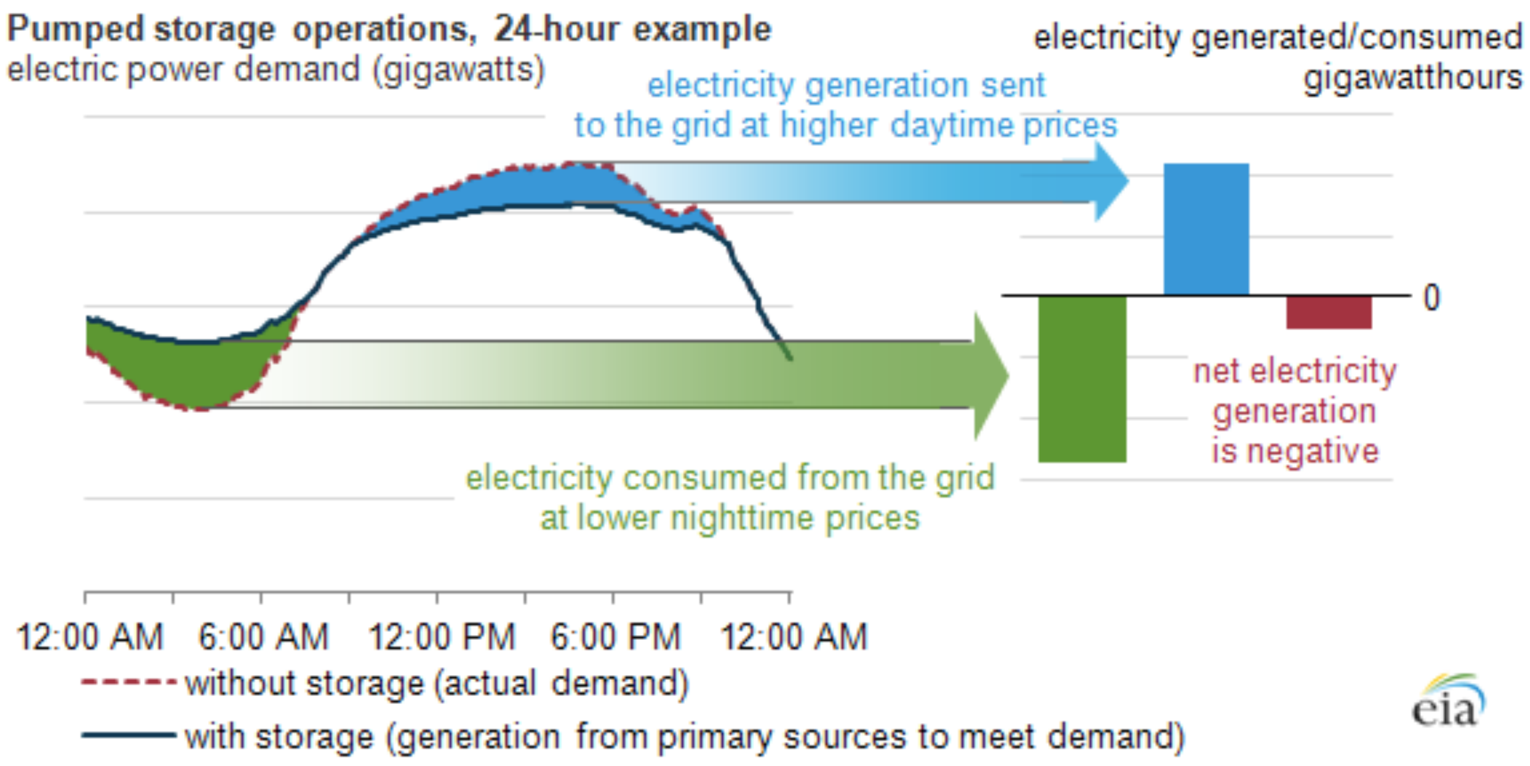
Long duration storage: context and overview

ARPA-E Workshop, December 7-8, 2017

Outline

- **Pumped storage demonstrates the value of long-duration storage**
- Wind and solar can contribute to long-term US economic strength
- Long-duration storage that is location independent offers many benefits
- Workshop participants and agenda

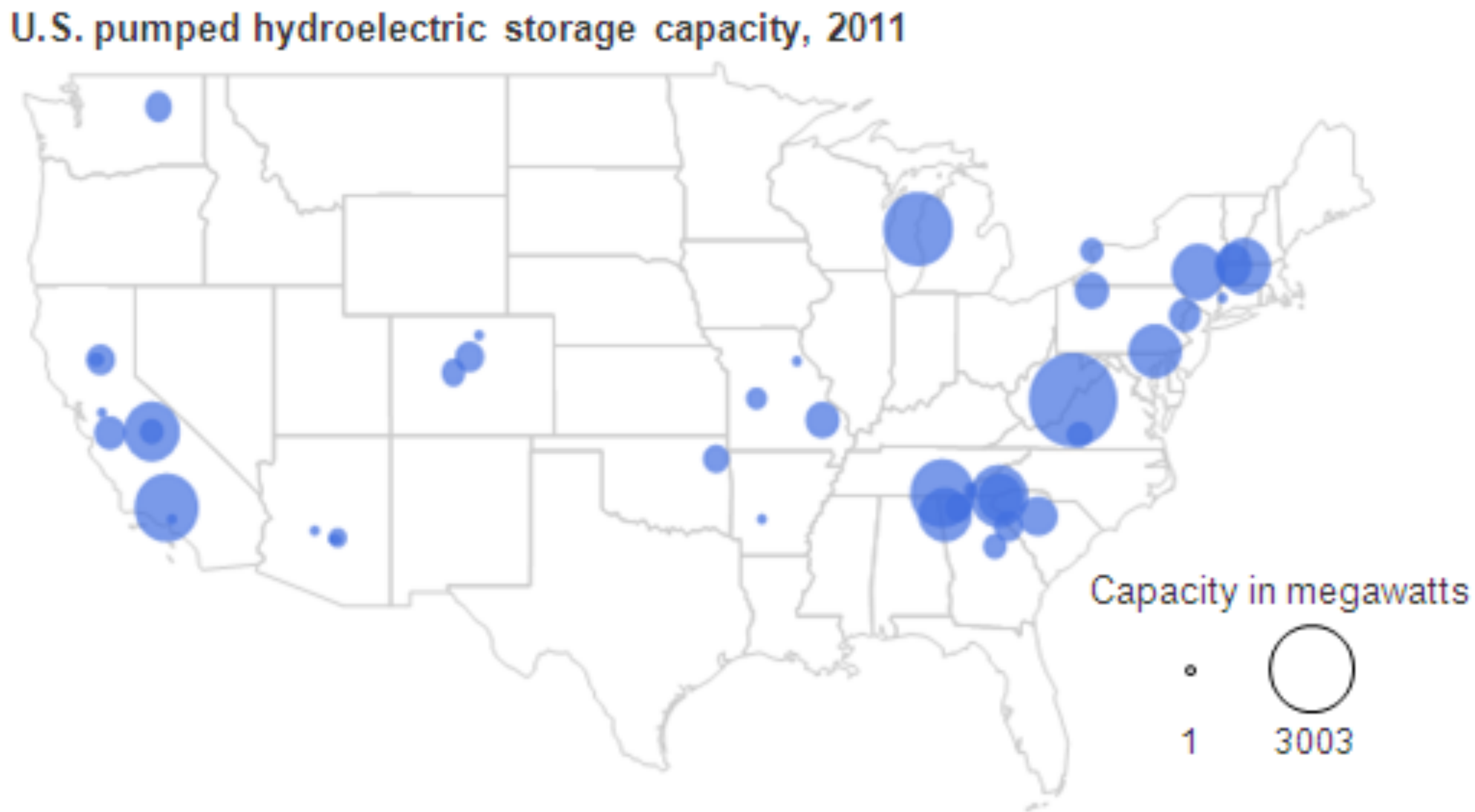
Pumped storage: long-duration storage today



