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Description:	UC Merced's slides for the workshop titled "Proposed Final Scenarios to Assess the Role of Long Duration Storage"
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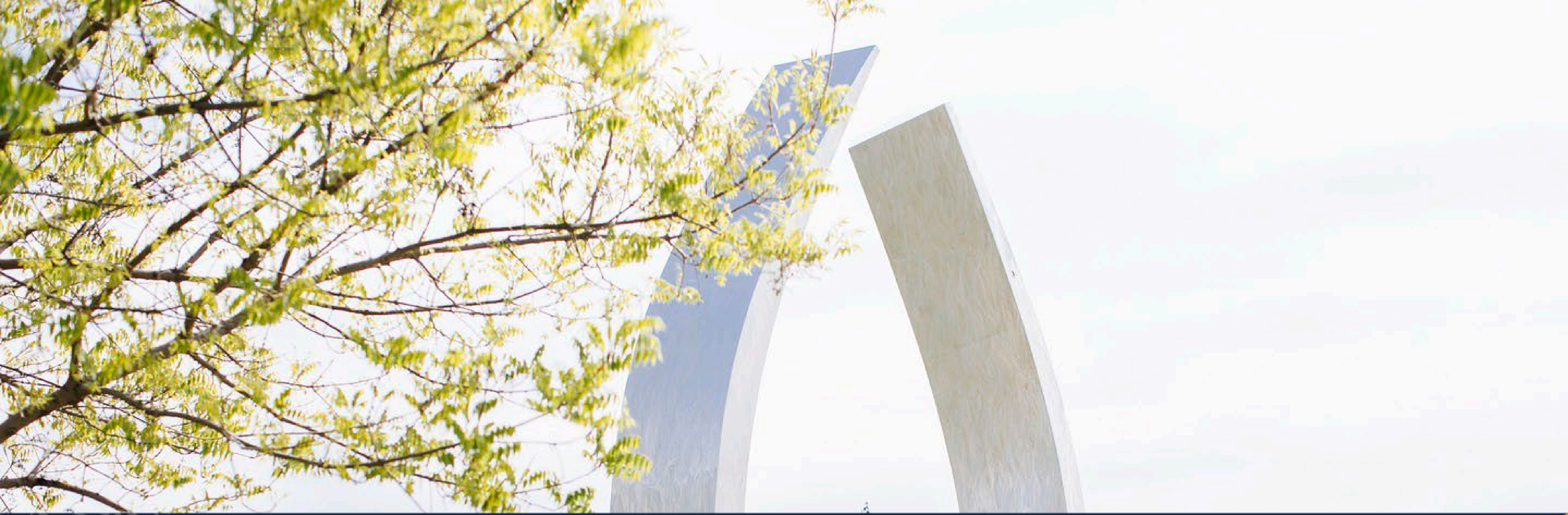

Long Duration Energy Storage
Public Workshop #3
July 12, 2022

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Agenda

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10:00 Welcome (Sunquist, Kurtz) – review team and objectives

10:05 UC San Diego-led studies (Hidalgo-Gonzalez)

- Effect of modeled time horizon on understanding role of LDES
- Value of LDES for 39 scenarios studied using SWITCH

10:45 Questions

10:55 UC Merced-led studies (Kurtz)

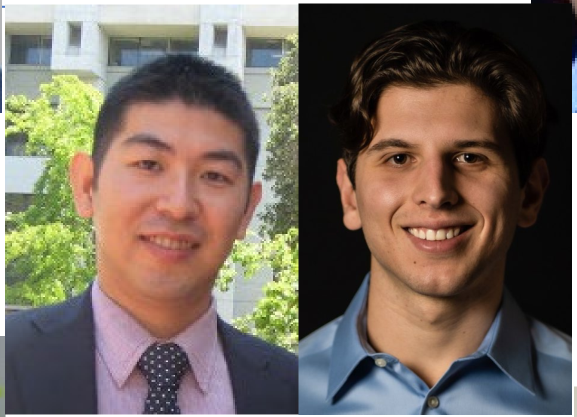
- Review of previous studies to set the stage for RESOLVE studies
- Defining modeling approach and final scenarios with RESOLVE

11:35 Questions

Research team

University of California Merced
Sarah Kurtz

University of California Berkeley
Dan Kammen
Sergio Castellanos



University of California San Diego
Patricia Hidalgo-Gonzalez

University of North Carolina Chapel Hill
Noah Kittner

PROJECT OBJECTIVES – CEC GUIDANCE

- **Solicitation Directed: Study Value of Long-Duration Storage**
  - What role(s) will long-duration storage play?
  - What cost target must a storage technology reach?

- **EPIC Funding Directs: Provide value to ratepayers**
  - Low electricity prices
  - Reliable electricity
  - Meet SB100 and other CA targets
  - Technical societal goals
    - Address climate change
    - Reduce air & water pollution
    - Adequate clean-water supplies
  - Broader societal goals
    - Stability of jobs
    - Social justice – move toward a more equitable world…

SB100 targets a decarbonized grid

What roles will storage play?

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PREVIOUS STUDIES – LAYING THE GROUNDWORK

•P.A. Sánchez-Pérez, Martin Staadecker, Julia Szinai, Sarah Kurtz, Patricia Hidalgo-Gonzalez, *"Effect of modeled time horizon on quantifying the need for long-duration storage"* Applied Energy, 2022 Article

•R. Jones and S. Kurtz, "*Optimizing the Configuration of Photovoltaic Plants to Minimize the Need for Storage*" IEEE Journal of PV, 2022. Open access

•Z. Mahmud, K. Shiraishi, M. Abido, D. Millstein, P. Sanchez, and S. Kurtz, "*Geographical variability of summer- and winter-dominant onshore wind*" Journal of Renewable and Sustainable Energy, Volume 14, 023303, 2022. Open access

•R. Shan, J. Reagan, S. Castellanos, S. Kurtz, and N. Kittner. "*Evaluating emerging long-duration energy storage technologies*" Renewable and Sustainable Energy Reviews, Volume 159, 2022. Article

