DEPLOYING BULK LONG DURATION ENERGY STORAGE

MEETING CAPACITY SHORTFALLS IN THE PACIFIC NORTHWEST

MAY 28, 2019

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Power & Utilities **Automotive** **High Tech & IT**

Building Tech **Telecommunications**

- Emerging value chain analysis
- Market sizing and forecasting
- Strategic marketing services
- Trend monitoring and analysis
- Market demand for new products
- Competitive intelligence

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- Home Energy Management
- Intelligent Building Management
- Lighting Innovations
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- Demand-Side Management
- DER Strategies
- Energy as a Service

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- AI and Advanced Analytics
- Energy Blockchain
- Energy Connectivity
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- Distributed Natural Gas
- Distributed Renewables
- Microgrids
- Wind Energy

ENERGY STORAGE

- Advanced Battery Innovations
- Distributed Energy Storage
- Grid-Tied Energy Storage

TRANSPORTATION ELECTRIFICATION

- Commercial Transportation Electrification
- Electric Vehicles
- Vehicle Charging Infrastructure

URBAN INNOVATIONS

- Mobility
- Smart Cities
- Transport and Logistics Innovations

INTRODUCTIONS

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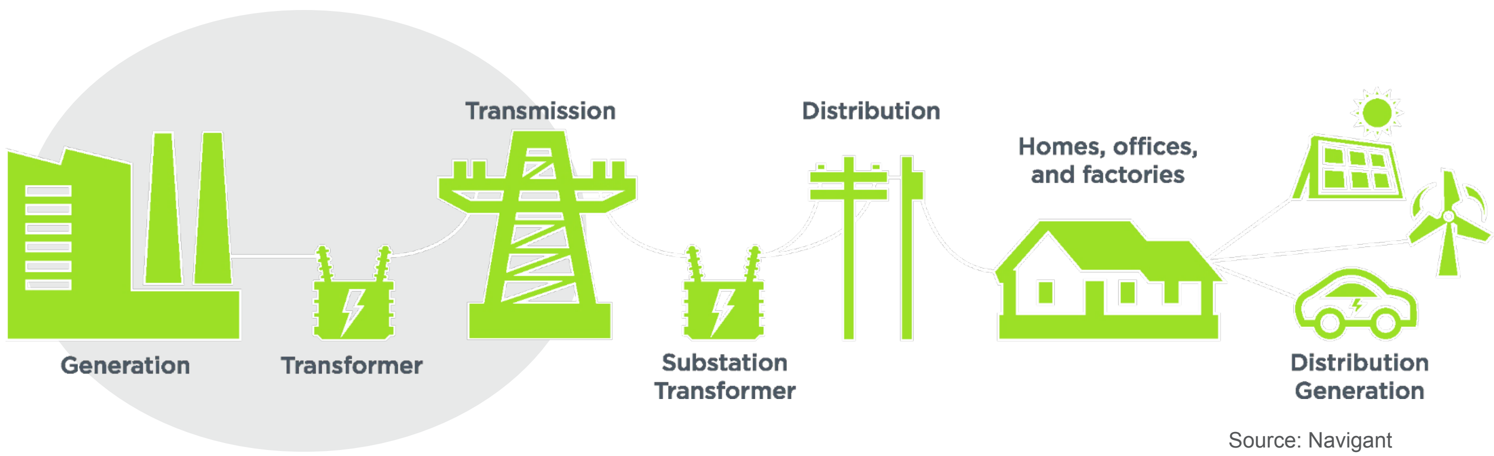
LONG DURATION ENERGY STORAGE

- Grid-tied energy storage encompasses many different applications and services that can be provided at all levels of the grid—from generation to residential
- Services provided by energy storage vary in terms of their scale, responsiveness, power output, and duration
- The vast majority of installed energy storage is large scale and built to serve as an energy resource, provide energy capacity, and support the transmission grid
  - These large-scale applications require energy storage to replicate the services provided by conventional grid equipment, often requiring long runtimes and high power output

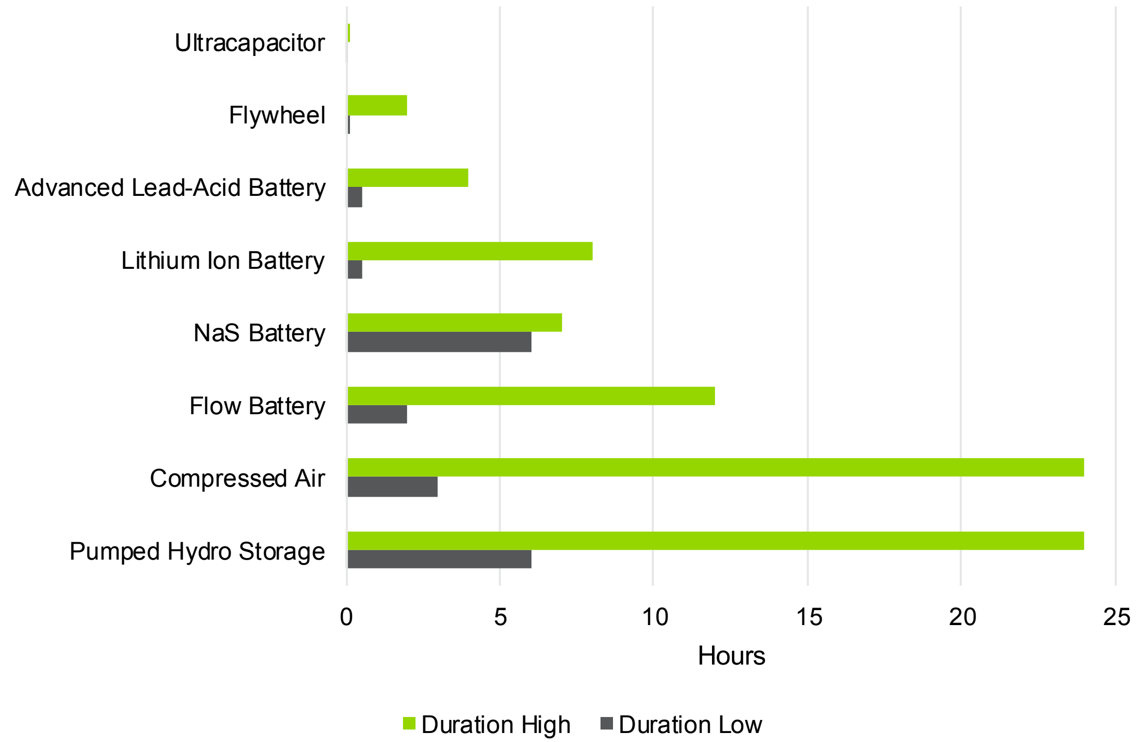


Source: Navigant

LONG VS. SHORT DURATION ENERGY STORAGE

- Eight primary energy storage technologies providing services on the power grid
- Technologies are varied in:
  - Average scale per project (kW to GW)
  - Average discharge duration
- Large-scale long duration energy storage provides greater flexibility to serve multiple applications from a single project
- Pumped hydro storage accounts for approximately 93% of operational energy storage capacity worldwide

Energy Storage Technologies: Discharge Duration Range



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WHAT IS DRIVING DEMAND FOR LONG DURATION ENERGY STORAGE?

Renewable Energy Curtailment

Curtailment rates are growing in markets with high penetrations of renewable generation. Curtailment results in significant economic inefficiencies and the inability to fully use available clean energy.

- In April 2019, California solar and wind farms curtailed approximately 190,070 MWh of electricity, breaking previous records, according to the California Independent System Operator (CAISO).

Transmission Congestion

Large-scale renewable plants are often located in remote areas with inadequate transmission infrastructure. Transmission line congestion is a major issue that results in lost revenue due to the curtailment of energy and excessive costs to develop projects that require transmission upgrades.

Dispatchable Capacity Requirements

These requirements are used to align variations in electricity supply and demand. As the penetration of non-dispatchable renewable generation grows to meet climate change goals, reserve services and dispatchable capacity will be increasingly important.

WHAT IS DRIVING DEMAND FOR LONG DURATION ENERGY STORAGE?

Limitations of Competing Technologies

Lithium ion (Li-ion) batteries are a popular choice for new stationary energy storage projects. However, the technology is not ideally suited to all grid storage applications and has several disadvantages:

Discharge Duration

Li-ion batteries typically have discharge durations that range from 15 minutes to 6 hours, much less than long duration energy storage technologies which can easily achieve durations of 8-16 hours.

Lifespan

In contrast to bulk energy storage systems like pumped storage hydro facilities, which have 50-100 year lifespans, Li-ion batteries need to be replaced after 5-15 years of use, adding considerably to their cost.

Scale

Long duration technologies such as pumped hydro and compressed air are optimally designed for larger capacities, able to store up to 10,000 MWh of electricity or more. A typical battery system may provide 100 MWh-500 MWh.

Safety

In the past 2 years, fires at large Li-ion battery storage plants around the world have drawn attention to the inherent risks of Li-ion and other battery technologies.

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THE ROLE OF LONG DURATION ENERGY STORAGE

Long Duration Energy Storage Applications

Application	Duration Requirement	Discharge Cycles per Year
Solar Energy Shifting	4-8 hours	200-365
Wind Energy Shifting	4-10 hours	200-365
Tx Asset Optimization	2-10 hours	50-600
Capacity and Reserves	2-10 hours	200-600

Source: Navigant Research

Renewable Energy Shifting

Energy storage aligns renewable generation supply with peak consumer demand.

Transmission Asset Optimization

Energy storage can greatly improve the utilization of existing transmission infrastructure and avoid the need for upgrades.

Capacity and Reserves

Long duration and large-scale storage resources are capable of providing firm capacity and energy reserve services required on the grid, replicating the services provided by conventional power plants.