https://www.eia.gov/todayinenergy/detail.php?id=11991

Pumped storage: capacity and geographic distribution

22 GW of capacity. A couple of hundred GWh.



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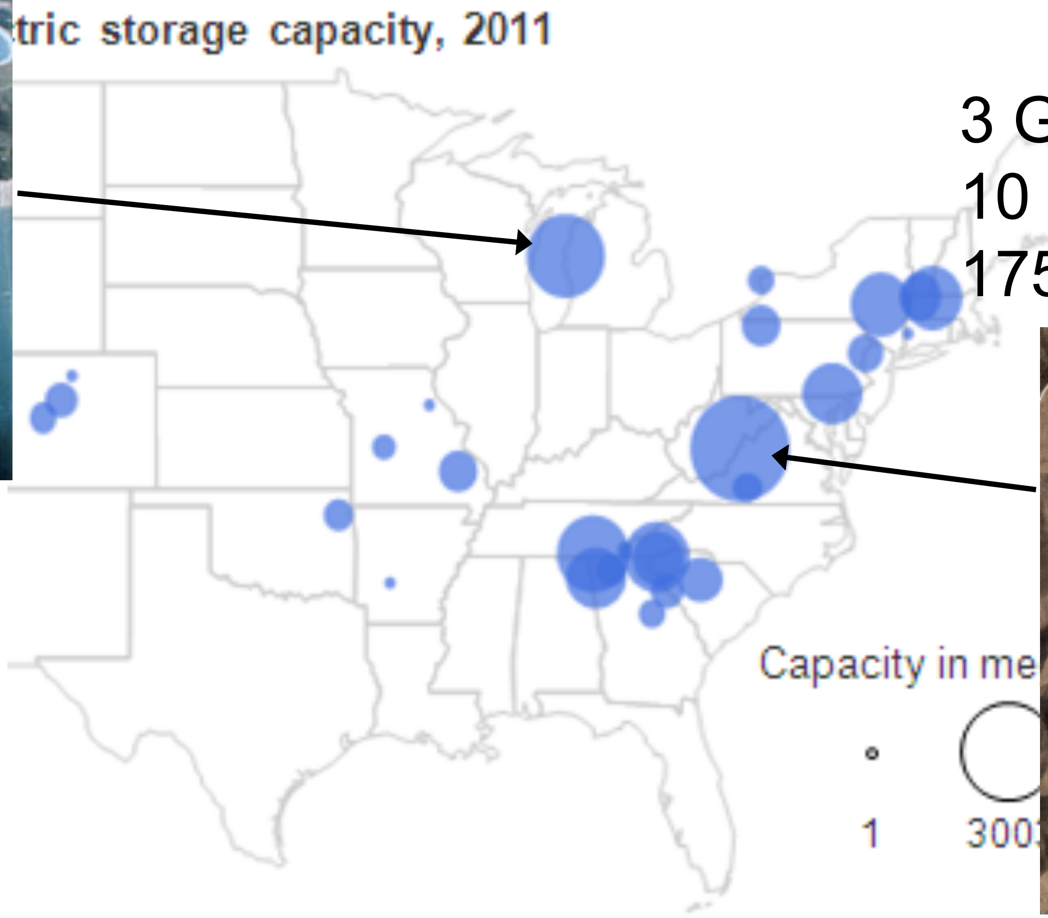
Pumped storage: example site specifications

2 GW, 25 GWh
13 hours at full power
1100 $/kW, 85 $/kWh



3 GW, 30 GWh
10 hours at full power
1750 $/kW, 175 $/kWh

Pumped storage has many benefits, but some key limitations

Benefits / Advantages

Increase overall system efficiency and asset operation

Reduce wholesale energy prices

Provides reserves and black start capability that contribute to system efficiency

Enable higher penetration of variable energy sources like wind and solar

Efficient, low cost, long cycle & calendar life

Limitations

Only works at certain locations

Requires large project sizes

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The opportunity: wind and solar are cheap and abundant

Onshore wind	Offshore wind	Solar
		
Median cost: 4.7 ¢/kWh	German bids now at 7 ¢/kWh	Median cost: 5.4 ¢/kWh
No emissions or water use	No emissions or water use No NIMBY for transmission lines	Zero emissions and little water use

arpa·e
CHANGING WHAT'S POSSIBLE

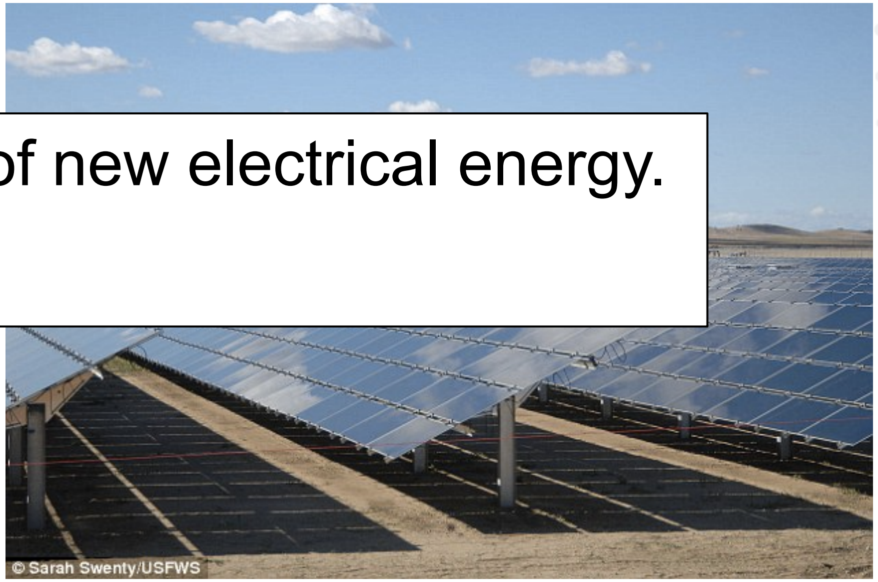
Source for costs: Lazard's Levelized Cost of Energy Analysis – Version 10, 2016,
https://www.ft.com/content/f5b164a6-20f8-11e7-b7d3-163f5a7f229c

The opportunity: wind and solar are cheap and abundant

Onshore wind

Offshore wind

Solar



These median values are the cheapest forms of new electrical energy.

Costs continue to fall!

