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23-24 March 2022 • Canada

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Session 2:
Innovative Hydropower Solutions for a Clean, Reliable and Flexible Grid

WEDNESDAY, 23 MARCH 2022 • 10:00 – 11:15 EDT / 16:00 – 17:15 CET

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Session 2
Scene setting

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Global perspective

Carlos Ruiz

Associate Programme Officer
Renewable Technologies
IRENA

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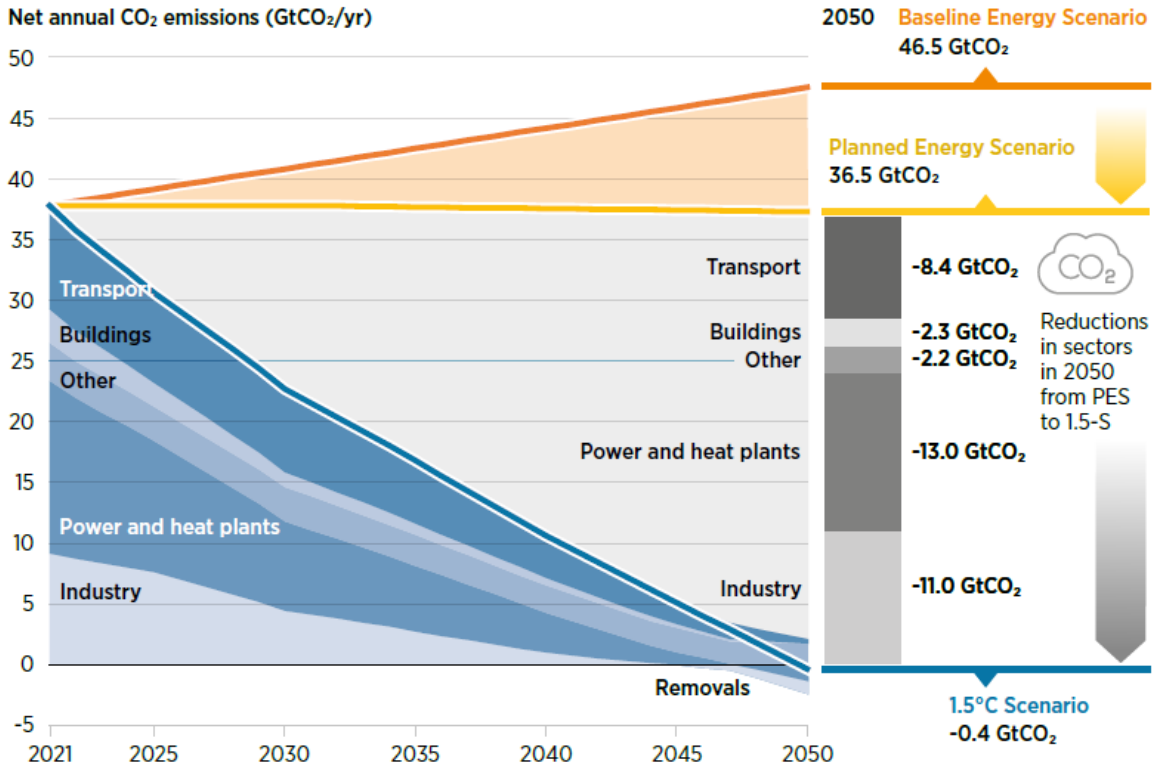
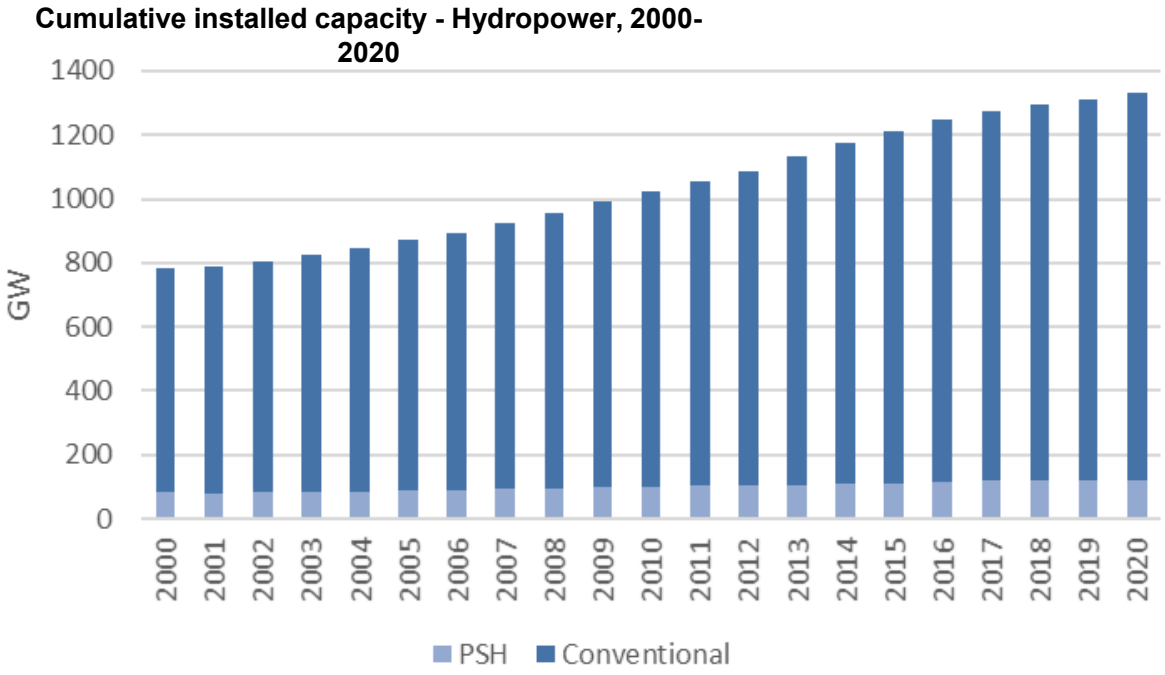
Global decarbonisation needs and hydropower's role



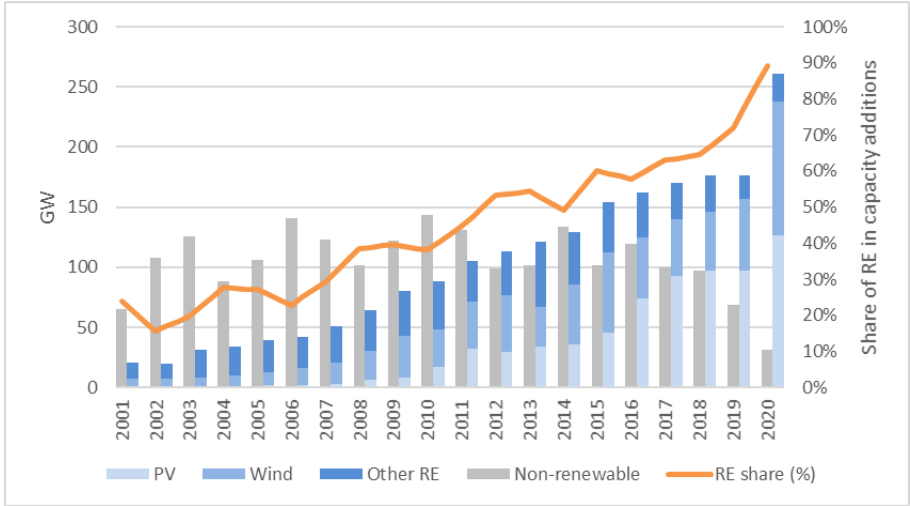


Implications of higher VRE shares for hydropower

- Higher VRE shares bring important changes in the way power systems are managed, requiring more flexible resource capabilities to ensure grid reliability.
- Historically, hydropower has been a source of base load generation. However, it is more and more frequently used as peaking capacity and as a source of ancillary services.
- Most hydropower plants were planned, designed and built to operate under different conditions than those of today, and therefore they are not unaffected by the changing power system.
- Consequences for hydro plants:
  - O&M: Additional wear and tear
  - Financial: limited generation volumes, higher costs

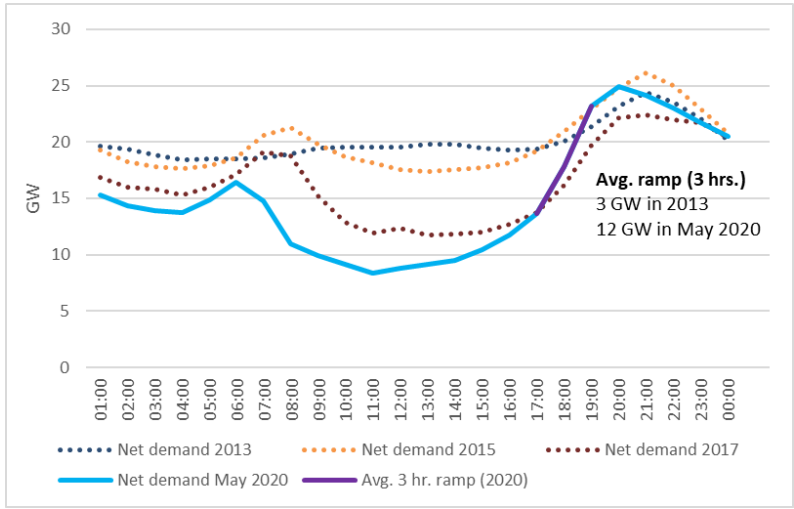
There is a need for innovation in operation, technology, policies and markets.

