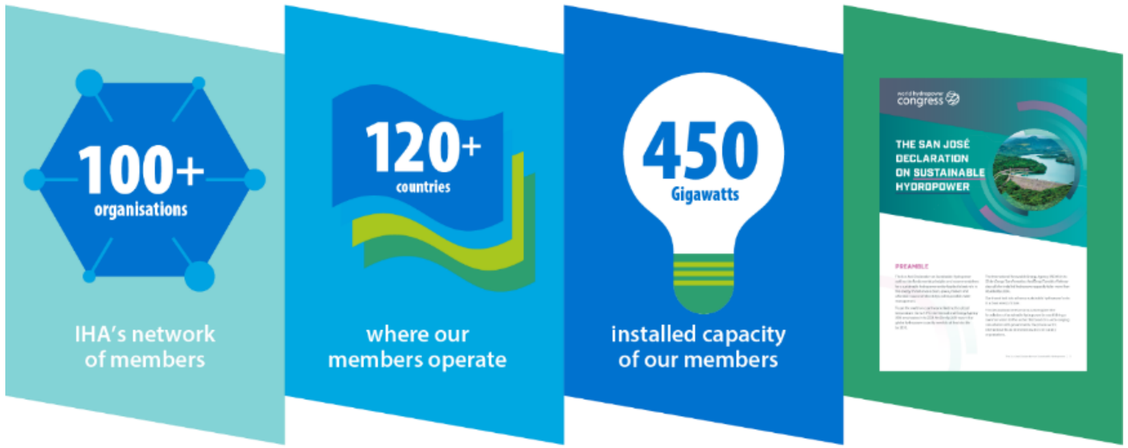
iha
international hydropower association

Pumped Storage Hydropower

The world's largest installed flexibility

What is IHA?

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.

hydropower.org

Why PSH is important in the energy transition:

Evolving need for flexibility

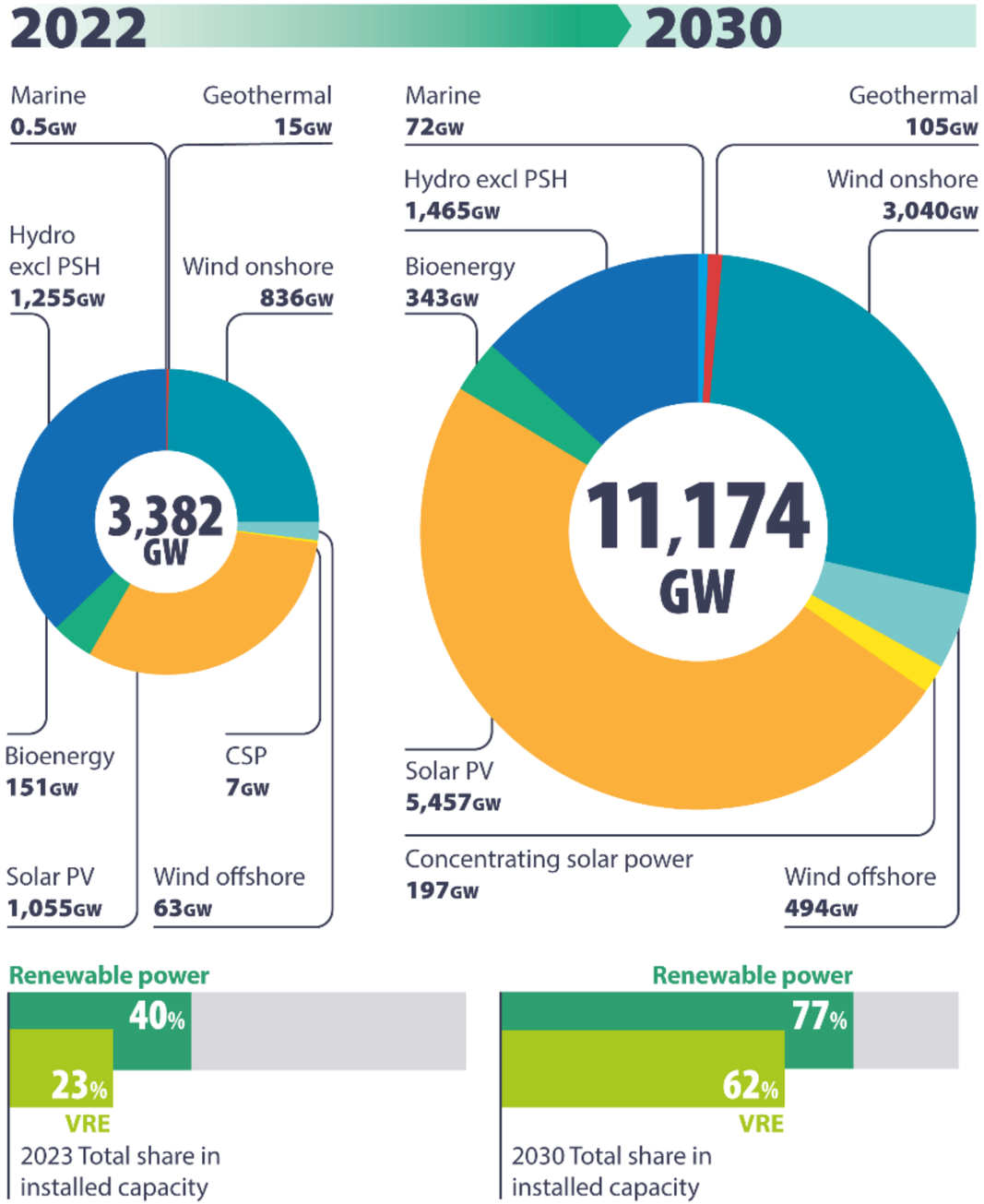
VRE drives the need for PSH

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.

Meeting this target will require hydropower (not including PSH) to grow from 1,255GW in 2022 to 1,465GW in 2030 (IRENA). It will also need a ramping up of storage, including long-duration storage.

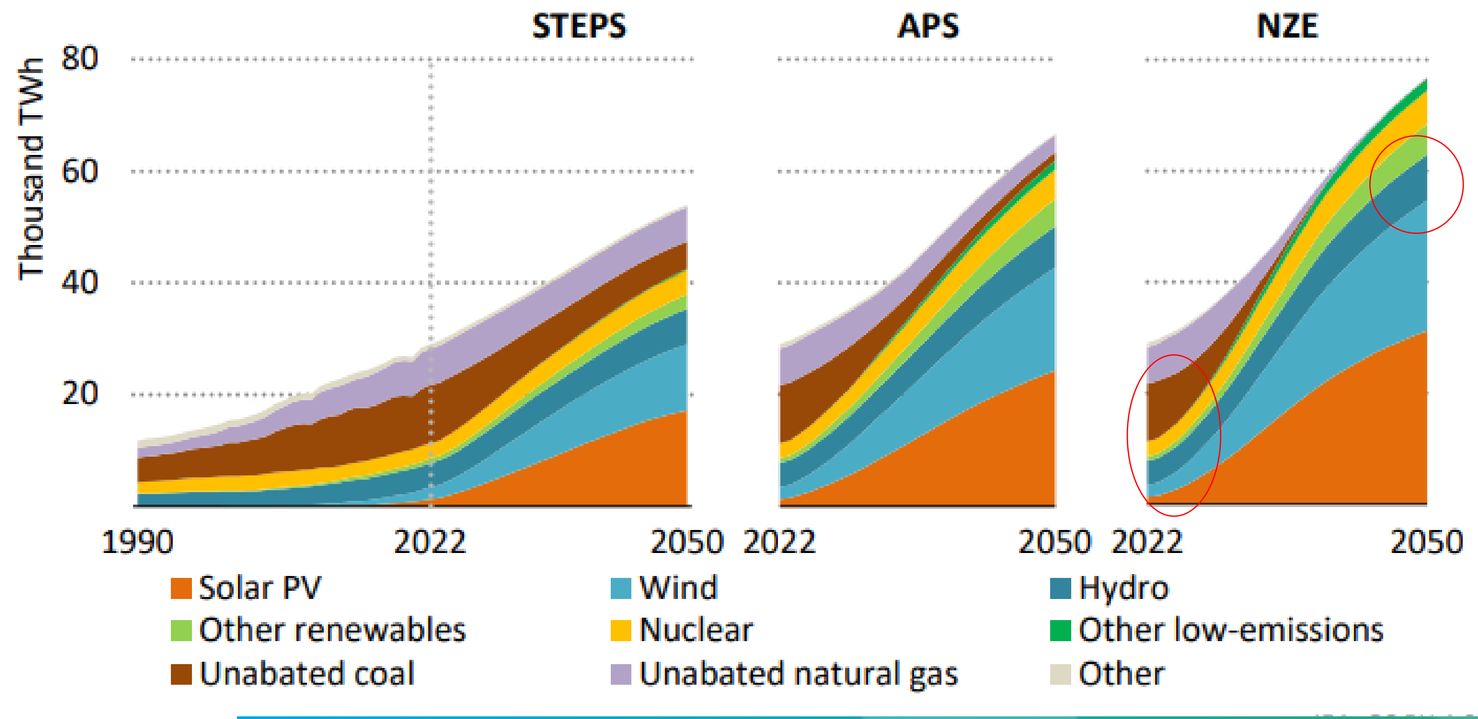
Pumped Storage is the only mature long-duration storage technology that can provide the flexibility and resilience needed at scale to support this growth.



Why water & energy?

- Net-Zero 2050 Scenarios will demand nearly 80,000TWh of electricity for 2050 targets.
- And the supply of electricity will significantly shift from fossil fuel (75% of 2022 generation) to low carbon electricity sources.
- How do we replace this flexible, fossil-fuel generation?