Median cost: 4.7 ¢/kWh

No emissions or water use

German bids now at 7 ¢/kWh

No emissions or water use
No NIMBY for transmission lines

Median cost: 5.4 ¢/kWh

Zero emissions and little water use

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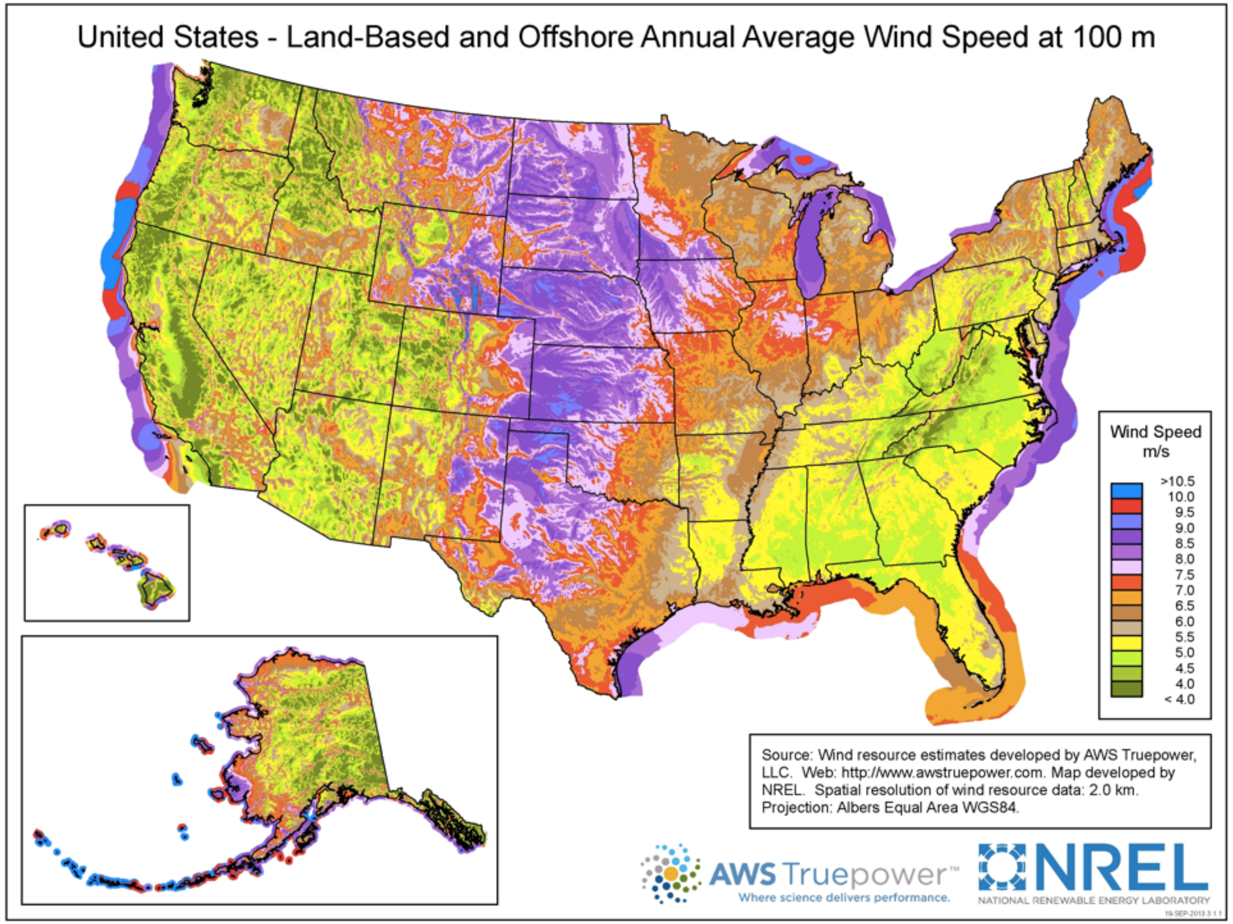
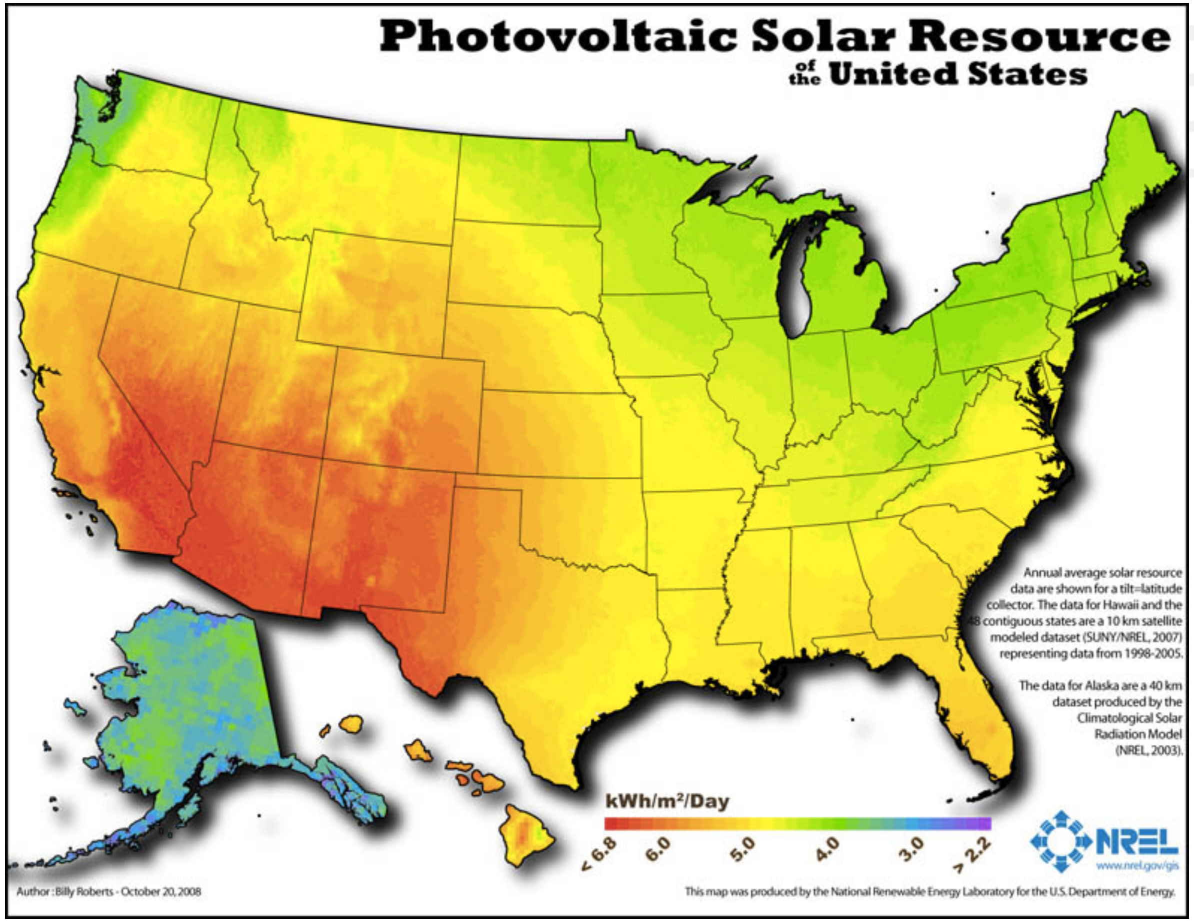
Wind and solar can provide a competitive economic advantage

