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IEA Hydropower

Seasonal value of hydropower storage

Nathalie Voisin, Atle Harby (IEA hydro Annex IX operating agent), Abhishek Somani

IEA Wind Task 51 Forecasting:
Seasonal Forecasting Workshop
Reading, 17-19 May 2023

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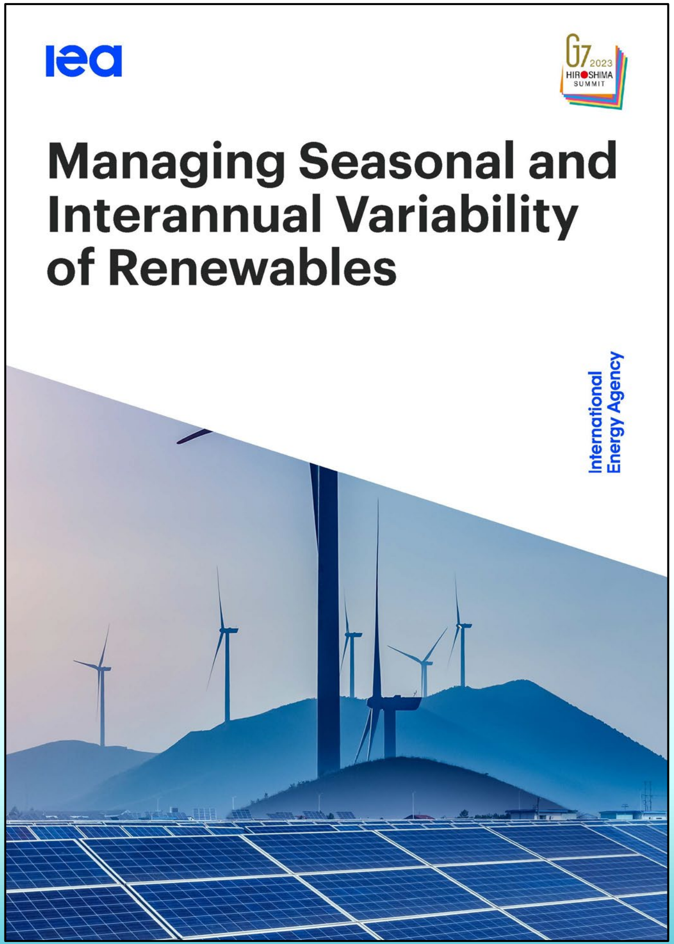
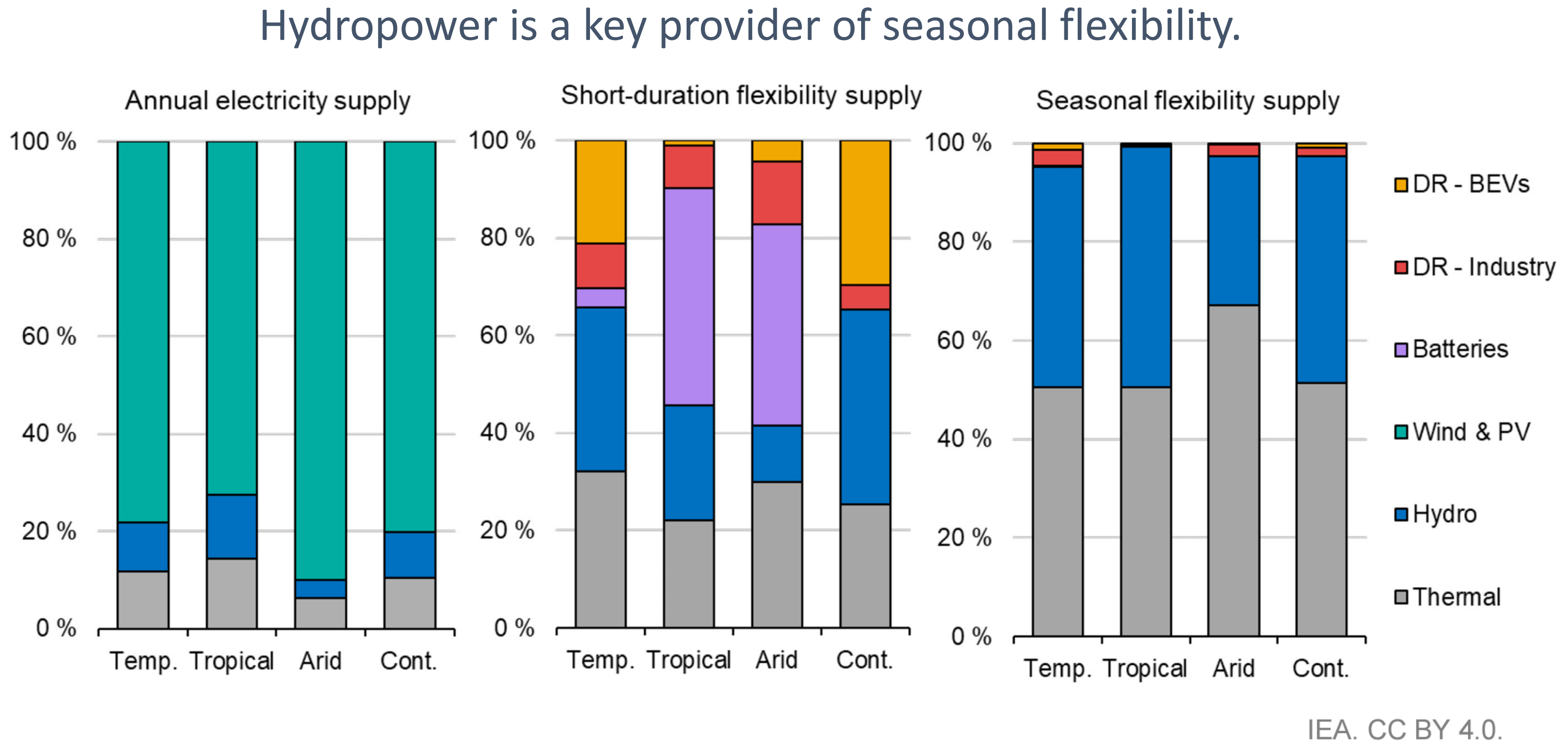
Sub-seasonal to seasonal hydropower provides unique opportunities for the evolving power grid and its increasing need for storage