Figure 3.15 ▷ Global electricity generation by source and scenario, 1990-2050

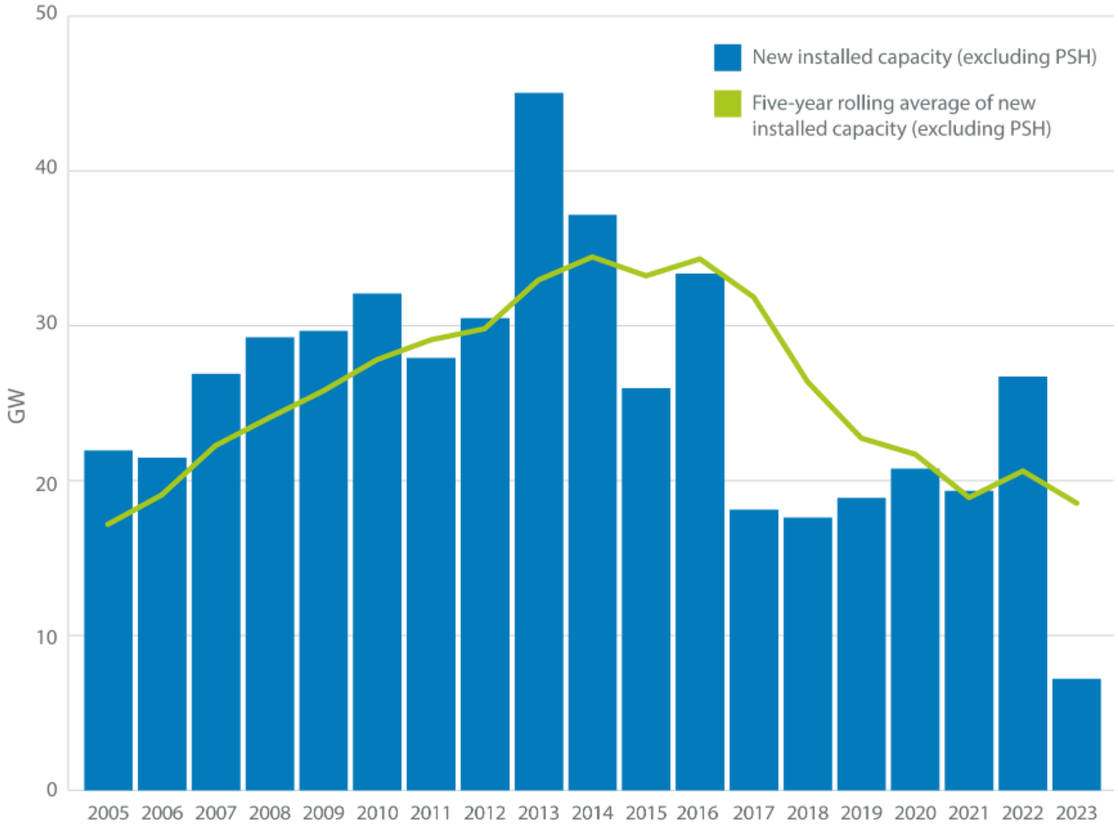


IEA World Energy Outlook 2023
Figure 3.15

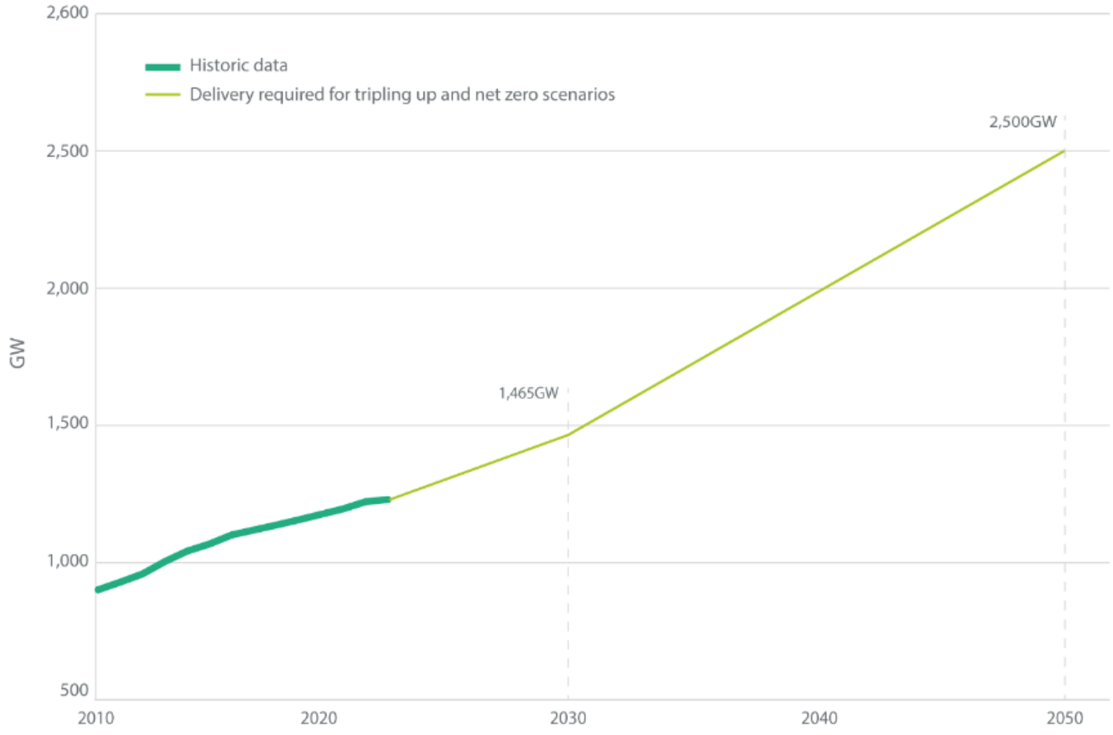
The scale of the challenge

What is needed to meet 2030 and 2050 scenarios?

New hydropower installed capacity 2005–2023 (excluding PSH)



Required cumulative installed hydropower capacity in IRENA tripling up and net-zero scenarios (excluding PSH)



Not just storage, also 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.

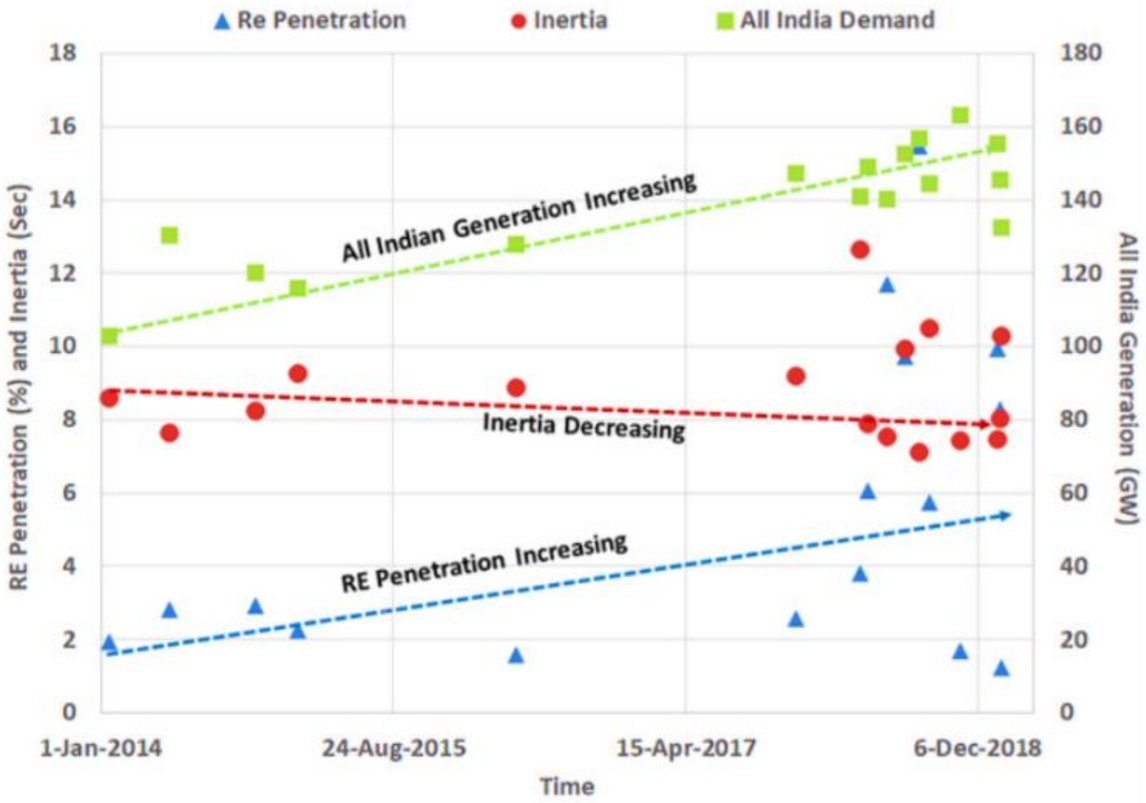
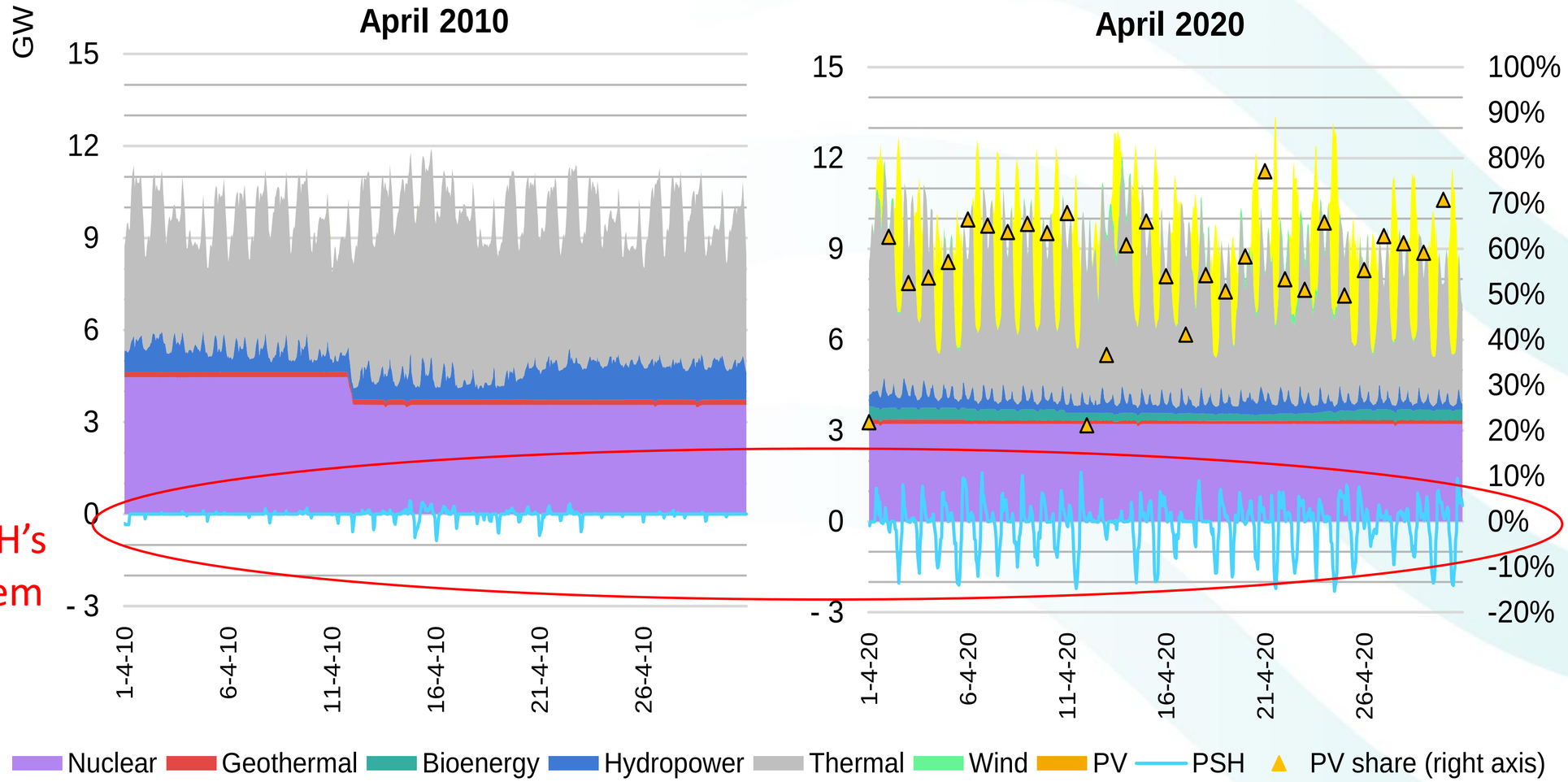


