibility and Hydropower: a natural partnership

Presentation to ESMAP

Introduction

The International Hydropower Association (IHA) is a non-profit membership association. We are **the global voice of sustainable hydropower**. Our members are committed to the responsible and sustainable development and operation of hydropower.



Mission

IHA's mission is to advance sustainable hydropower. IHA's broader objectives are:

To be the **global voice of sustainable hydropower**.

To **increase investment in sustainable hydropower** by engaging with global policymakers, financial decision makers, and the public.

To **position sustainable hydropower as a clean, green, modern and affordable** solution to climate change and energy security.

These objectives echo the commitments in the **San José Declaration on Sustainable Hydropower** adopted in September 2021.

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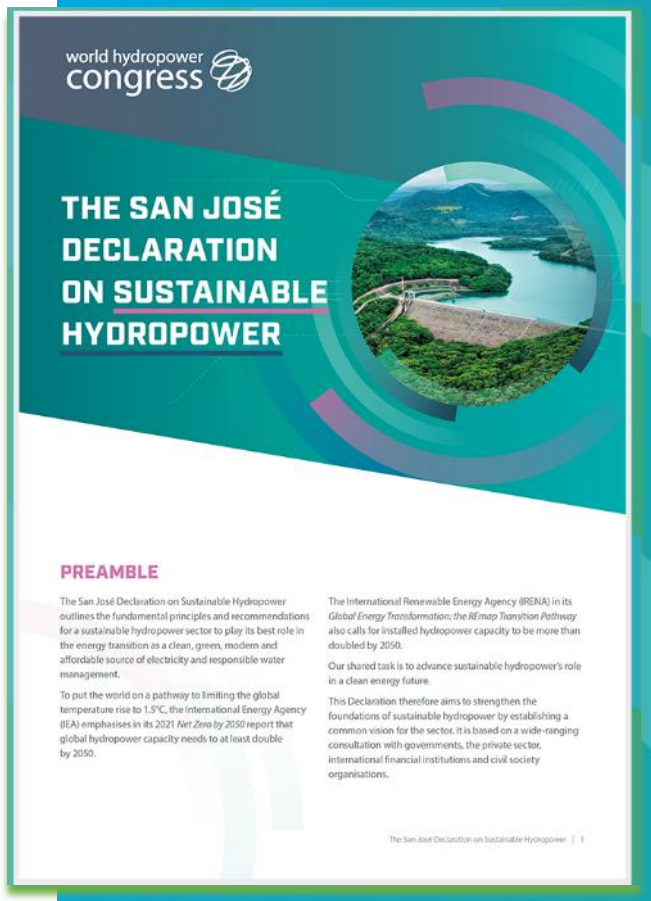
Embedding Sustainability

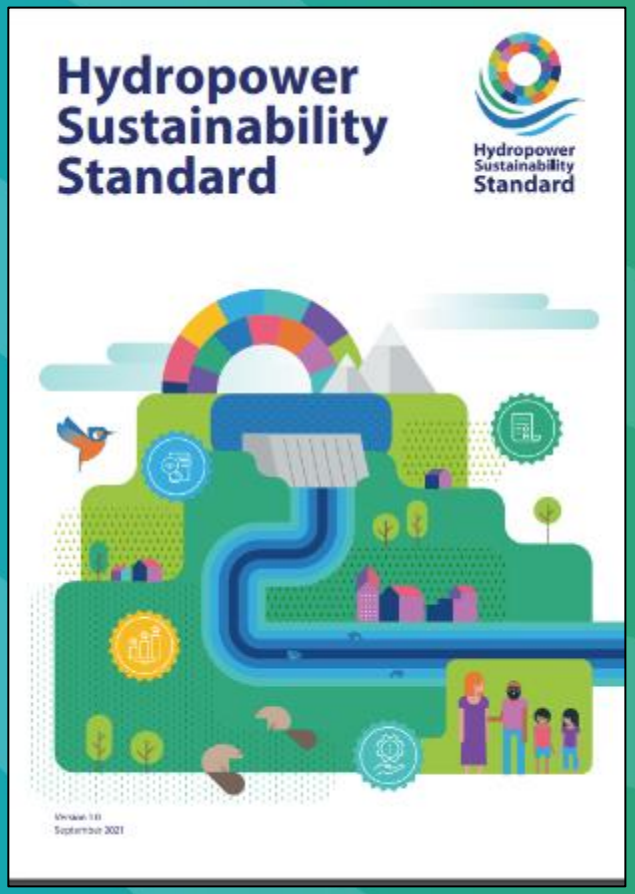
San Jose Declaration

- Says that hydropower is a clean, green, modern and affordable solution to climate change
- Going forward, the only acceptable hydropower is sustainable hydropower
- no-go commitments to develop in World Heritage Sites

Hydropower Sustainability Standard

- All projects can be independently certified
- Projects should mitigate impacts to environment and communities





