Northwest **Power** and **Conservation** Council

April 2, 2024

MEMORANDUM

TO: **Council Members**

FROM: **Dylan D'Souza**

SUBJECT: **Report on Multi Day Storage in the Pacific Northwest**

BACKGROUND:

Presenters: Mark Thompson, Senior Director, State Affairs, Patricia Levi, Senior Analyst, and Rachel Wilson, Manager of Strategy and Market Development, Form Energy

Summary: The role for energy storage in the Northwest power system has been growing since 2020 when the first utility scale projects began to be energized. Storage resources will likely be central in supporting the system's resiliency and flexibility needs while meeting regional decarbonization goals and growing loads. While short duration lithium-ion storage has been the commercial and available storage resource for several years, the characteristics of long duration energy storage (LDES) make it an attractive solution to potentially support the continued growth of renewable energy generation and fill the gap between generation and demand.

Form Energy will present on a new class of multi-day energy storage and its integration into the regional power system. Their Iron-Air battery is one of the LDES options available. These types of systems may play a role in the future of the regional power system. This presentation is expected to provide information on long duration energy storage and inform further discussions on the future of LDES for the region.

Relevance: The Council's 2021 Power Plan recognized the need for future research into emerging technology resource options. This recommendation focused on carbon-free resources that can help meet future regional power system needs, including energy storage.

Workplan: A.3.1. Tracking emerging technologies, both supply and demand side, providing periodic updates to the Council.

Background: In developing the recommended resource strategy for the 2021 Power Plan, the Northwest Power Act requires the Council to give priority to resources that are cost-effective. This includes resources that are "reliable and available within the time it is needed, and to meet or reduce the electric power demand […] at an estimated incremental system cost no greater than that of the least-cost similarly reliable and available alternative measure or resource." The Plan focuses on resources available today, while acknowledging there are many potential opportunities that might meet future power system needs at lower costs. The Council made two recommendations to this end: directing the region to support technological innovation and growth, and urging collaboration among regional stakeholders toward solutions in the best interest of the region.

More Info: See additional detail on the 2021 Power Plan, the Council's treatment of emerging technologies, and Emerging Trends in Battery storage, here:

- https://www.nwcouncil.org/2021powerplan_research-emerging-technologies-support-development-future-resource-options/
- https://www.nwcouncil.org/fs/18368/2023_07_p2.pdf
- https://www.nwcouncil.org/fs/18369/2023_07_p3.pdf

BREAKTHROUGH LOW-COST, MULTI-DAY ENERGY STORAGE

NWPCC Power Committee
April 9th, 2024

Form energy

Energy Storage
For A Better World

The Challenge

The electrical grid needs to fundamentally transform to meet the challenges posed by the energy transition

Intermittency of renewable assets creates periods of undersupply

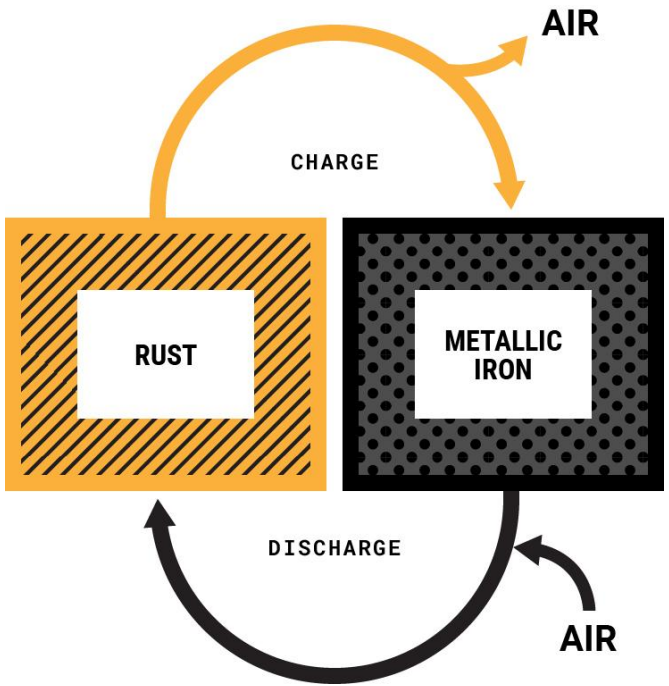
Clean energy goals and changing economics risk stranding fossil assets