Note: Electrolytic hydrogen provides both demand response (during production via electrolysis) and flexible supply (when used in thermal power plants). DR = Demand Response. BEVs = Battery Electric Vehicles.

https://www.iea.org/reports/managing-seasonal-and-interannual-variability-of-renewables

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About Seasonal Hydropower

Seasonal hydropower availability is subject to large inter-annual variability, and is changing due to climate change, environmental regulation, and evolving societal needs including flood control and water supply.

Task IX: Valuing Hydropower Services - Phase II (2018 - present) including Task IX/Task XII Joint Task (2019 - present)

Task XII: Hydropower & the Environment Task 1: Managing the Carbon Balance of Freshwater Reservoirs (2007 - Present)

Annex XVII - Measures to Enhance the Climate Resilience of Hydropower (2021 - present)

Annex XVIII - Decision Support for Comprehensive Utilization of Basin Water Resources (2021 - present)

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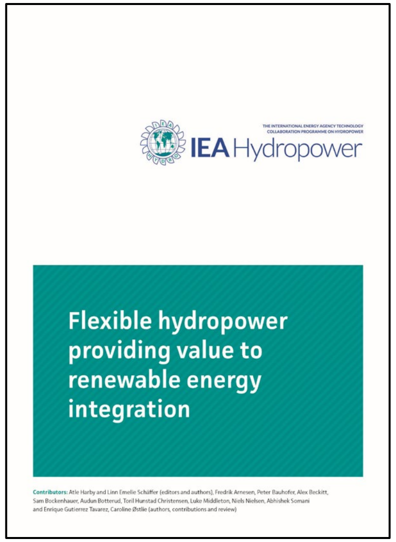
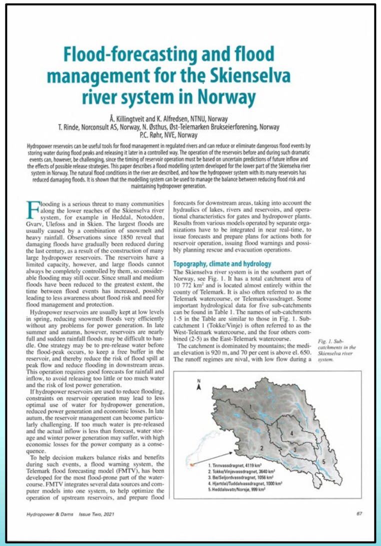
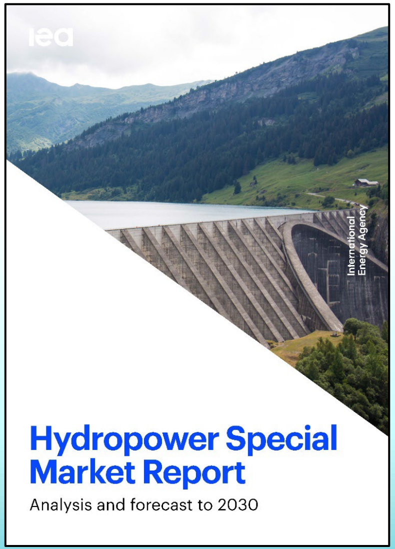
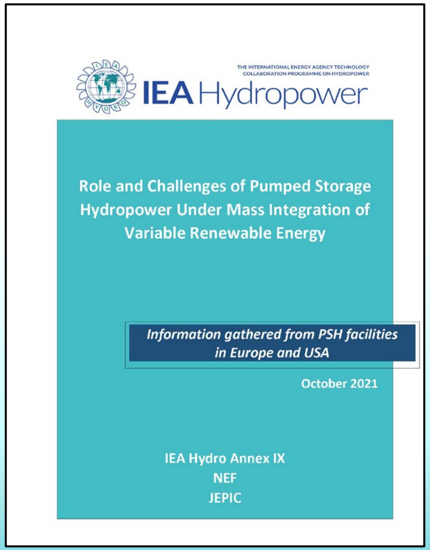
Studies, Analysis, Reports and White Papers

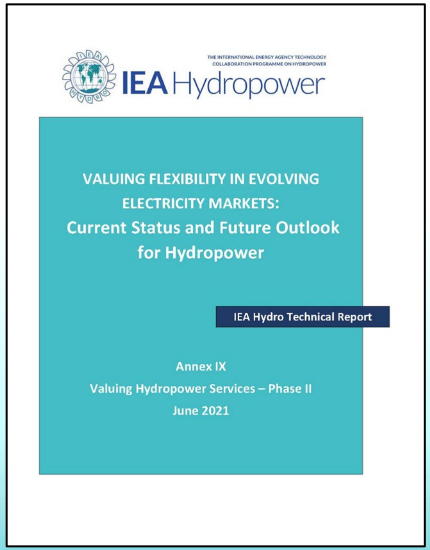
- Hydropower providing Flood Control and Drought Management Services
- Flexible hydropower providing value to renewable energy integration
- Role and Challenges of Pumped Storage Hydropower Under Mass Integration of VRE
- Valuing Flexibility in Evolving Electricity Markets: Current Status and Future Outlook for Hydropower
- Input to IEA Hydropower Special Market Report