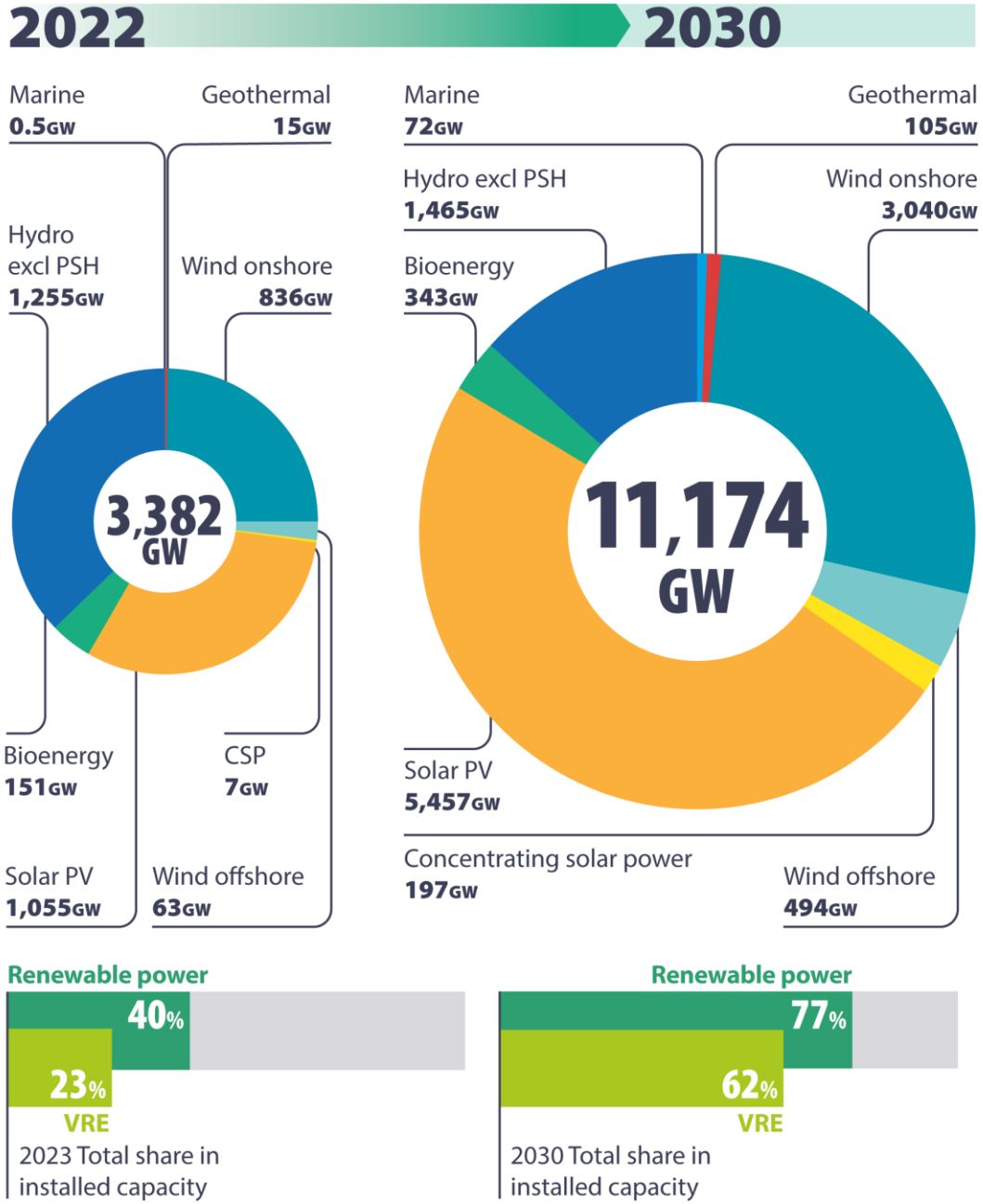
Tripling up renewables

World leaders at COP28 in Dubai committed to "tripling up" the world's renewable generation capacity from 3.8TW in 2022 to 11.2TW in 2030.

This will require a massive upscaling of variable renewables, especially wind and solar.

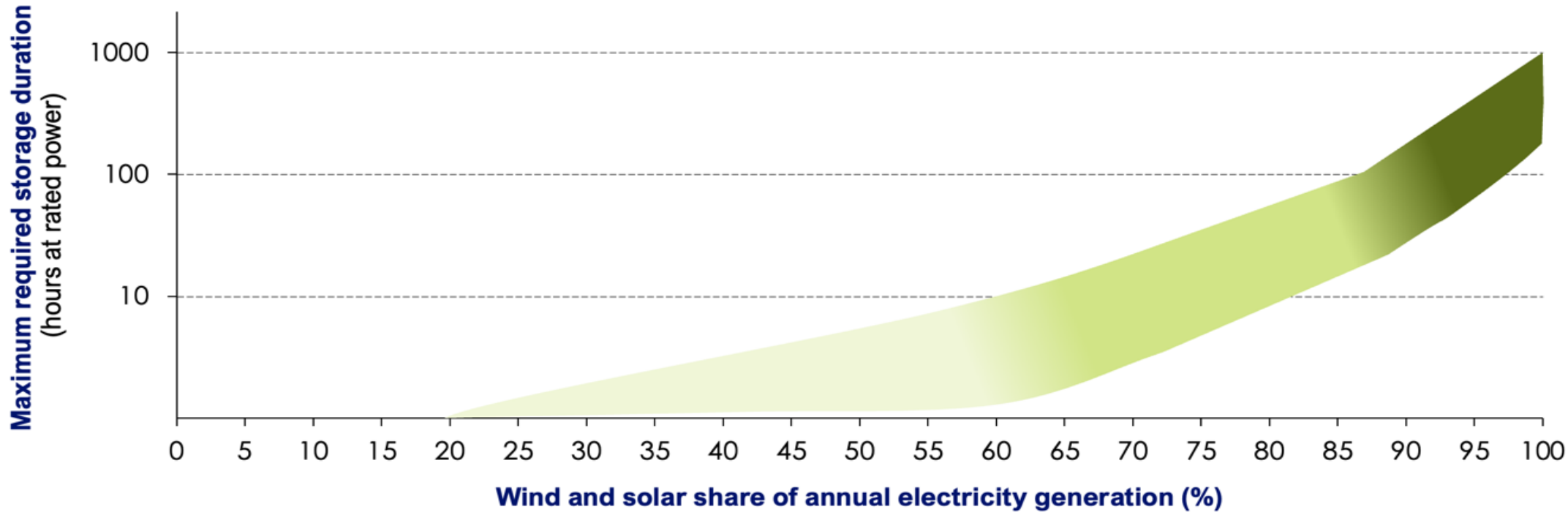
Hydropower is the only proven renewable technology that can provide the flexibility and resilience needed at scale to support this growth.