Extreme weather events are becoming more frequent and disruptive to customers

Transmission congestion and interconnection queues are increasing

Rechargeable iron-air is the best technology for multi-day storage

Form's 100-Hour Reversible Rust Battery



COST

Lowest cost rechargeable battery chemistry.
Chemistry entitlement <$1.00/kWh

SAFETY

No thermal runaway (unlike li-ion)
Non-flammable aqueous electrolyte

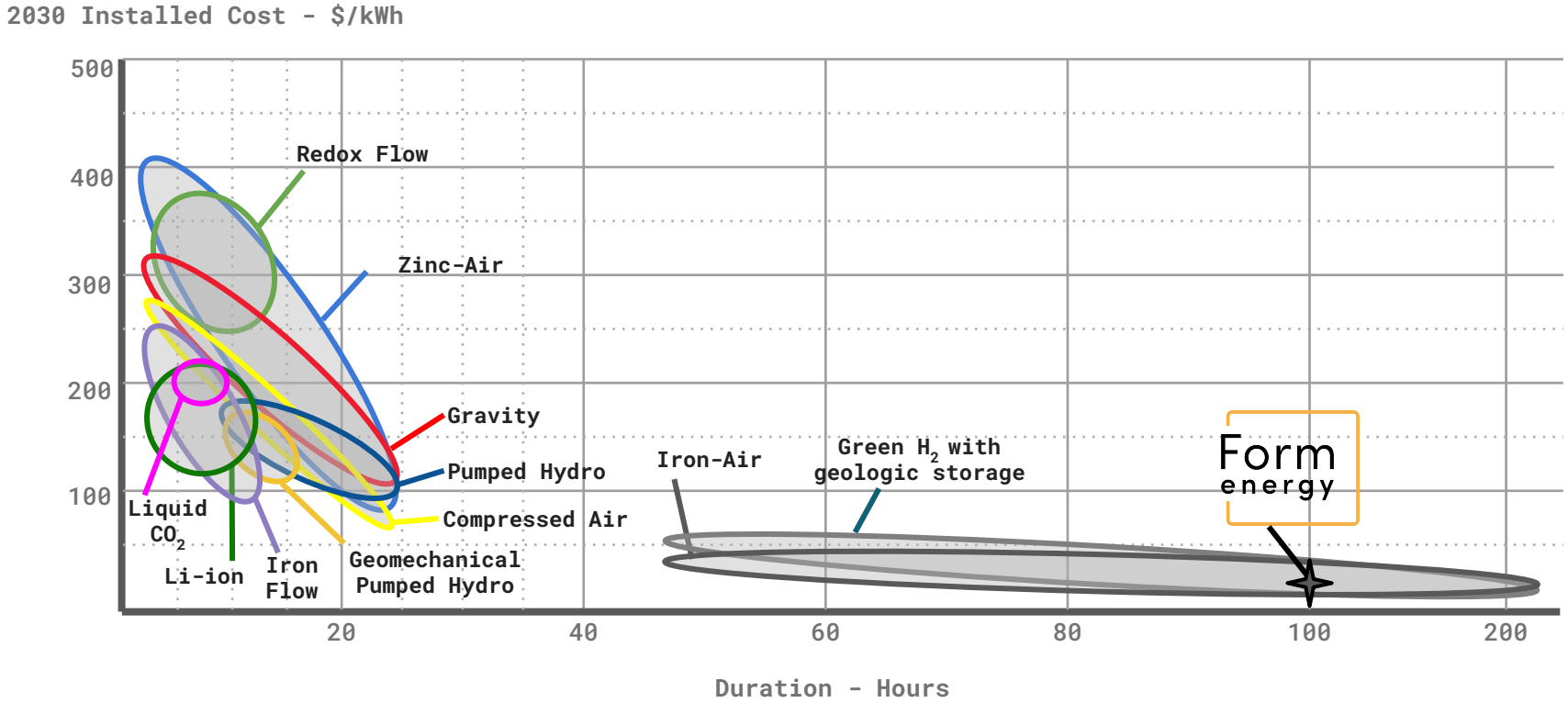
SCALE

Iron is the most globally abundant metal
Easily scalable to meet TW demand for storage

DURABILITY

Iron electrode durability proven through decades of life and 1000's of cycles (Fe-Ni)

Form's Fe-air battery is the only technology targeting multi-day duration without geographic constraints



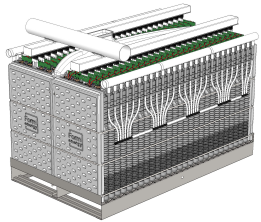
Form Energy's Modular 100hr Multi-Day Storage System

