Advancing breakthrough energy storage technologies

PJM Emerging Technologies Forum

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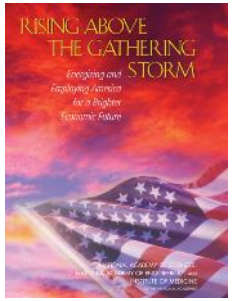
U.S. Department of Energy

March 16, 2023

ARPA-E OVERVIEW

Our history

In 2007, The National Academies recommended Congress establish an Advanced Research Projects Agency within the U.S. Department of Energy to **fund advanced energy R&D**.



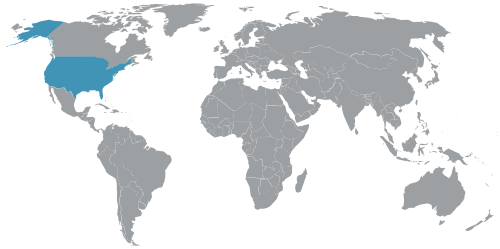
2007

Rising Above the Gathering Storm **Published** - Warning policymakers that U.S. advantages in science and technology had begun to erode

America COMPETES Act **Signed** – Authorizing the creation of ARPA-E

2009

American Recovery & Reinvestment Act **Signed** – Providing ARPA-E its first appropriations of $400 million, which funded ARPA-E's first projects



2023

1,415+ Awards
69+ Programs

Current Funding:
$470M
(FY'23)

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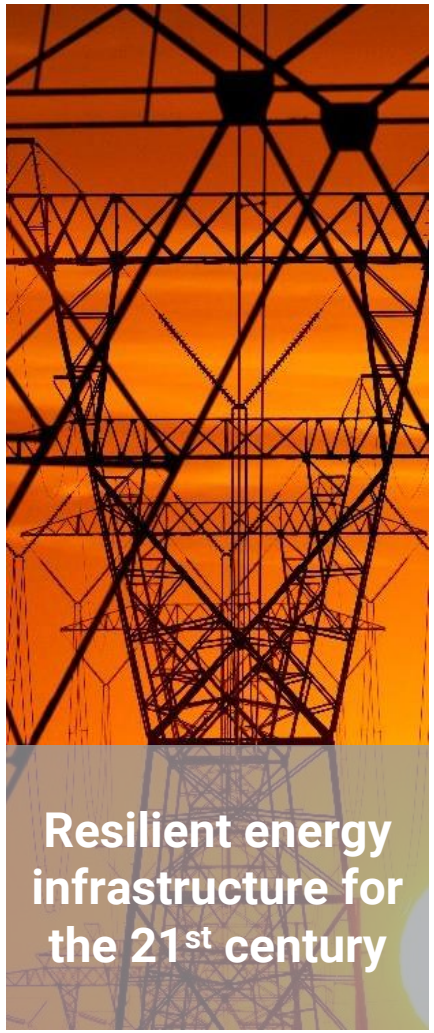
What problems are we trying to solve?