Meeting this target will require hydropower (not including PSH) to grow from 1,255GW in 2022 to 1,465GW in 2030 (IRENA).



Long Duration Energy Storage is required for net-zero systems

Illustration of how storage duration needs vary with wind and solar penetration



Storage with up to 10h duration is needed to reach 50-80% wind and solar share of electricity generation

Storage with 10-100 hour durations is needed to reach 70-90% wind and solar share of electricity generation

Storage with100+ hour durations is needed to reach 90%+ wind and solar generation

LDES Global Growth in 2023

>Over $4 billion invested in LDES technologies last year

What is hydropower's role today?

Electricity production

Stable and reliable base load production to power up the system 24/7

Storage capacity

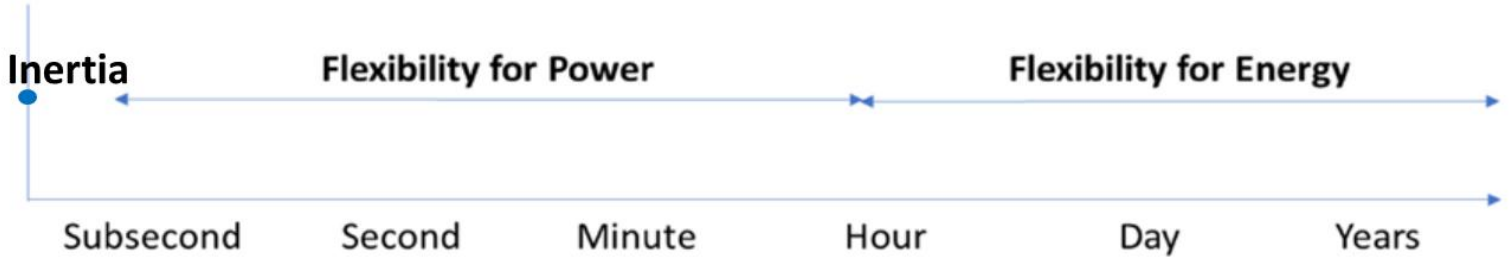
Storage capacity to accumulate energy reserve and store (PSH) surplus energy production from variable renewable energy sources.

Grid regulation

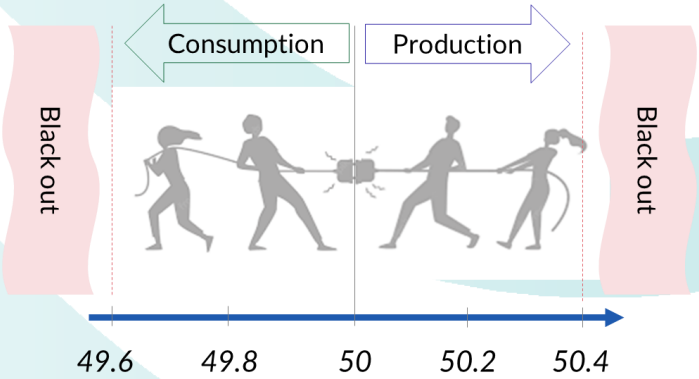
Instantaneous power regulation to control and stabilise the electric power system.

Grid frequency and stabilisation

Flexible Power vs Flexible Energy | What type of flexibility do we need?

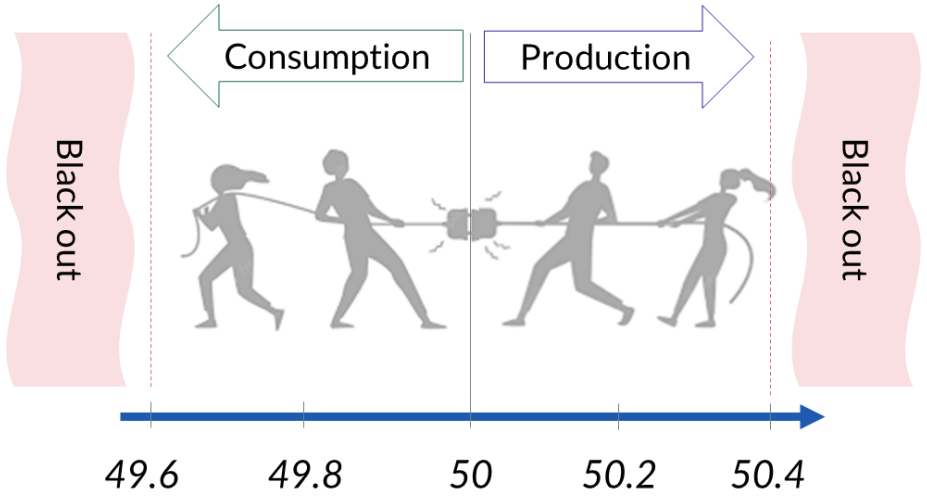


Time scale of the service provided



- **Inertia** corresponds to the weight of the participants (in both sides) to the tug-of-war game. The heavier the weight, the harder to unbalance.
- **Power Flexibility** corresponds to a quick, responsive yank on the tug-of-war rope
- **Energy Flexibility** corresponds to a sustained steady extra set of hands to keep the effort stable