Cell

Electrodes + Electrolyte

Smallest **Electrochemical** Functional Unit

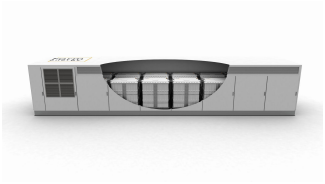
Battery Module



~30 **Cells**

Smallest Building Block of **DC** Power

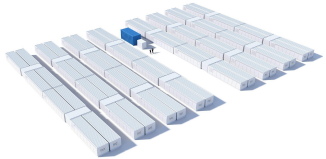
Enclosure



~10 **Modules**

Product Building Block with **integrated module auxiliary systems**

Power Block



~2.5 MW / 250 MWh

<1.2 acres

~64 **Enclosures**

Smallest independent system and **AC Power** building block

System

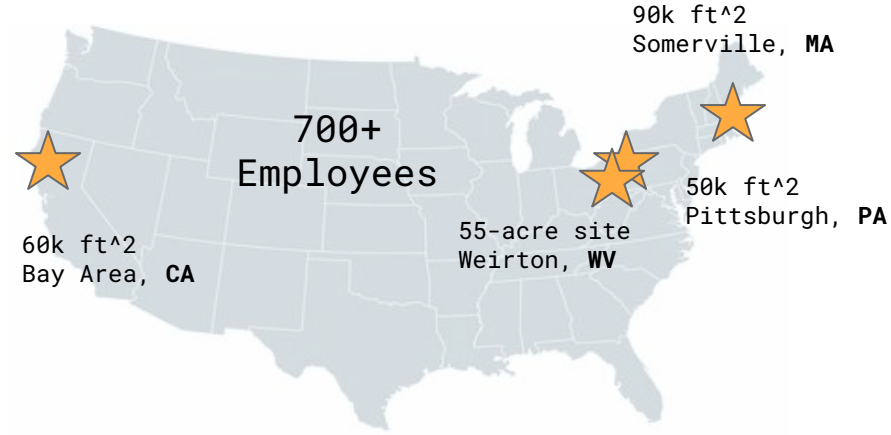
100+ MW / 10 GWh

50+ acres

10s - 100s of **Power Blocks**

Commercial Intent System

Rising to the grid's challenges with a team that will deliver



OUR INVESTORS: LONG-TERM AND IMPACT-FOCUSED

$820M in venture capital from top investors including: Breakthrough Energy Ventures (BEV), TPG's Climate Rise Fund, Coatue Management, GIC, NGP Energy Technology Partners III, ArcelorMittal, Temasek, Energy Impact Partners, Prelude Ventures, MIT's The Engine, Capricorn Investment Group, Eni Next, Macquarie Capital, Canada Pension Plan Investment Board, and other long-term, impact oriented investors

LED BY ENERGY STORAGE VETERANS

Decades of cumulative experience in energy storage

- 100's of MW of storage deployed

TESLA ENERGY

A123 SYSTEMS

SUNPOWER FROM MAXEON SOLAR TECHNOLOGIES

24M

NEXTera ENERGY

amsc

Massachusetts Institute of Technology

AQUION ENERGY

Over 5 GWh of Commercial Engagements Coming Online by 2026

First-of-its-kind **1.5 MW /150 MWh** MDS project in Cambridge, Minnesota to come online in 2024

Two 10 MW / 1,000 MWh MDS systems; one in Becker, MN and one in Pueblo, CO. Both expected to come online as early as 2025

5 MW / 500 MWh MDS system in collaboration with the California Energy Commission in Mendocino County; online by 2025

10 MW / 1000 MWh MDS system in New York to come online as early as 2025

15 MW / 1500 MWh MDS system in Georgia to come online as early as 2026

5 MW / 500 MWh MDS system in Virginia to come online as early as 2026

Form Factory 1: Commercial-Scale Manufacturing

Transforming Weirton Steel Land for Battery Manufacturing in West Virginia

Building rendering

March 2024 update

- **Total Local Investment:** $760 million
- **Construction Start:** Early 2023
- **Production Start:** Late 2024
- **Jobs:** Minimum of 750 full-time jobs

Location Benefits

- Close to our existing pilot manufacturing facility in PA
- Strong natural infrastructure
- Local manufacturing know-how

Factory Function

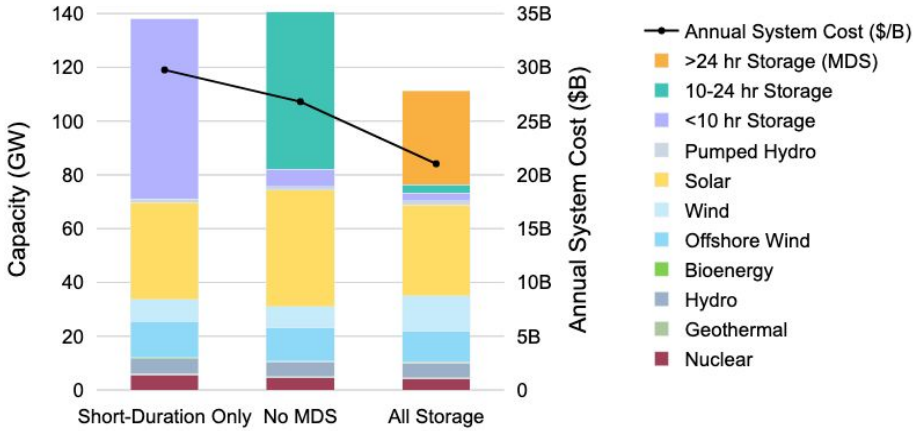
- Semi-to-fully automated cell, module, & enclosure assembly
- Ability to scale production in modular blocks