Figure: Inertia and renewables penetration in India, 2014-2018 (IEA, Renewables Integration in India 2021).

…and flexibility…

With the rapid rollout of variable renewables such as wind and solar, there is an increasing need for ancillary services to balance the grid:

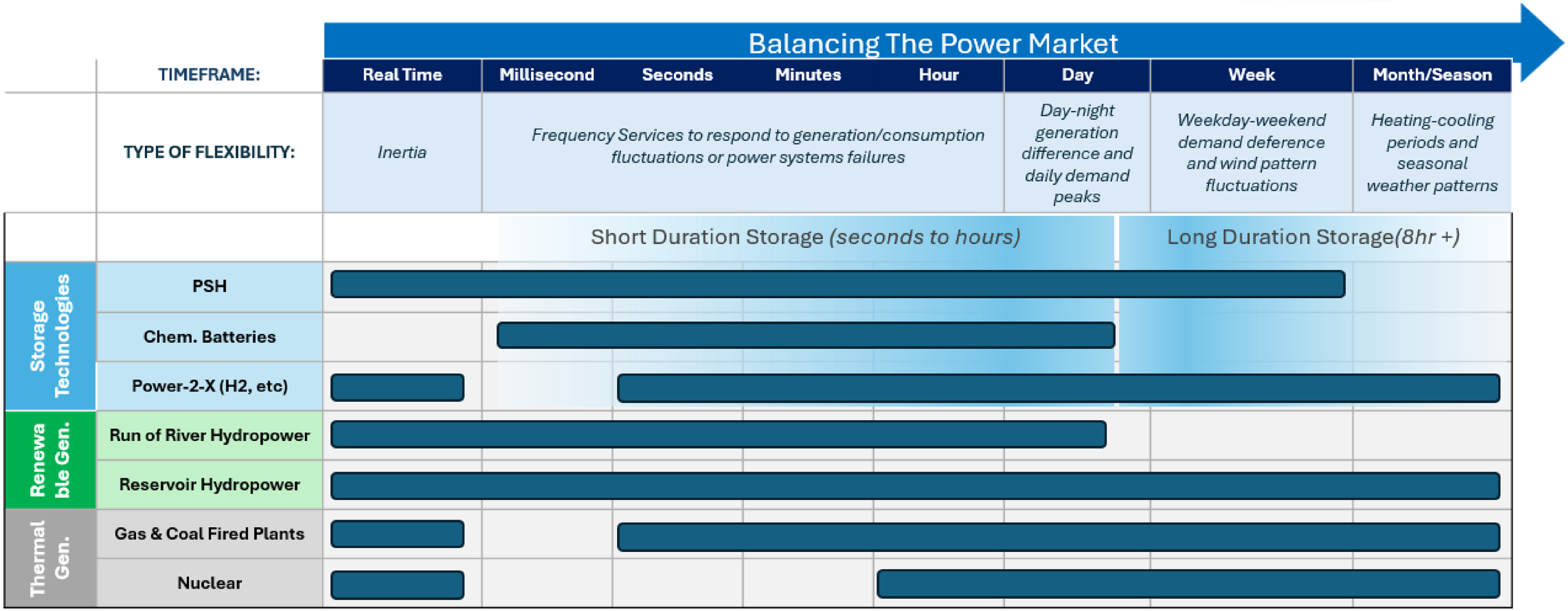
Evolution of PSH's role in the system



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

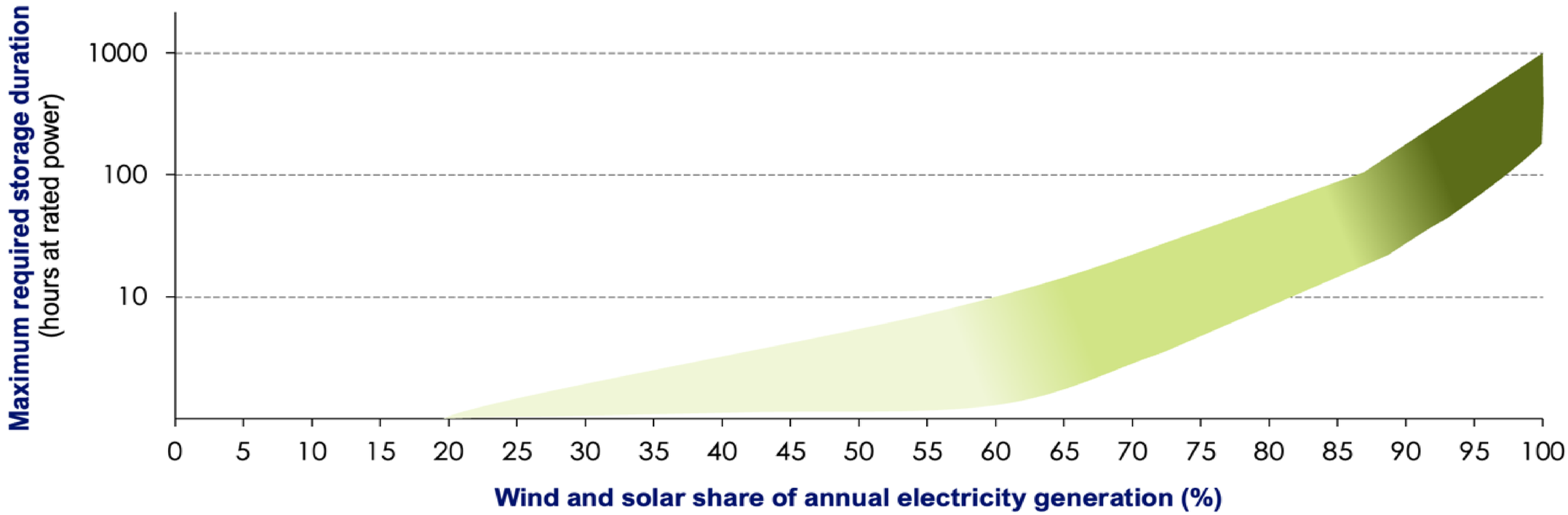
Evolution of PSH in flexibility and storage services between 2010 and 2020 in Kyushu Island, Japan (ref. IEA, 2021)

...and flexibility...



… *and also* storage

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

The curtailment paradox

Renewables will provide cheaper electricity!

We need more renewables to meet net-zero targets!

We need more investments in wind and solar!

At this rate, we're not going to meet net-zero targets

Grid can't take it!

Curtailment!

Why should I invest in this?

Why do we need more if we're "throwing away" so much?

Why am I paying more for my electricity?

Mix of services

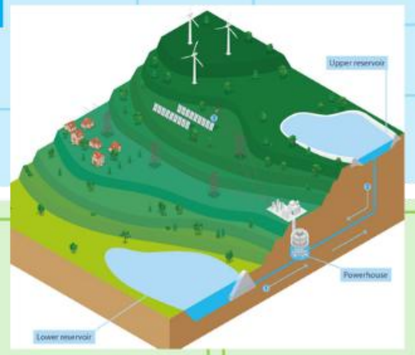
ENERGY SERVICES

Electricity Storage: Store and redispatch excess power, in large quantities and for a long period of time, when most needed by the power systems.

Curtailment reduction: Quickly available storage capacity to absorb excess power production from wind and solar power systems for several continuous hours.

Frequency Regulation: PSH can provide large amount of power reserves (both when generating and pumping) within a few seconds.