Hydropower's role in short-term flexibility



- **Spinning and fast ramping**
- **Frequency control**
- **Black Start**
- **Rotating inertia**
- **Reactive power control**

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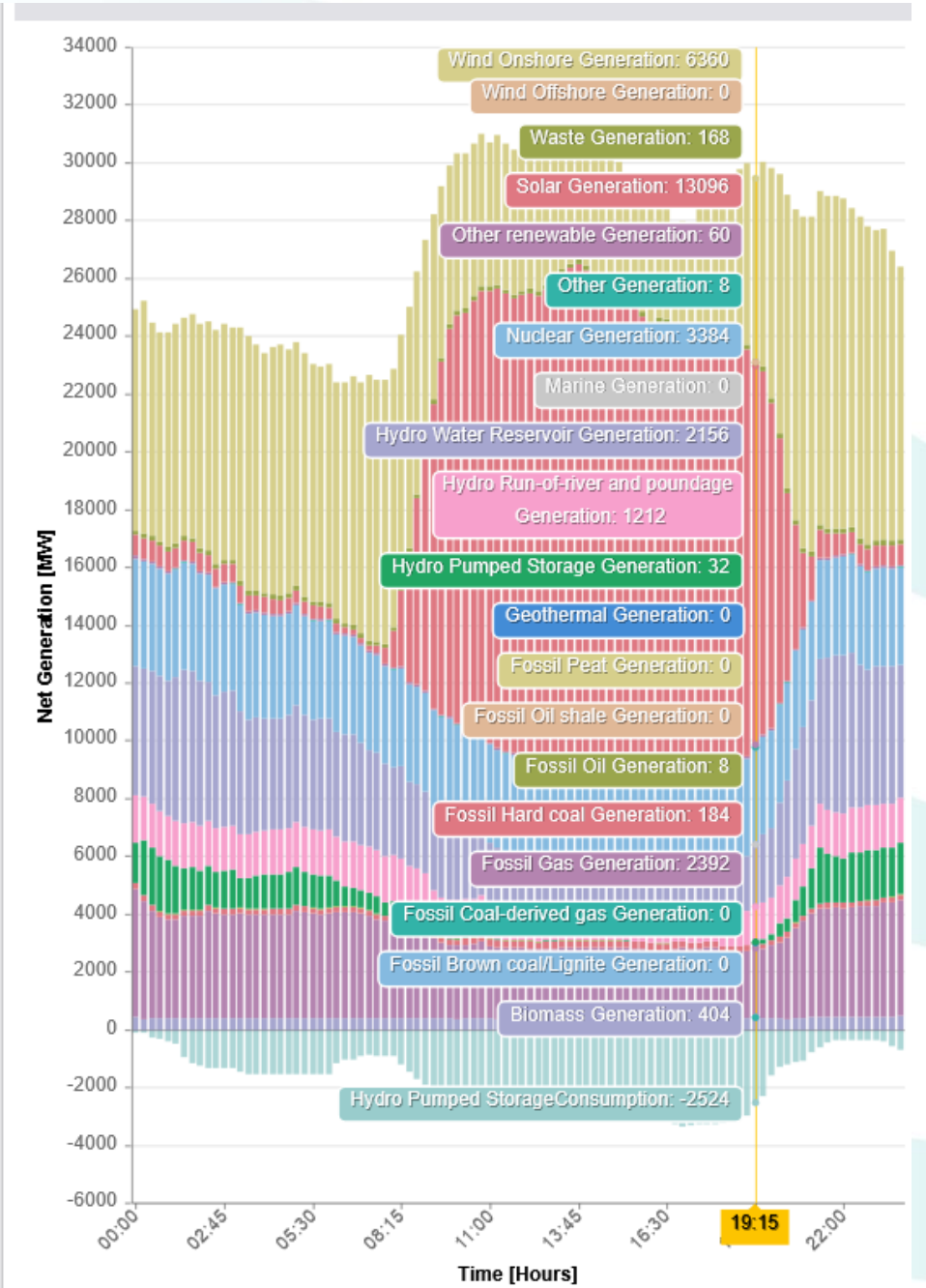
ENTSO-E Spain Actual Generation per Production type

26 April 2025



Reduced system inertia

Mechanical inertia provides an important "**self-healing**" stabilisation effect to the grid:

- spinning generators **resist drops in frequency** when a power plant or transmission fails, and this mechanical inertia, or stored kinetic energy, limits the gradient and the total drop of the grid frequency.

Thermal power plants are being phased out and power systems with high shares of VRE will lose a substantial part of their mechanical inertia.