Comparison of renewable and non-renewable net capacity additions



Source: IRENA

Net demand curve for a spring day in California in 2020



Source: CAISO, 2020

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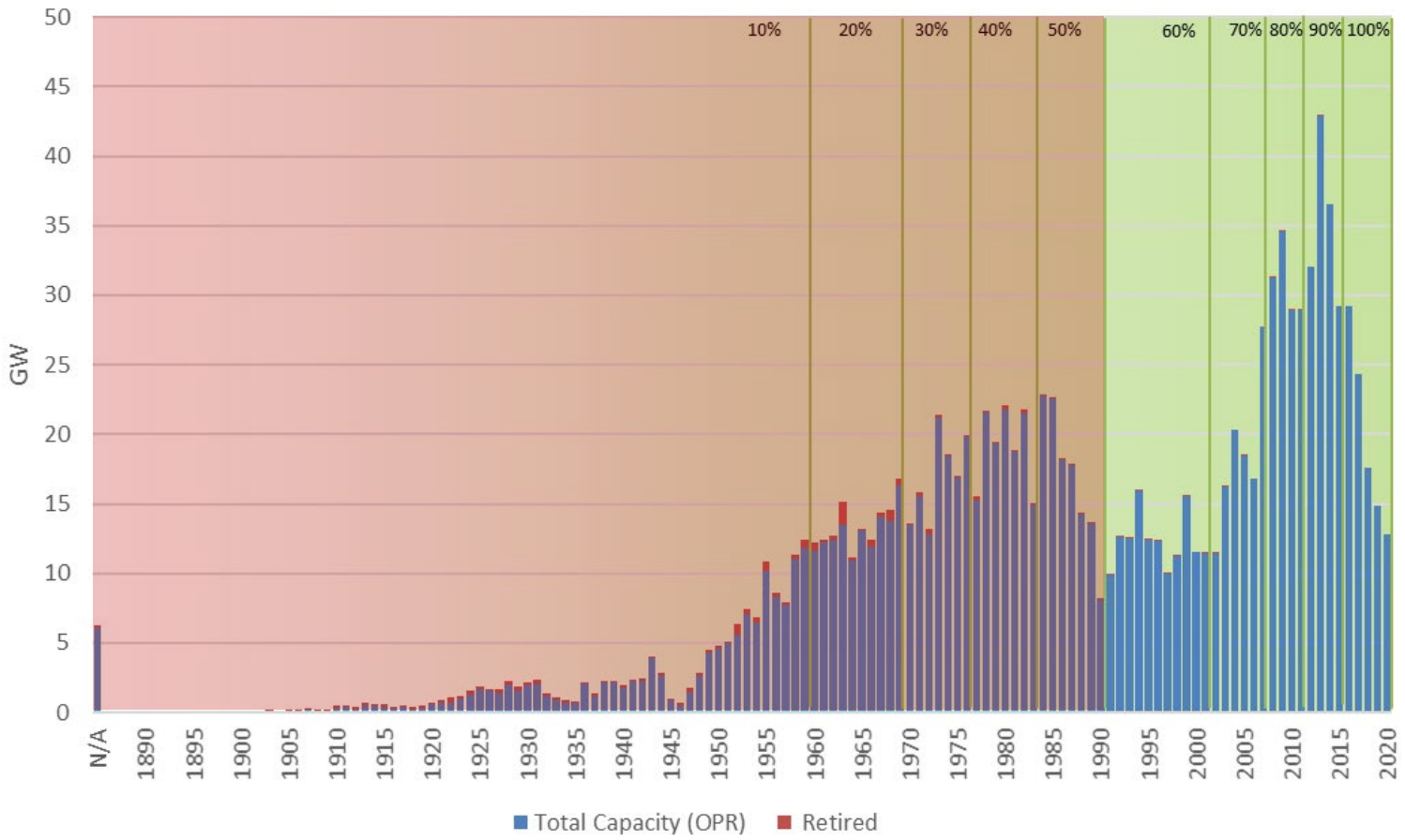
The global hydropower fleet is aging

- Hydropower is very long-lived, however fleet is aging.
- A large share of the installed capacity will soon need substantial upgrades, refurbishment or face the possibility of retirement.

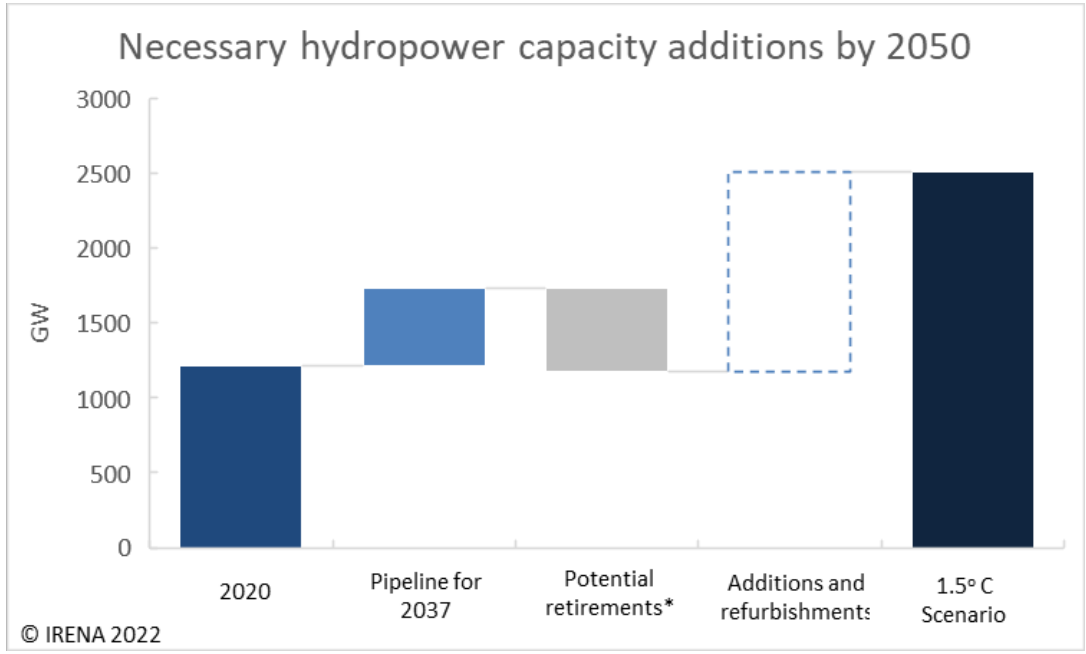
Global hydropower capacity by year of commissioning



Source: IRENA analysis based on (S&P Global, 2022)

Hydropower capacity requirements by 2050

- Approximately 650 GW of hydro are already in the pipeline.
- A similar amount will be in need of considerable refurbishments or face retirement by 2050.
- IRENA's 1.5°C scenario sees the need to roughly double hydro capacity by 2050 (excl. PSH).
- The vast majority of the remaining economic potential lies in the Asia-Pacific region, followed by South America and Africa.



IRENA Analysis based on WETO and S&P Global, 2022

*Assuming an average lifetime of 60 years

Key Takeaways

- **Hydropower is becoming increasingly valuable** based on its ability to provide flexible generation and energy services, ancillary grid services, water management, and socioeconomic benefits.
- **Large amounts of hydropower (incl. pumped storage) will be necessary** for the achievement of the Paris Agreement goals.
- The hydro **fleet is aging and will need substantial refurbishment**. This challenge presents an opportunity to **innovate, to introduce new technologies and to modernize plants** in a way that they fit the needs of today's power systems.
- Large investments will be needed and this will only be possible if **policies and markets that appropriately value the wide range of hydro services** are put in place.
- New projects will have to be developed under **transparent sustainability criteria**.
- IRENA is working on these issues through the **Collaborative Framework on Hydropower**.

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Thank you!

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IRENA International Technology Centre
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Canadian perspective