•M. Abido, Z. Mahmud, P. Sanchez, and S. Kurtz, "*Seasonal Challenges for a California renewable-energy-driven grid*" iScience, 2021. Open access

•Kittner, N., Castellanos, S., Hidalgo-Gonzalez, P., Kammen, D. M., & Kurtz, S. (2021). *Cross-sector storage and modeling needed for deep decarbonization. Joule*, *5*(10), 2529-2534. Article

•M. Abido, K. Shiraishi, P. Sanchez, R. Jones, Z. Mahmud, S. Castellanos, N. Kittner, D. Kammen, and S. Kurtz, "*Seasonal Challenges for a Zero-Carbon Grid in California*" 48th PVSC, 2021.PDF Presentation

•A. Leilaeioun, R. Jones, R. Sinton, and S. Kurtz, "*Demand Shifting as a Profitable Strategy for Solar Plant Operators*" 48th PVSC, 2021. PDF Article

•S. Kurtz, N. Kittner, S. Castellanos, P. Hidalgo-Gonzalez, and D. Kammen, "*For Cleaner, Greener Power, Expand the Definition of "Batteries"*" Issues in Science and Technology, 2021. Article

https://sites.ucmerced.edu/ldstorage/publications%20version%202

PREVIOUS STUDIES – LAYING THE GROUNDWORK

- As we just heard: *full-year* modeling gives different answers from partial-year modeling, especially when LDES reaches low costs

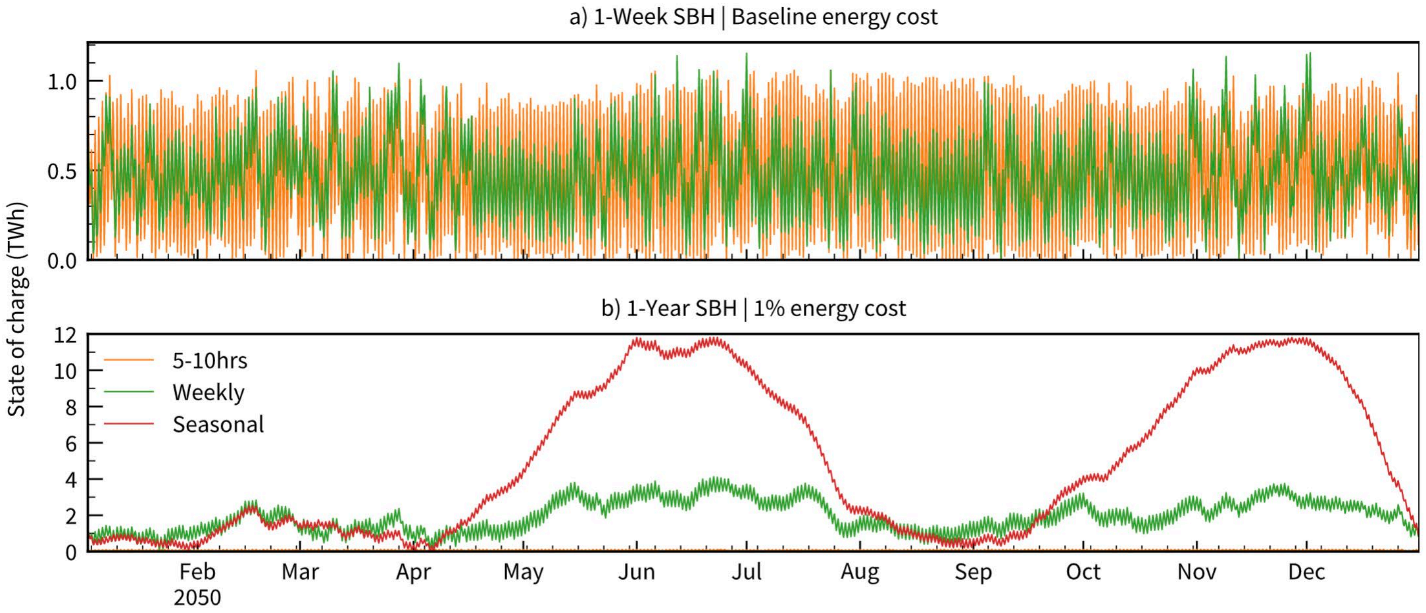

Fig. 6 Aggregated state of charge for all energy storage technologies installed throughout the WECC region. a) For the 1-week SBH using \$130/kWh and b) for the 1-year SBH with \$1.3/kWh. Duration of energy storage is classified according to its optimal range of duration. For weekly the range is between 10-100 hours and seasonal 100+ hours (energy to power ratio).

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PREVIOUS STUDIES – LAYING THE GROUNDWORK

- As we just heard: *full-year* modeling gives different answers from partial-year modeling, especially when LDES reaches low costs

- Therefore: develop a method for efficient full-year modeling

- Efficient modeling enables study of a wide range of scenarios

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Full-year modeling of storage

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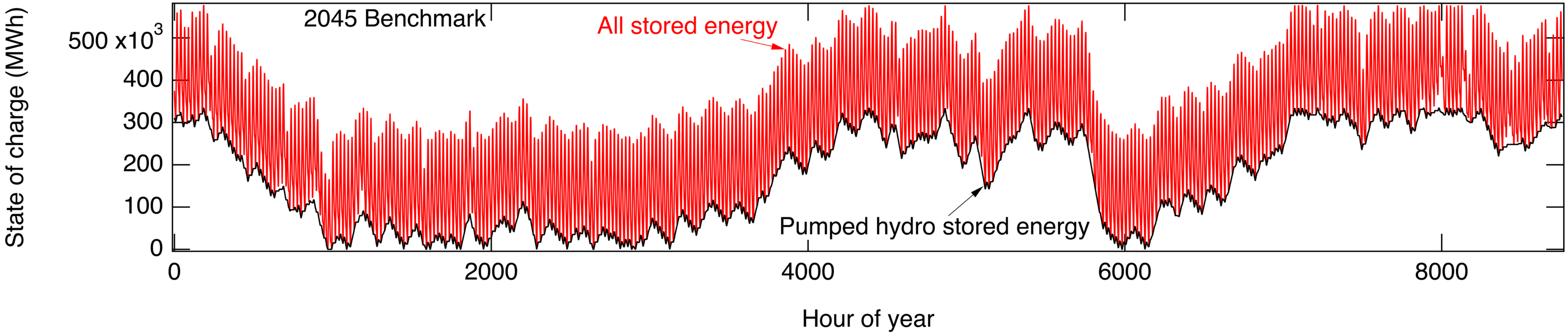
Modeling every hour of the year better reflects use of storage