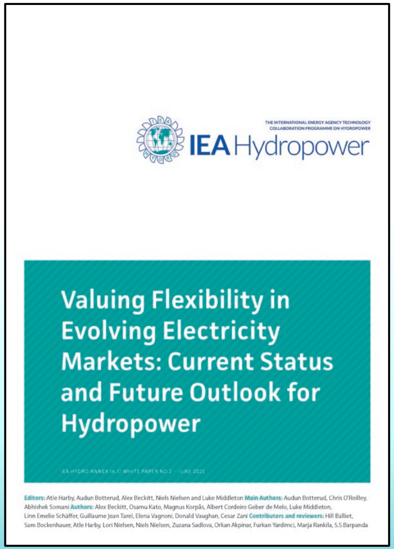












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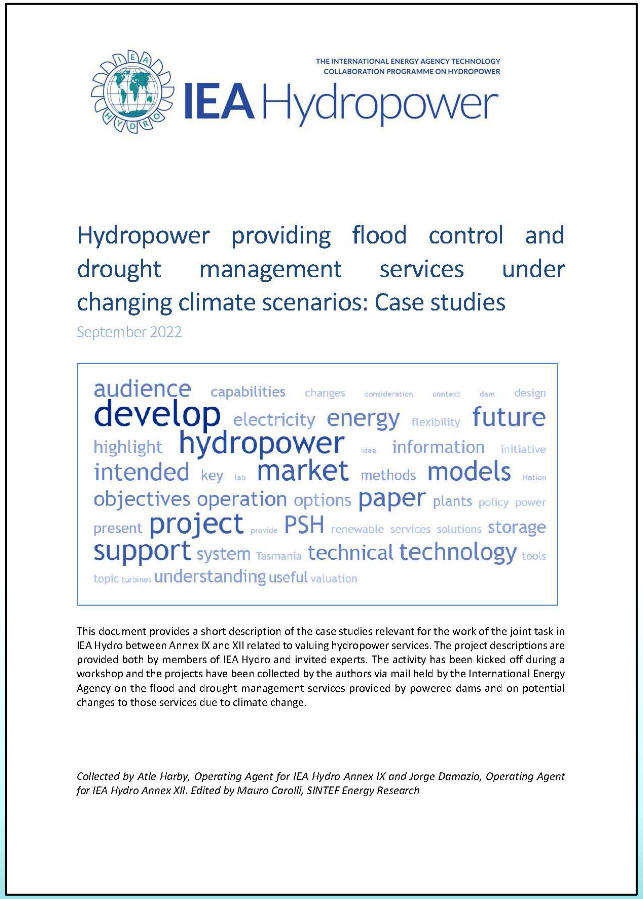
The value hydropower storage brings to societal services like flood control and drought management



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Hydropower providing flood control and drought management services under changing climate scenarios: Case studies

September 2022

This document provides a short description of the case studies relevant for the work of the joint task in IEA Hydro between Annex IX and XII related to valuing hydropower services. The project descriptions are provided both by members of IEA Hydro and invited experts. The activity has been kicked off during a workshop and the projects have been collected by the authors via mail held by the International Energy Agency on the flood and drought management services provided by powered dams and on potential changes to those services due to climate change.

Collected by Atle Harby, Operating Agent for IEA Hydro Annex IX and Jorge Damazio, Operating Agent for IEA Hydro Annex XII. Edited by Mauro Carolli, SINTEF Energy Research

- Understanding and documenting how various countries approach managing water resources under climate change scenarios
- Investigating the role of hydropower in minimising or mitigating risks associated with a changing climate
- Assessing the value that hydropower provides in minimising or mitigating risks associated with a changing climate

Report ready → Summarize into White Paper

How to quantify the value?

Contributions of Hydropower to Societal Benefits
Metrics in progress; metrics ≠ modeling constraints parameters