Resiliency

Long duration energy storage provides resiliency not offered by short duration technologies.

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CASE STUDY:
LOOMING CAPACITY SHORTAGES IN THE WESTERN US

Pacific Northwest

- In the US Pacific Northwest, a transition to a heavy reliance on renewable generation is underway and gaining momentum
- In early May, Washington state passed legislation mandating carbon-free electricity generation by 2045
  - Achieving this goal will require a major shift to reliance on solar and wind energy, in addition to the region's existing hydropower resources
- The region faces the potential for a 8 GW capacity deficit by 2030 unless new dispatchable capacity resources are developed
  - This deficit is driven by load growth and the replacement of retired fossil fuel power plants with variable renewable generation
- New fossil fuel generation plants will be challenging to build given the low carbon mandates in both Washington and Oregon

Where will the needed dispatchable capacity come from?

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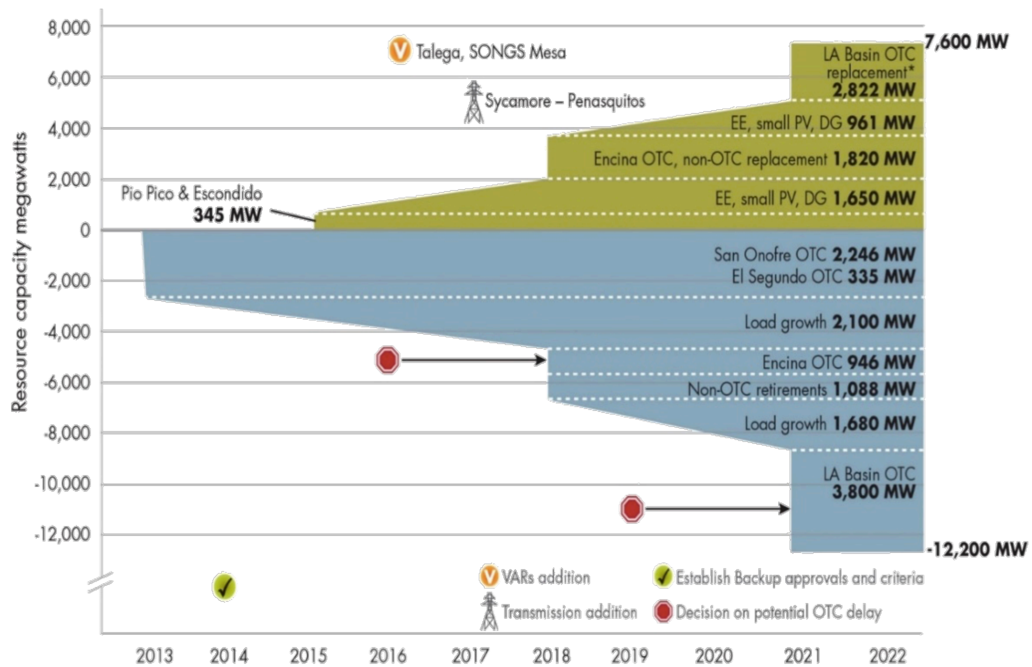
CASE STUDY:
LOOMING CAPACITY SHORTAGES IN THE WESTERN US

California

- California already has both standalone energy storage and renewable-plus-storage projects providing resource adequacy and capacity services
- Long term: CAISO has predicted that as more thermal resources retire and reliance on renewable resources grows, the duration of storage required to reliably operate the grid will increase

> "CAISO has found that the state faces up to about 9,660 MW of natural gas-fired generation retiring for economic reasons, with load following shortfalls beginning if less than 4,000 MW were to shut down."
>
> - Neil Millar, Director of Infrastructure Development at CAISO



Source: California Independent System Operator

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Deploying Bulk Long Duration Energy Storage

Ralph Dassonville – Strategy and Long-Term Analysis

Alpiq AG, Switzerland

Alpiq in brief

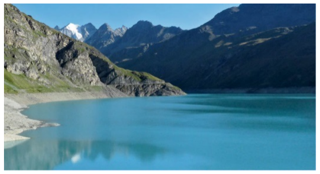
- Headquarters of the company in Lausanne, Switzerland
- Active in 30 countries throughout Europe
- Hydropower installed capacity (Switzerland): 2,677 MW
- Nuclear and conventional thermal (Europe): 2,955 MW
- Small-scale hydro, wind and PV (Europe): 306 MW
- Approximately 1,600 employees (1 August 2018)

Smart technologies

E-mobility

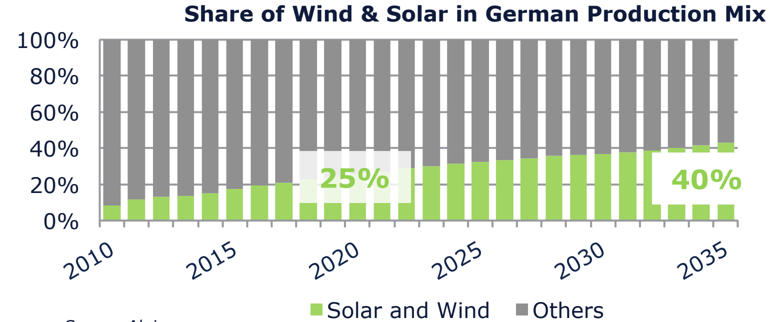
Energy Trading

Power Generation

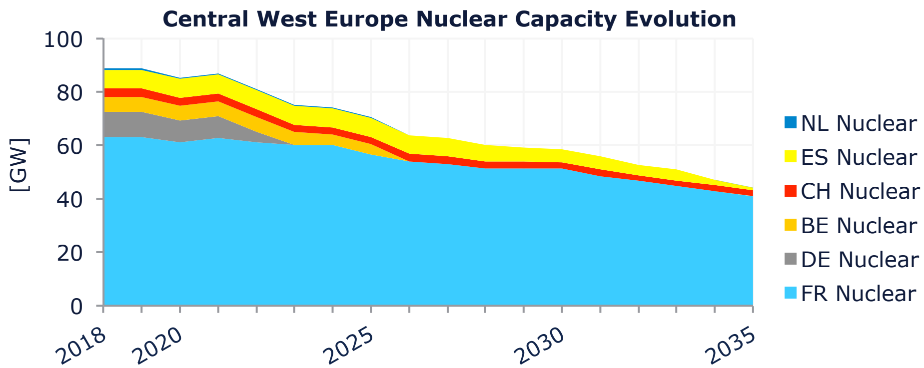


1. Trends in European Power Markets

Renewable energy penetration accelerates



Source:Alpiq



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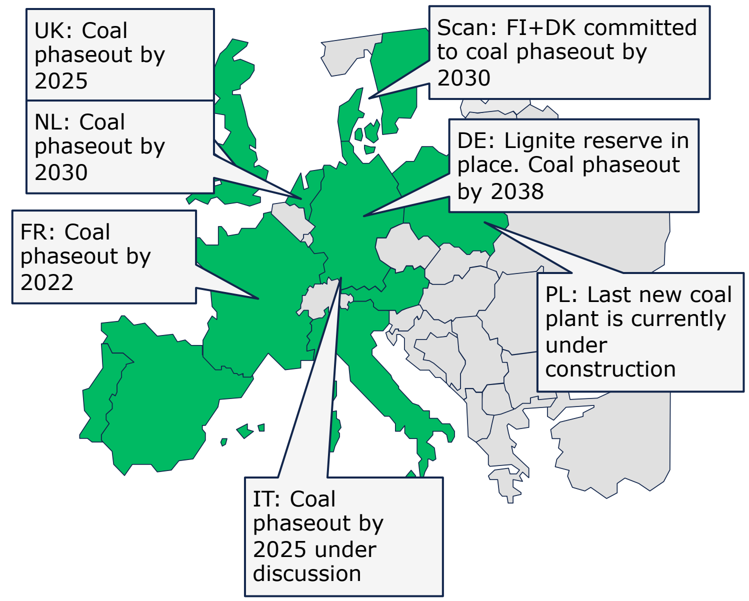


Several governments have plans to phase out coal plants

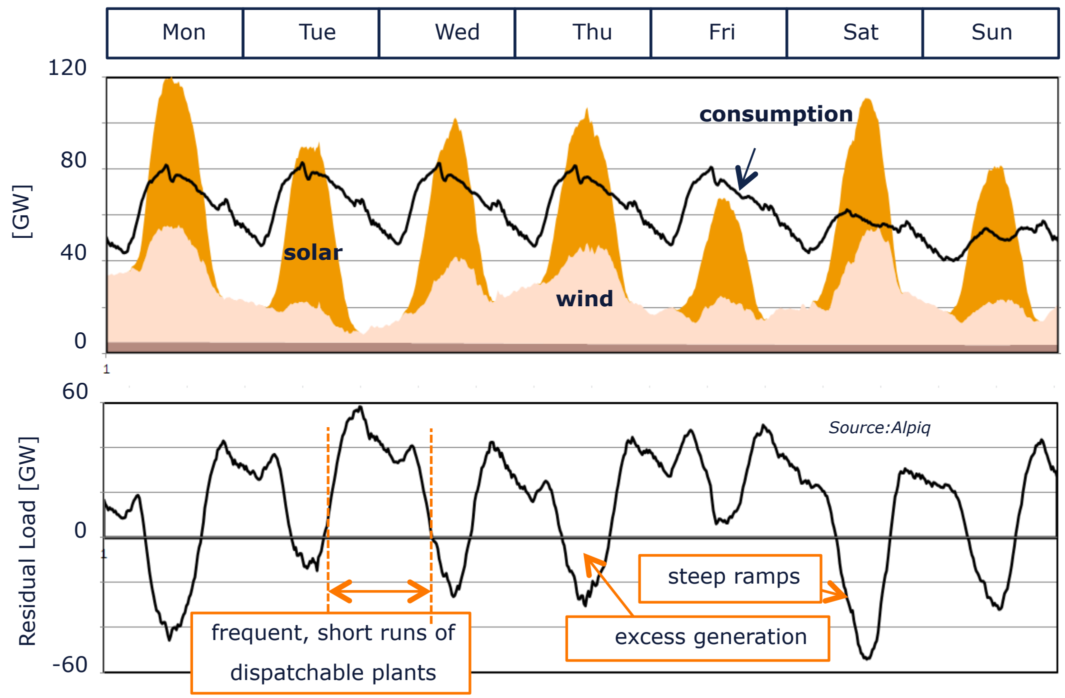
Source: Alpiq

- **EU renewable energy target:** 60% of electricity from renewables by 2030
- **German renewable energy target:** 65% by 2030, 80% by 2050
- **Closure of 50%** of CWE nuclear fleet by 2035
- **Closure of 60%** of Central West Europe coal capacity by 2035