E3 has rewritten RESOLVE (New-modeling-toolkit) to enable both representative days and full-year modeling to accomplish this

We are developing a complementary approach using the new code, but with modifications

Special thanks to E3 for allowing us access to the new software

Use critical hours to reduce size of problem

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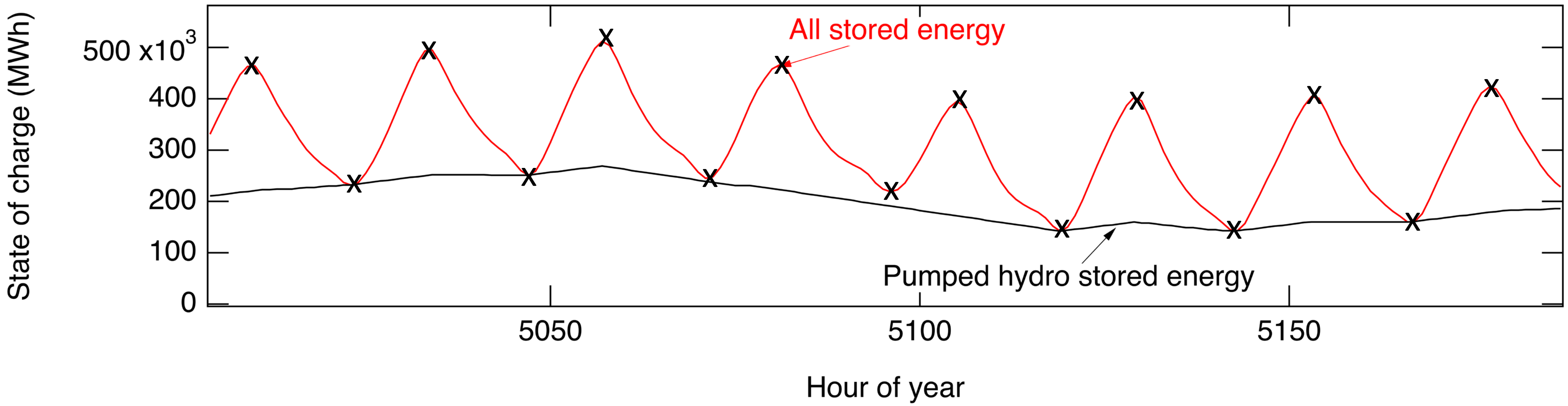

Modeling every hour of the year for multiple years is computationally demanding, so use a "critical time steps" method (1450 steps instead of 8760)

The "critical time steps" are identified as the hours of the day that best define the capacity expansion plan (use ~4 steps per day)

Two-step calculation

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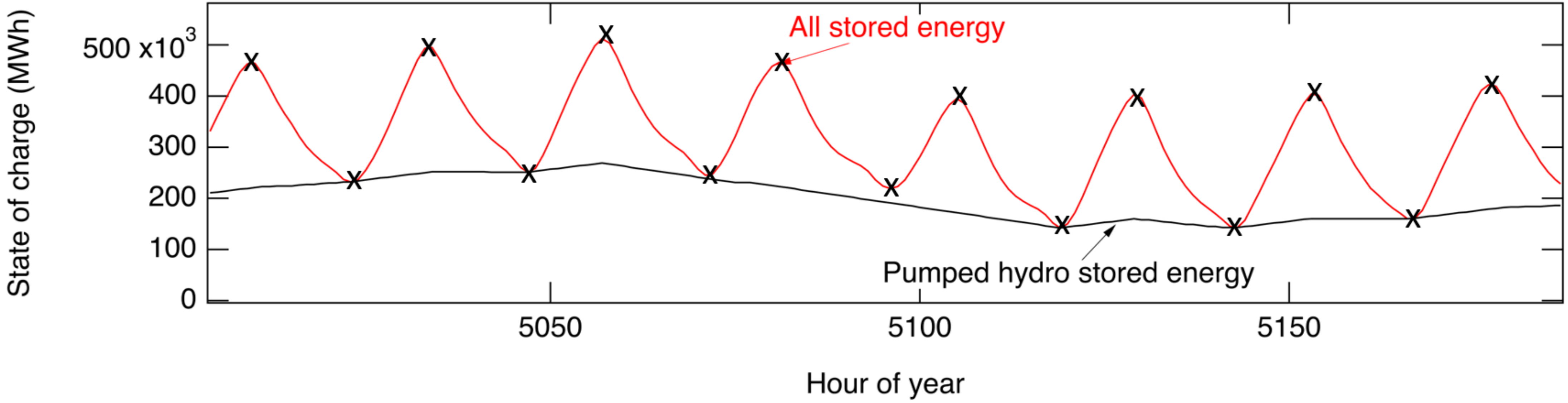