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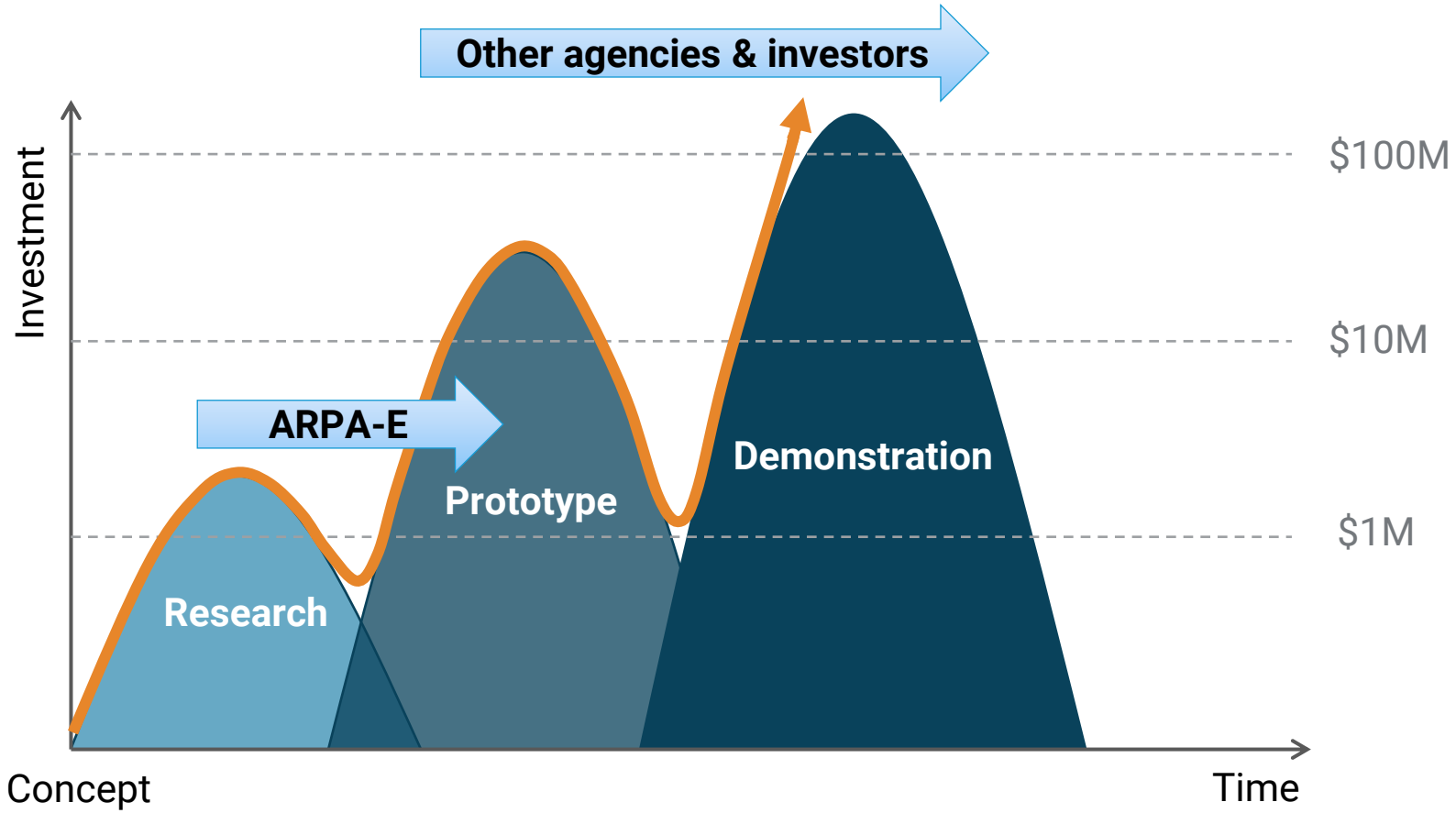
We create “mountains of opportunity” for energy technology



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ARPA-E program portfolio

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Our impact

Since 2009 ARPA-E has provided

$3.27 billion

in R&D funding to more than **1,415 projects**

200 projects

have attracted more than

$11 billion

in private-sector follow-on funding

131 companies

formed by **ARPA-E projects**

26 exits

market valuations worth

$21.8 billion

from mergers, acquisitions, and IPOs

281 projects

have **partnered with other government agencies** for further development

6,257

peer-reviewed **journal articles** from ARPA-E projects

934 patents

issued by U.S. Patent and Trademark Office

289 licenses

reported from ARPA-E projects

As of September 2022

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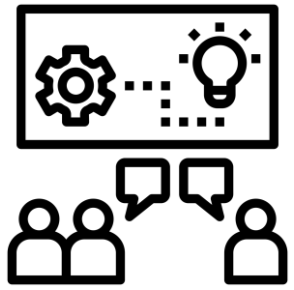
How to engage with us



Workshops

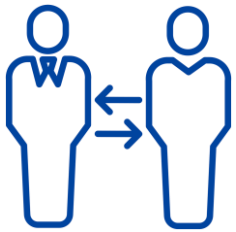
Teaming lists

Funding opportunity announcements

Annual meetings

Energy Innovation Summit

Regional showcases



1:1 engagements

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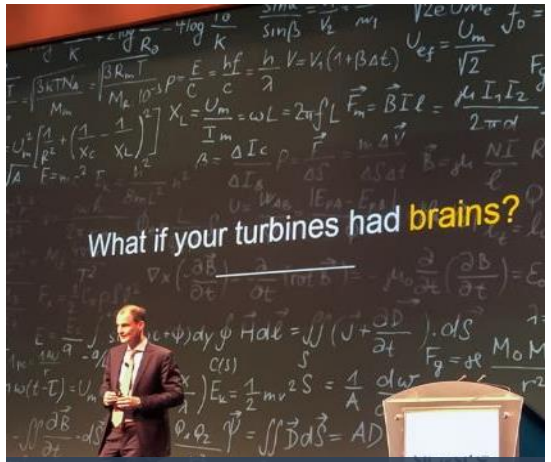
arpa·e energy innovation summit

Highly Selective Technology Showcase



Inspiring Keynotes

Unparalleled Networking

Fast-Paced Technology Pitches

arpae-summit.com

March 22-24, 2023 | National Harbor, Maryland


If it works...
will it matter?