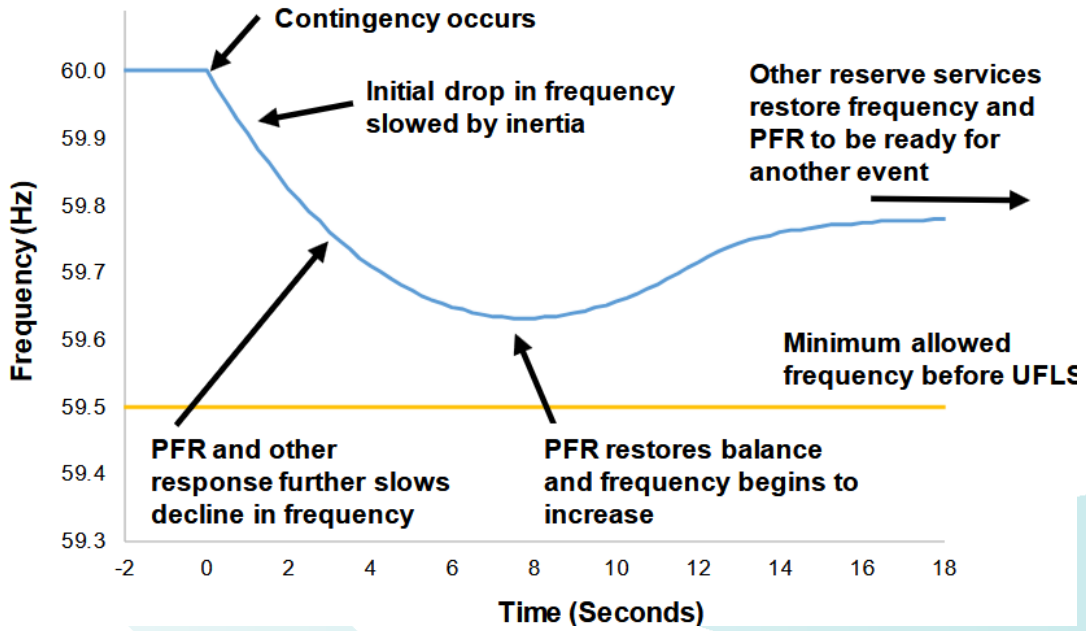


Figure: "Inertia and the Power Grid: A Guide Without the Spin" – NREL 2020

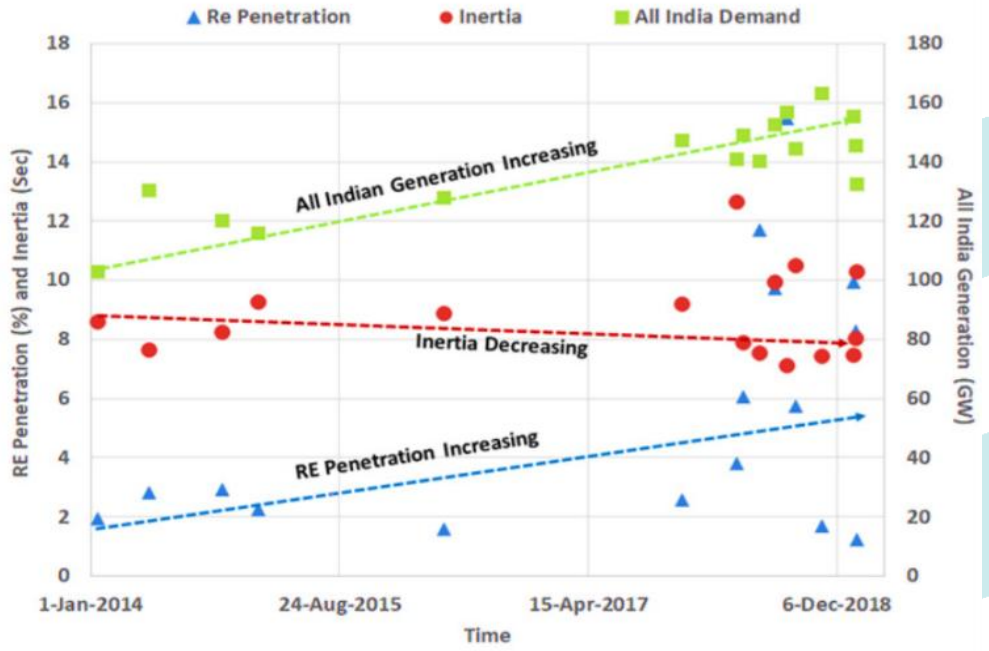


Figure: Inertia and renewables penetration in India, 2014-2018 (IEA, Renewables Integration in India 2021).

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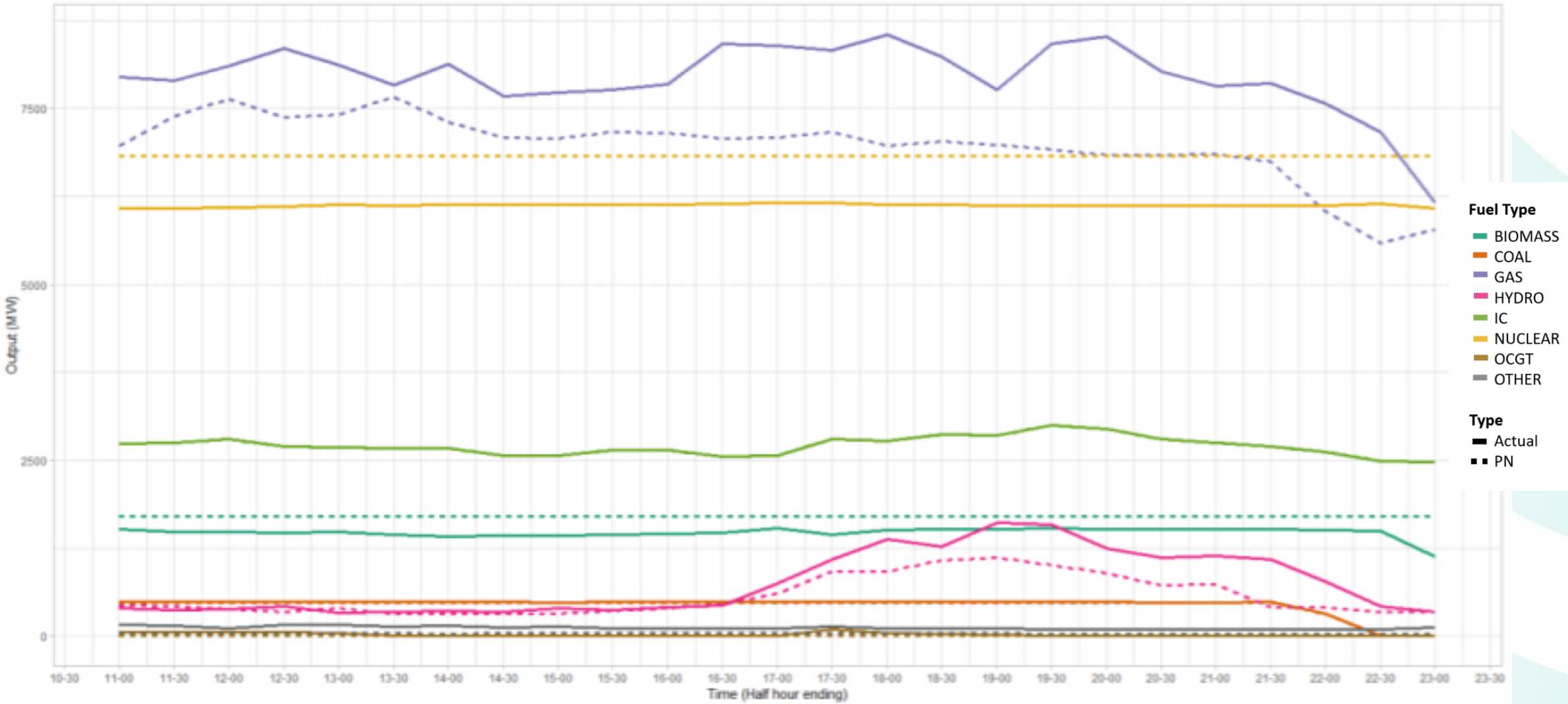
Near blackout – UK August 2019