Preparation steps

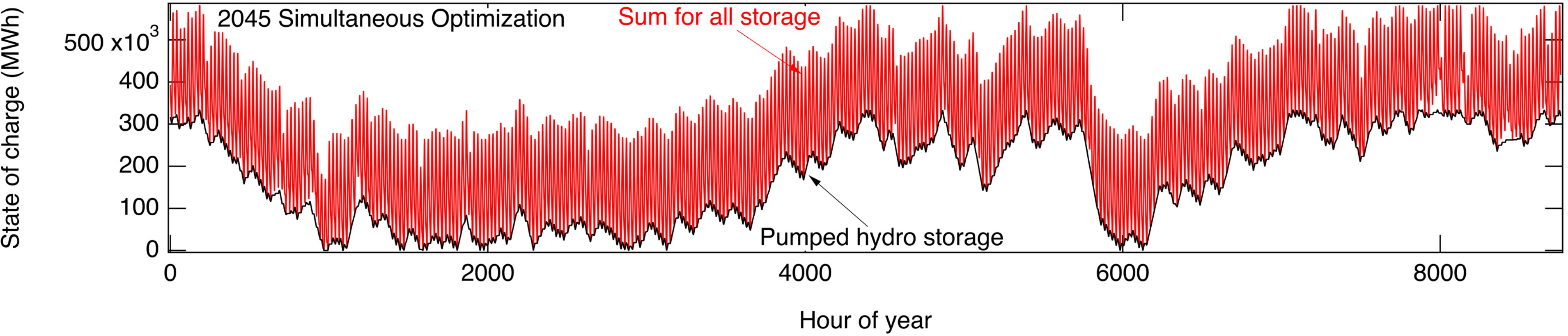
- Identify critical hours
- Calculate profiles (averaging between time points)

Two calculation steps:

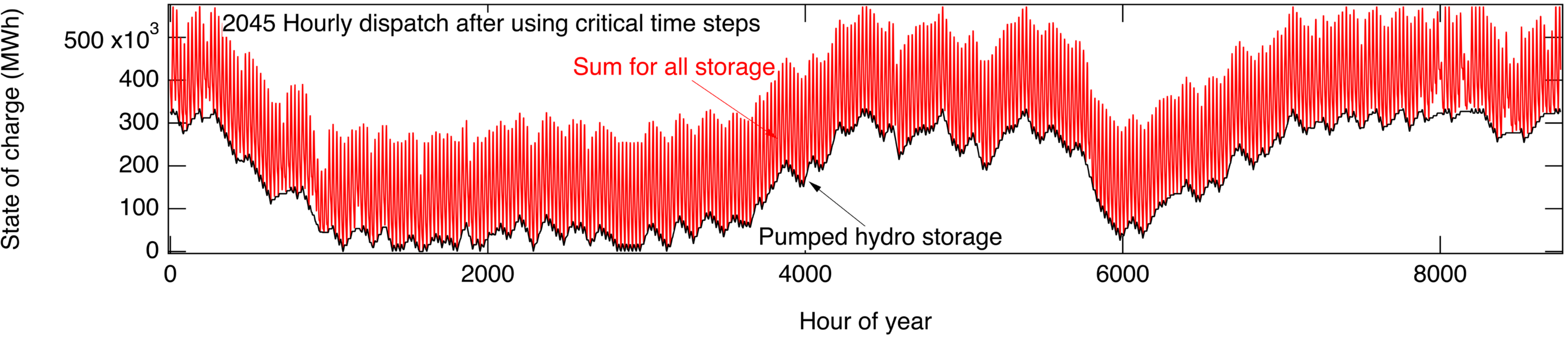
1. Run RESOLVE (code is modified) to obtain optimal capacity expansion
2. Use capacity expansion plan to optimize hourly dispatch for each year (RESOLVE)

Process reflects how the world works

Results implementing 2-step calculation



One step
Time required
2-4 hours



Two-step
Time required
5-10 min
+
60-75 min

2-step approach gives similar results in less time, especially for multiple-year calculations
When we are interested primarily in the expansion plan, the benefit is > factor of 10.

Results implementing 2-step calculation

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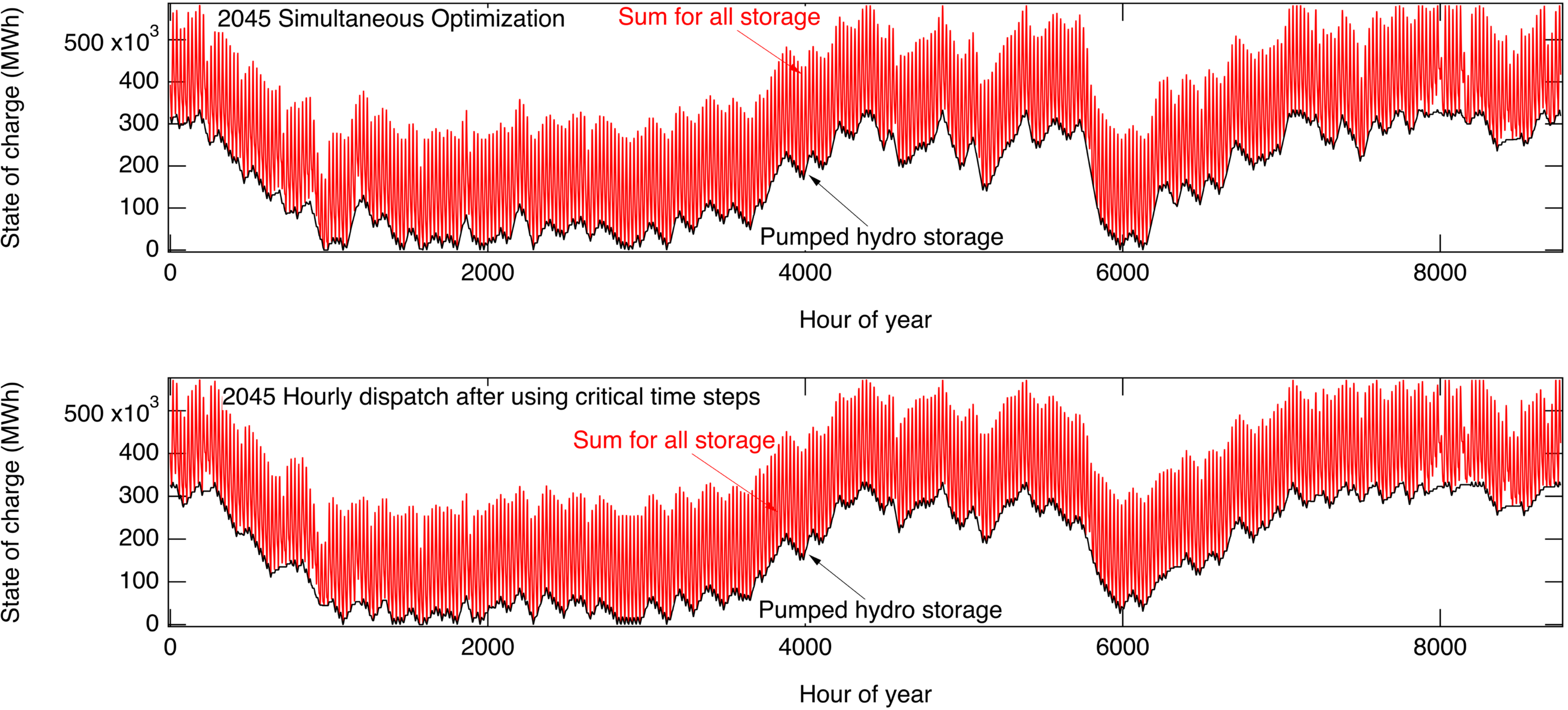