Power Systems Inertia: EPS's inertia is reducing due to retirement of coal and gas plants. PSH can provide while pumping and generating, but also without water consumption (*synchronous condenser mode*).



Power System Restart: Emergency process of restarting operation of a power plant after a grid black-out, from a completely non-energized operating state and without any power feed from the network.

Flood control: Water control during period of high precipitation.

Water management for non-energy uses: As for instance agriculture, industrial processes and human consumption, including also navigation, recreation and fire-fighting.

Drought mitigation: Water retention during period of low precipitation.

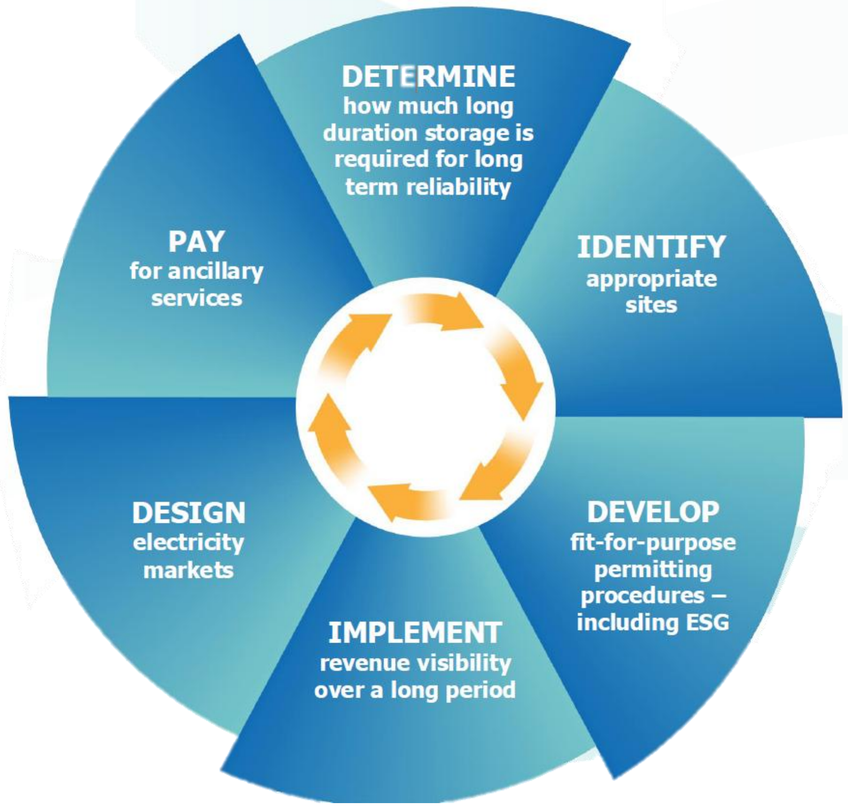
Climate change mitigation: Reduction of fossil fuel consumption and support to renewables energy deployment.

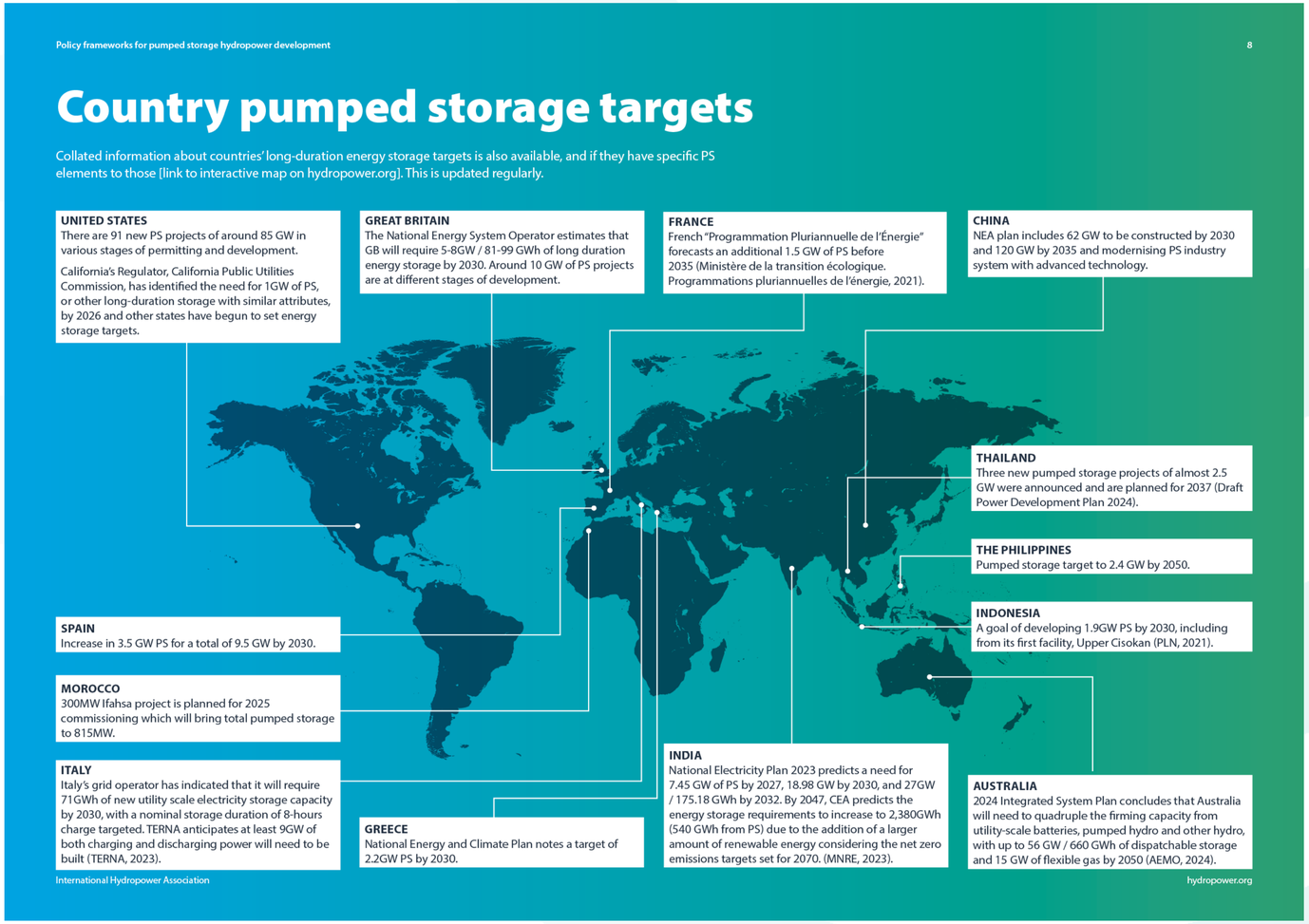
WATER & NON-ENERGY SERVICES

Where is PSH being delivered:

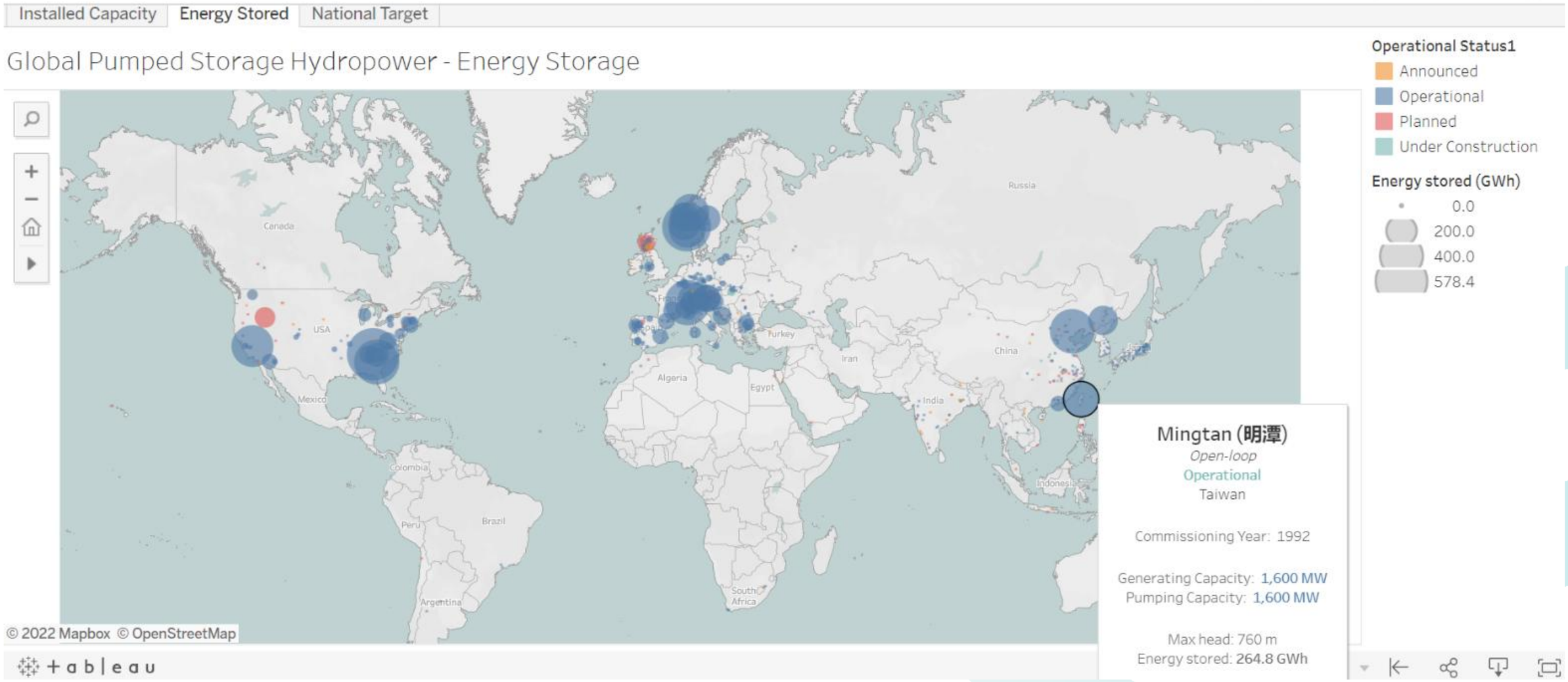
Governments are moving…

But LAC being left behind





PSH around the world



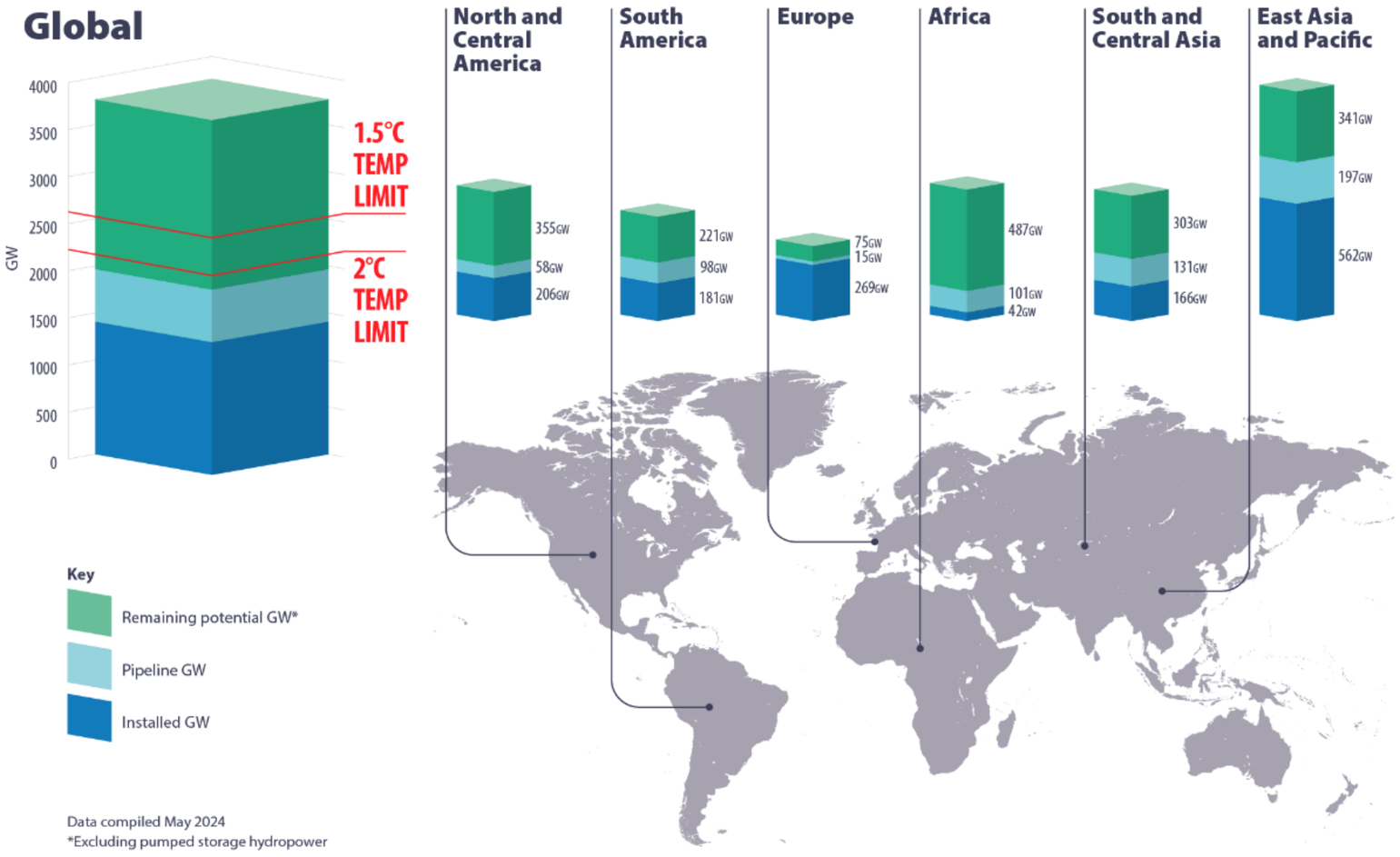
ANU and Global Pumped Storage Hydropower map

>600,000 potential sites with 23,000 TWh of storage

http://re100.eng.anu.edu.au/global
https://nationalmap.prod.saas.terria.io/#share=s-tPEnZ4T5NRAYIiLS0E3ftvcAzb

Global pipeline and potential

We are not “tapped out” of hydropower.



hydropower.org/outlook

How do we get it built?:

Enabling new pumped storage hydropower: a guidance note to de-risk PSH investment

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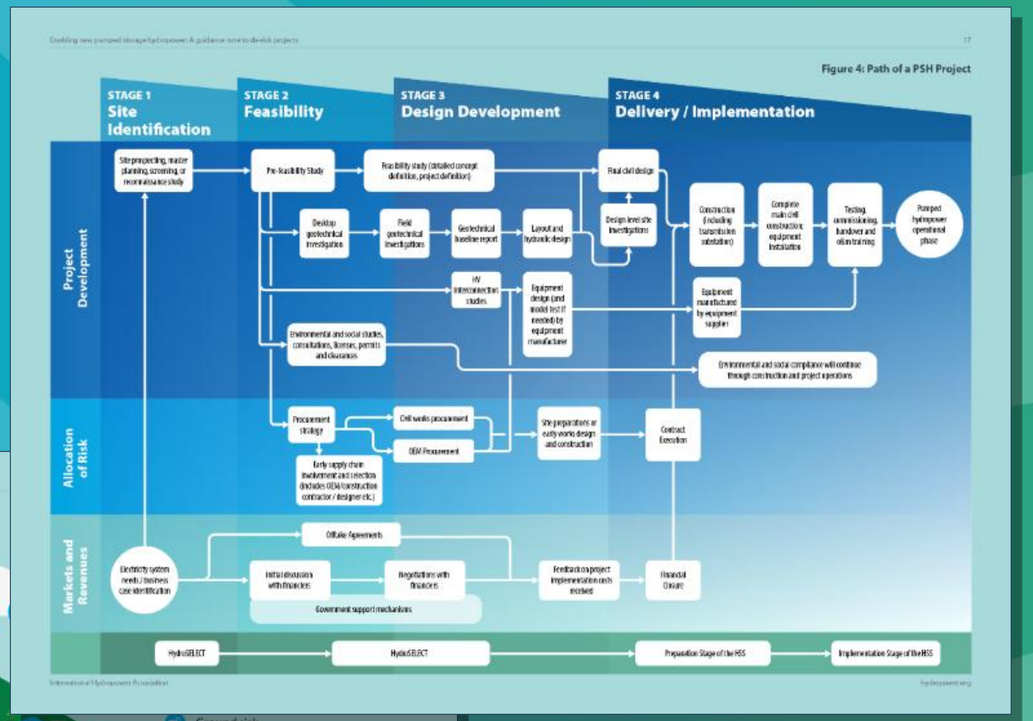
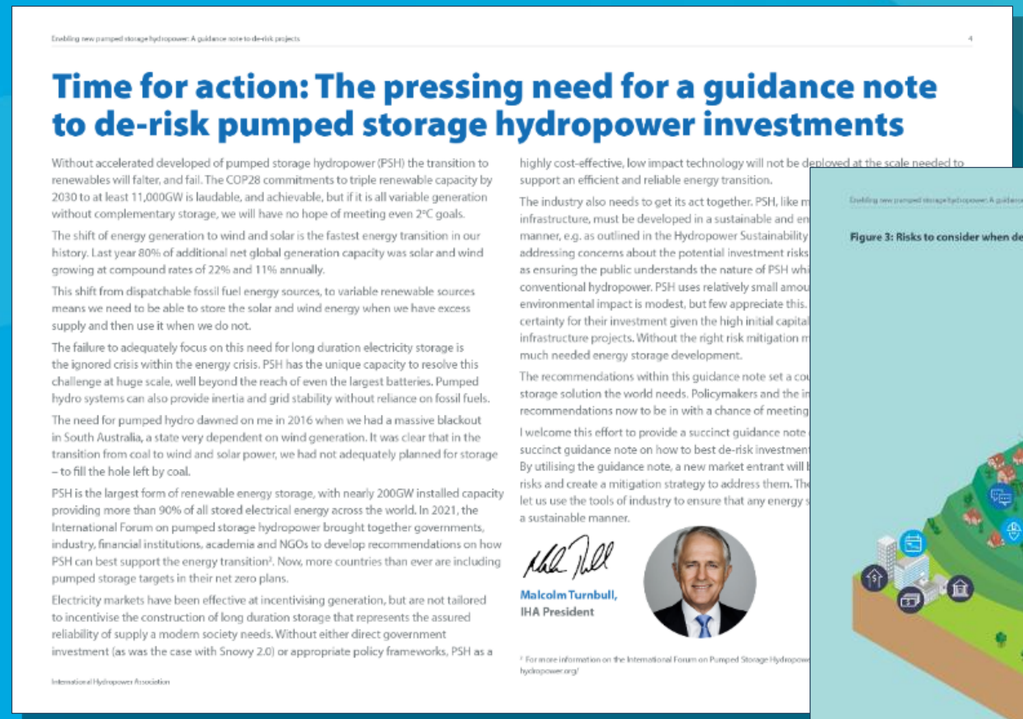
Guidance Note

- Introduction to PSH
- Risks critical to





Enabling new pumped storage hydropower: A guidance note to de-risk projects 4

Time for action: The pressing need for a guidance note to de-risk pumped storage hydropower investments

Without accelerated developed of pumped storage hydropower (PSH) the transition to renewables will falter, and fail. The COP28 commitments to triple renewable capacity by 2030 to at least 11,000GW is laudable, and achievable, but if it is all variable generation without complementary storage, we will have no hope of meeting even 2°C goals.