MDS provides cost-effective clean firm power for deep decarbonization

Examples of MDS in deep decarbonization scenarios (e.g. 2040/45)

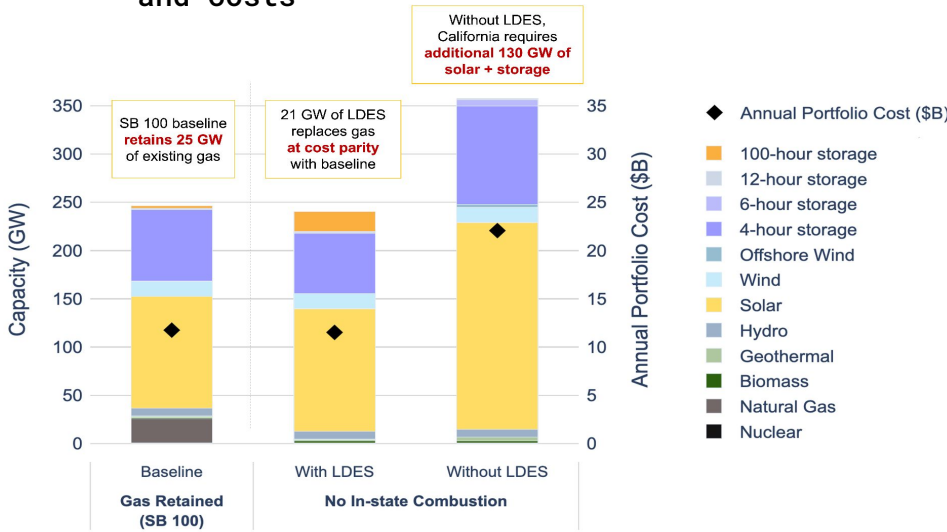
New York

2040 Installed Capacity and Annual System Costs (2014 Weather Year)



California

Least Cost 2045 CAISO System Portfolio and Costs



Modeling Multi-day Storage in the PNW

Multi-day storage (MDS) addresses a number of challenges in the PNW electric grid in 2030 and beyond

MDS can provide clean, firm peaking capacity to support demand growth and decarbonization

Turn renewable volatility into firm peaking capacity

MDS can shift excess hydropower and other renewable energy from the spring to peak summer months

Address rising demand while decarbonizing

MDS reduces reliance on existing fossil-fueled capacity and provides a firm alternative to new gas-fired capacity

Improve system resilience to extreme weather

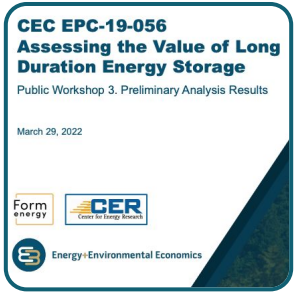
Portfolios that contain MDS address multi-day net load peaks with more buffer than portfolios without MDS

Model Used | Formware™ Capacity Expansion & Dispatch Model

Key Features

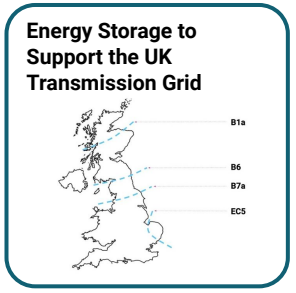
- **Hourly Temporal Granularity**
  - *Conducts annual 8,760 hour capacity optimization to capture realistic grid dynamics and resource variability*
  - *Necessary to accurately model high renewable grids and multi-day storage operations*
- **Multi-Weather-Year Analysis**
  - *Co-optimizes resource needs in conditions from multiple weather and hydro years*
  - *Identifies the optimal portfolio to meet cost and reliability requirements under a range of future weather and grid conditions*