- August 2019 Near UK Blackout

Electricity Market Design – European Commission

The revised rules aim to make the EU energy market more resilient and the energy bills of European consumers and companies more independent from the short-term market price of electricity.

The new electricity market design rules were adopted on 21 May 2024 and entered into force on 16 July 2024.

- the amending Directive EU/2024/1711
- the amending Regulation EU/2024/1747
  - Article 19: Member states should define indicative national objective for non-fossil flexibility and requires TSOs / DSOs to report the flexibility needs.

The Deadline for EU countries to transpose into national law was 17 January 2025.

Planning for flexibility

ENTSO-E Methodology 2025 – Based on EU 2024/1747

a. Electricity system needs, including:
   i. RES integration – a national target for each year derived from latest NECP
   ii. ramping needs – e.g. average amount of uncovered ramping needs, probability distribution
   iii. short-term flexibility needs based on 0.1 and 99.9 percentile of the probability distribution of the residual load forecast errors;

b. network needs at the distribution level

c. network needs at the transmission level

"Network flexibility needs are local and locally time specific, because congestion occurs where and when forecasted current exceeds operational limits on a given grid asset. Network flexibility needs depend on the local injection and demand patterns, on the local kinematics of connection applications or changes in injection consumption patterns, on grid topology and configuration."

XFLEX Hydro Ancillary Services Matrix

Table 3: The Ancillary Services Matrix

SERVICES PROVIDED BY HPPS	Generic HPP †	Variable Speed	Hydraulic Short Circuit	SPPS	Battery Hybridisation	Technology
		RSH, RoR and PSH	PSH*	RSH, RoR and PSH	RSH, RoR and PSH**	Applicability
Frequency Control Services						
Synchronous Inertia	●		●			
Synthetic Inertia		●			●	
FFR		●			●	
FCR	◐	●	◐	◐	●	
aFRR	◐	◐	◐	◐		
mFRR	◐	◐	◐	◐		
RR	◐	◐	◐	◐		
Black Start	◐	●			◐	
Voltage Control	●	●	●			

Legend: Applicable mode — Turbine, Pump

Impact on provision of services — Generic capability of HPP; Enables provision; Improves provision

Xflex hydro | reservoir storage at Alto Lindoso

Type of Units	Francis
Power	2 x 317 MW
Head	227m (min) – 275.6m (nom) – 288m (max)
Rotating speed	214. min-1

- The 0.500 kM€ ± 40% level of capital investment associated with the implementation of SPPS is relatively low.
- Focussed on operating range extension – below minimum power.
- Upgrade resulted in lower maintenance which reduced costs by € 36k per year.

Case	Operating range	Maintenance interval
Base	Pmin=25%; Pmax=100%	2000 h
SPPS & extension	Pmin=0%; Pmax=100%	> 2000 h

Table 5: Impact measured in terms of the provision of ancillary services - Upgrade Strategy 1

	Inertia		Primary Control		Secondary Control	Tertiary Control		Other Services	
	Synchronous Inertia	Synthetic Inertia	FFR	FCR	aFRR	mFRR	RR	Voltage Control	Black Start
Base Case (Pumping mode)									
SPPS + HSC (Pumping mode)									

Legend: Applicable mode — Turbine, Pump; Impact on provision of services — Generic capability of HPP, Enables provision, Improves provision

Xflex Hydro | pumped storage at Grand Maison

Type of Units	Pelton & multistage pump turbines
Power	Pelton: 170 MW X 4 Pump-turbines: 156 MW x 4
Head	820 m (min) – 918m (rated) – 955m (max)
Rotating speed	Pelton: 428 min-1 Pump-turbines: 600 min-1

- The 750 k€ ± 25% level of capital investment associated with all necessary hardware is already available in the plant to operate in hydraulic short circuit mode. Investment was required on the modelling and testing. Additional operating costs were < 500 k€., and these are related to the extra operational hours.
- Successfully trialled Hydraulic short circuit
- Allowed the plant to simultaneously store excess electricity and provide regulating power to the grid and is now capable of all grid services (FCR, aFRR, mFRR and RR), while storing excess energy from the grid
- Utilised SPPS to ensure optimal utilisation of the units – especially when in pumping mode.