1. Trends in European Power Markets

A more volatile residual load

A summer week, Germany 2030



Assumption: BEE Scenario 2030; wind = 205 TWh/a, solar = 125 TWh/a: data scaled from effective 2012 generation

- Increasing renewable energy penetration will increase volatility and **flexibility needs** at different voltage levels
- A significant amount of fast, flexible capacities needed for **evening load ramps**
- Bulk storage capacities needed to absorb **extra renewable energy production**

2. Nant de Drance Pumped Storage

Highly flexible, large storage capacity

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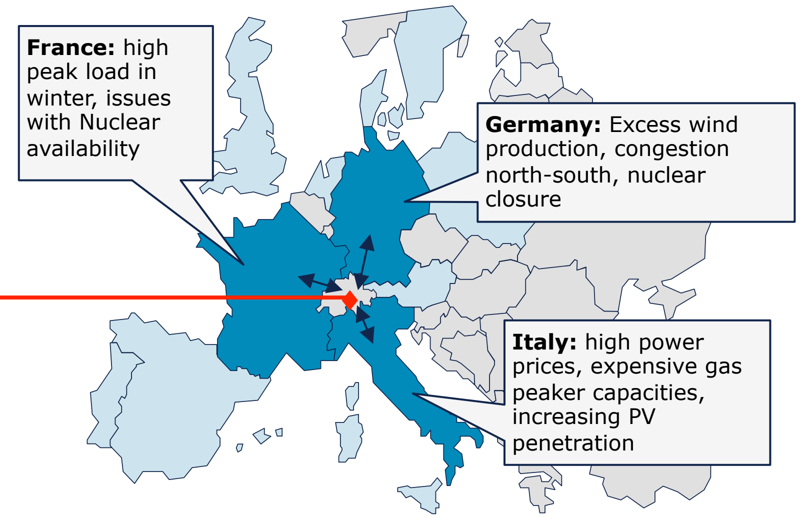
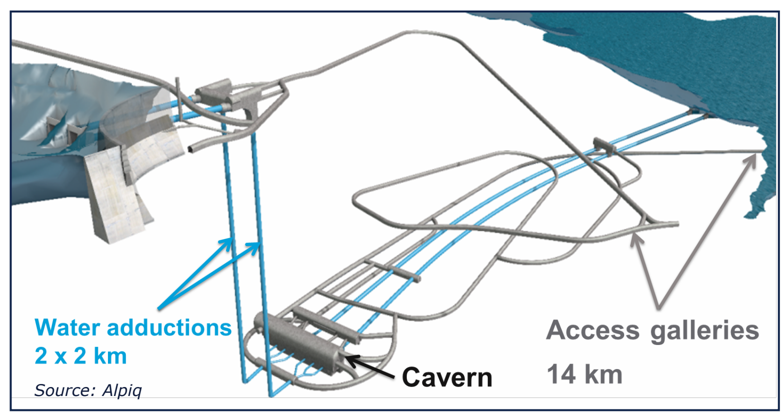
NANT DE DRANCE

Turbo-pumps	
Francis type	**6 each 150MW**
Motor- Generator	
Asynchron + variable speed	**~425 +/- 10 rpm**
Total output	**900 MW**
Maximum flow in turbine mode	**360 m³/s**
Water height	**250 à 395 m**
Annual production	**~2200 GWh**
Efficiency (Energy cycle)	**> 82 %**

900 MW



Nand de Drance can serve several countries



3. Pumped storage helps integrate renewables

Two examples

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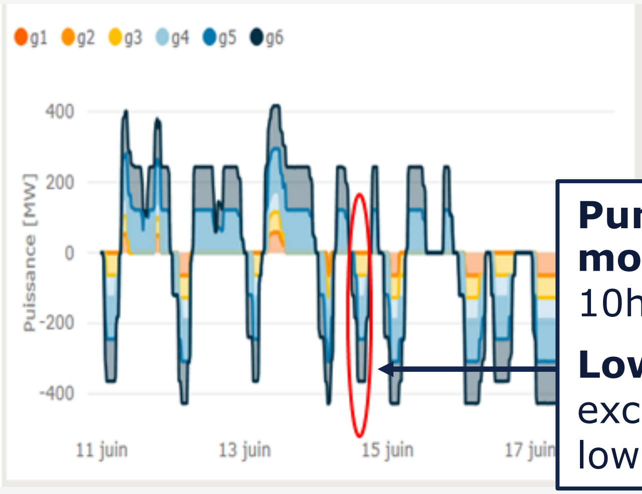
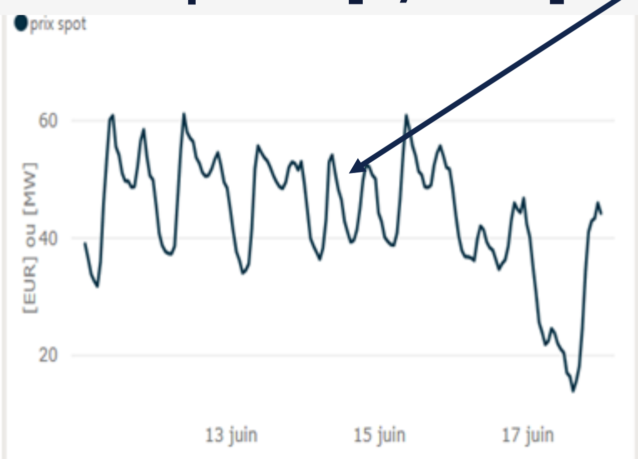
1 **400 MW FMHL Plant Output**



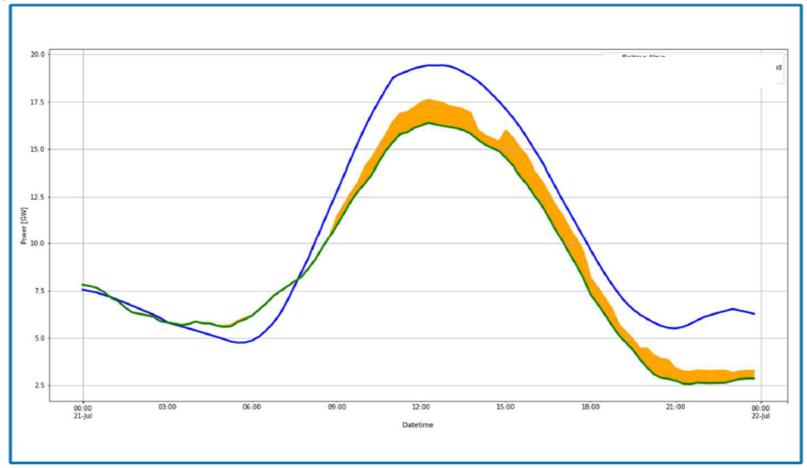
Pumping mode from 10h to 17h

Low prices: excess PV & low demand

Power prices [€/MWh]



2 ***Germany, PV, 21 July 2018***



Substantial deviation: forecast vs. actuals

- Capacity: -3.2 GW • Energy: -38 GWh

Germany only: high cost & CO_2 emissions

- Thermal power plants • Cost: 235 k€

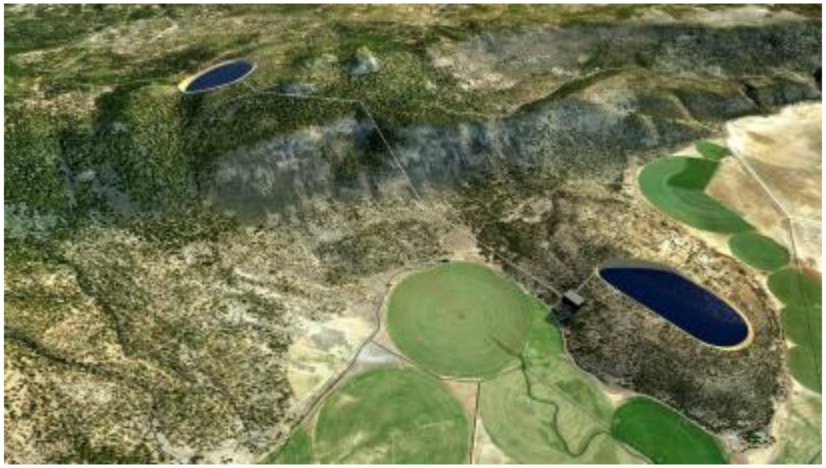
Swiss contribution: lower cost & CO_2 free