Thomas Levy

Senior Science & Technology Advisor
NRCan

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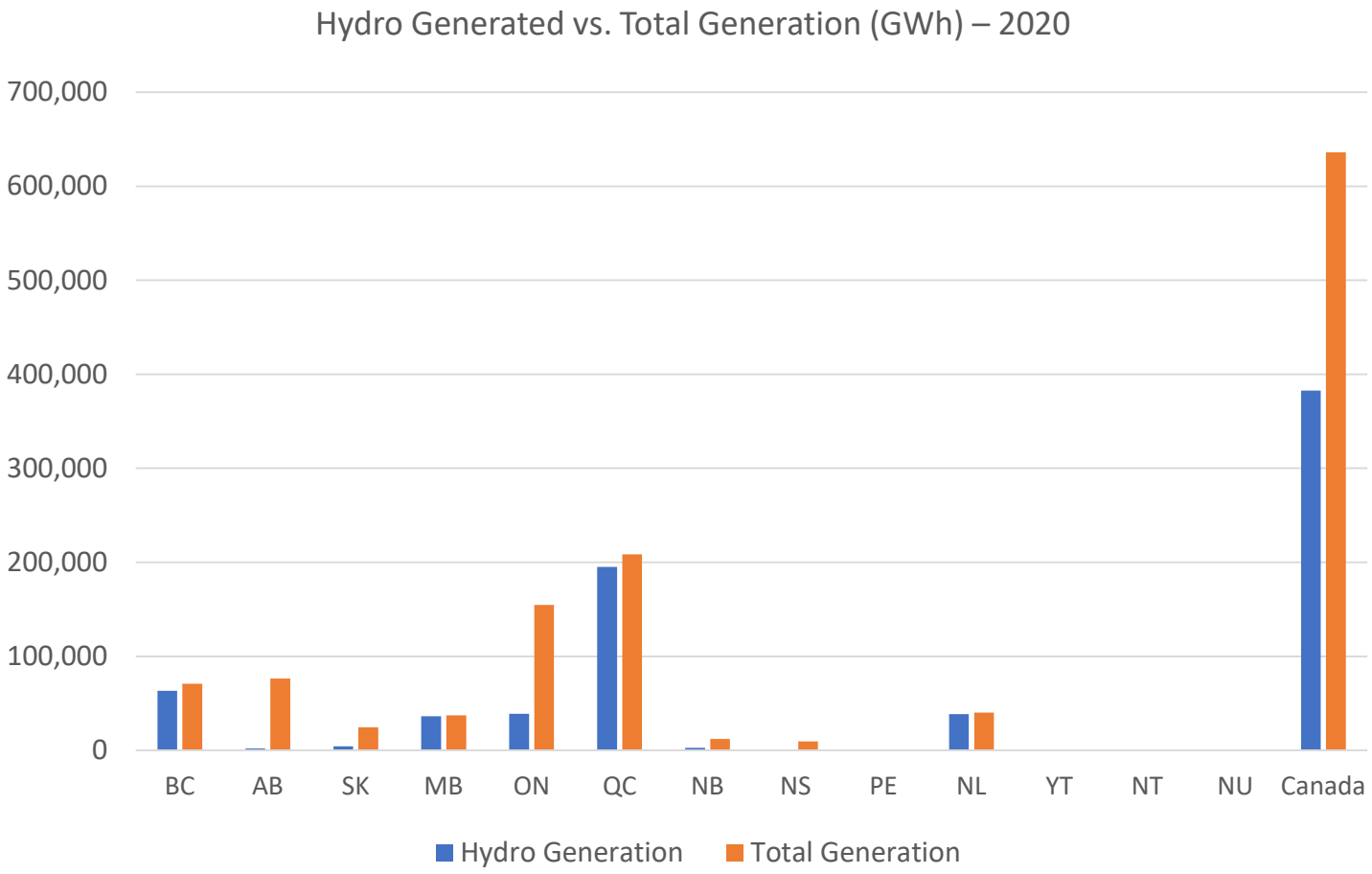
Canadian perspective – Agenda

- Canadian Hydropower at a Glance
- Hydropower & Power System Transformation: Problem Statement
- Unlocking Hydropower's Value
- Exploring Flexibility Value of Hydropower – NARIS
- Conclusions

Canadian Hydropower at a glance

- Canada is nearly 83% non-emitting
- Hydro provides about 60% of generation
  - 80,733 MW of hydro generating capacity in 2017
    - Small hydro (< 50MW) represents about 5%
  - Hydropower represents over 90% of electricity generation in BC, MB, QC, NL, and YT
  - 3rd largest hydropower producer globally



Hydropower & Power System Transformation: Problem Statement

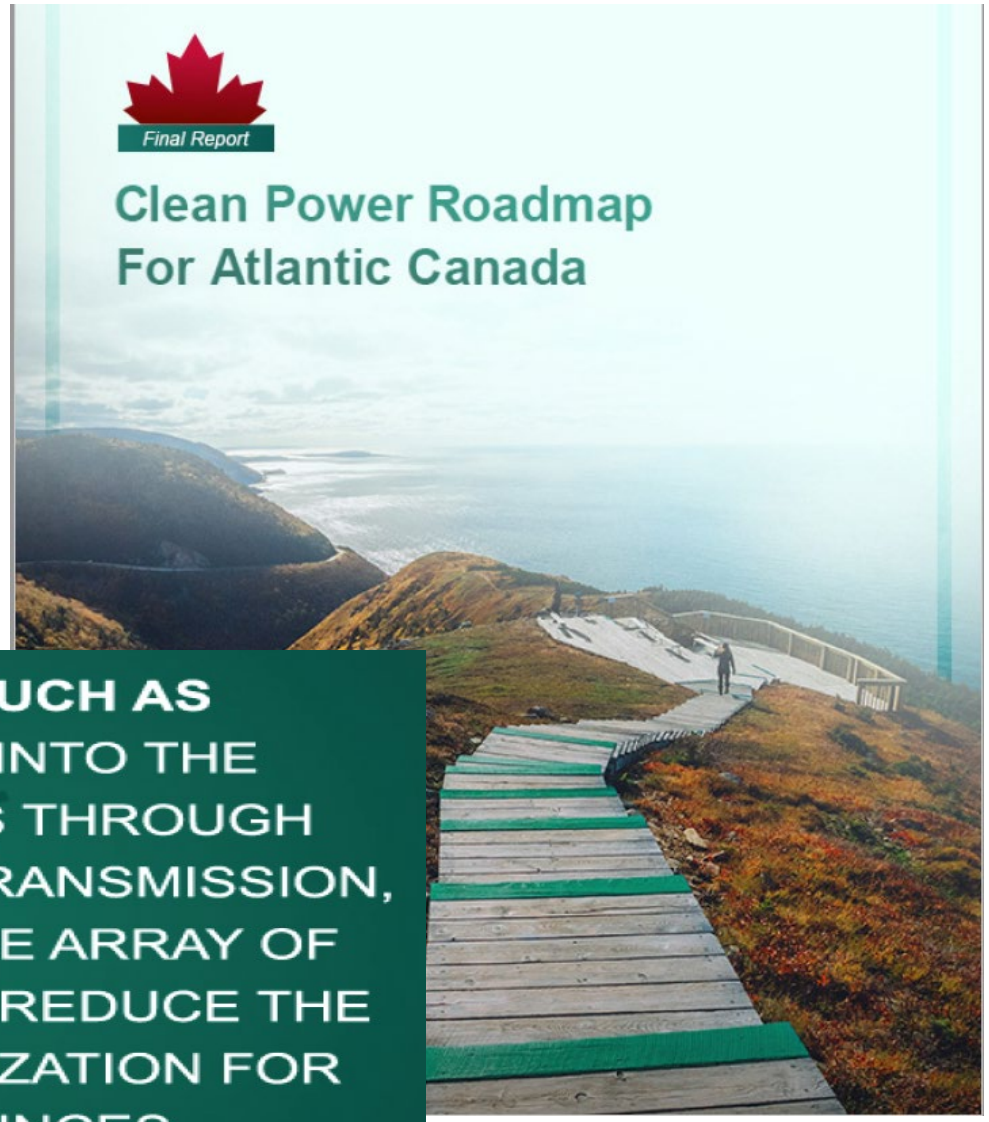
- The North American electricity system will have to rapidly and continuously integrate growing shares of variable renewables to support grid decarbonization and electrification
- This will require to significantly increase system flexibility
- Regional integration through increased transmission will be key to ensure cost-effectiveness
- Canada's hydro resources can play a key role in this interconnected future

Unlocking Hydropower's Value

Minnesota Power to reach 50% renewables in 2021 with Canadian hydropower

Published June 15, 2020

Catherine Morehouse



CLEAN ENERGY, SUCH AS HYDRO DELIVERED INTO THE MARITIME PROVINCES THROUGH ENHANCED REGIONAL TRANSMISSION, COULD PROVIDE A WIDE ARRAY OF SYSTEM BENEFITS AND REDUCE THE COSTS OF DECARBONIZATION FOR INDIVIDUAL PROVINCES.

Exploring Flexibility Value of Hydropower – NARIS

(The **N**orth **A**merican **R**enewable **I**ntegration **S**tudy)

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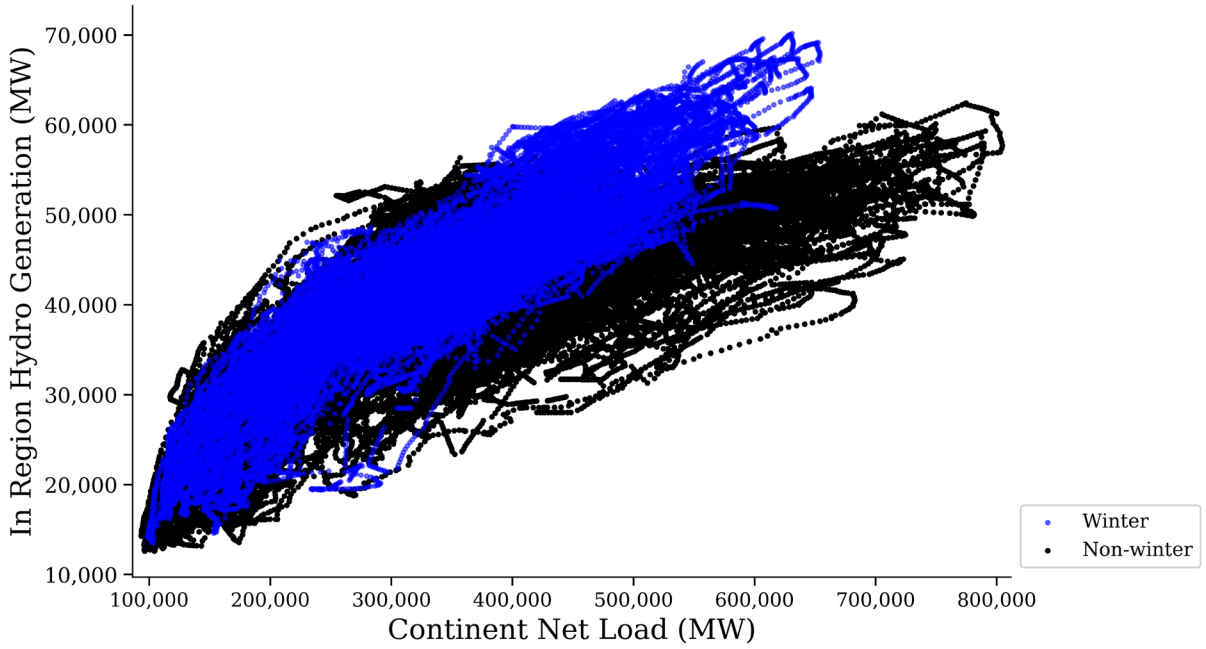
The North American Renewable Integration Study