Wind technical potential is >15 TW



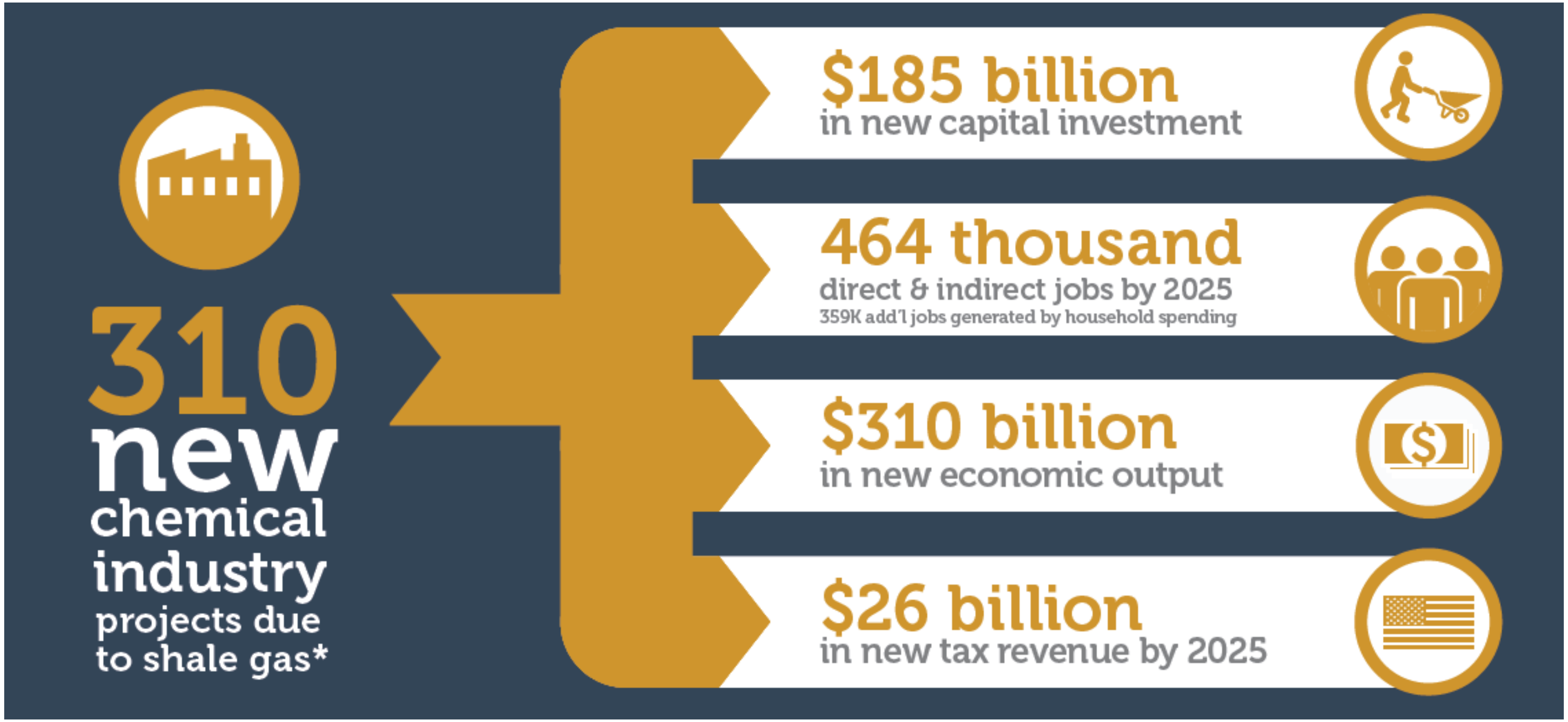
Solar technical potential is >100 TW



https://www.nrel.gov/docs/fy12osti/51946.pdf

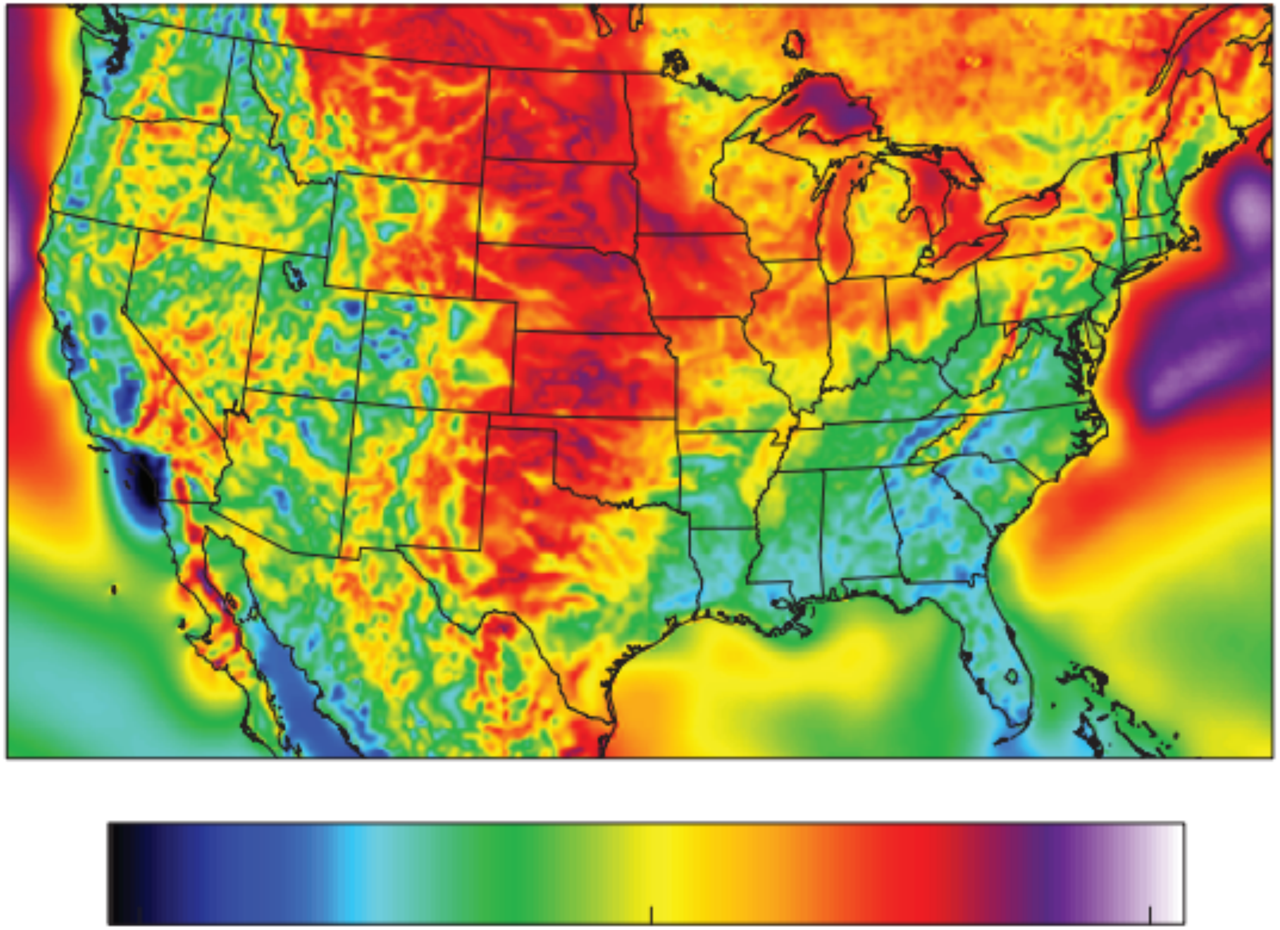
Low natural gas prices strengthen chemical, other industries

Impact of low natural gas prices on the chemical industry

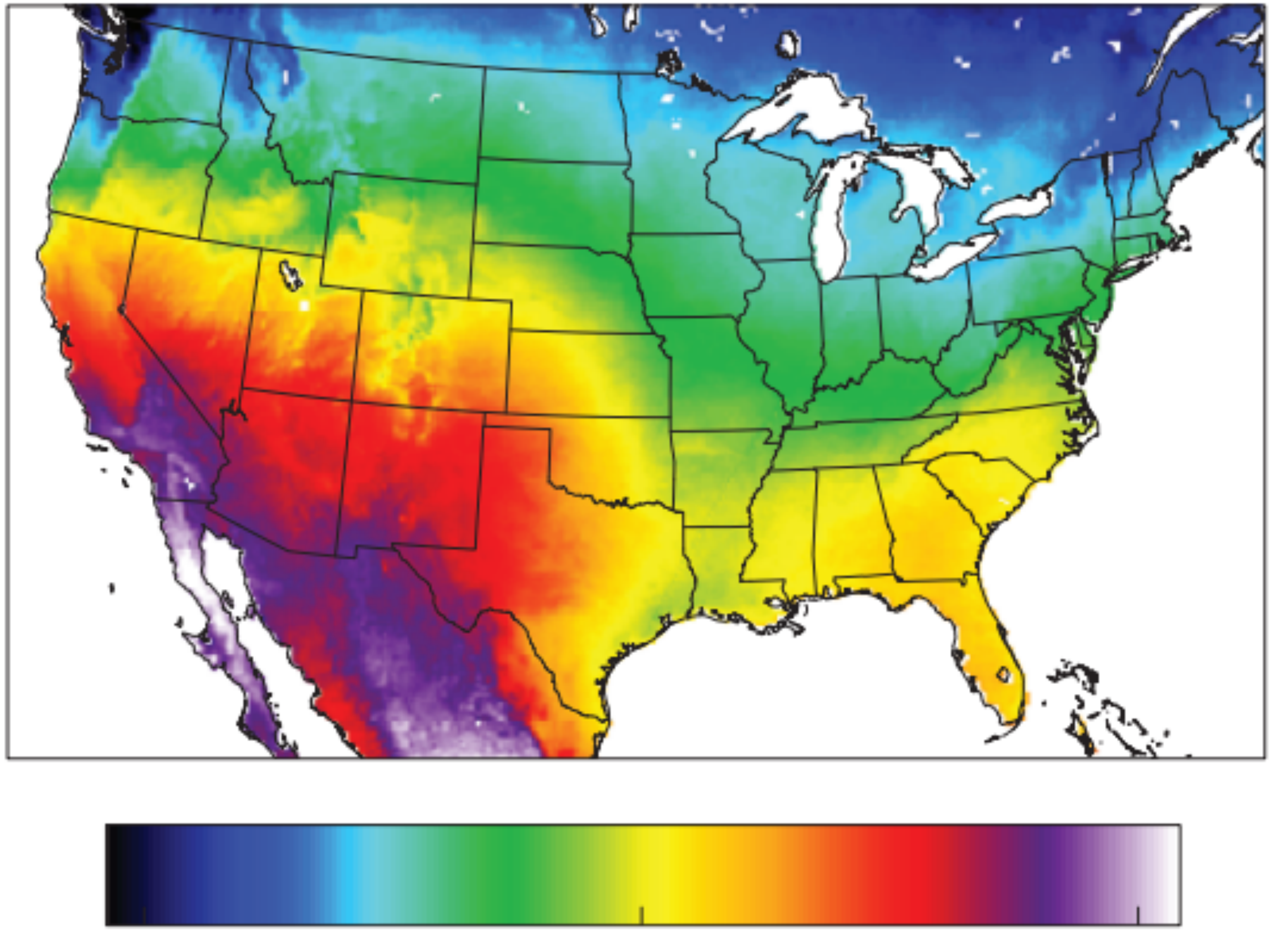


https://www.americanchemistry.com/Media/PressReleasesTranscripts/ACC-news-releases/US-Chemical-Industry-Investment-Linked-to-Shale-Gas-Tops-164-Billion.html