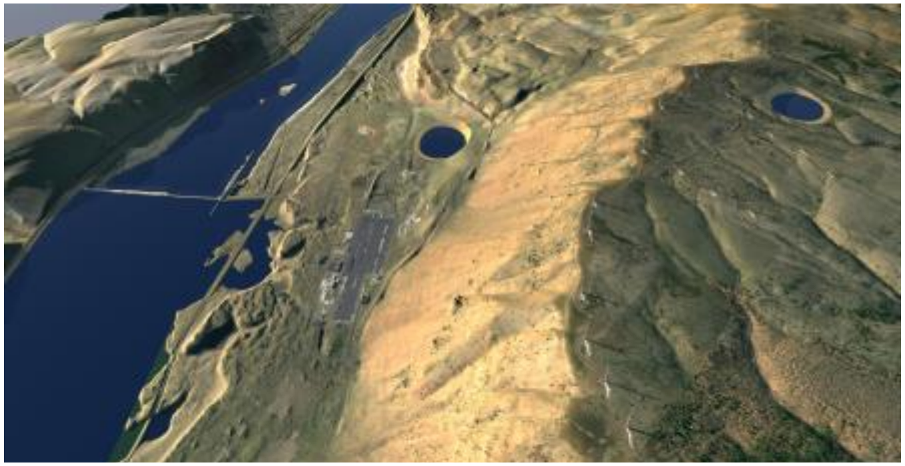
- Hydro, 1/3 of needs • Cost: 180 k€, -23%

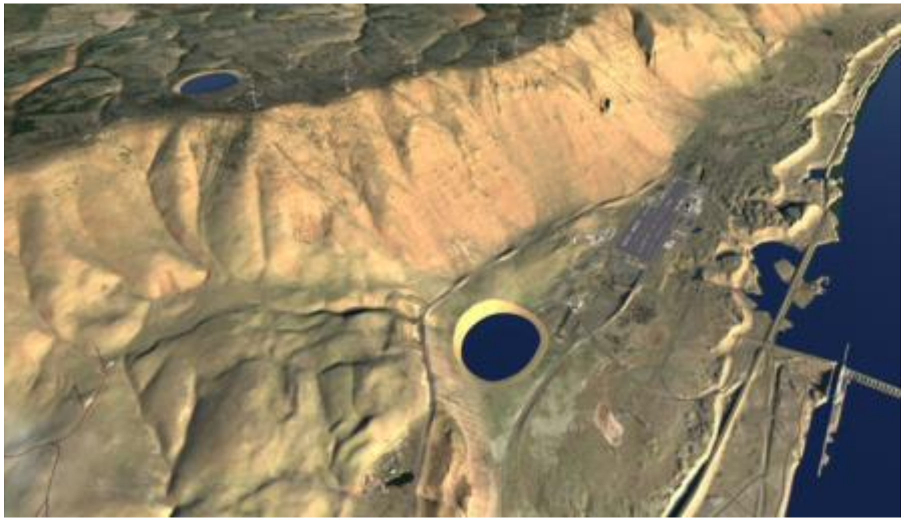
Cross-country trades help to reduce costs and emissions


STEPHAN
ML2

Pumped storage: long-duration bulk storage







400-MW "closed-loop" **Swan Lake Pumped Storage Project** in southern Oregon

1200-MW "closed-loop" **Goldendale Energy Storage Project** in eastern Washington

National Grid – one of the world's largest investor-owned energy utilities

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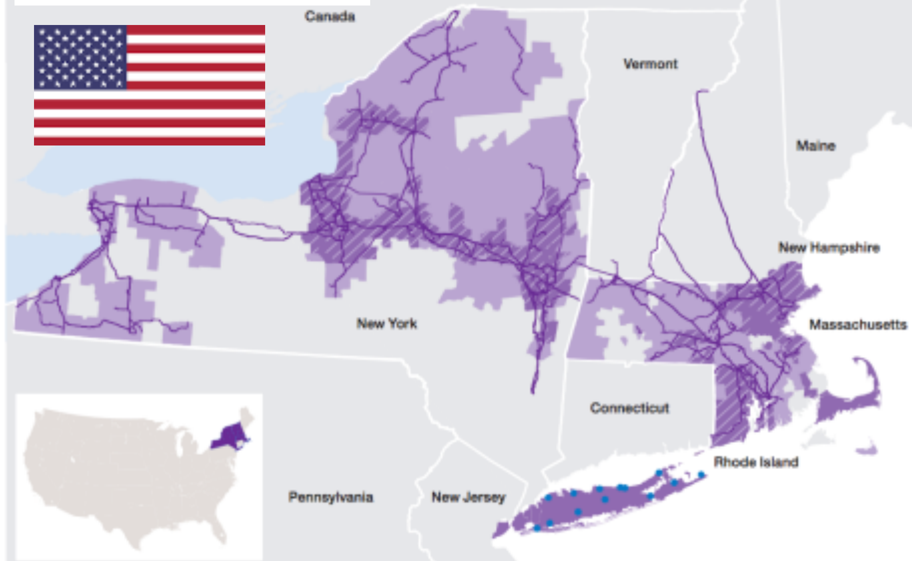
National Grid UK

National Grid US Regulated



- Own/operate the electricity transmission network in England and Wales (i.e. System Operator or "SO")
- Operate, but do not own, the Scottish networks
- Own/operate the gas National Transmission System in UK

- Own/operate transmission facilities across upstate New York, Massachusetts, New Hampshire, Rhode Island and Vermont
- Own/operate electricity distribution networks in upstate New York, Massachusetts and Rhode Island
- Own/operate gas distribution networks across the northeastern US, located in upstate New York, New York City, Long Island, Massachusetts and Rhode Island.

97% of energy storage globally is pumped storage

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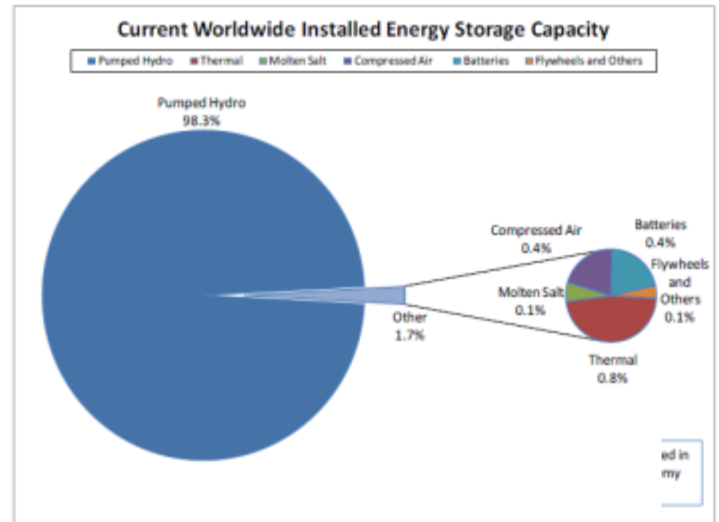
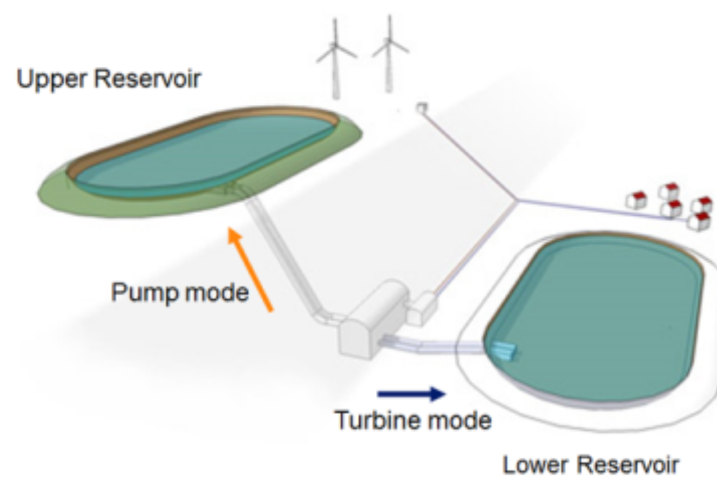
- Pumped storage is the only proven, cost-effective storage at scale
- Consists of pumping or generating by moving energy in the form of water through a powerhouse between an upper and lower reservoir
- Pumped storage is prolific in the US – there are 39 pumped storage plants in operation with a total installed capacity of about 22,000 MW; however, over 2 decades since last built in US
- Globally, there is nearly **144,000 MW** of pumped storage capacity currently in operation; currently building all over world *but US*
- Batteries still very expensive, uncertain viability in replacing thermal plants, don't last nearly as long and come with mining/toxic waste issues

Current Worldwide Installed Energy Storage Facility Capacity





Why pumped storage in the Western US

- Big problem #1 – almost 6 GWs of spinning mass / inertia *in just the Pacific Northwest alone* is slated for retirement
  - Difficult (if not impossible) to build new gas-fired plants given climate/clean energy policy goals
- Big problem #2 – California's periodic oversupply of intermittent renewables would be mitigated by addition of bulk, long-duration storage
  - California 100% modeling selects mostly solar (i.e. 111 GWs of solar and storage by 2050 to meet decarbonization goals)
  - Alignment of renewable generated electricity supply and consumer demand/peak loads pivotal piece of the decarbonization puzzle
  - Decreasing reliance on existing natural gas fleet and sustained, orderly retirement
- Solution – energy storage is critical to achieving decarbonization goals
  - Battery storage does not have sufficient duration and other associated limitations as the only resource option (i.e. scale, recycling/waste, supply chain, security of supply)
- Answer – pumped storage and strategically located projects (i.e. Swan Lake, Goldendale) can help solve these big problems and also facilitate greater penetrations of renewables cost-effectively/affordably and reliably

Location location location – Swan Lake/Goldendale attractive projects strategically located in high-voltage grid