- State-of-the-art analysis of the U.S., Canada, and Mexico power systems, from planning through operations
- Announced at 2016 North American Leaders Summit
- **Objective:** Accelerating grid modernization in North America

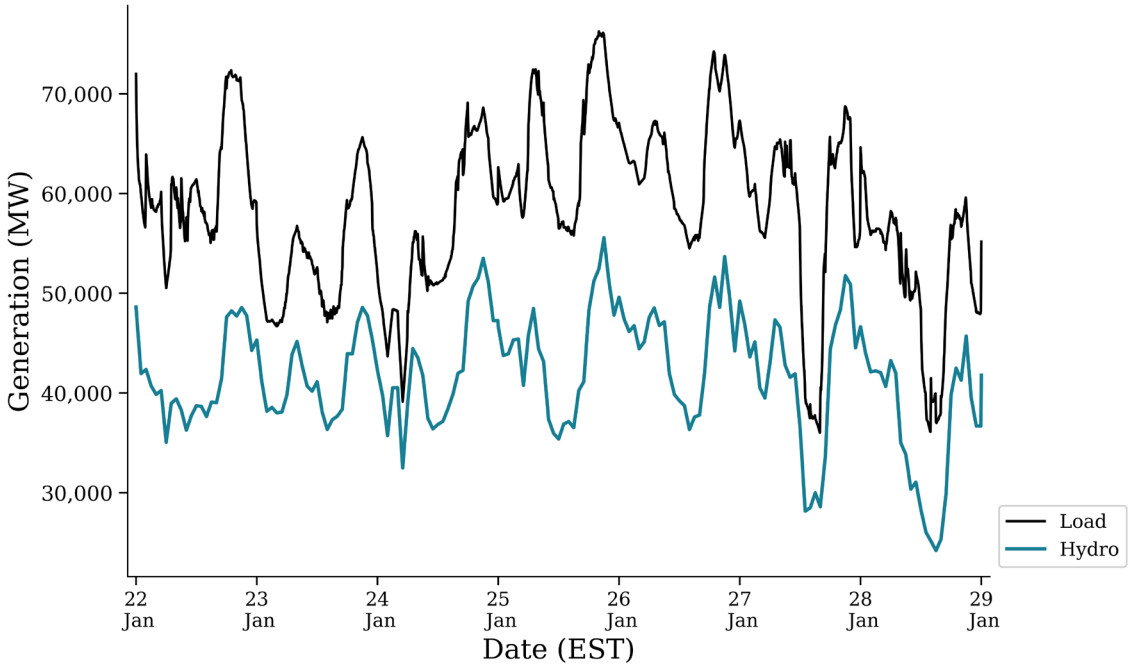
What this study encompasses

- Long-term pathways to a modern power system in North America
- Operational feasibility of high-penetration scenarios
- Weather variability and uncertainty
- Value of enabling technologies: flexible hydro, thermal generation, transmission, storage
- Value of operating and planning practices: interchange, transmission expansion, local generation

Hydropower provides all three system needs: Energy, Capacity, Flexibility/Reserves



Scatterplot of Canada hydro dispatch vs continental net load



Time series of Canada hydro dispatch and Canada net load

Hydropower flexibility brings multiple benefits

- Annual operating cost reductions of $2.3b
- Renewable Generation curtailment reduced from 8.9 to 8.3%
- Emissions from thermal generation reduced by 22 TWh
- Power System Emissions reduced by a further 1.3%

Conclusions

Canada has a wealth of hydropower assets across jurisdictions

- Providing flexibility and large renewable generation capacity

Large studies have identified the value of hydropower in Canada's Net Zero Transition

- NARIS insights

Ongoing work is taking place in Hydropower innovation and infrastructure development

- Continued research, demonstration, and development
- Atlantic Loop development

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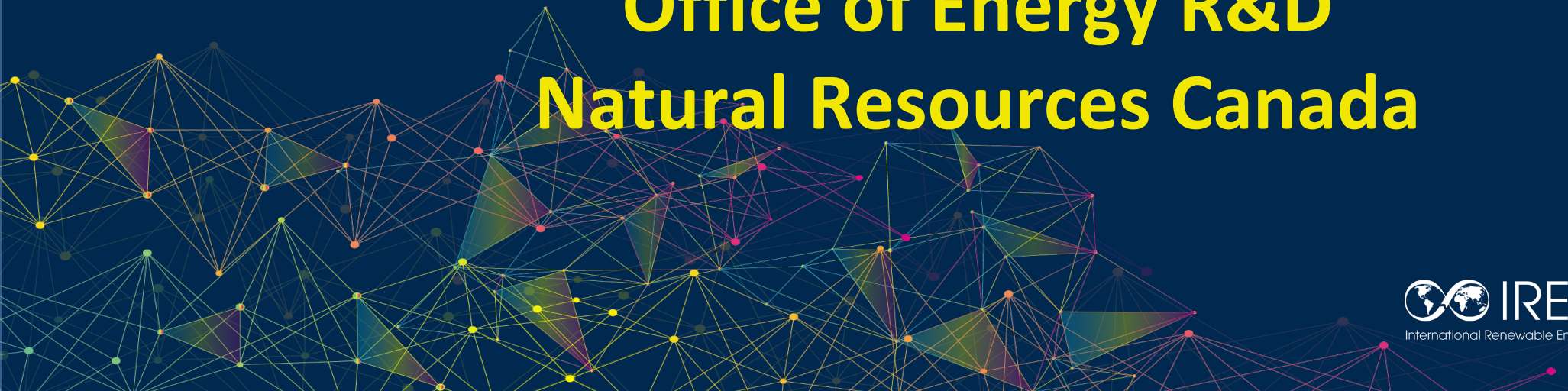
Thomas Levy
Office of Energy R&D
Natural Resources Canada



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Session 2: Innovative Hydropower Solutions - PANEL

Moderator

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Deputy Director
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Senior Policy Advisor
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David Havard

Head Of Product Marketing
GE Renewable Energy

Rebecca Ellis

Energy Policy Manager
IHA

IRENA International Renewable Energy Agency Canada

Session 2: Innovative Hydropower Solutions

Viviane Aubin & André Dagenais

Engineers
Hydro-Quebec

Storage hydropower has valuable features for VRE integration

As variable renewable energy sources (VRE) grow, issues within power grids arise.

VRE will be essential to decarbonize power grids and, eventually, the economy. However, VRE-related issues must be addressed.

VRE-related issues within power grids

- Uncertainty of generation
- Intermittency and variability of generation
- Mismatch with demand

There is a need for flexibility in terms of power grid management.

Storage hydropower can provide flexibility.

Storage hydropower features

- Energy storage
- Dispatchable generation
- Quick changes of generation levels
- Low GHG emissions
- Low costs

Hydro-Québec holds a unique position in the area

Hydro-Québec (HQ) is the **main power utility** in Québec. It is one of the largest hydropower producers in the world.

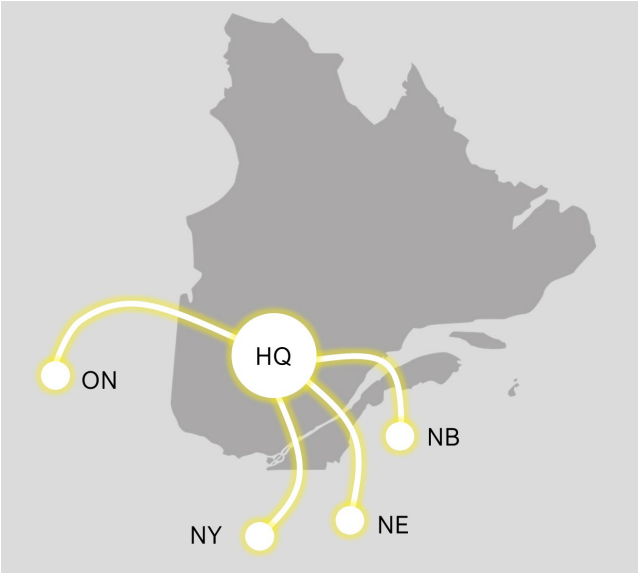
Total installed capacity : 37 GW

Total storage capacity in reservoirs : 176 TWh

Hydro-Québec and its neighbouring grids

As decarbonization targets are set and VRE are on the rise in HQ's export markets, interest is growing towards Québec's hydropower. HQ's max **export capacity** amounts to 8000 MW, for now.

Recent **commercial agreements** require steady flows from Quebec. Within the current **market structure**, it is a straightforward way to **finance new transmission lines**. But a more **flexible** behaviour might be more useful for VRE integration.



Hydro-Québec must prepare for the energy transition

The energy transition is and will be taking place outside and inside the province of Québec.

Assessments of impacts of the energy transition on operations

- Wind power integration
- Solar power integration
- Battery energy storage systems integration
- Peak shaving potential
- Evolution of neighbouring markets

Economic analyses

- The current electricity market structure does not provide strong incentives for flexibility.