The shift of energy generation to wind and solar is the fastest energy transition in our history. Last year 80% of additional net global generation capacity was solar and wind growing at compound rates of 22% and 11% annually.

This shift from dispatchable fossil fuel energy sources, to variable renewable sources means we need to be able to store the solar and wind energy when we have excess supply and then use it when we do not.

The failure to adequately focus on this need for long duration electricity storage is the ignored crisis within the energy crisis. PSH has the unique capacity to resolve this challenge at huge scale, well beyond the reach of even the largest batteries. Pumped hydro systems can also provide inertia and grid stability without reliance on fossil fuels.

The need for pumped hydro dawned on me in 2016 when we had a massive blackout in South Australia, a state very dependent on wind generation. It was clear that in the transition from coal to wind and solar power, we had not adequately planned for storage – to fill the hole left by coal.

PSH is the largest form of renewable energy storage, with nearly 200GW installed capacity providing more than 90% of all stored electrical energy across the world. In 2021, the International Forum on pumped storage hydropower brought together governments, industry, financial institutions, academia and NGOs to develop recommendations on how PSH can best support the energy transition[1]. Now, more countries than ever are including pumped storage targets in their net zero plans.

Electricity markets have been effective at incentivising generation, but are not tailored to incentivise the construction of long duration storage that represents the assured reliability of supply a modern society needs. Without either direct government investment (as was the case with Snowy 2.0) or appropriate policy frameworks, PSH as a highly cost-effective, low impact technology will not be deployed at the scale needed to support an efficient and reliable energy transition.

The industry also needs to get its act together. PSH, like m
infrastructure, must be developed in a sustainable and en
manner, e.g. as outlined in the Hydropower Sustainability
addressing concerns about the potential investment risks
as ensuring the public understands the nature of PSH wh
conventional hydropower. PSH uses relatively small amou
environmental impact is modest, but few appreciate this.
certainty for their investment given the high initial capita
infrastructure projects. Without the right risk mitigation m
much needed energy storage development.

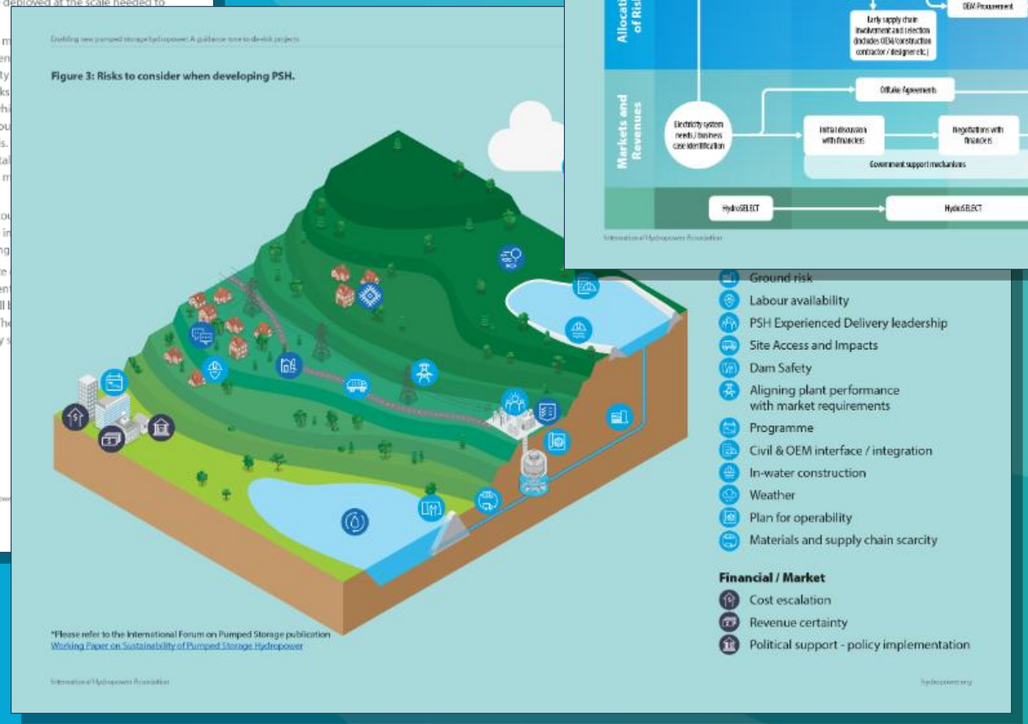
The recommendations within this guidance note set a co
storage solution the world needs. Policymakers and the in
recommendations now to be in with a chance of meeting

I welcome this effort to provide a succinct guidance note
succinct guidance note on how to best de-risk investment
By utilising the guidance note, a new market entrant will
risks and create a mitigation strategy to address them. Th
let us use the tools of industry to ensure that any energy
a sustainable manner.

Malcolm Turnbull,
IHA President

[1] For more information on the International Forum on Pumped Storage Hydropow
hydropower.org/

International Hydropower Association



Enabling new pumped storage hydropower: A guidance note to de-risk projects

Figure 3: Risks to consider when developing PSH.

*Please refer to the International Forum on Pumped Storage publication Working Paper on Sustainability of Pumped Storage Hydropower

- Ground risk
- Labour availability
- PSH Experienced Delivery leadership
- Site Access and Impacts
- Dam Safety
- Aligning plant performance with market requirements
- Programme
- Civil & OEM interface / integration
- In-water construction
- Weather
- Plan for operability
- Materials and supply chain scarcity

Financial / Market

- Cost escalation
- Revenue certainty
- Political support - policy implementation

International Hydropower Association hydropower.org

hydropower.org

Key Considerations

Markets & Revenues

- **Storage capacity and grid services should be considered based on a dedicated storage masterplan** to quantify the future needs of the national power system in line with their energy and climate plans.
- **Policymakers should engage with the market to design tailored support mechanisms for PSH**, ensuring clarity on policy timelines and setting energy storage targets.
- **Policymakers and project developers** when performing economic comparisons between different storage technologies **should follow a consistent and technology neutral approach** and consider the full-lifecycle benefits of assets.

Project Development

- **Appoint complete delivery teams early in the development process**, including Owner, Operator, Designer, Constructor, OEM etc.
- **Invest in development**, for example ground investigations, to de-risk, and specialist expertise of delivery teams.

Allocation of Risk

- Parties need to be clear that **the balance of risk will be different in PSH projects** than in other sectors
- **Procurement and contract management should ensure fair, transparent, and economically most advantageous conditions of the project**.
- **Contracting strategy should reflect and foster environmental and sustainability** (E&S) aspects of the project.

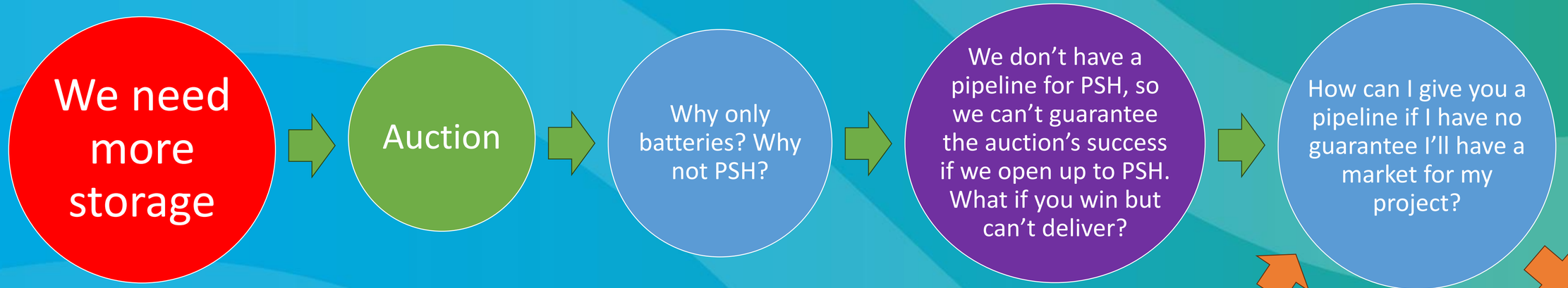
Private sector developed – public sector enabled

Long-term investment with a long payback

Consistent policy with a long-term horizon

1. Assess storage needs, given VRE targets
2. Recognise market won't be able to deliver by itself
3. Prioritise policy measures to enable investments
    1. Financial mechanisms
    2. Policy interventions
    3. License streamlining, etc.

The chicken and the egg



"A finalidade do leilão de baterias é impulsionar a tecnologia no Brasil, para que possa contribuir para um sistema elétrico mais confiável, resiliente, acessível e competitivo", afirma o ministro Alexandre Silveira.

Why not the same for PSH?

Policy guidance (two versions)

Publication

Read more here

Recommendations for policy makers

RECOMMENDATION 1
Assess how much long duration storage and system flexibility is needed in the long-term

Pumped storage (PS) takes a long time to develop, build and pay back. At the same time, energy systems are rapidly transforming to accommodate changes in demand and supply, particularly growth in wind and solar power, making it essential to plan for future reliable energy systems which have sufficient long duration energy storage. If developers have confidence in the need for PS projects and the quantity of long duration energy storage required, then they can put the right amount of development money in upfront, de-risking projects and bringing them in on time and on budget. To deliver this win-win, Governments should seek expertise on how to assess, plan for, and build reliability, flexibility and security into energy systems.

RECOMMENDATION 2
Identify appropriate sites for pumped storage plants

Policymakers can accelerate development of pumped storage in their countries by filtering the many potential sites and highlighting those with the best economic, social and environmental outcomes. The efficiency of the energy system can be greatly enhanced by integrating the development of pumped storage with the extension of grid infrastructure, and with wind or solar energy. Holistic site planning will therefore bring significant system benefits.

Please see Australia National University atlas of potential sites.

RECOMMENDATION 3
Implement fit-for-purpose permitting procedures

A predictable and time-bound permitting process will speed up approval and reduce costs, ultimately benefitting consumers. Streamlining processes so that developers are dealing with only one agency and ensuring all branches of government are adequately resourced to respond quickly will result in timely decisions. Aligning environmental and social permitting with international standards, such as the Hydropower Sustainability Standard, ensures that the regulations, financial approvals, and company systems all align with recognised international good practice.