One step

Time required

2-4 hours

Two-step

Time required

5-10 min

+

60-75 min

This approach enables exploration of larger parameter space in more detail

Proposed scenarios for RESOLVE studies

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Starting point for scenarios in RESOLVE is Preferred System Portfolio

PSP: 38MMT_20210812_PSP_LSEplan_2020IEPR_2020IEPRHighEV

Modifications:

- 365-day modeling with 2030, 2035, 2040, and 2045 periods
- Zero emissions (in California, also no imports with emissions) by 2045
- Existing hydropower: use dry-year generation profile (2021)
- Generation profiles and generation mixtures (wind vs solar, etc.)
- New pumped hydro – instruct model to build or not build – no optimization
- Vary EV charging profiles
- Allow model to select to build and operate electrolyzers and sell hydrogen
- Key question: how do we introduce the candidate LDES technologies?

How to model long-duration energy storage?

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- The attributes of most of the new technologies are not well defined, so it will be useful to model a range of attributes
- One company posed the question: "I'm developing a product – what duration should I target?"
- The CEC asks us: "If we are investing in LDES, what duration should we prioritize?"
- Advice from CESA: "Study the entire parameter space"

Thought experiment

- If I can add a larger energy reservoir to my storage product, how much more will people be willing to pay for it?
- If the storage is charged from solar electricity, need enough hours to get through the night; will more hours increase market share for a given price?
- To answer this question, we introduce a variable-cost candidate LDES resource with specified attributes:
  - Instantaneous efficiency
  - Duration
  - Loss rate (decreases efficiency if charge and discharge occur on different days)

Defining the cost of a storage product (with energy reservoir)

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Total cost/kW = Cost/kW + Duration * Cost/kWh

Duration = energy capacity rating / power capacity rating

Split cost $/kW	Split cost $/kWh	Duration	Total cost
$100	$10	4 h	$140/4-h 1-kW battery

This approach is useful if the duration is optimized:
The model selects to build more power and/or energy

Cost attributed only to power ($/kW)
$140/kW

or

Cost attributed only to power ($/kWh)
$35/kWh

This approach is useful when the duration is fixed

Thinking in the context of *"If I can add a larger energy reservoir to my storage product, how much more will people be willing to pay for it?"* we use $/kW for the specified product (rather than separating the cost of the energy reservoir)

Thought experiment about market

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If you can make an 8-hour battery,
at what cost will it compete with 4-hour batteries?

If long-duration storage is needed,
you may replace two 4-hour batteries with one 8-hour battery
So, maybe the 8-h battery can be twice the cost of the 4-h

May also depend on efficiency and other attributes
In example, assume 85% 4-h and 81% 8-h batteries

Vary the cost of candidate storage

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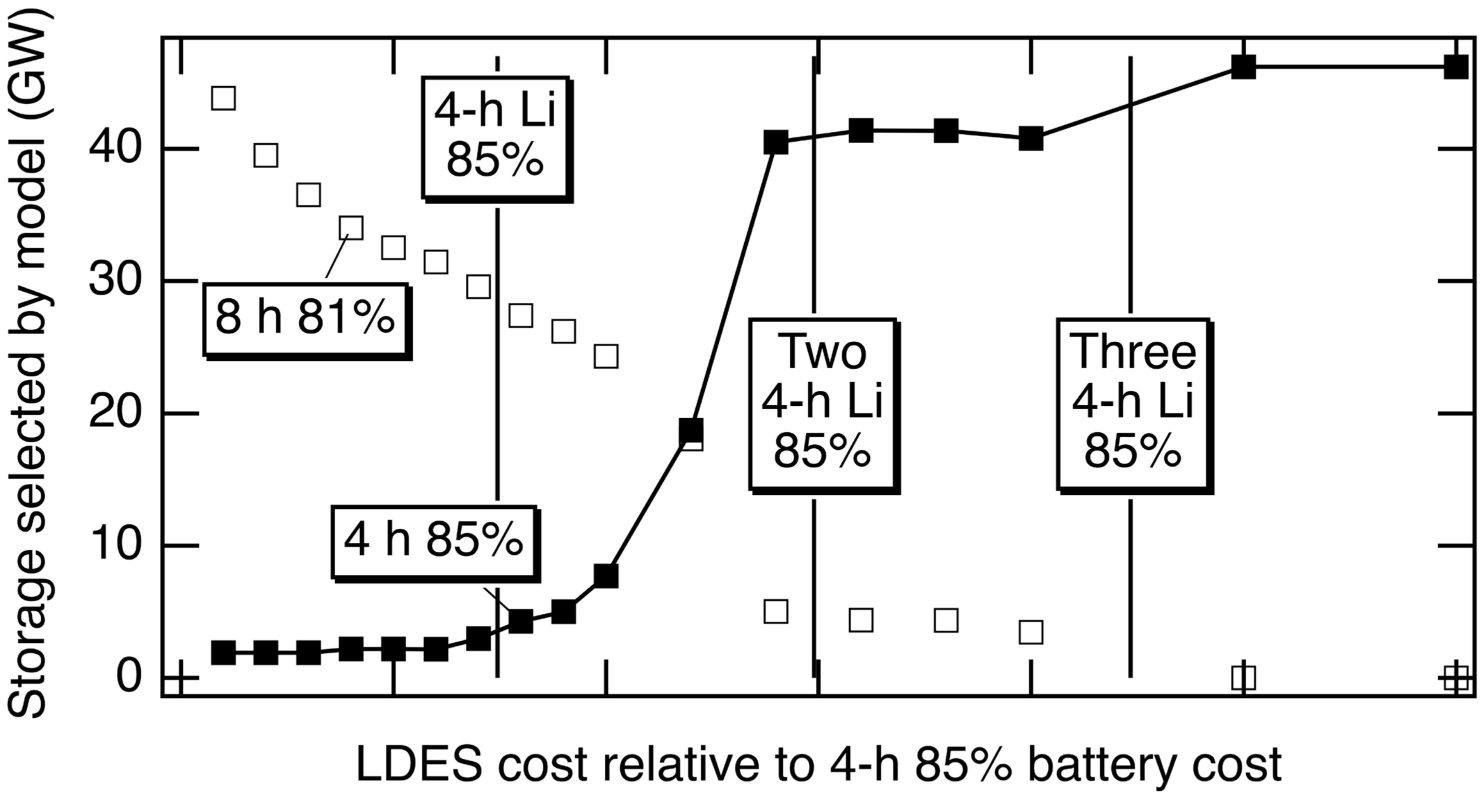
Vary the cost and see when the model adopts the 8-h storage