Innovation

- Adapting the generation
- Adapting the grid

Transmission planning in Quebec - Energy transition context

Classic – Planning for **peaks** using **large hydro**

- Winter peak, when it's cold and that all equipment can carry more current
- **Unique 735 kV AC network** designed to be fully loaded for a few hours a year
- Asynchronous 60Hz grid from the rest of the Northeast region

Current – **Aging** grid and **rising load factor**:

- Highly loaded interconnections (load factor near 1)
- Wind energy penetration does not affect operations

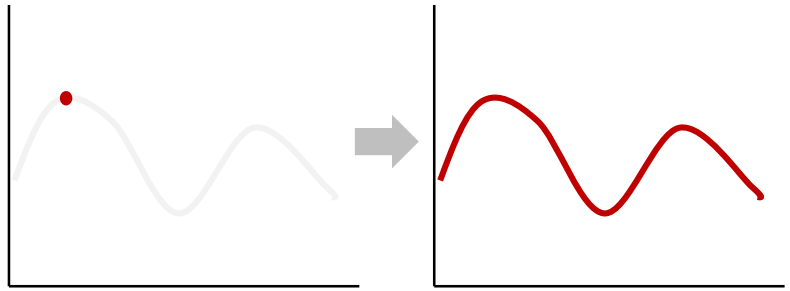
Energy transition – Higher **variable energy** penetration:

- Grid will need to "transmit" hydro's flexibility
- Find ways to maximize grid capacity to integrate variable renewable
- Finance new infrastructure

Transmission Planning evolution example – OSER Project

(**O**util de **S**imulation de l'**E**xploitation du **R**éseau)

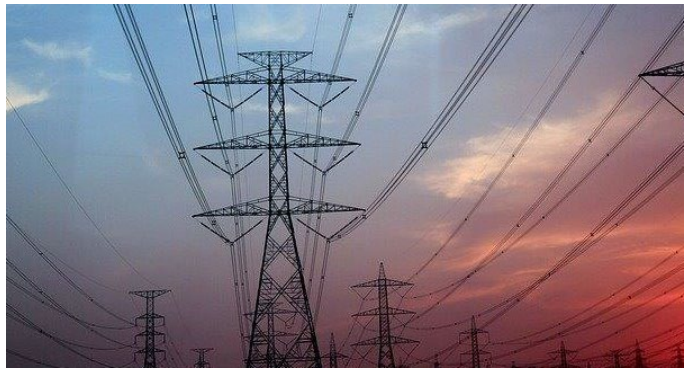
Year-long planning scenarios



Now: Planning studies focus on winter peak

OSER will allow to **study any point in time**

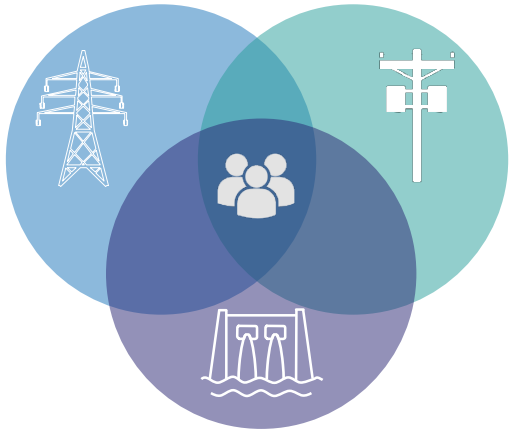
Transmission planning evolution



Allows to **study time-dependent issues** (ramps, energy losses, etc.)

Opens new probabilistic transmission planning options

Allows vertical planning optimization



Find **optimal solutions** for all transmission grid users

Put forward **new technology management strategies** (battery cycles, demand response, EV charging, etc.)

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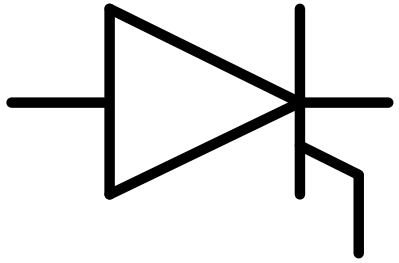
Classic and new toolkits for the Energy Transition – Examples

Classic toolkit

Line-Commutated Converters



Existing interties

Special Protection Systems - Automation

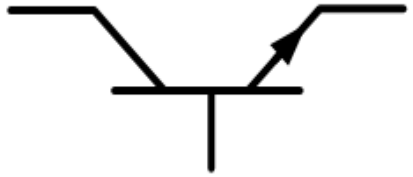
Series Compensation

Lines and Substations

Increasing the existing BULK power system capacity

New toolkit

Voltage Source Converters



Future interties
Connect remote off-grid systems
Contribute to grid stability?

Grid-scale Batteries

Provide emergency power, peak relief

Inverter-based Resources Control Simulation

EMTP-RV

Study variable generation interactions

Demand Response

Hilo

Explore demand-side solutions

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Viviane Aubin & André Dagenais
Hydro-Quebec

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Session 2: Innovative Hydropower Solutions

Chelsea Donelon

Senior Policy Advisor
TransAlta

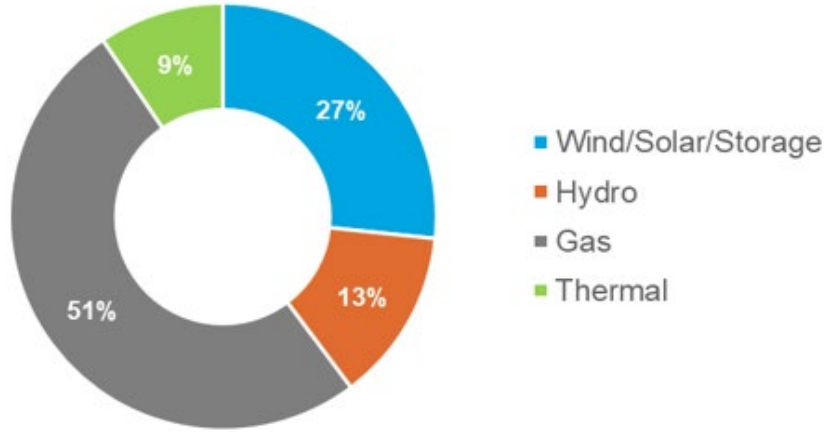
TransAlta: Who We Are

- 110+ years of generating experience with 7,000 MW of owned capacity at 75+ facilities
- In 2021, we achieved emissions reductions of 70% from 2005 levels – a reduction of 29 MTCO2e
- With 60% of our generation in Alberta, we're deeply invested in providing reliable, affordable, carbon neutral power to Albertans

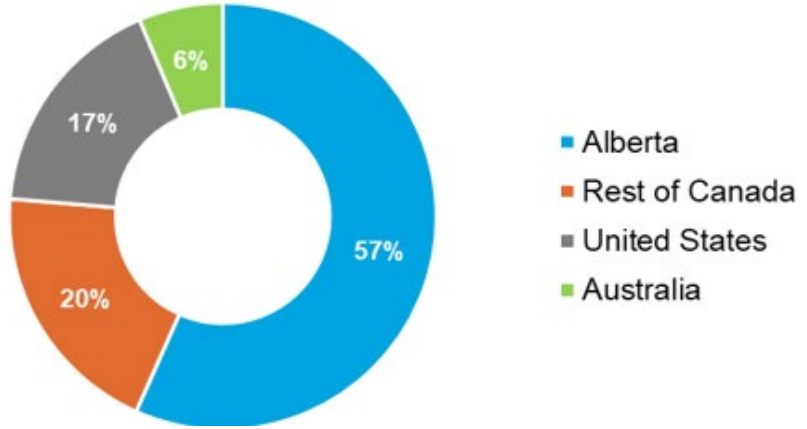
Four things to know about Alberta's electricity market:

1. It's a deregulated, free market
2. Limited intertie capacity
3. It's removed ~5,000 MW of coal generation and will be off-coal seven years ahead of federal and provincial mandates
4. It's seeing an explosion of renewables growth