RECOMMENDATION 4
Apply mechanisms that deliver the necessary revenue visibility over a long period

The bulk of investment in PS projects is in the construction phase, which must be paid back over a long period. Combined with high capital costs and long build schedules, this makes these projects especially vulnerable to long-term revenue risk. If the project's income is uncertain (e.g. due to unknowns such as electricity markets or policies), then the return demanded by lenders and investors will be higher. Consequently, it is difficult for the market alone to deliver these projects. Projects need a mechanism that provides revenue certainty, which will attract greater investment.

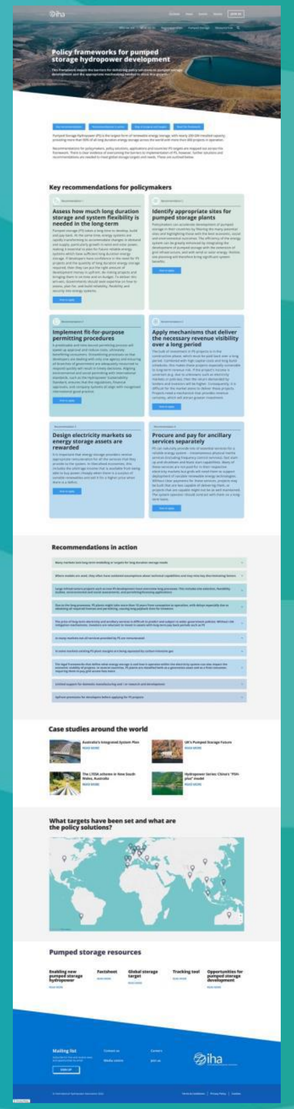
RECOMMENDATION 5
Design electricity markets so energy storage assets are rewarded

It is important that energy storage providers receive appropriate remuneration for all the services that they provide to the system. In liberalised economies, this includes the arbitrage income that is available from being able to buy power cheaply when there is a surplus of variable renewables and sell it for a higher price when there is a deficit.

RECOMMENDATION 6
Procure and pay for ancillary services separately

PS can naturally provide lots of essential services for a reliable energy system – instantaneous physical inertia services (including frequency control services), fast start-up and shutdown and black start capabilities. Many of these services are not paid for in their respective electricity markets but grids will need them to support deployment of variable renewable energy technologies. Without clear payments for these services, projects may be built that are less capable of delivering them, or projects that are capable might not be as well maintained. The system operator should contract with them on a long-term basis.

Website landing page



Read more here

Addressing barriers

Barriers to PSH development:

Planning and modelling

- Many markets lack long-term modelling or targets for long duration storage needs.

Licensing and permitting

- Large infrastructure projects such as new PSH development are subject to long processes.

Financial Considerations

- Long-term electricity and ancillary services prices are difficult to forecast and subject to wider government policies.
- In many markets not all services provided by PSH are remunerated.
- In some markets existing PSH plant margins are being squeezed by carbon-intensive gas.

Storage Classification

- In several countries, PSH plants are classified both as a generation asset and as a final consumer, requiring them to pay grid access fees twice.

Catalogue of policies

The table below summarises the policies used in a number of countries to overcome the barriers to implementation of PS.

RECOMMENDATION	COUNTRY/REGION	POLICY SOLUTION APPLICATIONS
Financing / Planning and modelling / Storage Classification / Licensing and Permitting	India	Pumped storage guidelines developed to promote development of PS. These set out: • Transparent criteria forwarding project sites. • Self-identification of off-river pumped storage sites. • Removal of upfront premium for project allocation. • Market reforms for monetisation of ancillary services provided by pumped storage. • Government land, if available, at concessional rate to the developers on an annual lease rent basis. • Exemption of pumped storage plants from free power obligation. • Rationalisation of Environmental Clearances for off-river pumped storage sites. • Utilisation of exhausted mines for development of pumped storage plants. National Framework for promoting energy storage systems. Hydropower and pumped storage consumption obligations for designated consumers. Waiver of Inter State Transmission System (ISTS) charges. Budgetary support towards cost of enabling infrastructure (i.e. roads and bridges). Faster decision-times for Pumped Storage Projects through guidelines for formulation of detailed project reports for Pumped Storage. Storage Classification by Central Energy Administration / Ministry of Power. A national pumped storage target of 27.7 GW by 2031-32 was based on a CEA study that indicated the pumped storage exploitable potential is about 181.4GW.
Planning and modelling / Storage Classification	EU	Member States are required to assess and draw up a report on the need for flexibility. Based on these reports, each Member State will define an indicative national objective for demand side response and storage. This indicative national objective will also be reflected in Member States' integrated national energy and climate plans (Electricity markets design reform). EU Member states are required to submit National energy and climate plans (NECPs) which cover activities from 2021-2030 on decarbonisation, energy efficiency, energy security, internal energy market, as well as research and innovation. Many include hydropower and pumped storage activities. Each country must submit a progress report every two years to support implementation. The first update was due in 2023. Revision of the Energy Taxation Directive made it possible to consider energy storage facilities as redistributors so to avoid double taxation (Revision of the Energy Taxation Directive - Fit for 55 package).
Planning and modelling / Storage classification / Financing	China	14th Five-Year Plan (2021-2025) highlights energy storage as a priority to enhance consuming and storing renewable energy. The National Energy Administration (NEA) has set an ambitious target of 120GW PS to be commissioned by 2030. A key approach by China has been the "PS-plus" model, which sees planning for large renewable energy zones or corridors matched with the development of PS capacity. The grid operates some of the energy storage (the State Grid in the North and China Southern Power Grid in the South with some local grids operating). Pumped storage revenue models and pricing mechanisms have been developed. These include a "two-part tariff": a fixed element set by government authorities that is paid based on meeting peak demand and providing ancillary services; and a floating element for the arbitrage value of charging the PS when power is cheap.
Financing	United States	Tax credits under the Inflation Reduction Act. Capacity market payments. Direct funding (Bipartisan Infrastructure Law) which includes financial assistance to eligible entities to carry out project design, transmission studies, power market assessments and permitting for a pumped storage project to facilitate long-term storage of renewable electricity.
Planning and Modelling / Licensing and Permitting	Portugal	Portugal has set a target for hydropower, within which it has set an objective of 3.9 GW of pumped storage by 2030. It has also established strict criteria for the selection of sites that require an integrated analysis of environmental, social and economic components.

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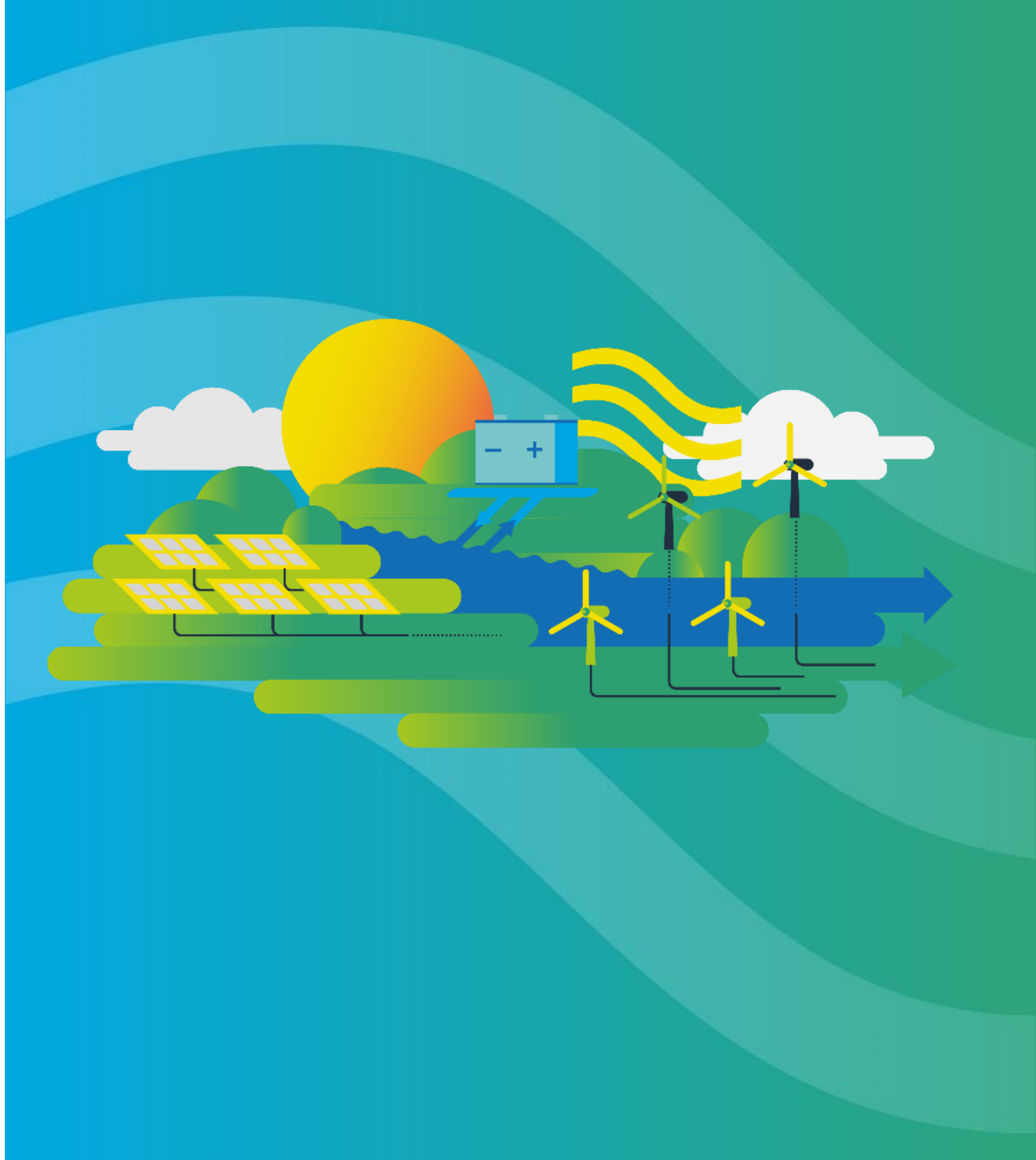
International Forum Pumped Storage Hydropower

9-10 September 2025 | Paris



International Forum Pumped Storage Hydropower

9-10 September 2025 | UNESCO House, Paris

The International Forum on Pumped Storage Hydropower will bring world leaders and experts together to develop the policies and practices needed to unlock the development of this essential technology.