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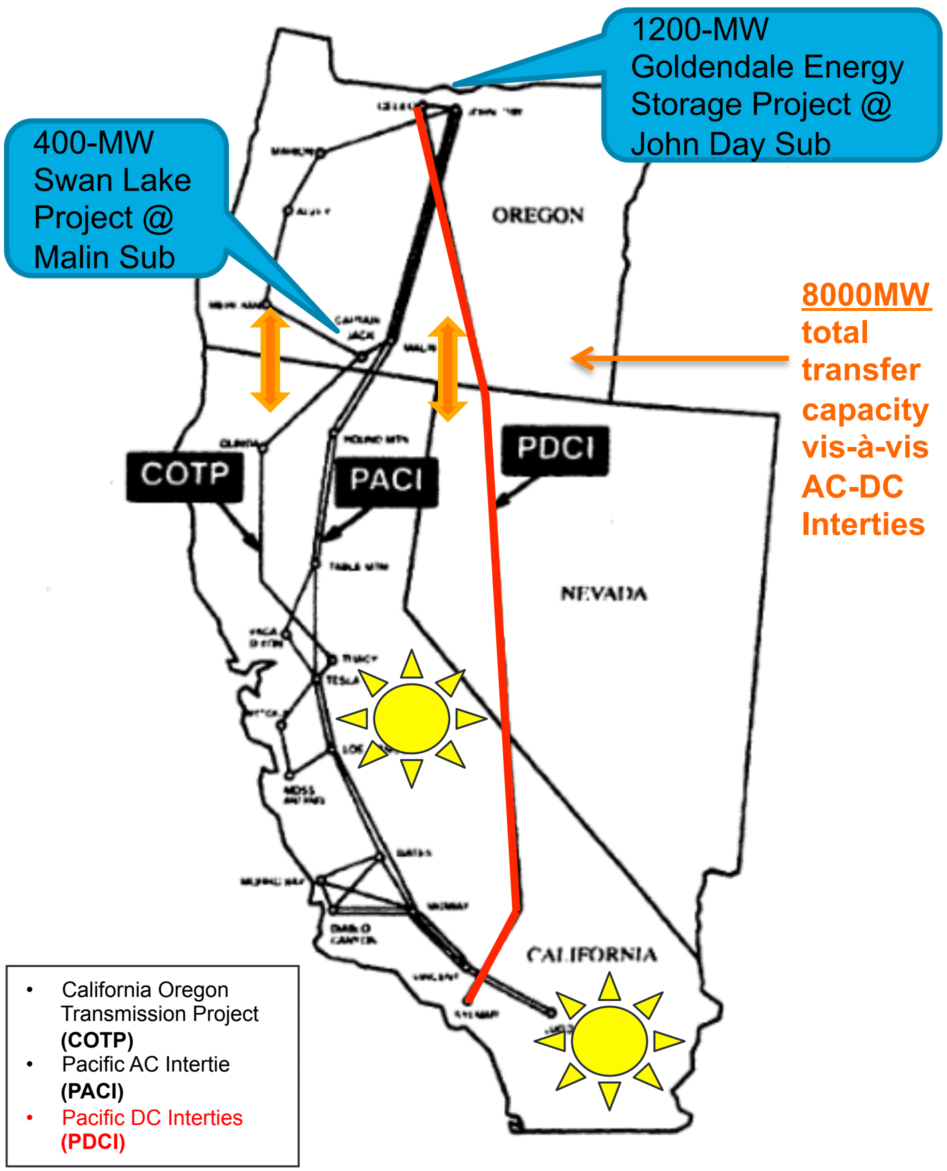

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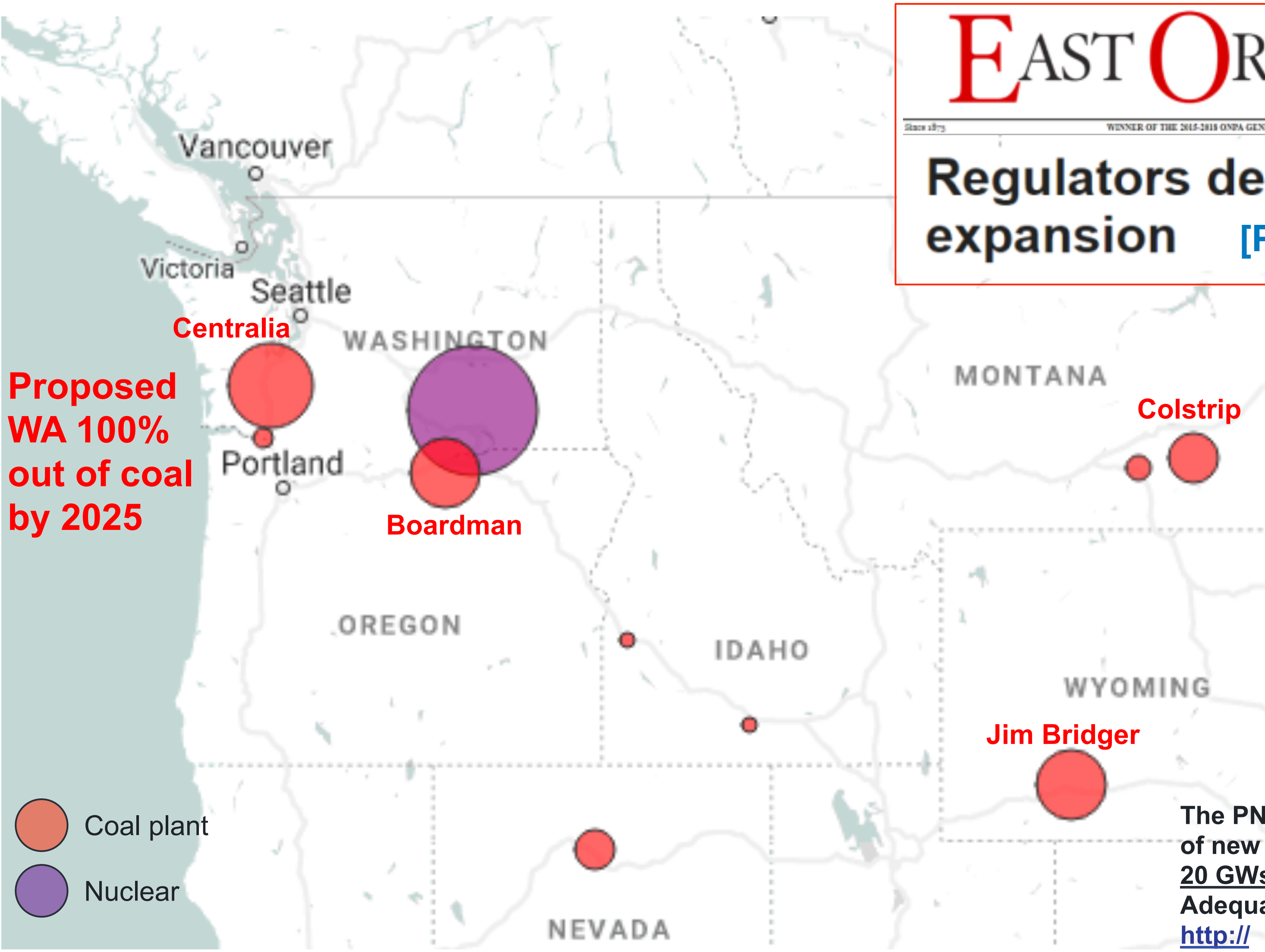
Comparison of Swan Lake/Goldendale Projects

	Swan Lake Pumped Storage Project	Goldendale Energy Storage Project
Project Type	"Closed-loop" Pumped Storage Hydropower (PSH) Project	"Closed-loop" PSH Project
Project Description	400-MW PSH project located in southern Oregon near Klamath Falls interconnected into the AC Intertie	1200-MW PSH project located near Goldendale, Washington at the top of the Pacific DC and AC Interties
Estimated CAPEX	$866 Million	$2.14 Billion
Hours of Storage	9 hours / 3556 MWh	12 hours / 14,745 MWh
Configuration	3 x 138MW variable-speed pumped-turbine generators; above ground conveyances/tunnels	3 x 400MW variable-speed pumped-turbine generators
Potential Commercial Off-takers	Portland General Electric (PGE), PacifiCorp, Puget Sound Energy (PSE), Avista	PSE, PacifiCorp, Los Angles Department Water & Power, Tacoma Power
Regulatory Status/FERC Licensing	50-year FERC License to construct/operate issued on April 30, 2019	FERC Preliminary Permit issued in March 2018. Pre-Application Document and Traditional Licensing Process petition recently filed/ accepted /granted by FERC. Required FERC licensing public held meeting May 1s in Goldendale, WA
Water Rights	Ground water secured from private landowners with no conductivity to Klamath River Basin	Columbia River water right from former aluminum smelter conveyed to Klickitat Public Utility District (KPUD). WA state law enacted that water rights can be used for the specific use of pumped storage. Water rights would not be a part of the FERC licensing process; KPUD would provide water at project boundary.
Commercial Operation Date	2025	2028

Almost 6 GWs of spinning mass/inertia slated for retirement; very difficult (if not impossible) to build new gas-fired plants



EAST OREGONIAN
OCTOBER 10, 2018

Regulators deny gas plant expansion [PGE Carty 2]

The PNW system will need 8 GWs of new effective capacity by 2030, 20 GWs by 2045 per E3 Resource Adequacy study.
http://www.publicgeneratingpool.com/e3-carbon-study/

Large coal plants serving NW load, closure profile and 2024 scenarios

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Washington State 100% legislation enacted (phase out of all coal by 2025)