Expect that might see adoption when 8-h battery costs about twice the 4-h battery

Will a 12-h battery be adopted at thrice the 4-h battery cost?

Vary the cost of candidate storage

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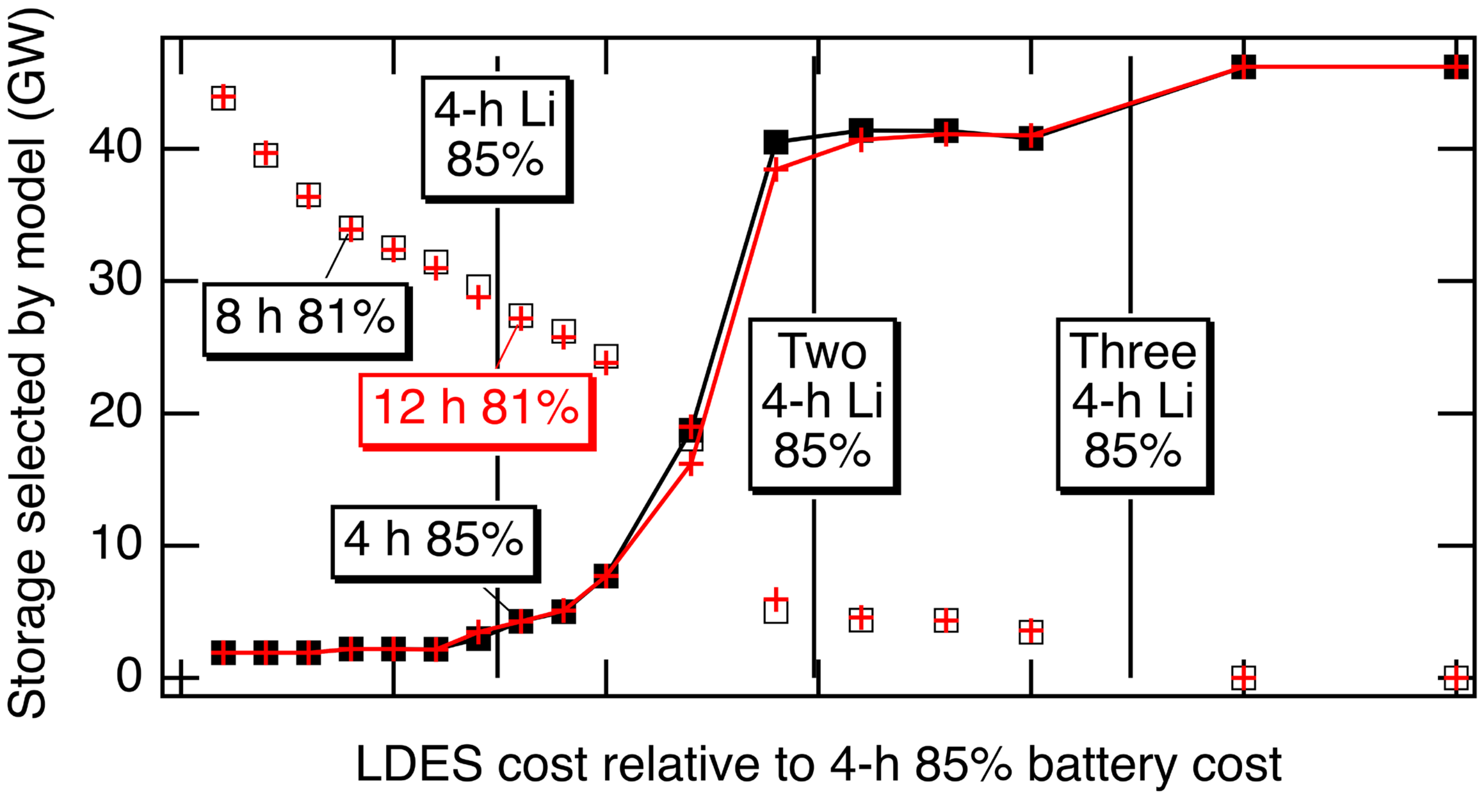
Vary the cost and see when the model adopts a 12-h storage