Case	Operating range	Plant efficiency
Base (pumping)	Turbine: from 15% to 100% Pump: - 100% (No regulating margin)	Turbine: Min=81% Max=88% Pump: Min=84% Max=87%
SPPS & extension	Turbine: from 10% to 100% Pump: from -100% to -2%	Turbine: Min=81% Max=88% Pump: Min=84% Max=87% HSC: Min=66% Max=81%

Table 8: Impact measured against the ancillary services provision - Upgrade Strategy 2 (presented only in pump mode)

	Inertia		Primary Control		Secondary Control	Tertiary Control		Voltage Control	Systems re-start
	Synchronous Inertia	Synthetic Inertia	FFR	FCR	aFRR	mFRR	RR	Voltage Control	Black Start
Base Case (Pumping mode)								N/A	N/A
SPPS + HSC (Pumping mode)									N/A

Legend: Applicable mode — Turbine, Pump

Impact on provision of services — Generic capability of HPP; Enables provision; Improves provision

Longer-term flexibility
Swiss winter reserve

2022-23 - Swiss recognised long-duration energy storage needs.

January 2023 – Winter Reserve Ordinance entered into force. Federal Council awarded the contract for reserve power plants to DETEC - consisting of three hydropower reserves and aggregated poolers

Winter tenders:

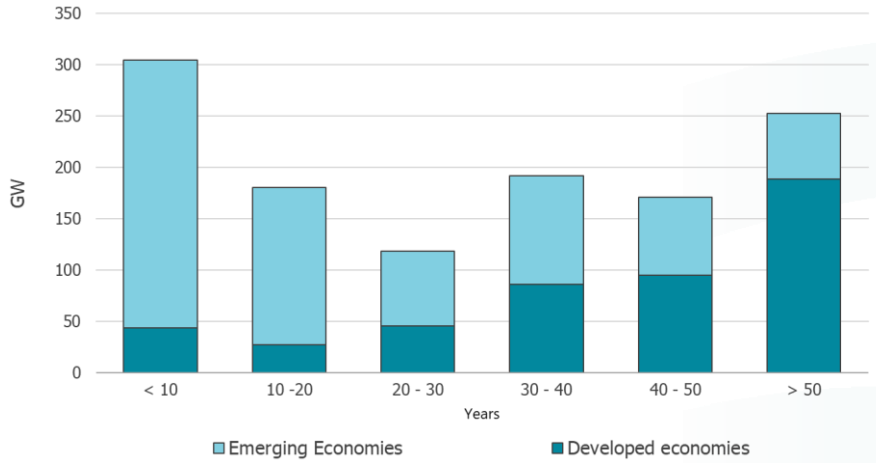
For the winter of 2023/24, a total volume of 400 GWh was procured at an average price of 138.67 euros/MWh (previous year: 739.97 euros/MWh).

2024 Three Tranches - A total energy volume of 250 GWh (winter of 2023/24: 400 GWh) was procured at an average price of 66.12 €/MWh (previous year: 138.67 €/MWh).

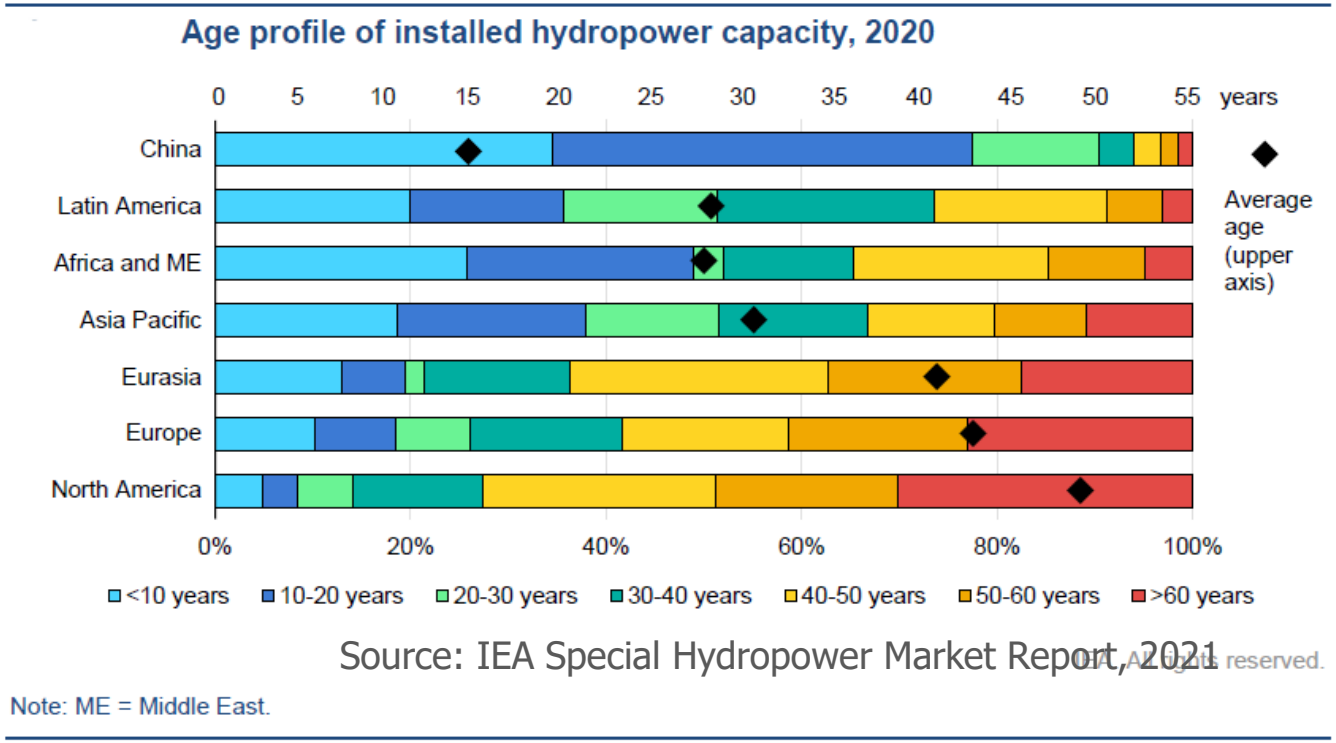
1. 63 GWh were awarded at an average price of 53.17 €/MWh
2. 82 GWh at an average price of 68.2 €/MWh
3. 105 GWh were awarded at an average price of 72.28 € /MWh