Hydropower
Local Revenues

Flood control
Flood reduction
Avoided Damages

Navigation routes

Municipal & industrial use
Socio-economics
Development

Water Supply – Irrigation
Crop yield
Properties values

Eco-Tourism & Recreation
Local revenues
& Employment

Fish passage & protection

Water quality & temperature

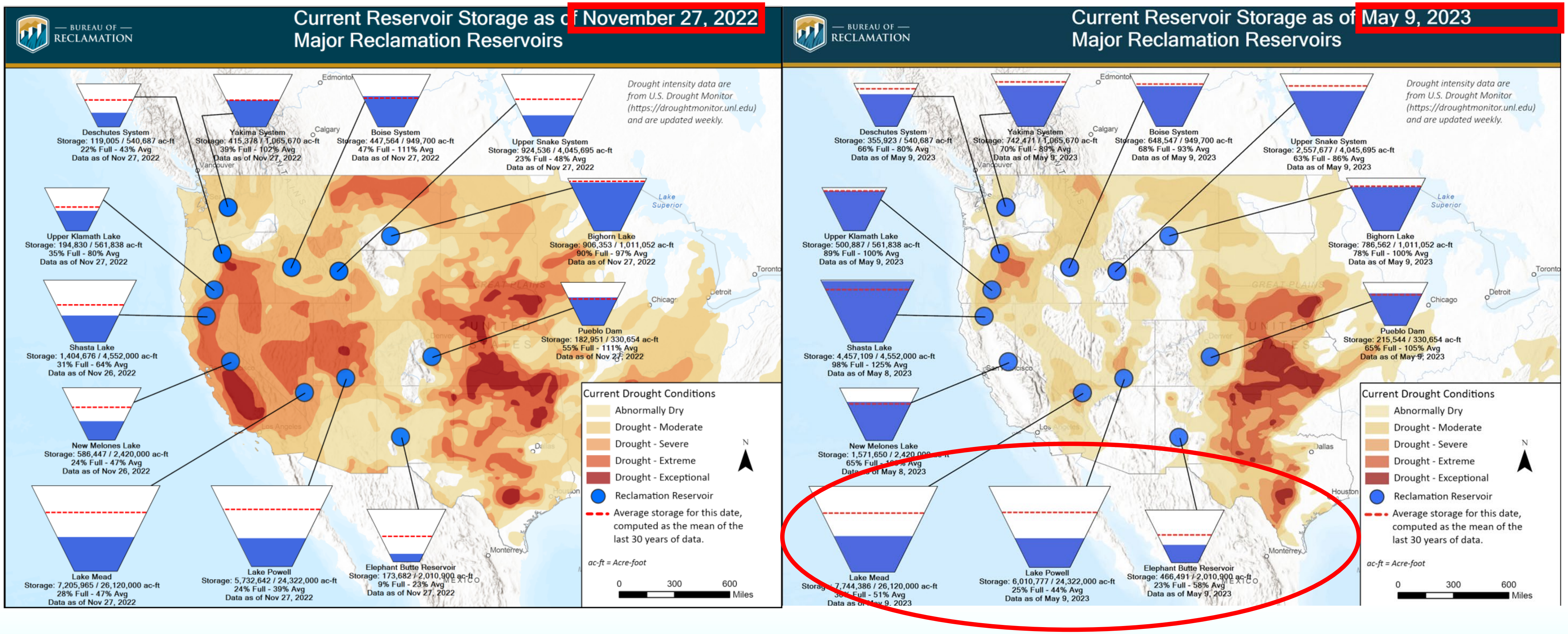
Wildlife habitat

Native cultural resources

Recent Advances

1) In snowmelt-controlled regions, seasonal water management is typically aligned with hydropower needs.
2) In regions with substantial hydropower generation, co-optimization is needed due to complex dynamics of energy markets.
3) Priorities between societal benefits is driven by institutions.
4) Non-monetized metrics for societal benefits remains a challenge.
5) Value proposition for hydropower storage as Long Duration Energy Storage is advancing through the characterization of energy supply droughts and energy deficits.