But wind and solar have limitations: low capacity factor

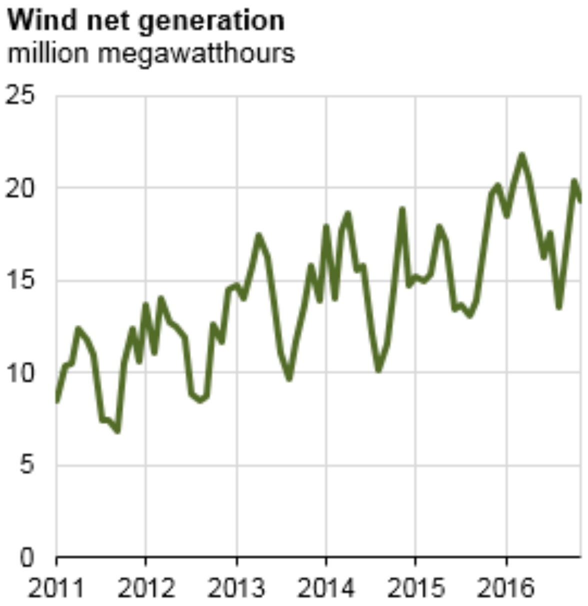


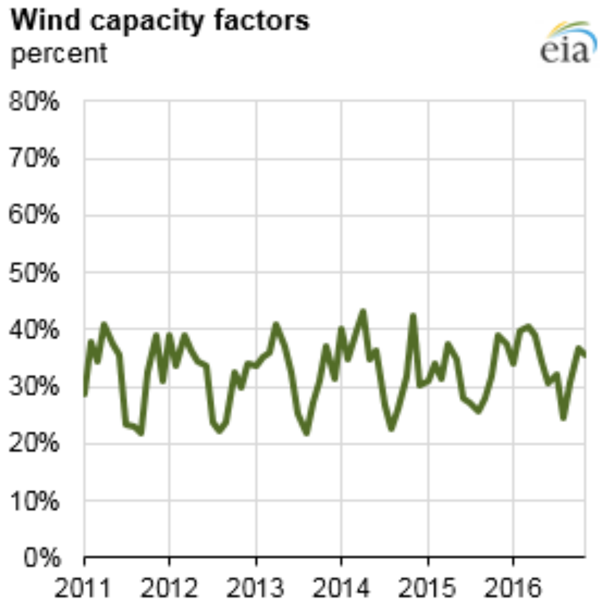
Wind capacity factor (90 m)

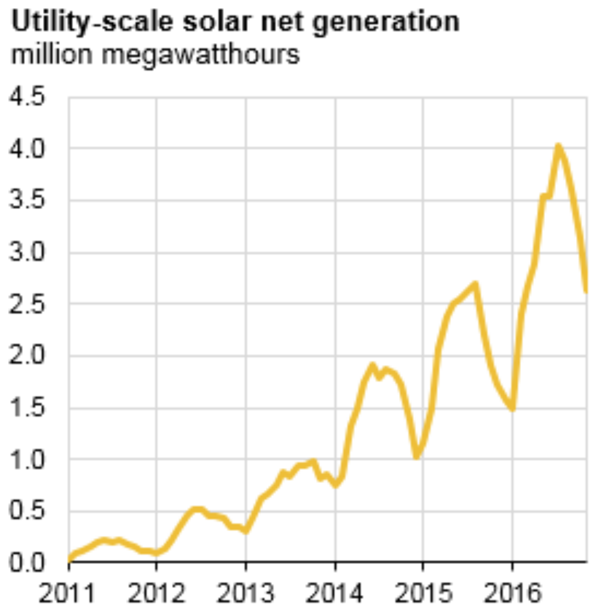


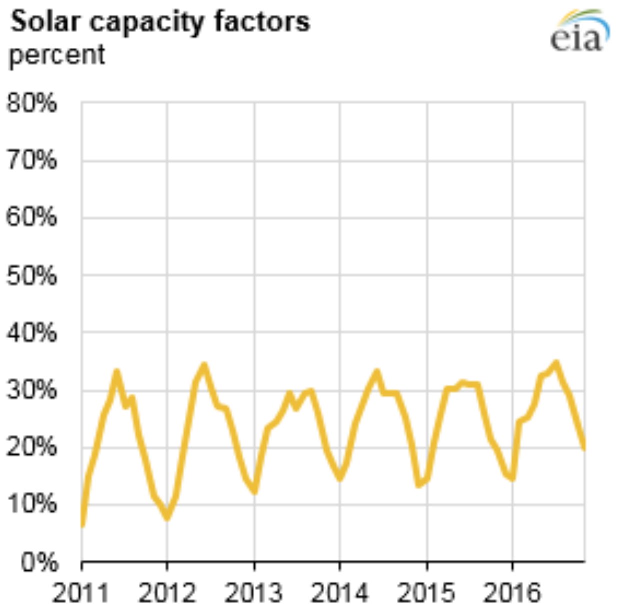
Solar capacity factor

Wind and solar are also non-dispatchable and variable









https://www.eia.gov/todayinenergy/detail.php?id=31032#tab1
https://www.eia.gov/todayinenergy/detail.php?id=31072