Owned Generating Capacity by Fuel Type*



Owned Capacity by Geography*



Intermittency and Reliability in a Constrained Hydro Province

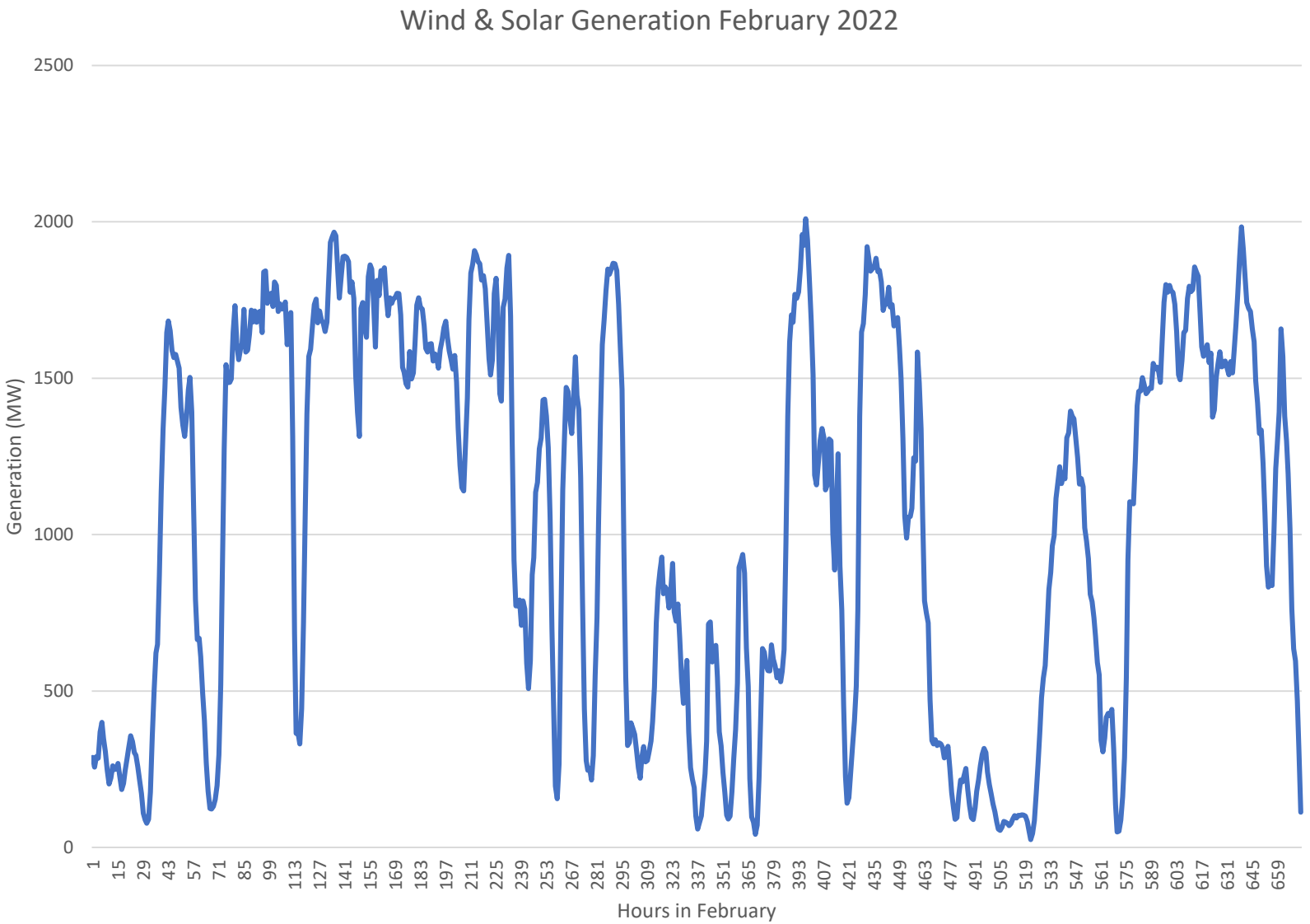
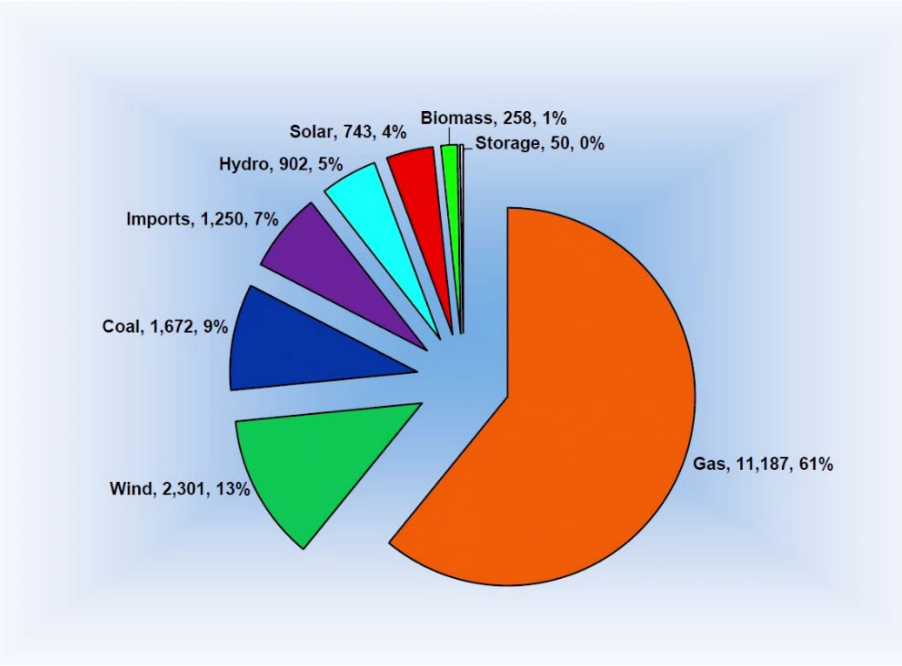
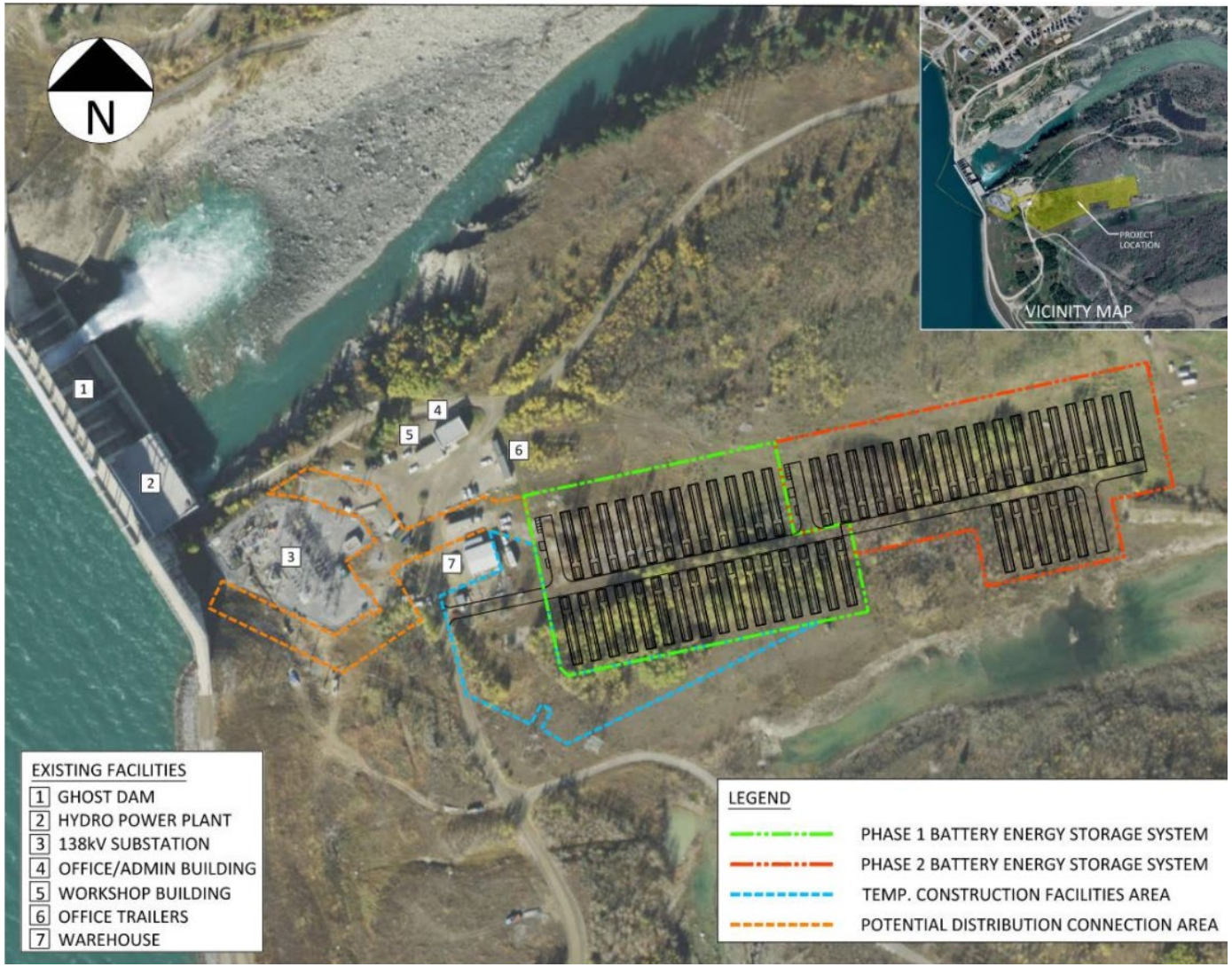


Figure 3 – 2021 Gross Generation Capacity by Fuel Type (MW)



Maximizing Existing Hydro: Project WaterCharger



- Up to 180 MW Battery Energy Storage System collocated with 58 MW Ghost Hydroelectric facility
  - Permitting for up to 180 MW to allow for “shovel-ready” future expansion
- Maximize the value of minimum must-flow hours and allow the facility to provide expanded grid services from the 1929 Ghost hydroelectric dam

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Chelsea Donelon
TransAlta

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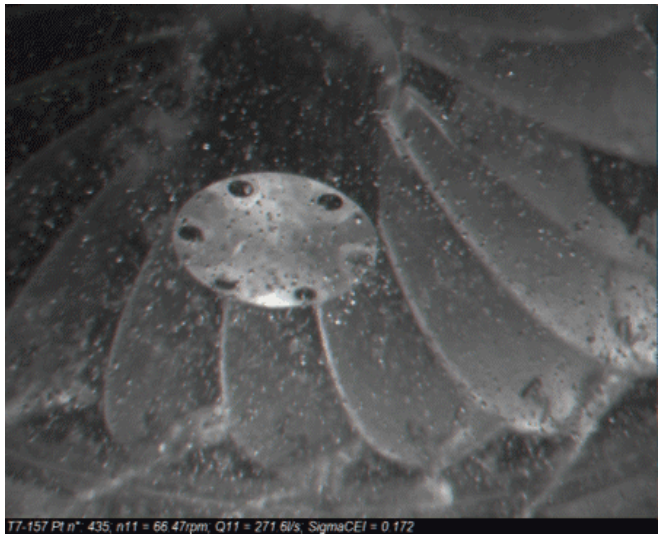
Hydropower is critical for the Energy Transition