For more information about the International Forum scan QR code or go to hydropower.org/iha/pump-it-up

Two-day global conference

1. Senior addresses and plenary sessions:

Key opportunities and challenges for PSH, both external and internal.

2. Parallel sessions:

- **Policy and Markets track**

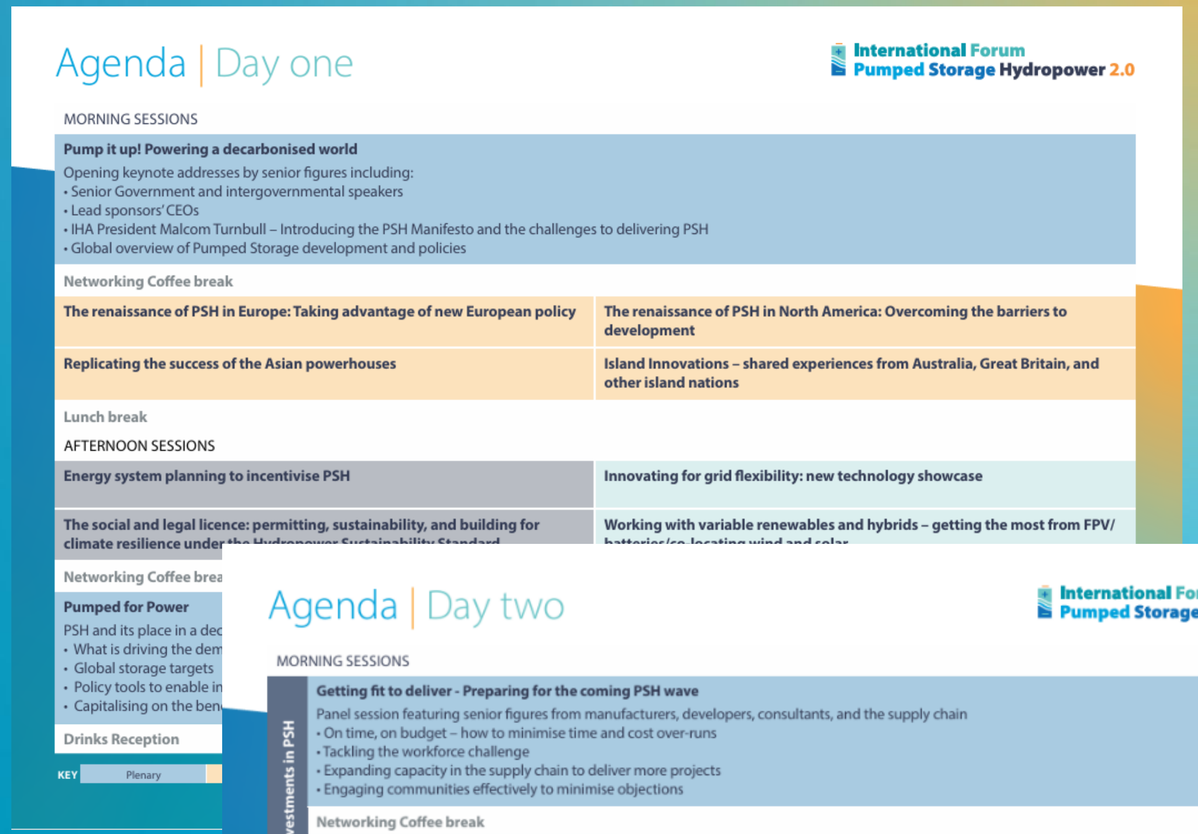
  Key issues concerning project feasibility and profitability.

- **Technical track**

  Technical determinants of success, such as design parameters, operational approaches, technological innovations and site selection.

- **Regional Track**

  Main drivers and challenges for the development of PSH facilities on a regional basis.



Agenda | Day one

International Forum Pumped Storage Hydropower 2.0

MORNING SESSIONS

Pump it up! Powering a decarbonised world

Opening keynote addresses by senior figures including:
- Senior Government and intergovernmental speakers
- Lead sponsors' CEOs
- IHA President Malcom Turnbull – Introducing the PSH Manifesto and the challenges to delivering PSH
- Global overview of Pumped Storage development and policies

Networking Coffee break

The renaissance of PSH in Europe: Taking advantage of new European policy	**The renaissance of PSH in North America: Overcoming the barriers to development**
Replicating the success of the Asian powerhouses	**Island Innovations – shared experiences from Australia, Great Britain, and other island nations**

Lunch break

AFTERNOON SESSIONS

Energy system planning to incentivise PSH	**Innovating for grid flexibility: new technology showcase**
The social and legal licence: permitting, sustainability, and building for climate resilience under the Hydropower Sustainability Standard	**Working with variable renewables and hybrids – getting the most from FPV/ batteries/co-locating wind and solar**

Networking Coffee brea

Pumped for Power

PSH and its place in a dec
- What is driving the dem
- Global storage targets
- Policy tools to enable in
- Capitalising on the ben

Drinks Reception

KEY Plenary

Agenda | Day two

International Forum Pumped Storage Hydropower 2.0

MORNING SESSIONS

Derisking investments in PSH

Getting fit to deliver - Preparing for the coming PSH wave

Panel session featuring senior figures from manufacturers, developers, consultants, and the supply chain
- On time, on budget – how to minimise time and cost over-runs
- Tackling the workforce challenge
- Expanding capacity in the supply chain to deliver more projects
- Engaging communities effectively to minimise objections

Networking Coffee break

Making projects economically feasible through revenue support mechanisms, maximising arbitrage trading value, and remunerating ancillary services	**Site identification and development, getting the right design for the right services**
Securing finance in an energy transition	**Right first time: contracting and procurement for smooth delivery**

Lunch break

AFTERNOON SESSIONS

New projects, new ideas: showcasing projects demonstrating leading edge technologies	**Building on Brownfield, opportunities and challenges of converting sites**

Networking Coffee break

Stakeholder Forum: Opportunity for participants to speak from the floor on commitments and announcements

Closing addresses from selected conference participants/reports from the two parallel tracks

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Global Alliance
For Pumped Storage

iha

GAPS objectives

- Raise awareness and understanding of the key role of PSH in a reliable and secure clean energy mix.
- Share best policies and practices on PSH development.
- Support the Paris International Forum on Pumped Storage.
- Develop a call to action for PSH for the Forum.

Global Alliance
For Pumped Storage

iha

Governance

- Initially a light intergovernmental movement of the willing – no members, no Terms of Reference, no commitments.
- Assume use of flag unless specifically instructed otherwise.
- Seek to establish a more formal structure at International Forum
  - Possibility including companies and civil society?
- Welcome financial contributions to support GAPS. Any contributions now will be acknowledged as “Government/Agency Partners” at the International Forum. Please let us know and we will follow up.

Making it sustainable: The role of the Hydropower Sustainability Standard

hydropower.org

Hydropower Sustainability Standard

Assessing & certifying good ESG practice in hydropower

OVERVIEW

All projects can be assessed using the HS Standard

Certification against the HS Standard recognises performance achievements at the time of the assessment only

Findings cover two levels of performance:

- Good practice (minimum requirements)
- Best practice (advanced requirements)

12 ESG TOPICS

E&S Assessment & Management

Resettlement

Governance & Procurement

Labour & Working Conditions

Biodiversity & Invasive Species

Communications & Consultation

Water Quality & Sediments

Indigenous Peoples

Hydrological Resource

Community Impacts & Infrastructure Safety

Cultural Heritage

Climate Change Mitigation & Resilience

OVERVIEW

A certification system for all hydroelectric projects

Run-of-river | Storage | Pumped storage | Multipurpose

Tailored to specific life-cycle stages

Preparation

Implementation

Operation

INDEPENDENT ASSESSMENTS

carried out by
Accredited Assessors
bring:

- Expertise
- Impartiality
- Credibility
- Consistency

FROM ASSESSMENT TO CERTIFICATION

1 **ASSESSMENT** — Third-party, evidence-based process by assessors

2 **PUBLICATION** — Results open to all stakeholders

3 **APPLICATION** — Application submitted to HS Secretariat

4 **CERTIFICATION** — Multistakeholder oversight

Hydropower Sustainability Standard

GOLD
Project: **Lorem Ipsum**
Stage: **Preparation**
Date: **March 2023**

Hydropower Sustainability Standard

SILVER
Project: **Lorem Ipsum**
Stage: **Preparation**
Date: **March 2023**

Hydropower Sustainability Standard

CERTIFIED
Project: **Lorem Ipsum**
Stage: **Preparation**
Date: **March 2023**

BENEFITS FOR ALL

DEVELOPERS & OPERATORS

- Enhanced reputation
- Improved performance
- Access to funding
- Risk mitigation

FINANCIAL INSTITUTIONS

- De-risk investment
- Long-term sustainability
- Market recognition & influence

GOVERNMENTS & REGULATORS

- Regulatory compliance
- Demonstratable progress
- Sustainable development

CIVIL SOCIETY & NGOS

- Advocacy support
- Drive accountability
- Positive impact

RESEARCH & ACADEMIA

- Data & insights
- Case studies
- Knowledge-sharing

COMMUNITIES

- Well-being & agency
- Environmental safeguards
- Infrastructure development
- Job opportunities

WORLDWIDE IMPACT

Thank you

- www.hydropower.org
- @iha_org