Use in Peer Validated Studies



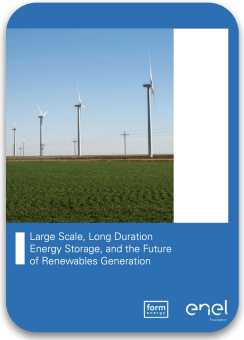
CEC-Funded Study of LDES in California

E3 + Form Energy
December 2023



National Grid ESO / Form Energy Analysis

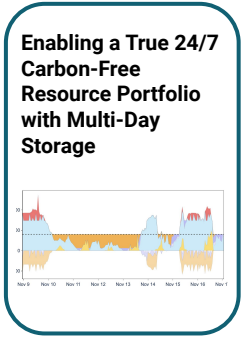
October 2021
Webpage; Tech Appendix



Long duration storage to manage wind farm risk of returns

Form Energy + Enel Foundation

2019



Great River Energy + Form Energy

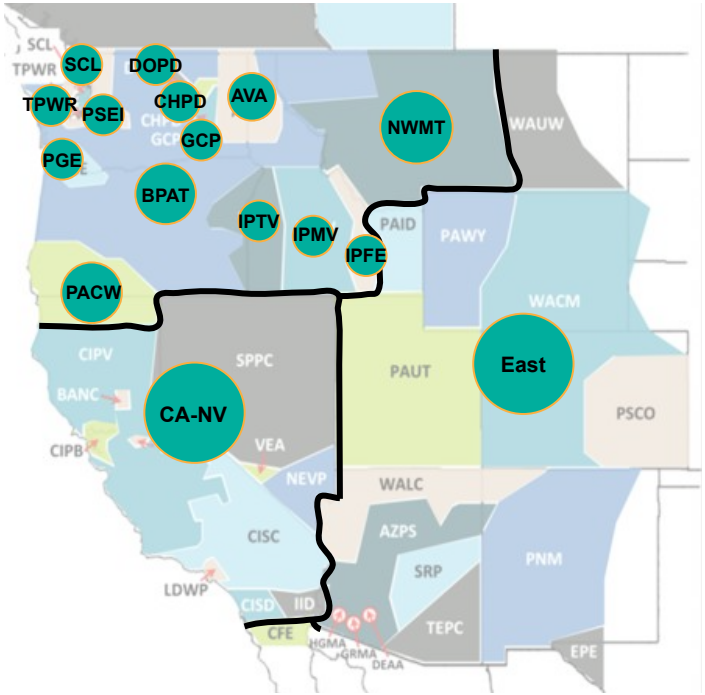
April 2023

Model Setup & Assumptions

Key Input Features

- **2030 grid needs and operations**: Model optimal investment & dispatch in 2030
- **2030 decarbonization targets:** All currently binding state emissions and RPS policies enforced
- **High quality hydropower modeling:** Hydro model based on NWPCC simulations
  - *Monthly capacity factor targets*
  - *Hourly capacity factor min & max*
- **Reliable data:** WECC's 2032 Anchor Data Set used as much as possible
  - *Transmission limits derived from WECC ADS via GridLab's GridPath RA toolkit*
- **Policy incentives:** IRA incentives applied to eligible technologies