Recent Drought and Reservoir Conditions

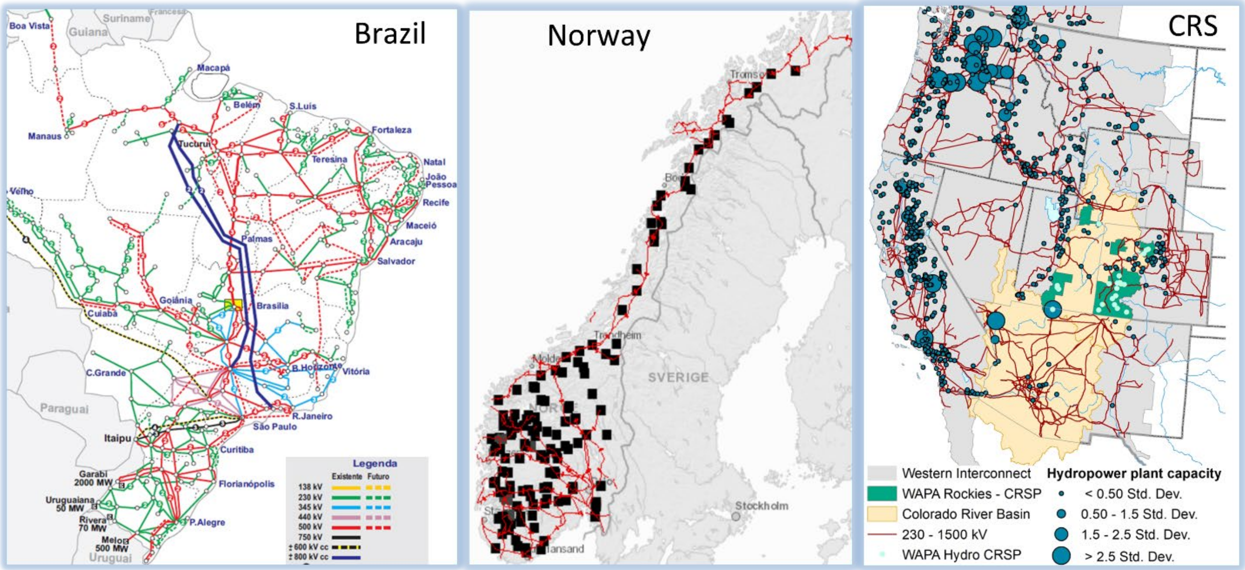


Reservoir storage in some systems has recovered from drought conditions however low storage persists for reservoirs with large multiyear capacity (Lower Colorado)

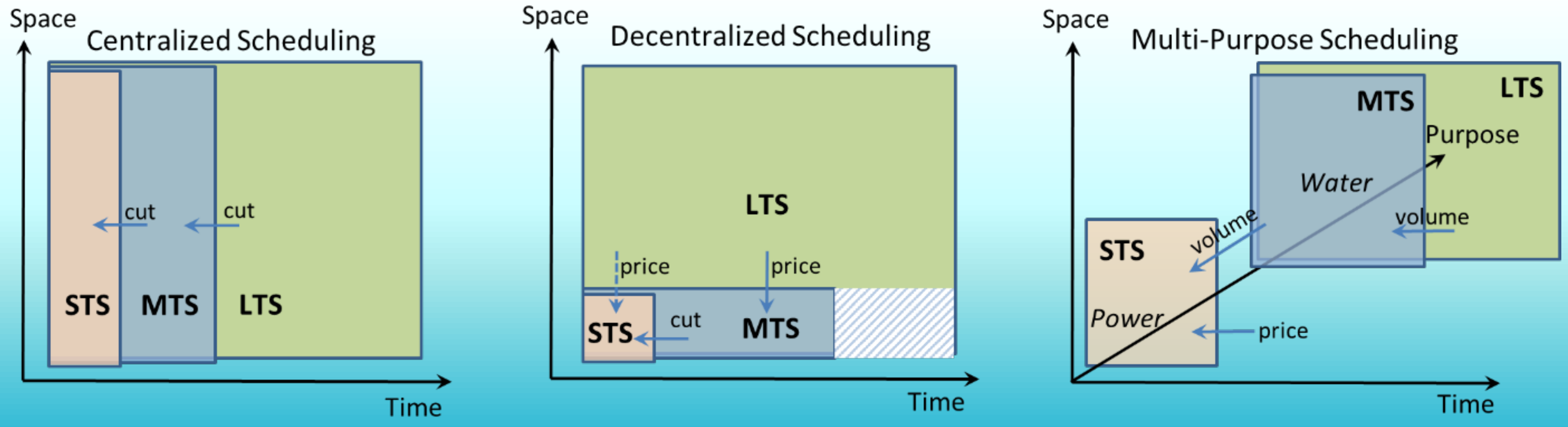
The recovery of natural water storage (soil moisture, groundwater) from drought often occurs at longer timescales

Chris Frans USBR May 11 2019

Seasonal scale displays the largest diversity in hydropower scheduling toolchains as influenced by institutions



Helseth et al. (2023). Hydropower Scheduling Toolchains: Comparing Experiences in Brazil, Norway, and USA and Implications for Synergistic Research. Journal of Water Resources Planning and Management. 2023 Jul 1;149(7):04023030.



Advances in LDES opportunity for hydropower through the characterization of Dunkelflaute

Definitions:

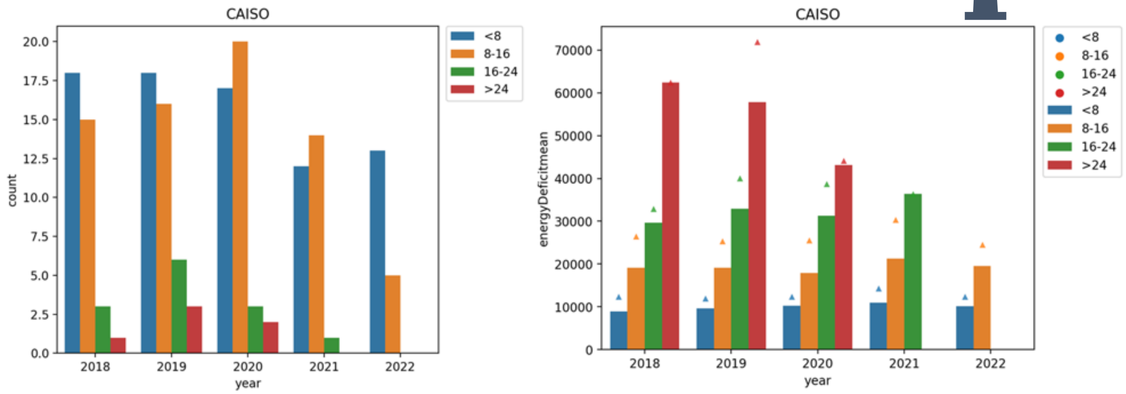
- Resource “drought”: A multi-hour period during which average hourly wind output is less than Z% of the average hourly output over the reference period. Z=10% for wind, 30% for solar
- Energy Deficit = "Load Served by " Resource ("Non−drought – Drought) ∗ Drought Duration"

Possible Indicators for need of LDES:

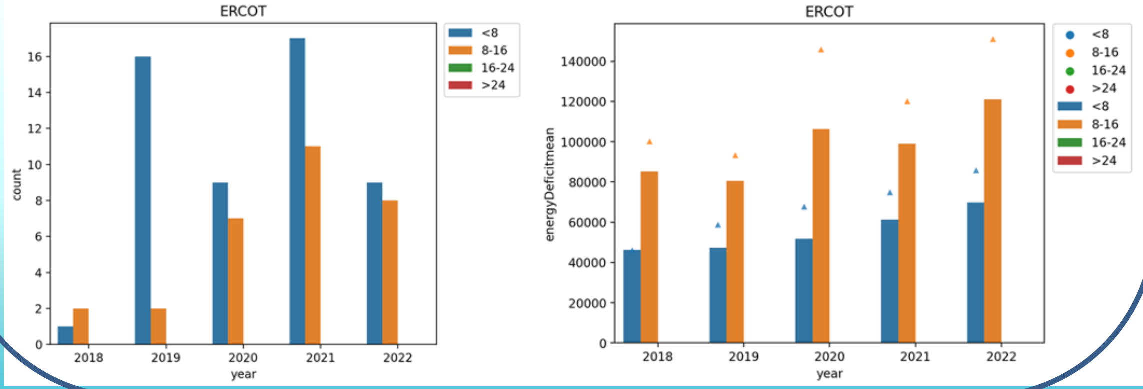
- Duration: Number of 8-hour (or longer) wind droughts
- Frequency: Number of VRE droughts each year
- Impact: Energy deficit due to VRE drought events

Inter-annual variability in seasonal resources droughts requires careful selection of years for resources adequacy studies