Key opportunities for expanding flexibility

The existing hydro fleet has urgent modernisation needs



Source: World Hydropower Congress 2019 (IEA, IHA)



Source: IEA Special Hydropower Market Report, 2021

Note: ME = Middle East.

Why invest in modernisation?

- Low impact
- Quick win
- Improved plant productivity
- Increased power and energy flexibility
- Climate resilient

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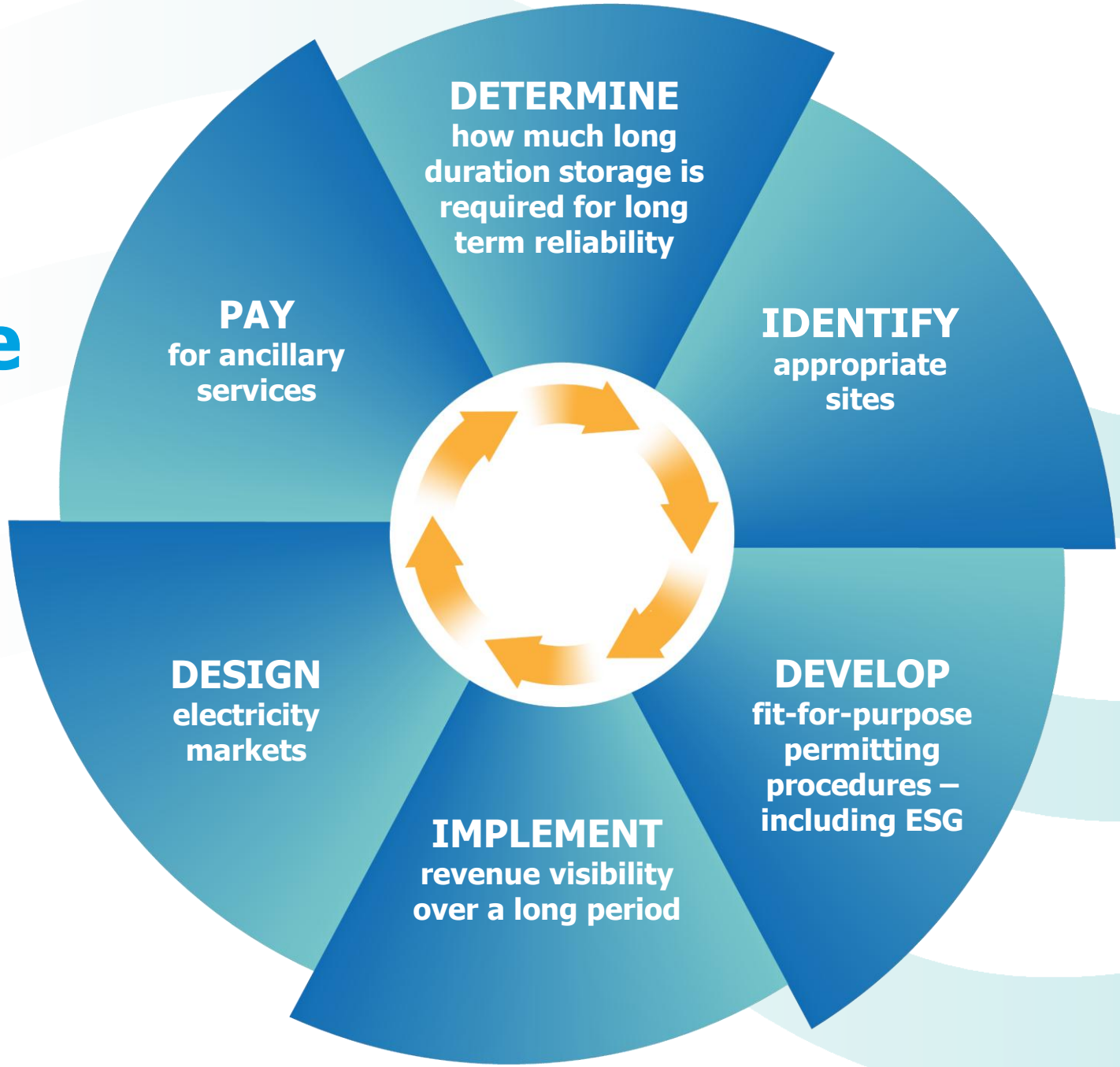
Actions Governments can take to support flexible hydropower:



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Thank you

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