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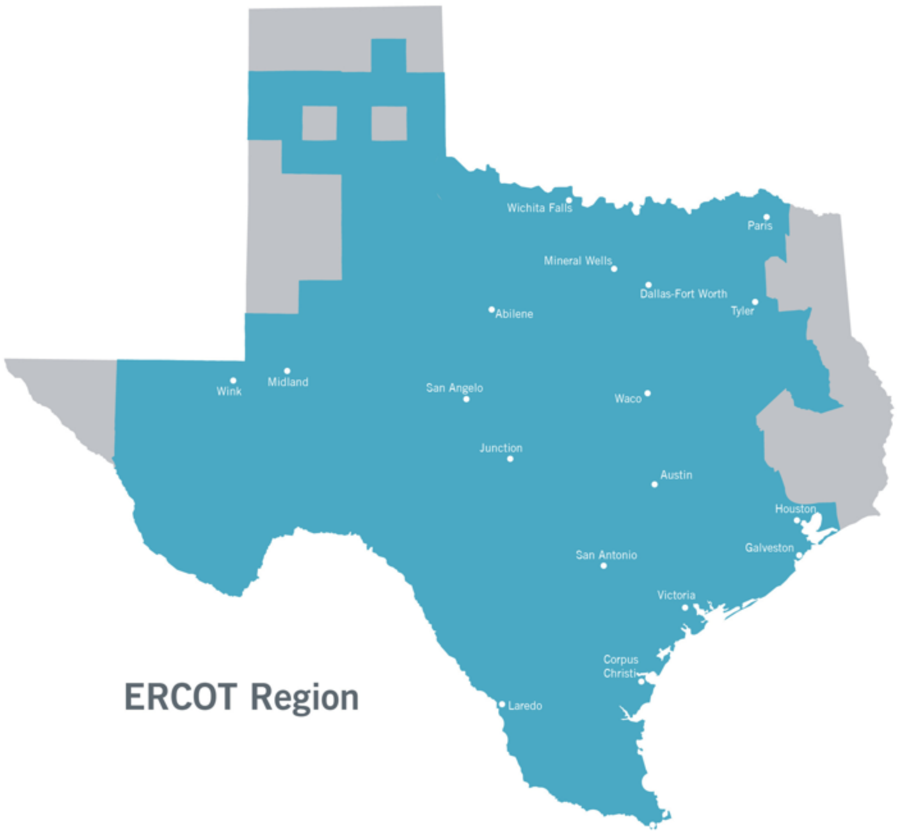
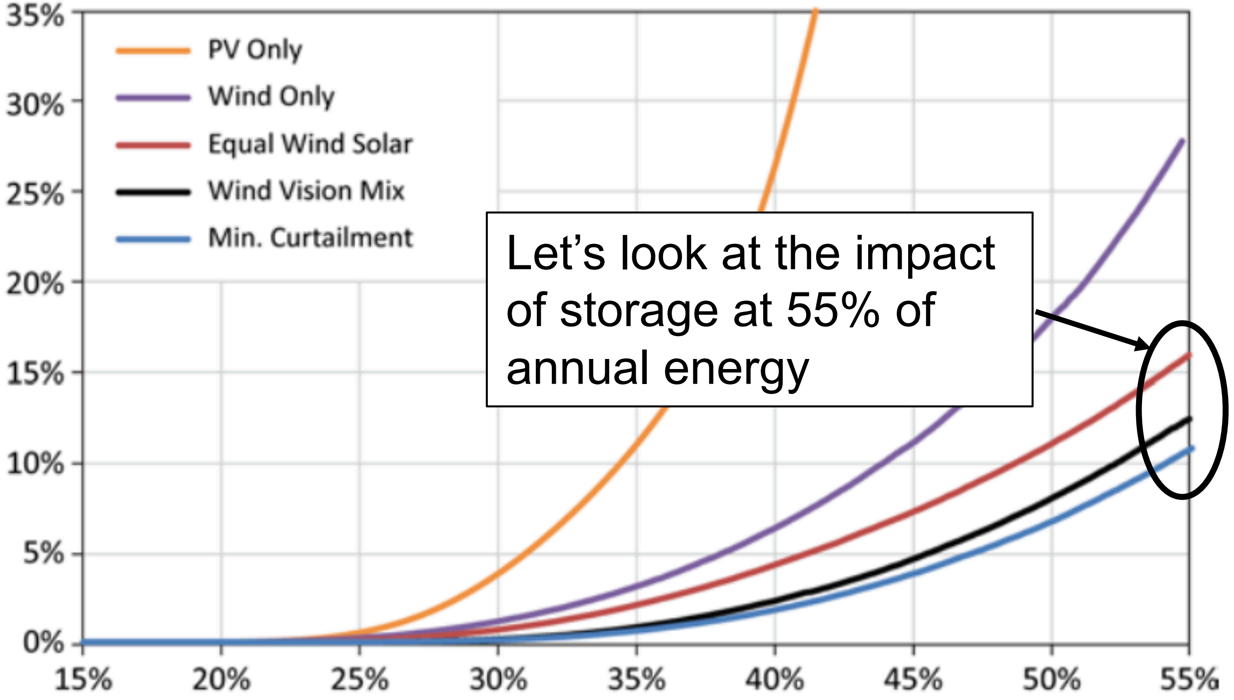
Wind and solar hit challenges at >30 to 50% penetration

ERCOT is a large grid, >70 GW peak demand today
NREL looks at ERCOT renewable integration through 2050



Fraction of wind and solar curtailed
(*no storage*)