Plant Name	Scenario 1: Reference Case	Scenario 2: Early Coal Retirement
Boardman (522 MW)	Out	Out
Centralia 1 (670 MW)	Out	Out
Centralia 2 (670 MW)	In Service	Out
Colstrip 1 (154 MW)	Out	Out
Colstrip 2 (154 MW)	Out	Out
Colstrip 3 (518 MW)	In Service	In Service
Colstrip 4 (681 MW)	In Service	In Service
Bridger 1 (530 MW)	In Service	Out
Bridger 2 (530 MW)	In Service	Out
Bridger 3 (530 MW)	In Service	In Service
Bridger 4 (530 MW)	In Service	In Service

Serving WA load; 2025 phase-out (Centralia 1 through Bridger 4)

(TOTAL = 5489 MW)

CA 100% modeling selects mostly solar and storage to meet decarbonization goals

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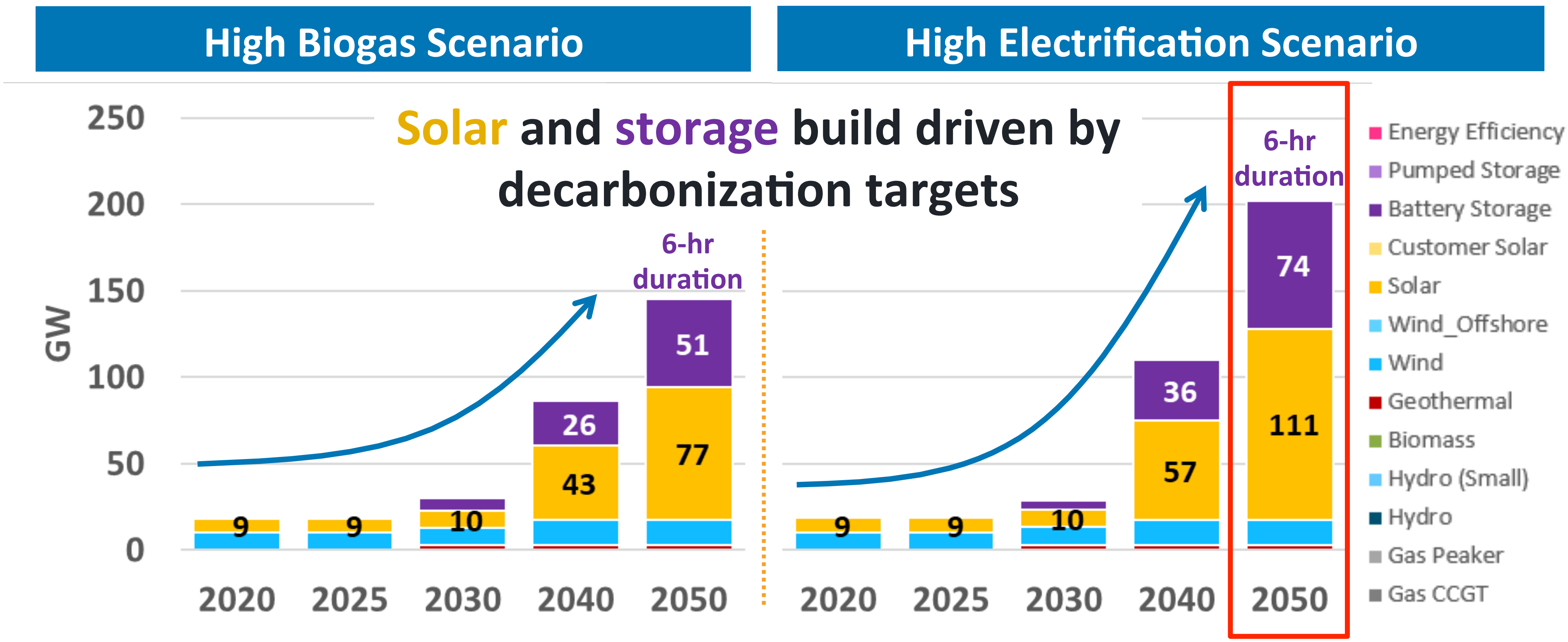
- 100%+ RPS achieved by 2050 in both scenarios
- E3's RESOLVE utilizes a Planning Reserve Margin constraint but does not examine resource adequacy in detail



Pumped storage can address PNW “Tri-Fecta” with CA solar oversupply

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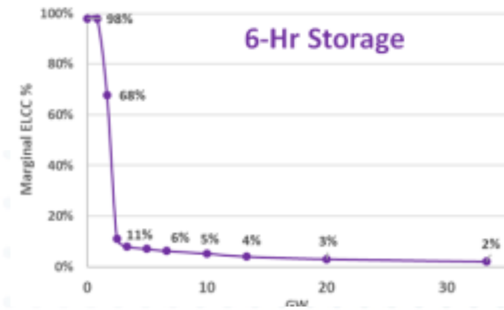
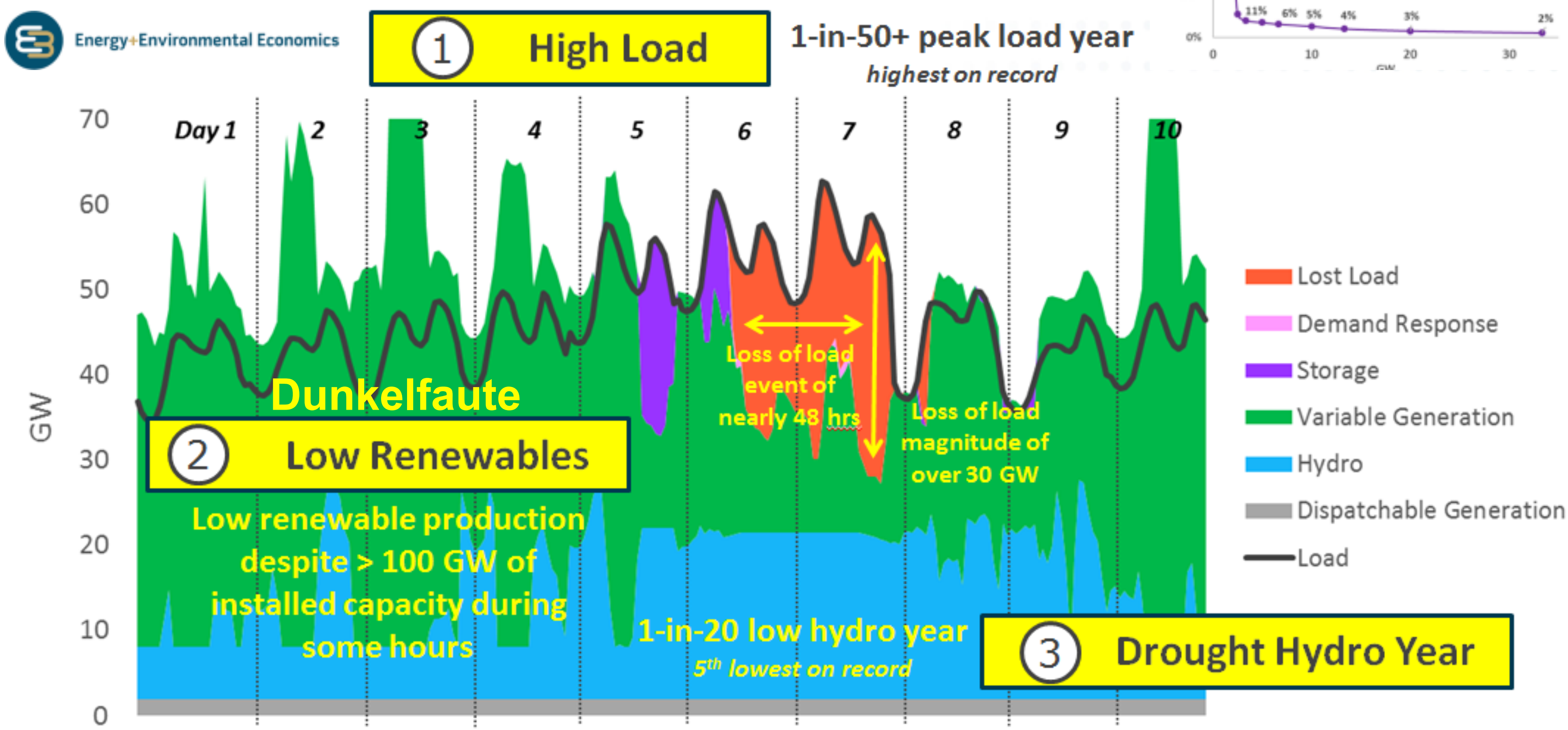
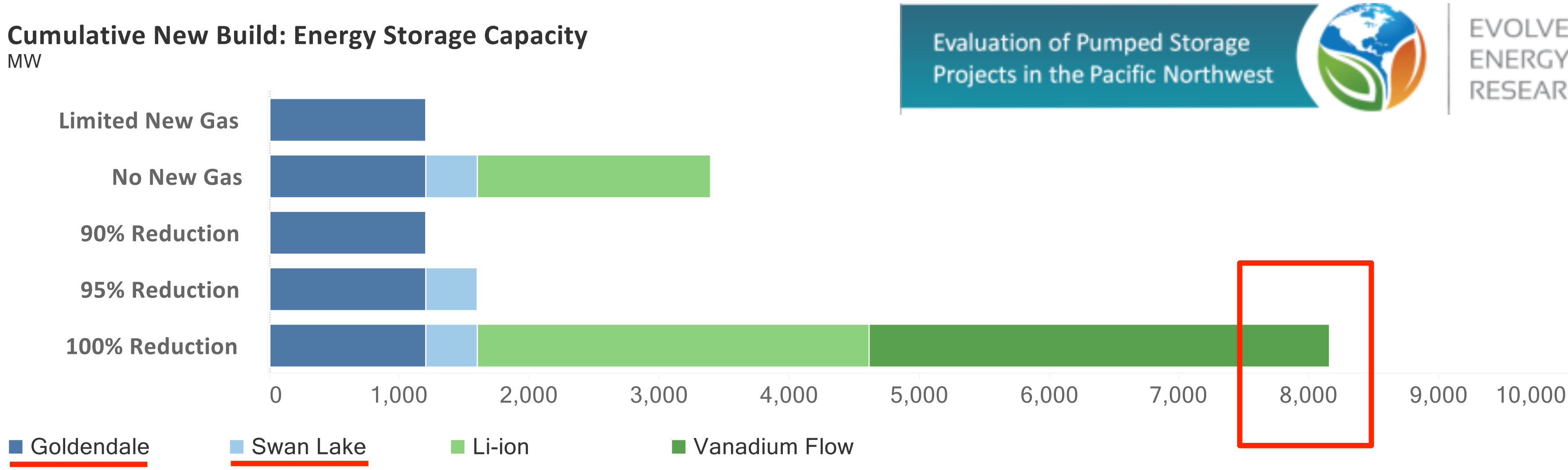
- Assumes without gas (i.e. 8000MW by 2030, 20GW by 2045), the system is energy deficient during prolonged stretches of low wind and solar production, and
- Renewables and storage could fill the void in theory, but only by massively oversizing the system