Getting more FLEXIBILITY out of Existing Assets

Low Head (<~50m) Francis-Driven units



Damaging phenomena below 50% output, need to strengthen equipment

Innovative design of airfoils, extra air admission for aquatic life

PLUS

- **Site test campaign**
- **Scale model test**
- **Numerical Simulations**
- **High-Frequency on-site monitoring**

2-in-1 solution : Environment & Flexibility

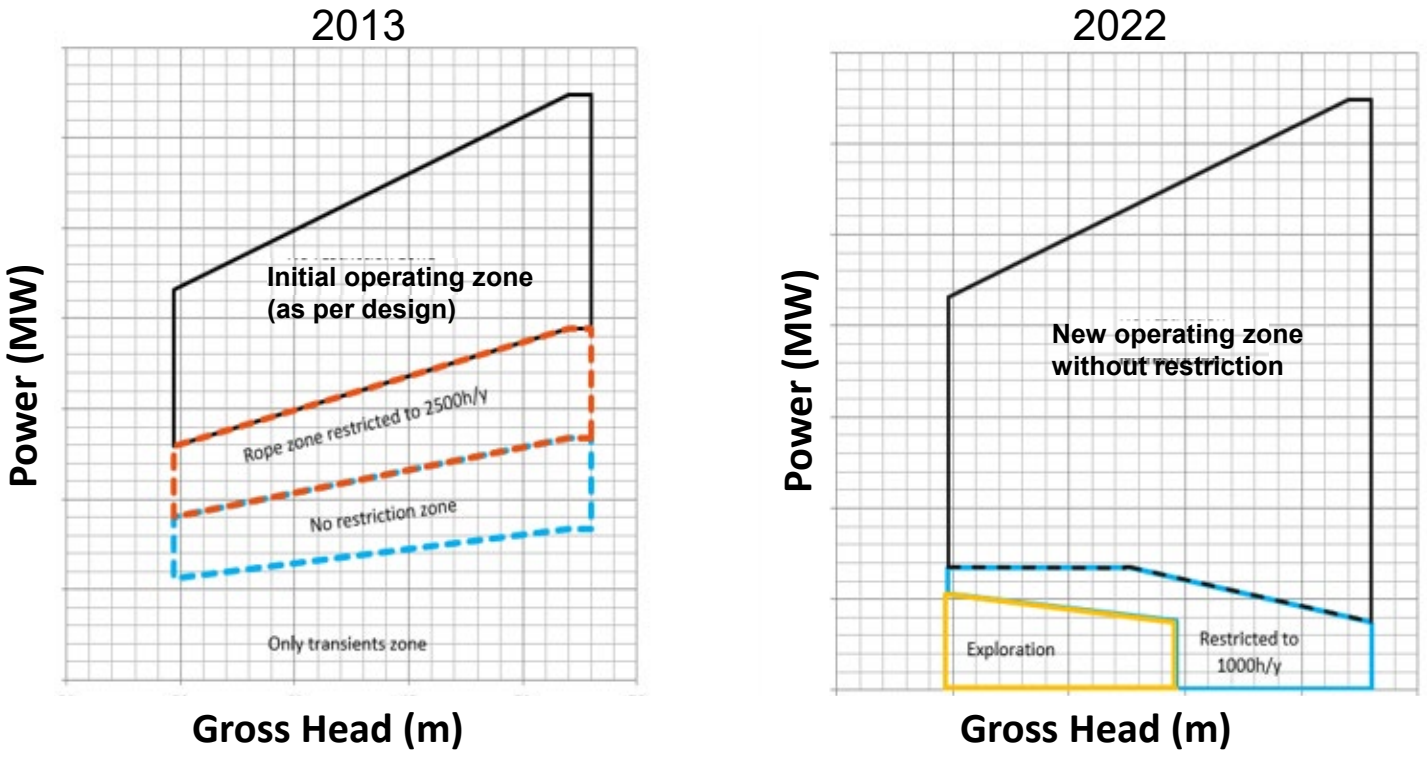
Doubled operation range, 0-100% output

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Water Power Technologies Office Award Number DE-EE0008942

Getting more FLEXIBILITY out of Existing Assets

Reversible Francis (Pumped Hydro Storage)

Increasing the Operating Range in Generation mode



- (Site testing)
- **Tools:** Numerical Simulations including deep part load
- **Data:** High-Frequency on-site monitoring during one year

www.xflexhydro.net

The Hydropower Extending Power System Flexibility (XFLEX HYDRO) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857832.

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General Electric Renewable Energy

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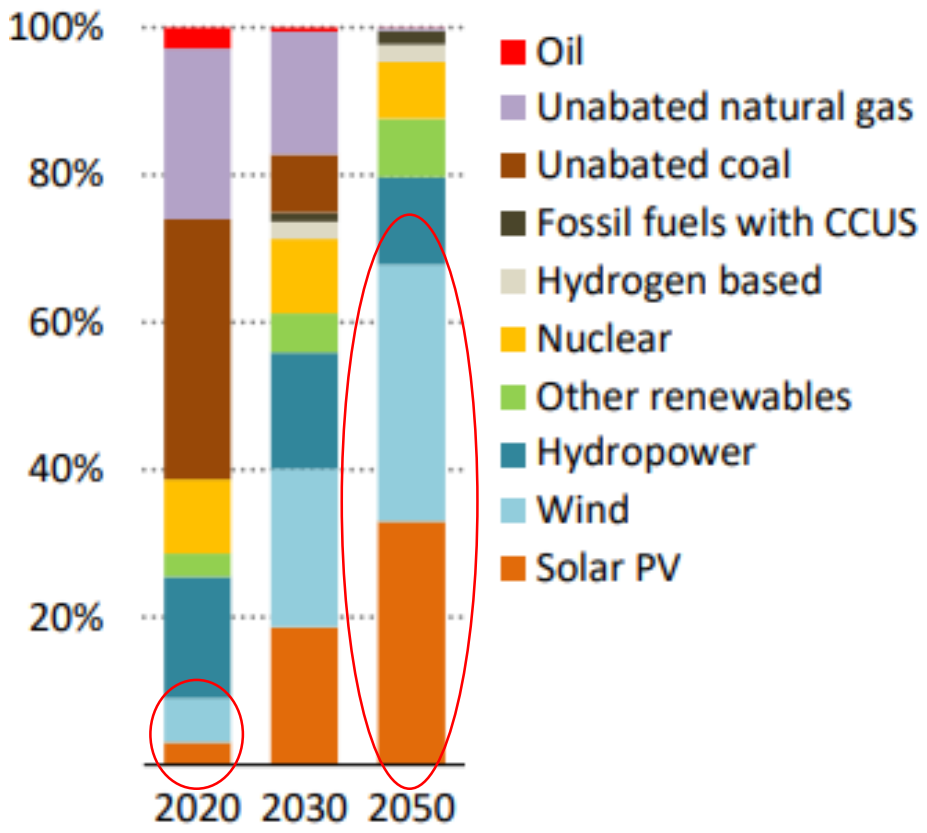
Rebecca Ellis

Energy Policy Manager
International Hydropower Association

PSH in the clean energy transition

Pumped Storage Hydropower International Forum

- Today around 160GW of pumped storage hydropower (PSH) accounts for **over 90% of storage capacity** in grid scale applications globally.
- There will be huge growth in the proportion of variable wind and solar on electricity grids – increasing demand for flexibility.
- But uncertainty around the business model and long lead-times means there is currently **very little private sector-led or financed PSH capacity**.
- Recent growth mainly driven by **China, led by government or public utilities**.
- The International forum came together to develop guidance and recommendations on how PSH can best support the energy transition.



Global electricity generation by source, Net Zero scenario (IEA 2021 – Net Zero by 2050)

International Forum on Pumped Storage Hydropower

Pumped Storage Hydropower International Forum

Steering Committee
Gov't & IFIs

Partners
Industry, Academia & NGOs

Secretariat
iha

A government-led multi-stakeholder platform to help address the key challenges facing pumped storage development

This year-long initiative brought together:

- 13 governments, with the U.S. Department of Energy the lead sponsor
- 7 multilateral development banks including the World Bank
- Over 80 partner organisations from industry, finance community, academia and NGOs

IHA was the secretariat to the wider Forum, the Steering Committee, and the three working groups.