Fraction of annual energy from wind and solar

Storage is one way to add more wind and solar

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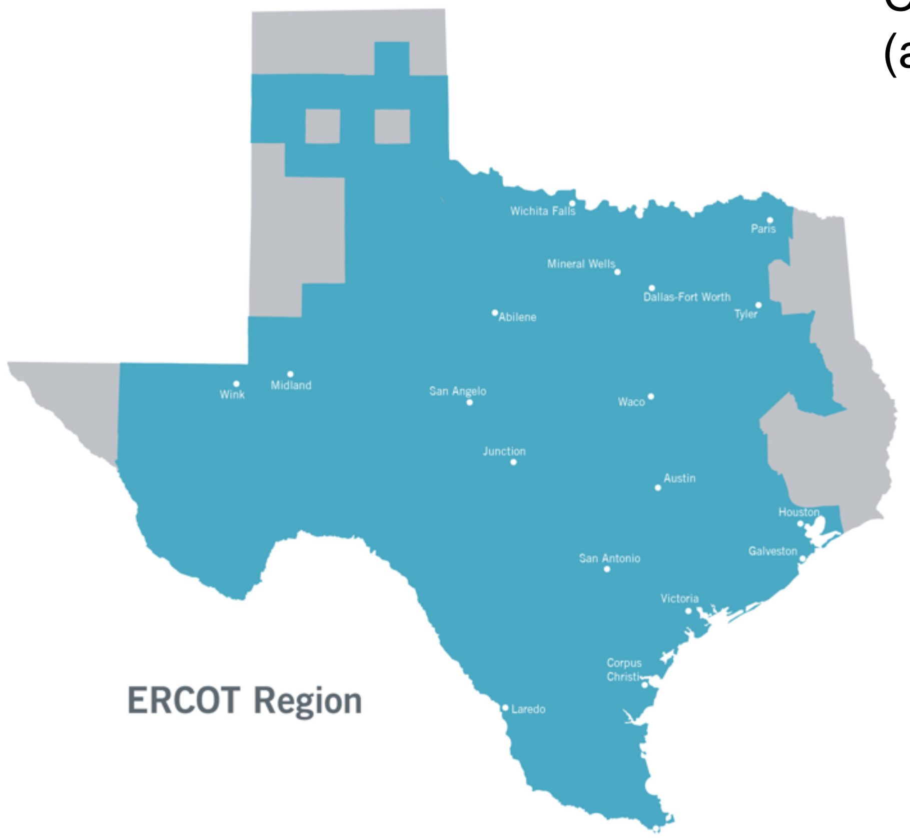
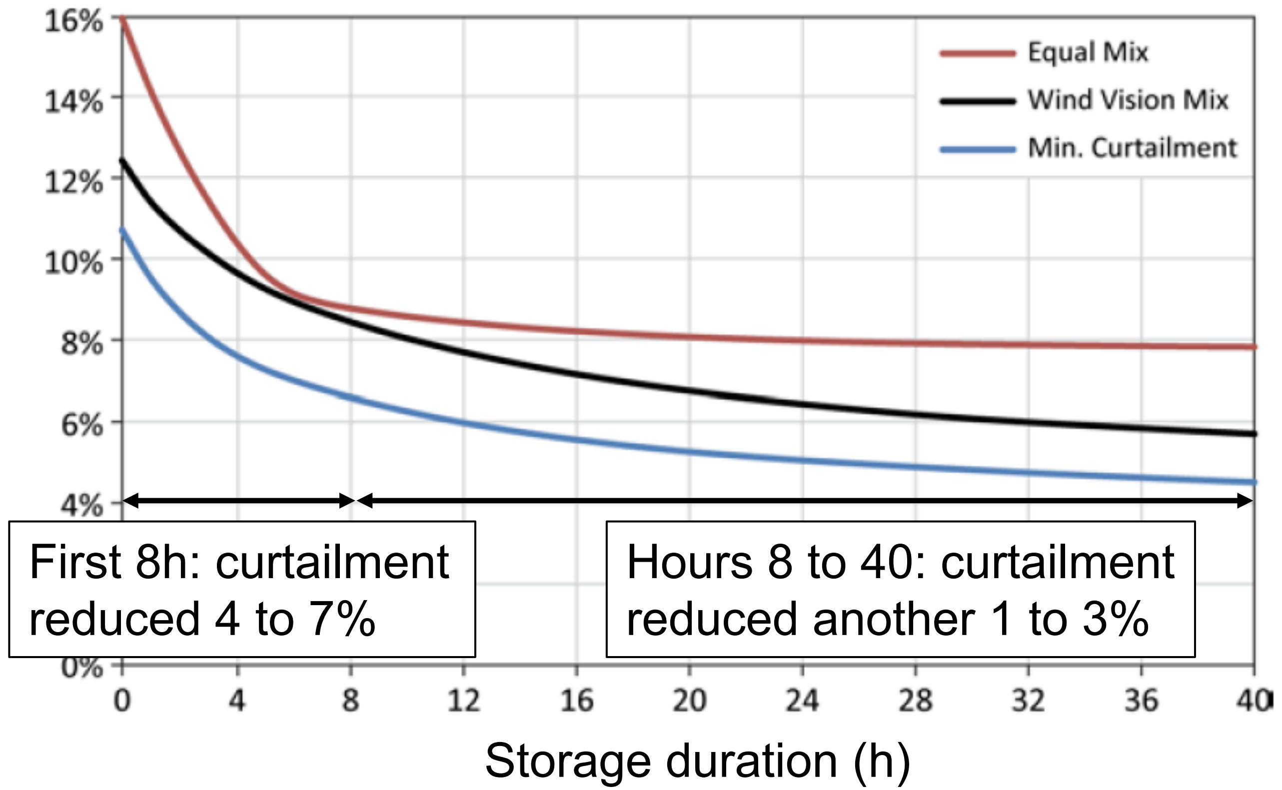
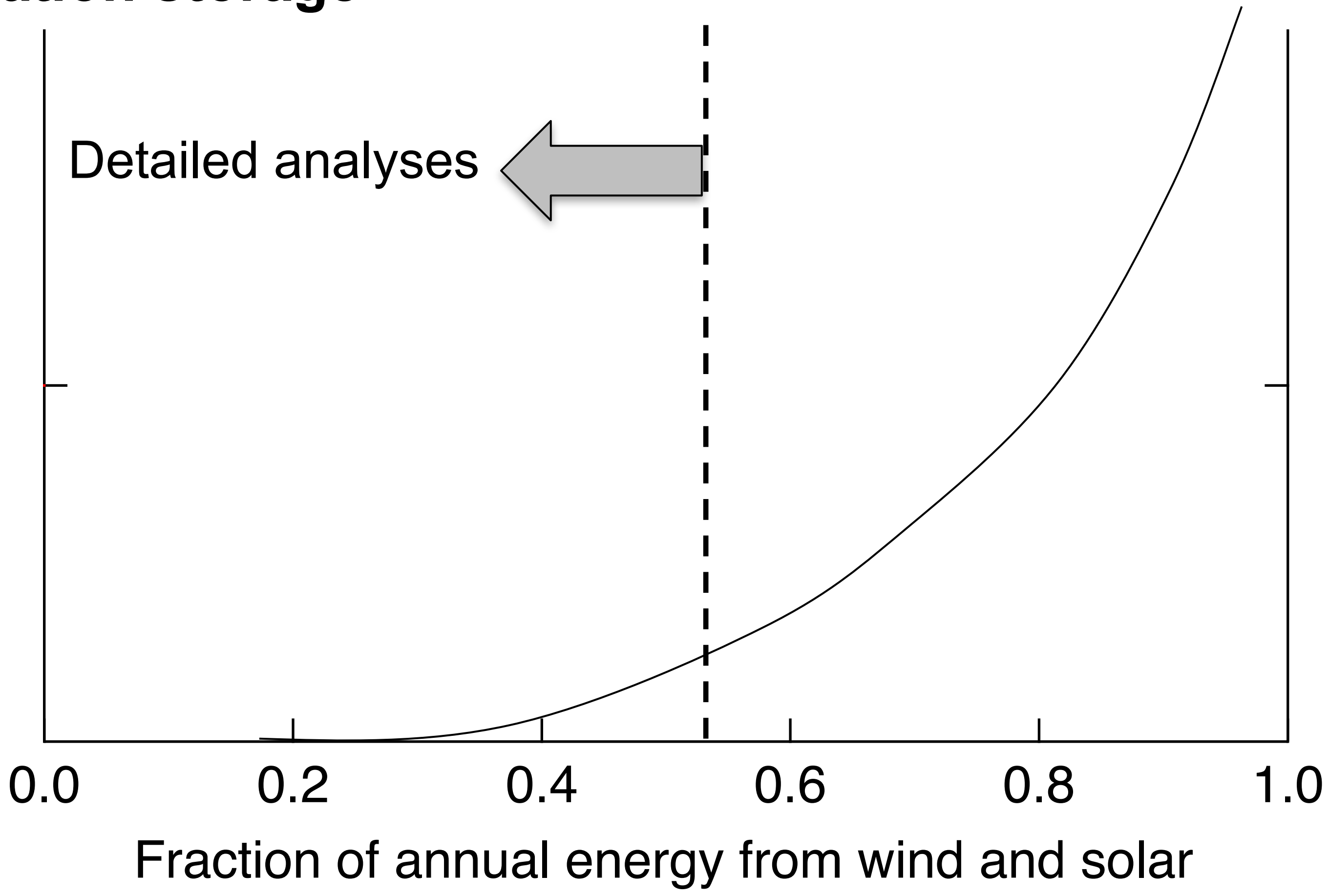


Curtailment at 55% of annual energy
(assuming 8.5 GW of storage)



Wind and solar at >55% annual energy will be a challenge

Role for new/better technologies, including long-duration storage



Credit to Paul Denholm for this figure

Resiliency/backup: storage durations of 24 to 96 hours are typical

- Example: for hospitals, required backup durations are 24 to 96 hours.
- Backup generators cost ~500 $/kW installed.

http://www.facilitiesnet.com/healthcarefacilities/article/NFPA-110s-Fuel-Requirements-Can-Help-Guide-Backup-Power-Plan-For-Hospitals-Facilities-Management-Health-Care-Facilities-Feature--14338

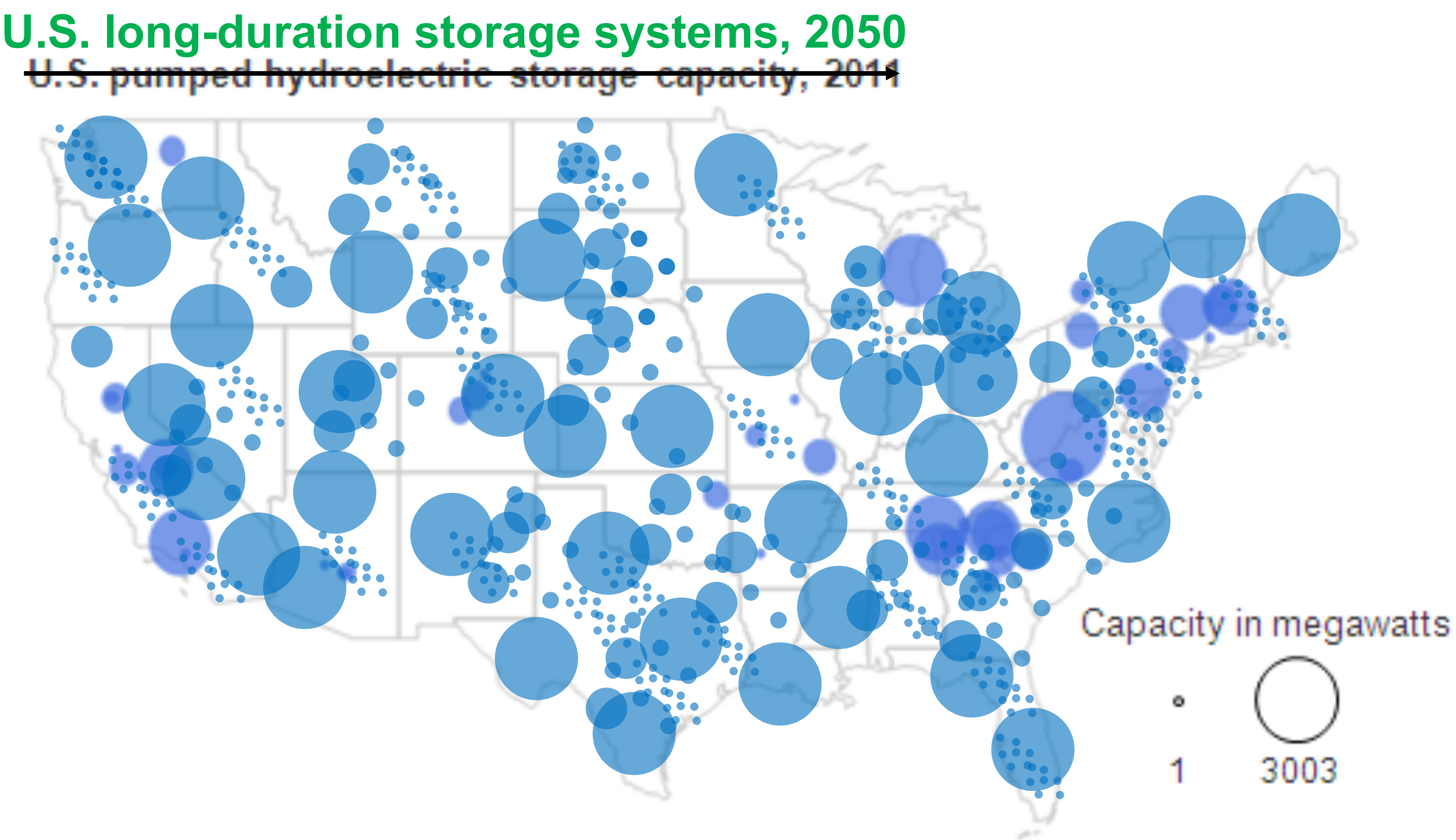
Transmission deferral: 8h projects are happening now