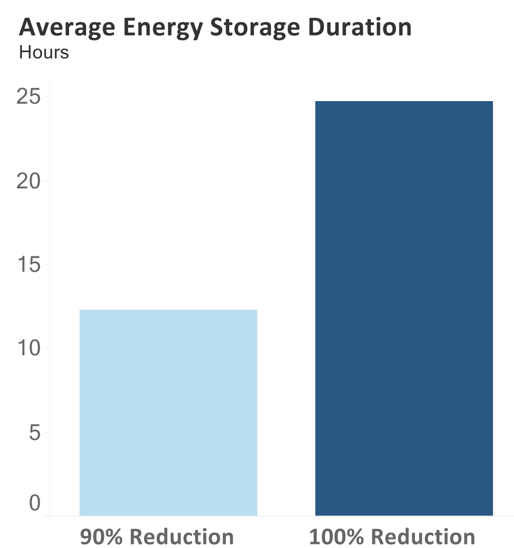




With new natural gas not an option for capacity, energy storage critical to decarbonization



- 8000 MWs of energy storage needed for 100% reduction; pumped storage built in all scenarios
- Increasing value for long-duration energy storage; ideally suited for pumped storage
- Very few pumped storage projects under active development in the Pacific Northwest represents a “blue ocean” strategy (i.e. uncrowded, untapped market space, very little competition)



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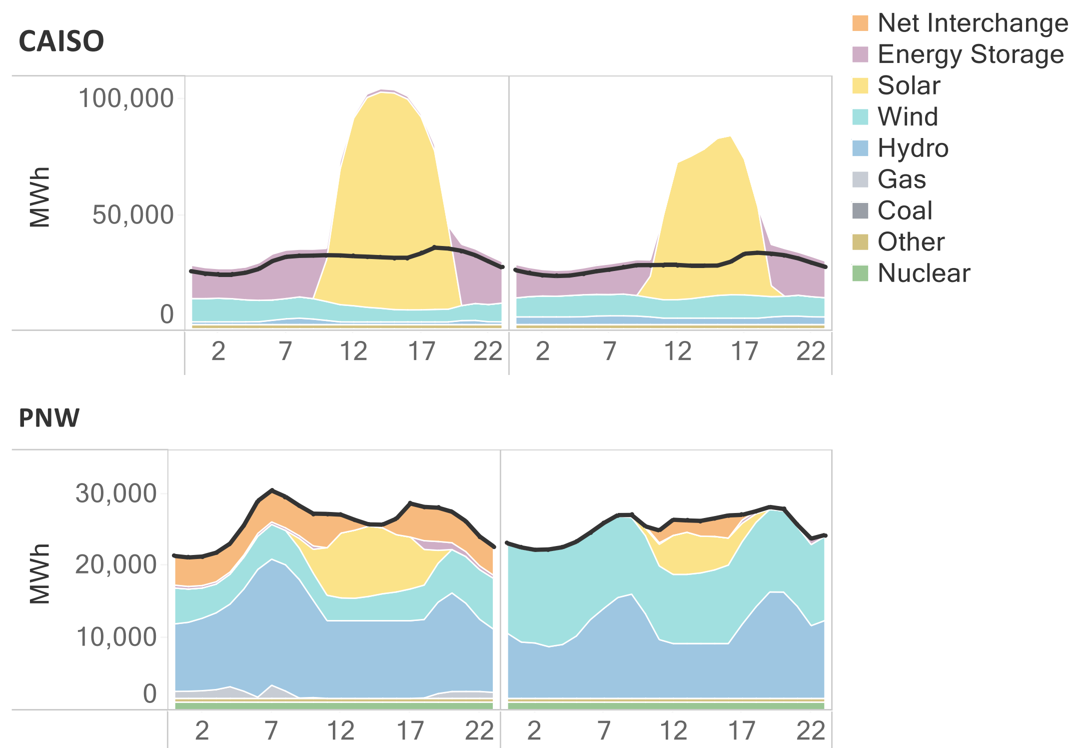
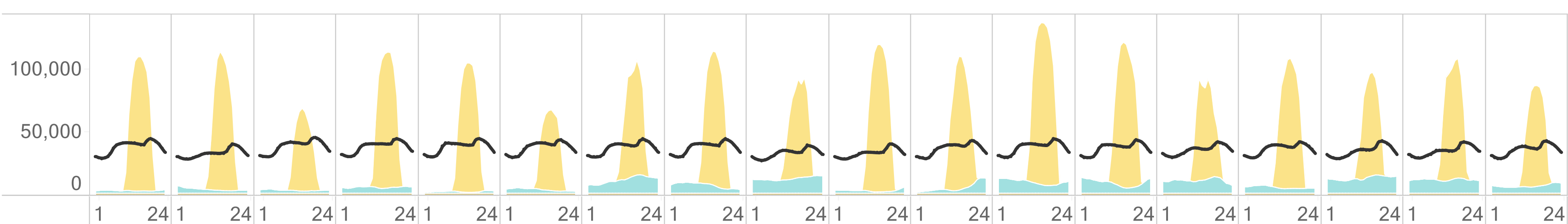
Excess solar in CA can be exported to PNW vis-à-vis better transmission utilization of AC and DC Interties

- Modeling shows that California's 100% clean electricity requirement results in significant amounts of excess renewable generation during the winter when loads are low
- Excess renewables could potentially be exported over *existing transmission* (i.e. flow south-to-north over COI & PDCI), allowing pumped storage to recharge and discharge to provide reliable supply on a daily basis



California Load and Renewables: Winter Sample Days in 2045
MWh



"Battle for Flexibility" – PSH is a cheaper storage technology than Li-ion batteries

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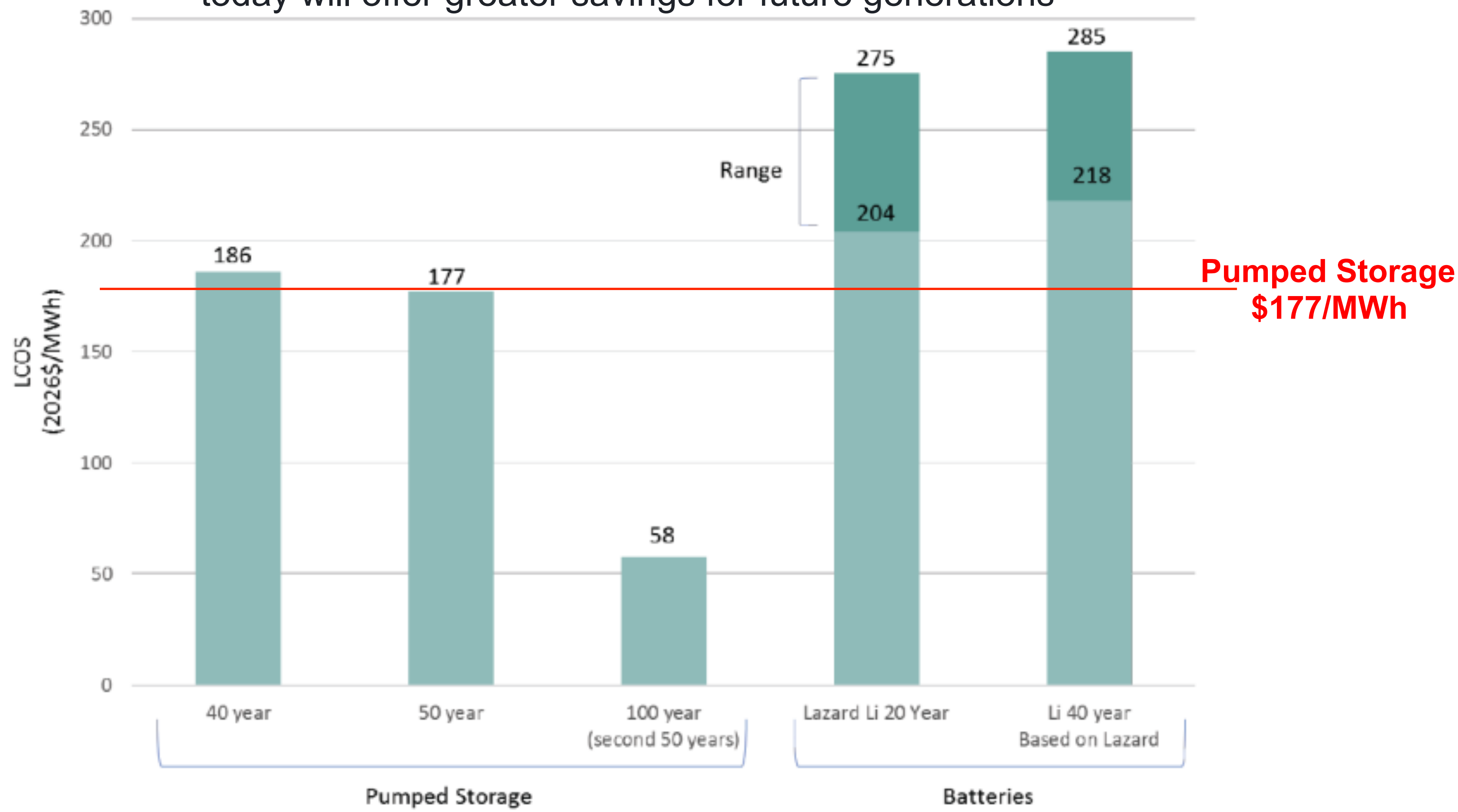
When evaluating large-scale energy storage options, the two most mature technologies demonstrate favorable options to cost effectively integrate renewable energy on grid. With the long, reliable project life of pumped storage, investments today will offer greater savings for future generations



https://www.sdcwa.org/sites/default/files/White%20Paper%20-%20Pumped%20Energy%20Storage%20V.15.pdf