The 12-h storage is very similar to the 8-h storage

What scenario? 38 MMT allows some emissions and keeps some natural gas

Vary the cost of candidate storage

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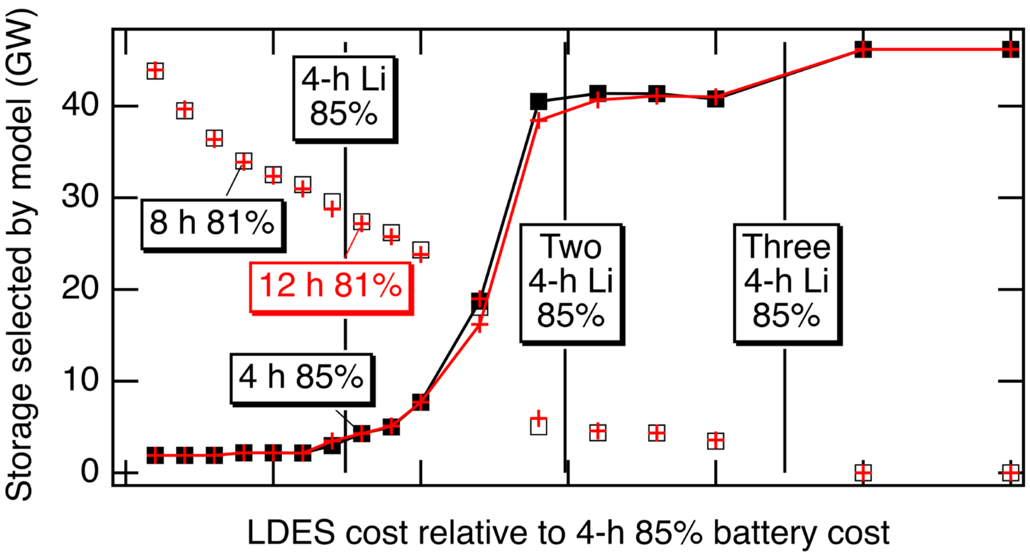
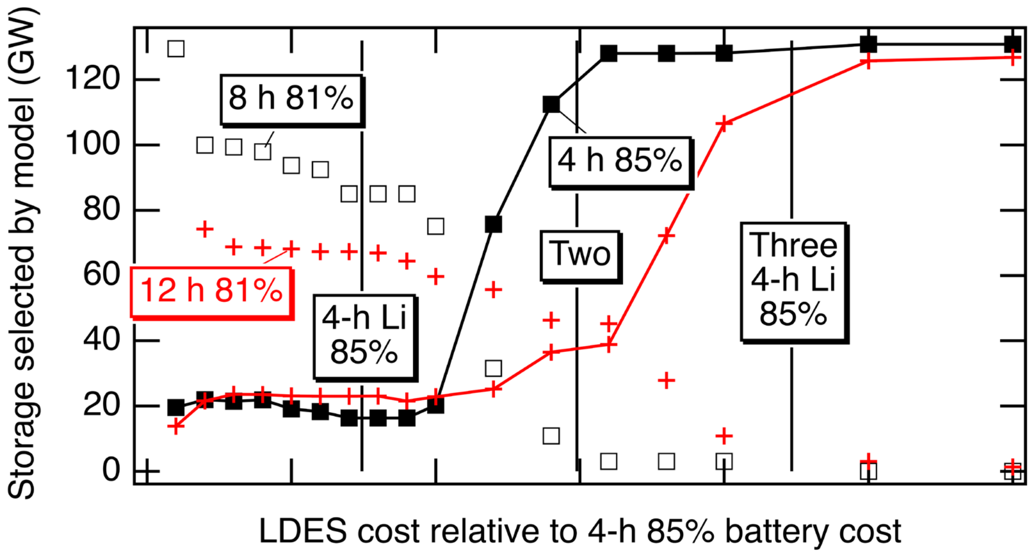
Role of LDES is very different for different scenarios





38 MMT

0 MMT (even in imports)

Requirement of no emissions:

- Increases demand for LDES *and* values 12-h storage over 8-h storage

Identify cost targets for each candidate

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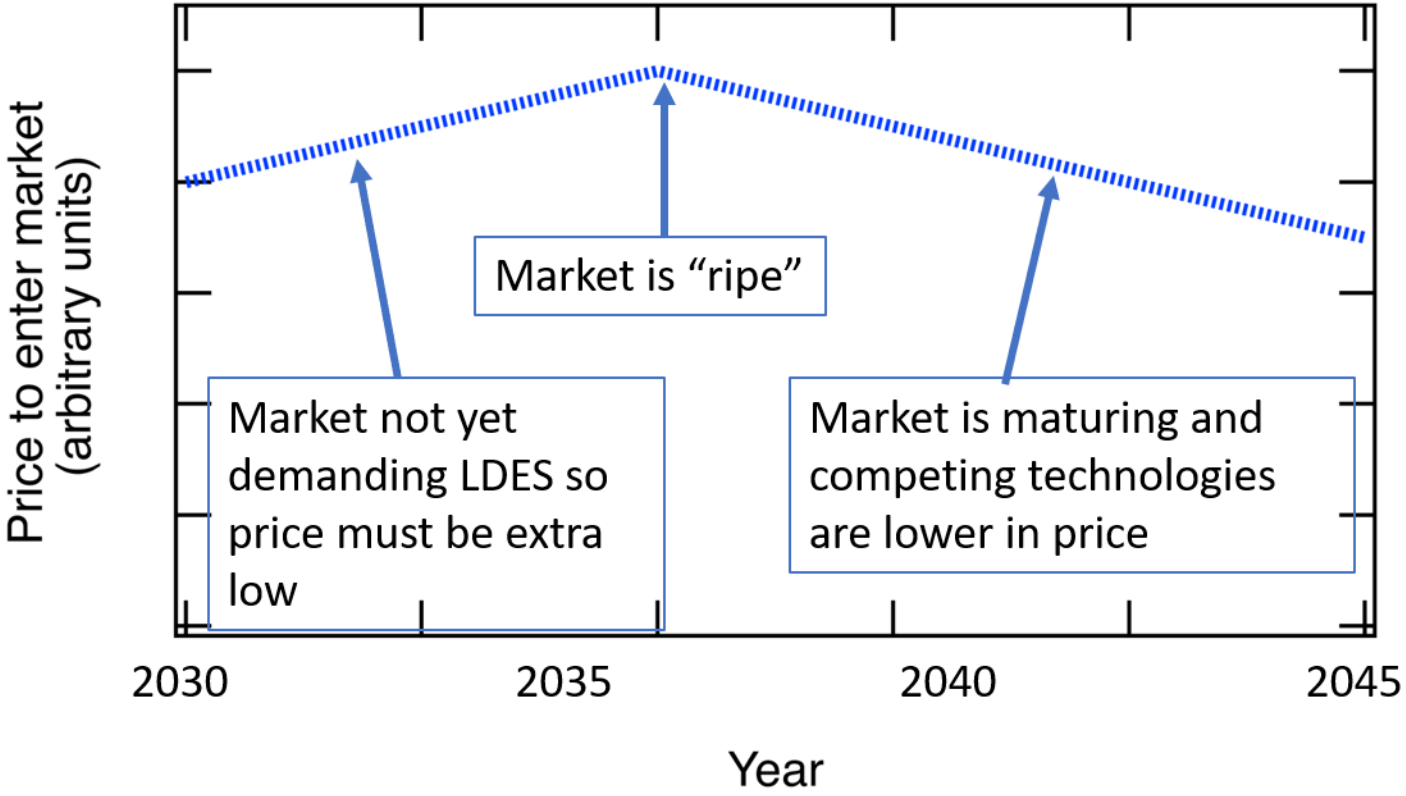
Use data from previous slide to generate graphs to guide investments