Nodal Topology Layout



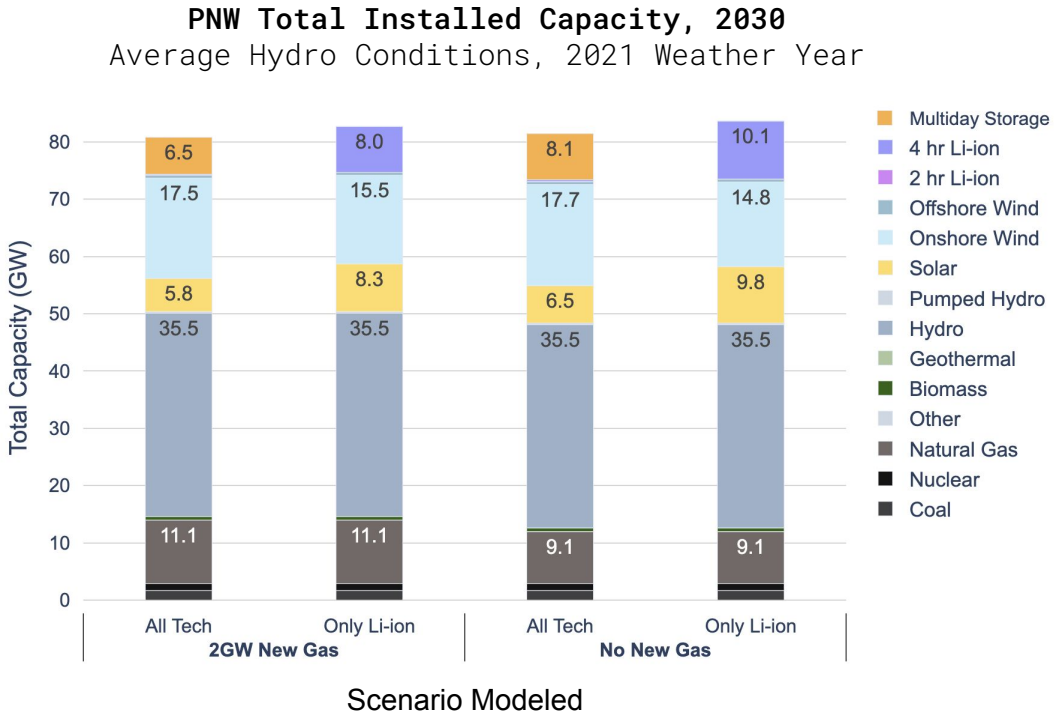
Preliminary Key Findings

Pacific Northwest Resource Needs | 2030

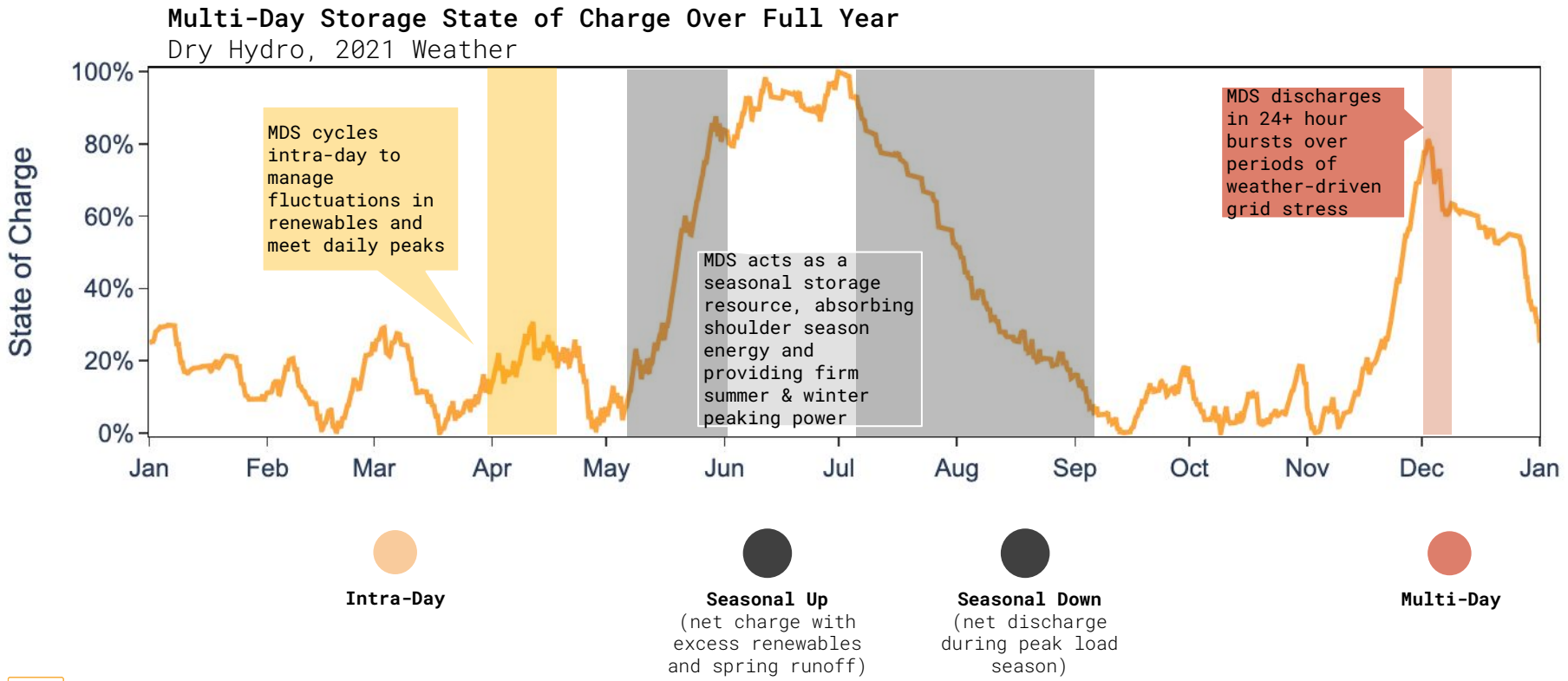
Formware 8,760 hour modeling shows that MDS unlocks 2030 climate goals with fewer resources across a range of hydro and weather conditions

Across 13 weather scenarios…

- We find that **4.4 - 9.4 GW of MDS** is part of the least-cost portfolio that avoids new gas build in 2030.
- MDS results in **average savings of ~6%** annually
- ~0.8 GW MDS substitutes for 1GW new gas build at equivalent costs or with small cost premia (<1.6%).



Multi-day storage (MDS) seasonally shifts renewables & balances their hourly and multi-day variability