Framing project need/value as capacity and not ancillary services key, similar to Snowy 2.0

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Only options for new capacity when can't build a gas plant is 1) PSH or 2) expensive, short-lived batteries with issues concerning recycling/waste and security of supply

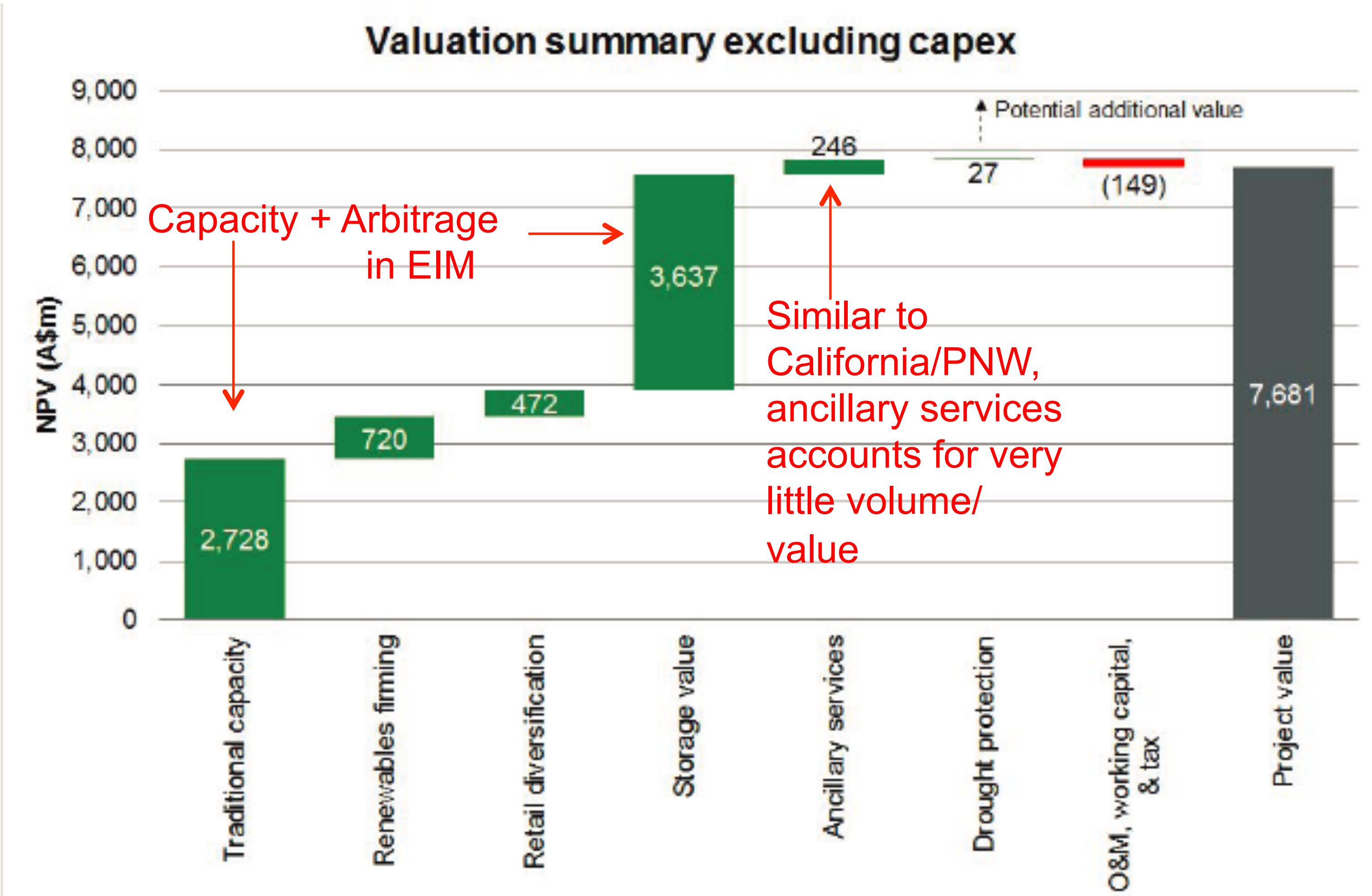

Figure 1: Valuation summary excluding capital cost

https://www.snowyhydro.com.au/our-scheme/snowy20/fid/

Path to commercialization – Portland General Electric 2019 IRP Preferred Portfolio

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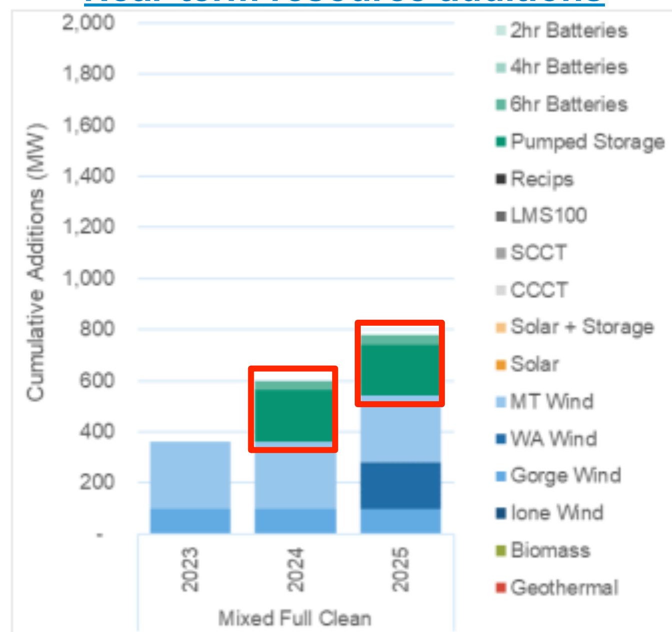
- PGE identified a capacity need of **368 MW in 2024**, growing **to 685 MW by 2025** in the Reference Case
- When considering uncertainty in economic conditions, changes in the load forecast, and customer adoption of distributed energy resources and electric vehicles, potential capacity needs in 2025 range from **309 MW to 1,065 MW**
- Approximately **350 MW** of this growing capacity need links to the **expiration of contracts**, *suggesting that the need to develop new capacity resources in 2025*
- However, if cost competitive options for existing resource capacity are not available and conditions evolve as they do in the High Need Future, PGE may require over **1,000 MW** of new capacity from an RFP

Near-term resource additions



Dispatchable Capacity in Preferred Portfolio	Reference Case 2023	2024	2025
Storage Resources			
6hr Batteries (MW)	0	37	37
Pumped Storage (MW)	0	200	200
Total Storage (MW)	0	237	237
Capacity Fill (MW)	123	79	358
Total Dispatchable Capacity (MW)	123	316	595

Q&A

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FREE WHITE PAPER

Navigant Research and National Grid Ventures collaborated on a **free white paper** that complements today's webinar titled "**What is Driving Demand for Long Duration Energy Storage?**"

Download it at www.slenergystorage.com/resources.html

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WHITE PAPER

What Is Driving Demand for Long Duration Energy Storage?

Commissioned by National Grid Ventures

Published 2Q 2019

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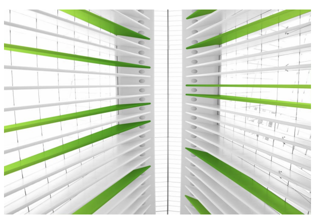
UPCOMING WEBINARS

SMART CITIES EVOLUTION: FROM VISION TO SCALE

How Cities Can Move the Metrics on Urban Challenges

June 10, 2019 – 2:00 p.m. EST

Navigant Research director Eric Woods will talk with Lani Ingram, VP of Smart Communities at Verizon about the evolution of smart city programs and how cities can accelerate the move to deploying successful solutions at scale. They will explore the challenges facing cities, how they are addressing those issues, and key steps that cities and their partners can take to accelerate the adoption of effective solutions.



EVOLVING MARKET FRAMEWORKS FOR SOLAR PV IN EUROPE AND THE US

The European Experience with Feed-in Tariffs, Competitive Procurement, and Self-Consumption

July 16, 2019 – 2:00 p.m. EST

In this webinar, Navigant experts will discuss the different approaches to incentivizing solar PV in Europe and the US. They will also address the challenges to integrating solar PV in the power system and compare regulatory solutions and lessons learned.

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