Role of LDES is very different by scenario so select a wide range of scenarios

The big picture for storage

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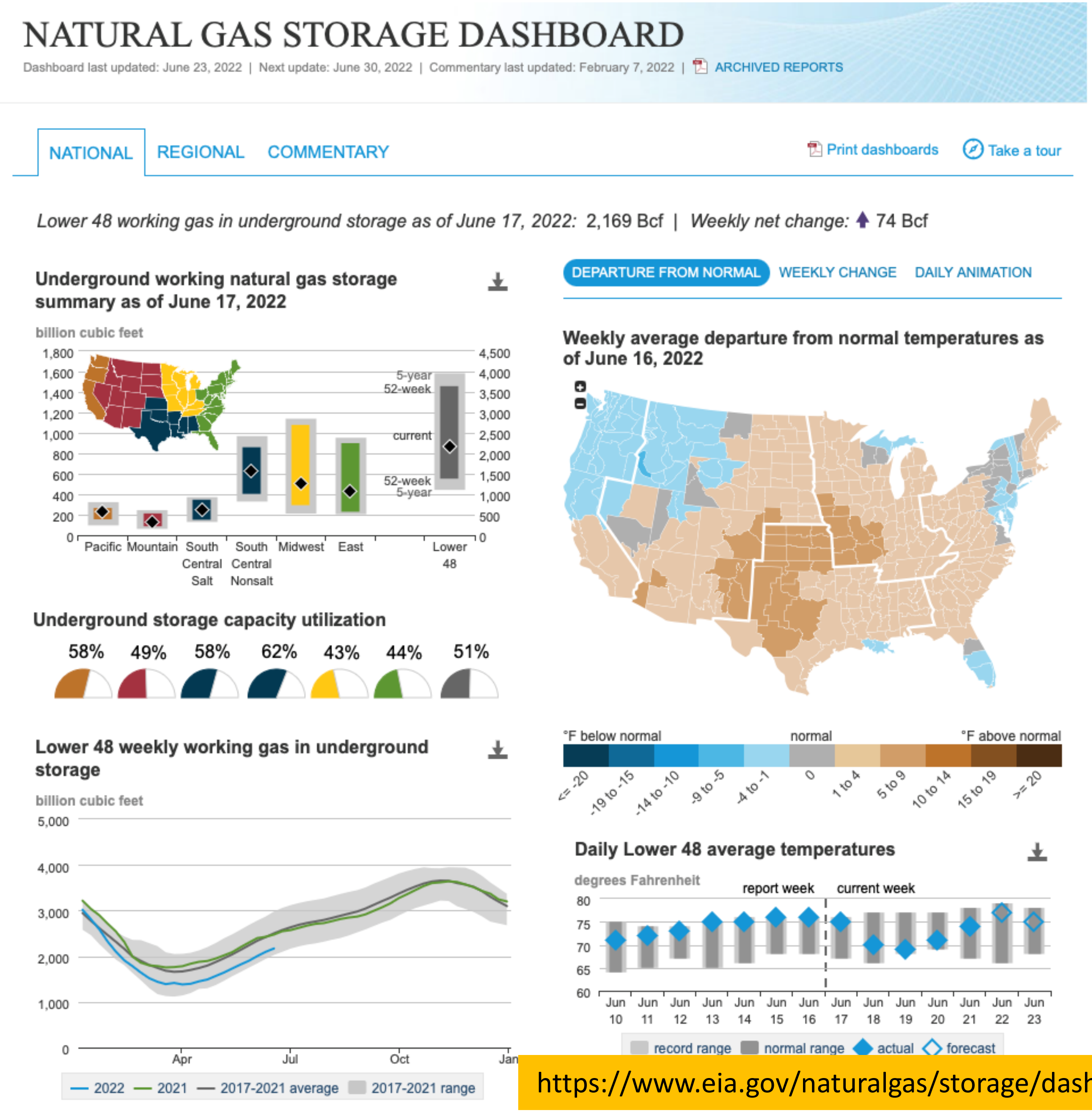

Today's energy system requires massive storage

- EIA dashboard shows 1500 to 3500 billion cubic feet of natural gas storage
- > 1,000,000 barrels of oil

Today's supply chain issues reflect need for reserves

What storage will a decarbonized world need?

As investment in hydrogen skyrockets for many applications, how will that affect the grid?
Propose to build electrolyzers and 'sell' hydrogen

https://www.eia.gov/naturalgas/storage/dashboard/

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- New pumped hydro – instruct model to build or not build – no optimization
- Vary EV charging profiles
- Allow model to select to build and operate electrolyzers and sell hydrogen
- Sensitivities: geothermal, biogas with oxycombustion, imports, transmission

Questions

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- Interested in being more involved? Join our mailing list by emailing skurtz@ucmerced.edu