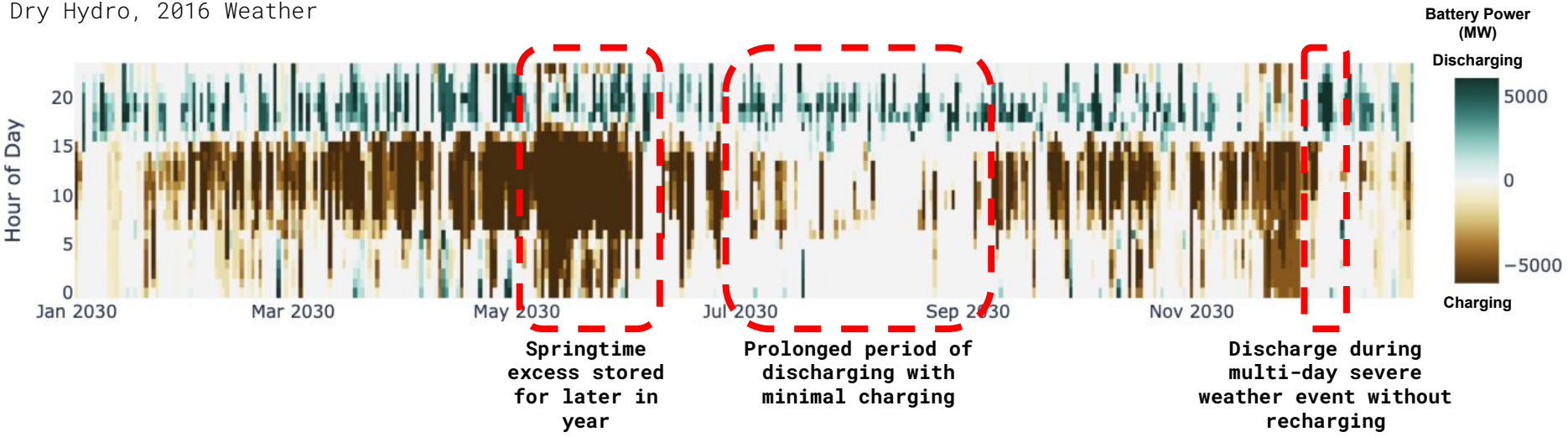


MDS turns excess energy into firm peaking capacity

Large energy storage capacity supports grid during severe weather-driven events

Multi-day storage operations, 2030

Dry Hydro, 2016 Weather



> 25% reduction in curtailment

3% - 5% reductions in emissions under identical policy

Reduced reliance on gas & imports in dry hydro years

MDS's interweek shifting turns excess energy into reliable capacity during cold, windless winter weather events.