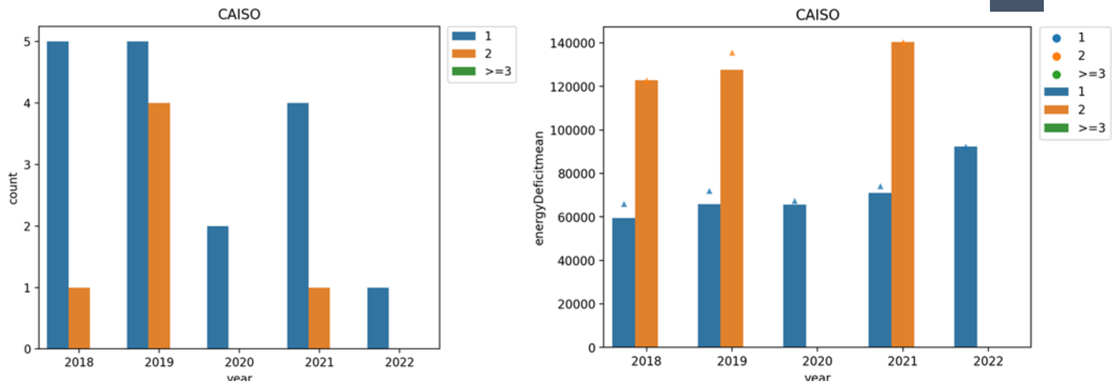
Wind Droughts in USA – CAISO



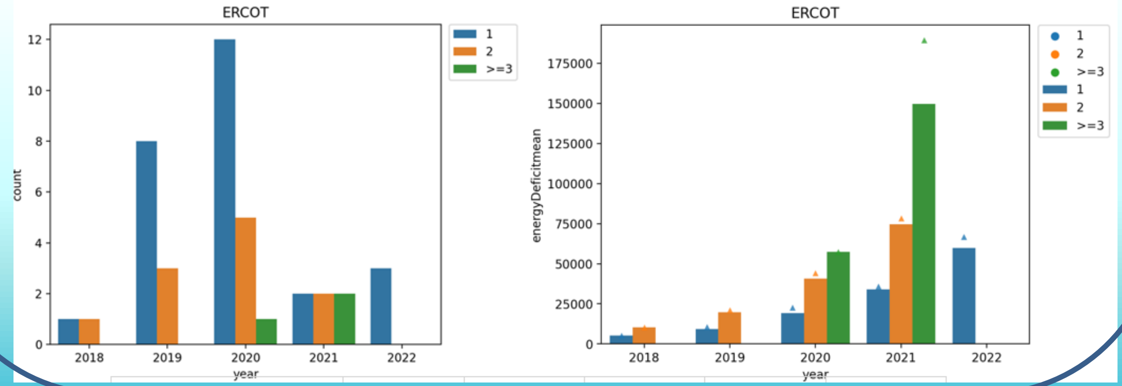
Wind Droughts in USA – ERCOT



Solar Droughts in USA – CAISO



Solar Droughts in USA – ERCOT



Metrics based on annual wind and solar average generation. Wind is based on 10% threshold and Solar based on 30% threshold. Coincidence not shown.

Discussion Points

- Initial hydrologic conditions provide the largest contribution to seasonal flow forecast accuracy
- Water management alleviates seasonal and inter-annual variability
- Value of seasonal to inter-annual hydropower storage is complex
- Management of hydropower storage is driven by institutions (values of societal benefits, balance with benefits to the energy system, and market incentives)
- Characterization of LDES opportunity to be further evaluated with hydro time scales

Challenges moving forward include:

- Diversity in hydropower scheduling
- Spatial diversity in seasonal flow forecast accuracy

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Thank you

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- Slides from:
  - Atle Harby, SINTEF Energy Research
  - Ilka Hannula, IEA
  - Chris Frans, USBR
  - Dor Hirsh Bar Gai, NWPCC
  - Abhishek Somani, PNNL and Zhi Zhou, ANL
  - Nathalie Voisin, PNNL

BackUp Slides

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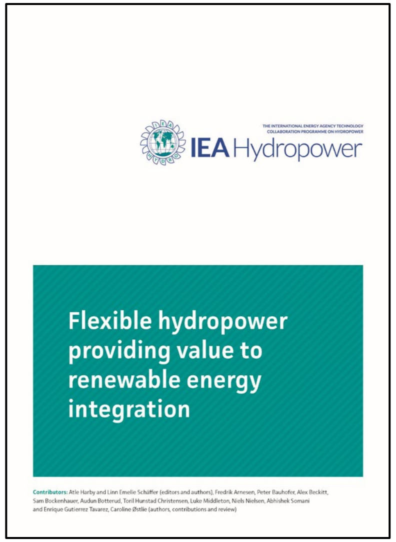
Hydropower Value to the power system

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)



Resource Drought Metrics

#1

$$\text{Resource Drought Event} = \frac{\Sigma^{\text{n(hours)}}\text{Resource Output}}{\text{n(hours)}} < Z\% \; \frac{\Sigma^{\text{x(days)}*24}\text{Resource Output}}{\text{x(days)} * 24}$$

Period of Evaluation — Reference Period

#2

$$\text{Energy Deficit} = \text{Load Served by Resource (Non-drought} - \text{Drought)} * \text{Drought Duration}$$

Notes:

- **Z**% refers to the **threshold**, below which a period of time may be considered “resource drought”. The value of **Z** is going to be different for wind vs. solar dominated systems because of the differences in resource characteristics.
- The default **reference period** in this study is annual average VRE generation output. A different reference period, for instance, the yearly average output of a resource will yield different results.
- The **minimum number** of blocks considered at a time is 4 consecutive hours. Changing that to a different minimum will also yield different results.