Partners

EDF, Hydro Tasmania, GE, VOITH, AFRY, ALPIQ, ANDRITZ, Australian National University, BHA, University of Cambridge, C.R.E.A.R., EPFL, ellomay Capital Limited, Espejo de Tarapacá, Genex Power, GESEL, HYDRIA, HPAU, HydroCen, CIGB ICOLD, IHE Delft, INHA, ipto, Intelligent Land Investments Group, IIASA, MCWe, MINE STORAGE, Mott MacDonald, NHA National Hydropower Association, NREDCAP, New Horizons Energy, Norwegian Energy Partners, PacificHydro, Pacific Northwest National Laboratory, POSOCO, PREMIUM ENERGY, PSR, ΔEH, PUMPED HYDRO STORAGE, REH Renewable Energy Holdings, San Diego County Water Authority, SINTEF, SMEC, Southern Company, Stantec, SUNHYDRO, TERNA ENERGY, teri, VALHALLA, voltalia, Waterpower Canada Hydroelectricity Canada, Worley, XFLEX HYDRO

Steering Committee Members

iha

European Investment Bank The EU bank

African Development Bank Group / Groupe de la Banque africaine de développement

ADB Asian Development Bank

The World Bank

European Bank for Reconstruction and Development

IDB Inter-American Development Bank

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Policy & Market Frameworks

Pumped Storage Hydropower International Forum

- Global position paper
- Country and regional papers

Seven recommendations for action:

1) **Assess long-term storage needs** now, so that the most efficient options, which may take longer to build, are not lost.
2) **Ensure consistent, technology neutral comparisons** between energy storage and flexibility options.
3) **Remunerate** providers of essential electricity grid, storage, and flexibility services.
4) **Licensing and permitting** should take advantage of internationally recognised sustainability tools.
5) **Ensure long-term revenue visibility** with risk sharing to deliver the lowest overall cost to society.
6) **Assess and map for PSH potential** existing hydropower assets and prospective sites.
7) **Support and incentivise** PSH in green recovery programmes and green finance mechanisms.

To learn more, please visit:

pumped-storage-forum.hydropower.org

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Sustainability

- Working Paper on Sustainability of PSH

Key findings

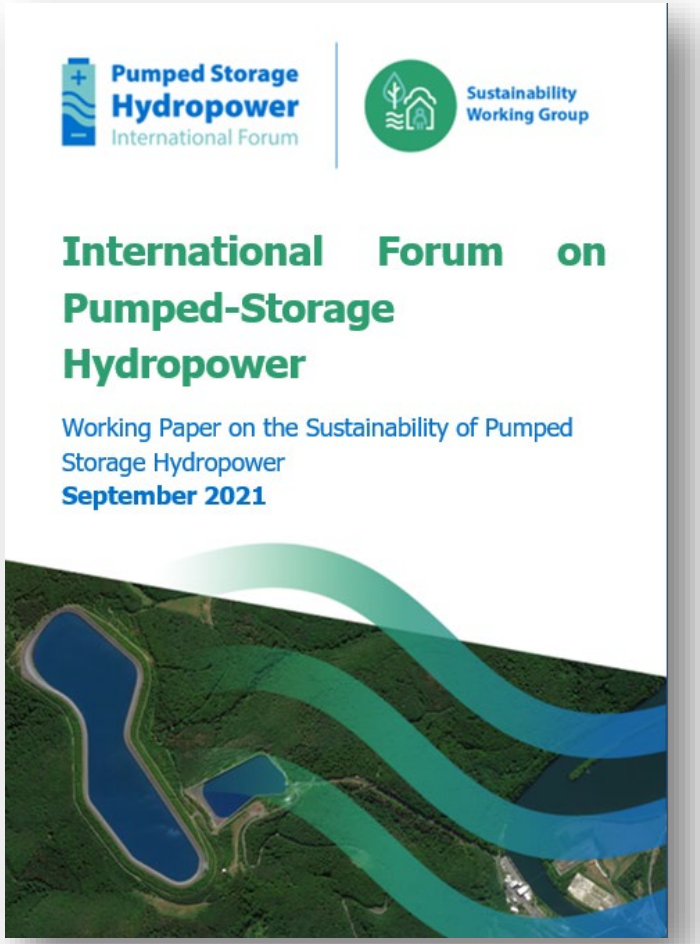
1) PSH should be considered as a **key enabler of the clean energy transition**, alongside other energy storage technologies.

2) Three level assessment framework: adopt **system needs assessment**; **technology options assessment**; and **project optimisation** to avoid, minimise and mitigate social and environmental impacts.

3) PSH impacts are site-specific. The internationally recognised **Hydropower Sustainability Tools** can navigate these nuances.

4) Use of Life Cycle Analysis on PSH requires specific attention on the boundaries and functional units of the power system (e.g. the underlying energy mix) to avoid misleading conclusions.

5) Consider **one-time or permanent local benefits of PSH** in sustainability assessment.



To learn more, please visit:

pumped-storage-forum.hydropower.org

Capabilities, Costs and Innovation

- PSH Capabilities and Costs
- Innovative PSH Configurations and Uses
- Interactive online map on global PSH potential

Key findings

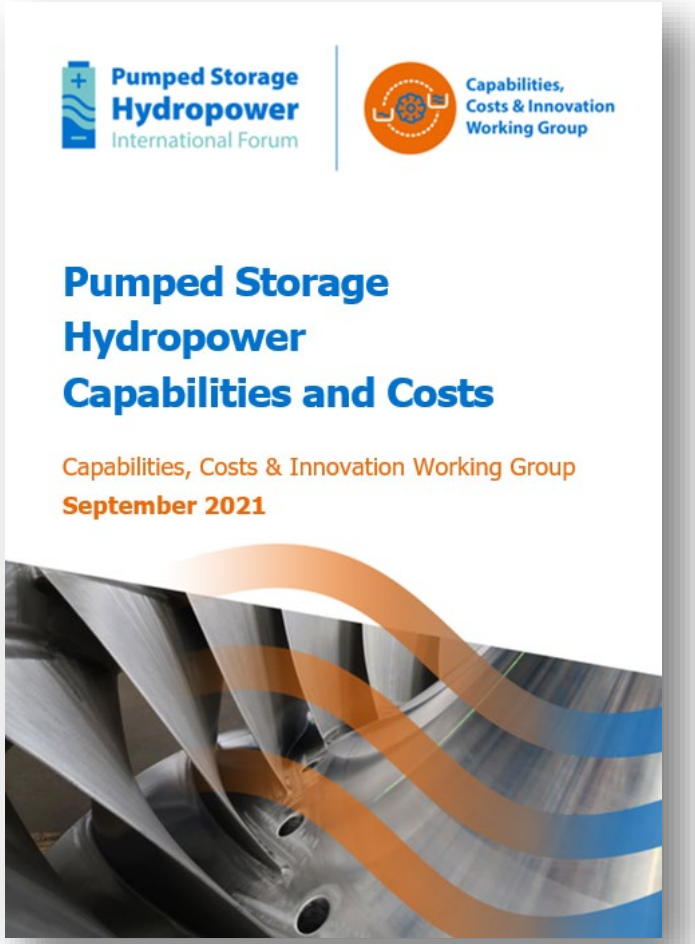
1) PSH is a **proven long duration energy storage** technology.

2) PSH provides a range of **essential grid services**, which will be increasingly important with the phasing out of fossil fuel generation.

3) Capital expenditures (CAPEX) comparisons could be misleading as PSH has a much longer lifetime and hence **lower effective lifetime costs**.

4) Innovations in **retrofitting** existing infrastructure, flexibility **upgrades** and **hybridisation** with batteries, floating solar PV, heat storage and desalination, provide new opportunities.

5) Significant remaining potential for new PSH.



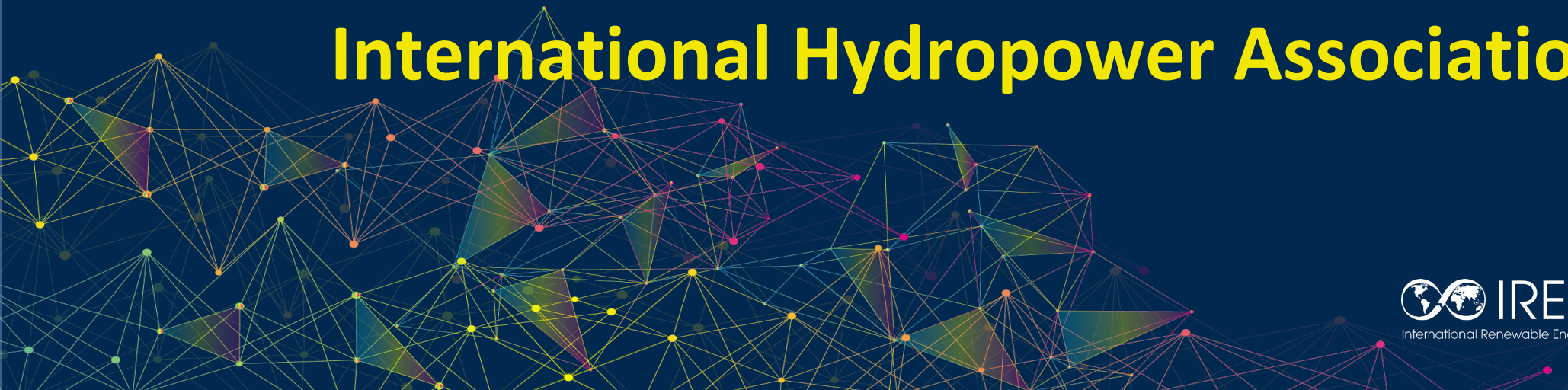
To learn more, please visit:

pumped-storage-forum.hydropower.org

IRENA INNOVATION DAY

Thank you!

Rebecca Ellis
International Hydropower Association



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Wrap up of Day 1

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Closing remarks - Wrap up of Day 1 – IRENA

Dolf Gielen

Director
Innovation and Technology Centre
IRENA

Closing remarks - Wrap up of Day 1 – Natural Resources Canada

Abigail Lixfeld

REED Senior Director
Natural Resources Canada