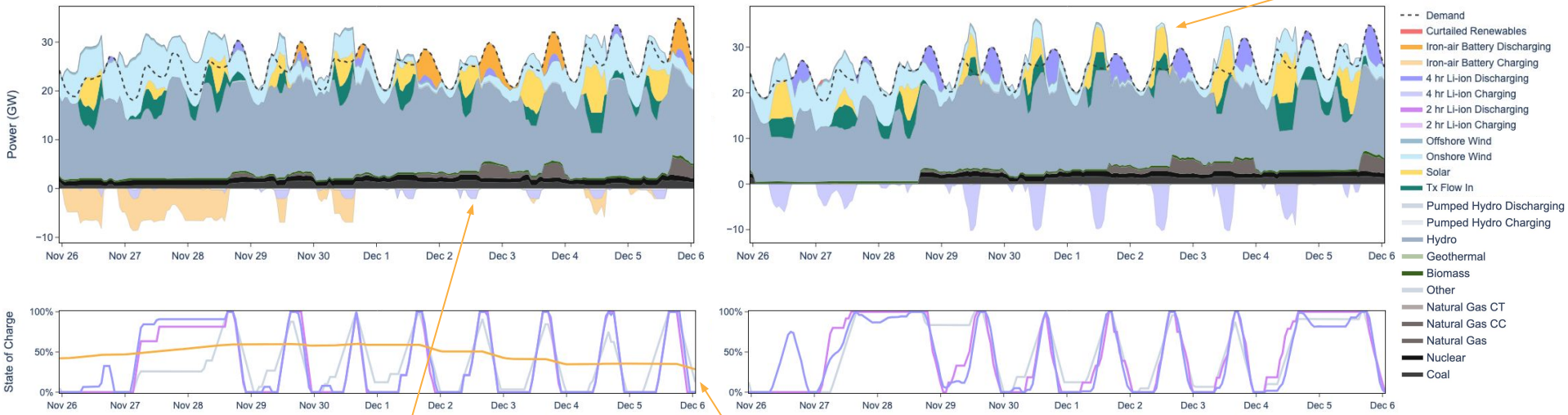
MDS Sensitivity

2030 with avg hydro and 2018 weather

No MDS Sensitivity

2030 with avg hydro and 2018 weather

Additional solar required to recharge li-ion daily



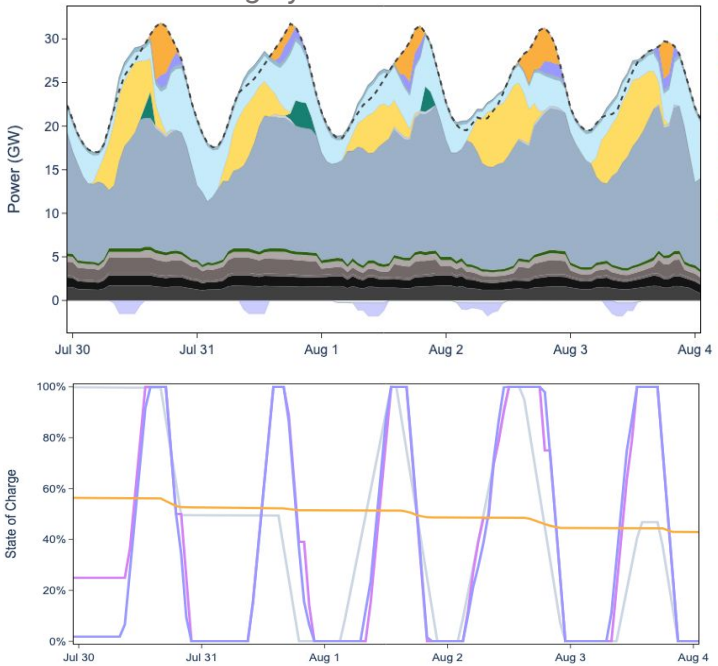
MDS allows high efficiency lithium to charge with available energy

MDS has residual charge at the end of multi-day event

During summer demand spikes, MDS provides peaking capacity and a buffer for extended heat waves.

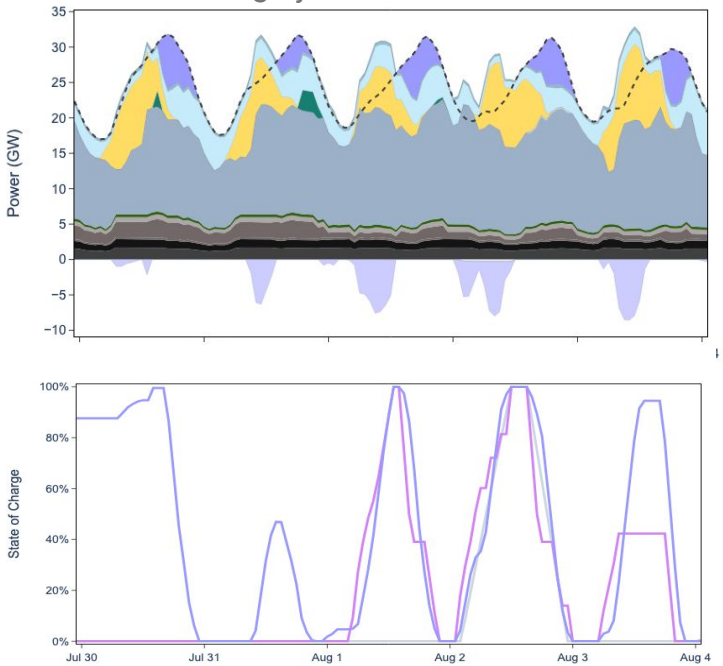
MDS Sensitivity

2030 with avg hydro and 2018 weather



No MDS Sensitivity

2030 with avg hydro and 2018 weather



Residual state of charge at the end of peak load event provides resiliency.

Limited energy storage capacity requires careful management throughout event.

Summary

Summary Findings and Key Takeaways

The Pacific Northwest can lower the costs of meeting its clean energy goals by building a multi-GW market for emerging multi-day energy storage technologies in 2030

- **Multi-day Storage Provides Substantial Value in the Pacific Northwest in 2030**
  - *4.4 GW to 9.4 GW of multi-day storage in 2030 are part of a least-cost resource portfolio, depending on the weather year and hydro conditions assumed in that year.*
- **Emerging Long-Duration and Multi-Day Storage Can Lower Cost of Achieving 2030 Climate Goals**
  - *A portfolio with multi-day energy storage results in 5.8% lower system costs by 2030 under a range of weather and hydro conditions, relative to a portfolio with short-duration storage only.*
- **Multi-Day Storage Reduces Reliance on Natural Gas while Maintaining Reliability**
  - *MDS allows grid operators to address severe weather-driven events with lower reliance on fossil fuels, reducing emissions by 2.2% on average, and up to 8% in select years.*
- **Multi-Day Storage Turns Excess Renewable Energy into Clean, Firm Capacity**
  - *MDS captures excess hydro and other renewable generation, dispatching that energy during peak load periods and/or over multi-day renewable lulls.*

Building a Market for Multi-Day Storage in the PNW

- **Demonstrate:** Deploy multi-day storage at relevant scale in 2025/2026 to demonstrate new applications and system value, and to accelerate learning cycles.
- **Plan:** Include emerging technologies in **Integrated Resource Plans** to understand near and long-term value. Model atypical weather and 8,760 operations.
- **Develop** multi-day storage at scale to support system reliability, resilience, and lower-cost decarbonization. Act with urgency to maximize opportunities from the IRA.
- **Design markets** that seek firm resources, plan for atypical events, and recognize the reliability and portfolio benefits of multi-day storage.

Thank you!

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