Tesla Powerpacks will supply Nantucket's backup power

The 48 megawatt-hour system will require over 200 Powerpacks.

6 MW, 48 MWh to stabilize the grid and defer the addition of a new sub-sea transmission cable

Future long-duration storage map?



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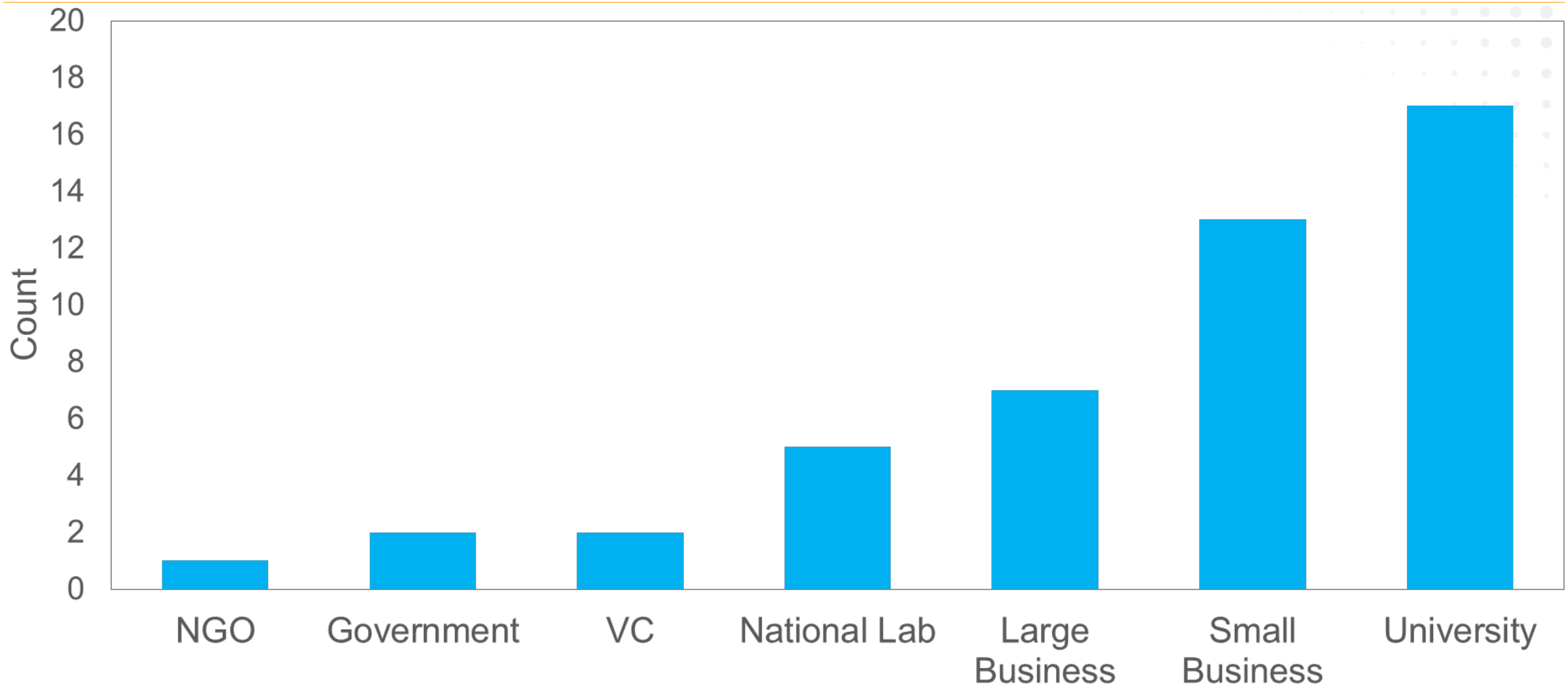
- **Workshop participants and agenda**

A variety of institutions are in attendance



Thursday, December 7th

Time	Agenda Item
10:00 a.m.	1-on-1 meetings with ARPA-E Program Director and staff (Medallion Room)
	NOTE: Lunch will not be served on Day 1.
11:00 a.m.	Registration Opens
12:00 p.m.	Eric Rohlfing, ARPA-E Acting Director Paul Albertus, ARPA-E Program Director
12:25 p.m.	Marco Ferrara, Baseload Renewables
	Ryan Jones, Evolved Energy
	Aidan Tuohy, EPRI
	Raj Apte, X
	Panel discussion with presenters
1:45 p.m.	Break
2:00 p.m.	Paul Albertus, ARPA-E Program Director
	Jarrod Milshtein, Giner
	Justin Raade, former CEO of Halotechnics
	Ravi Annapragada, UTRC
	Panel discussion with presenters
3:20 p.m.	Break and transition to breakout session #1
3:45 p.m.	Breakout Session 1: *Establish performance and identify technology development opportunities for current state of the art electricity storage systems with 8 to 20 hours of duration* *Breakout Group 1: Signature Ballroom (same room as General Session)* *Breakout Group 2: Medallion Room (Lobby Level, near Gift Shop)* *Breakout Group 3: Duet Room (2nd Floor)* *Breakout Group 4: Leander Rom (2nd Floor)*
5:40 p.m.	Break and transition back to main room for readout
6:00 p.m.	Readout and panel discussion from Breakout Session 1

Friday, December 8th

Time	Agenda Item
7:30 a.m.	Breakfast & Networking
8:00 a.m.	Imre Gyuk, DOE Office of Electricity
	Jay Whitacre, Carnegie Mellon University
	Yet-Ming Chiang, MIT
	Rob Braun, Colorado School of Mines
	Josh Posamentier, Congruent Ventures
9:30 a.m.	Break and transition to breakout session 2
9:45 a.m.	Breakout Session 2: *Identify innovative approaches to scale electricity storage systems beyond 20 h at rated power. Discuss lower limits on cost for various technology classes and how aggressive cost targets can be realized. Provide feedback on proposed program problem statement, scope, and target metrics.* *Breakout Group 1: Signature Ballroom (same as General Session)* *Breakout Group 2: Medallion Room (Lobby Level, near Gift Shop)* *Breakout Group 3: Duet Room (2nd Floor)* *Breakout Group 4: Leander Room (2nd Floor)*
11:30 a.m.	Break and transition back to main room for readout
11:45 a.m.	Readout and panel discussion from Breakout Session 2
12:20 p.m.	Lunch (provided)
12:30 p.m.	1-on-1 meetings with ARPA-E Program Director and staff (Medallion Room)
1:30 p.m.	Adjourn (except those with scheduled 1-on-1 meetings)
2:00 p.m.	1-on-1 meetings conclude