OUR WORK TO ADVANCE BREAKTHROUGH ENERGY STORAGE TECHNOLOGIES

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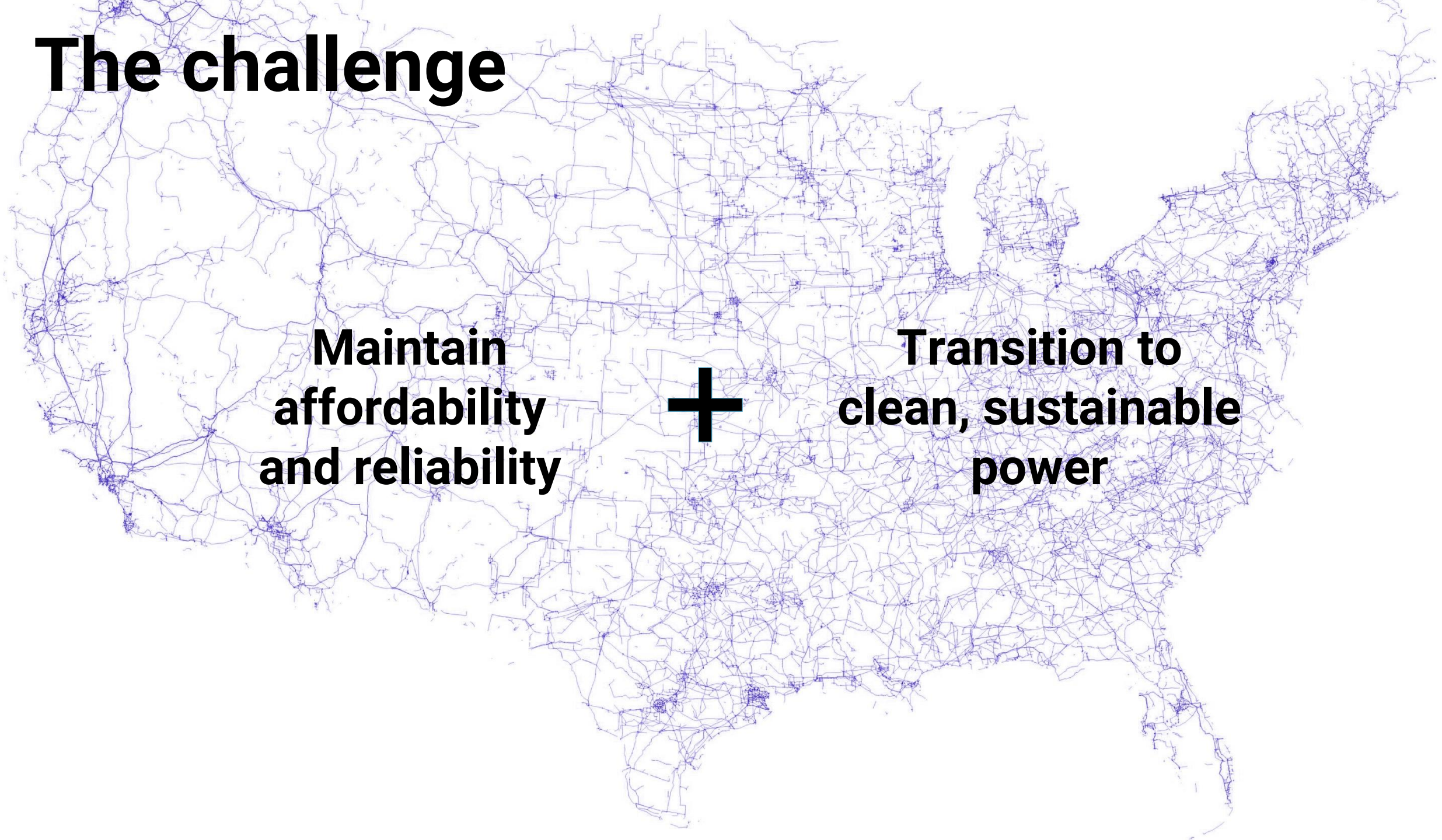
The world’s largest machine

The challenge



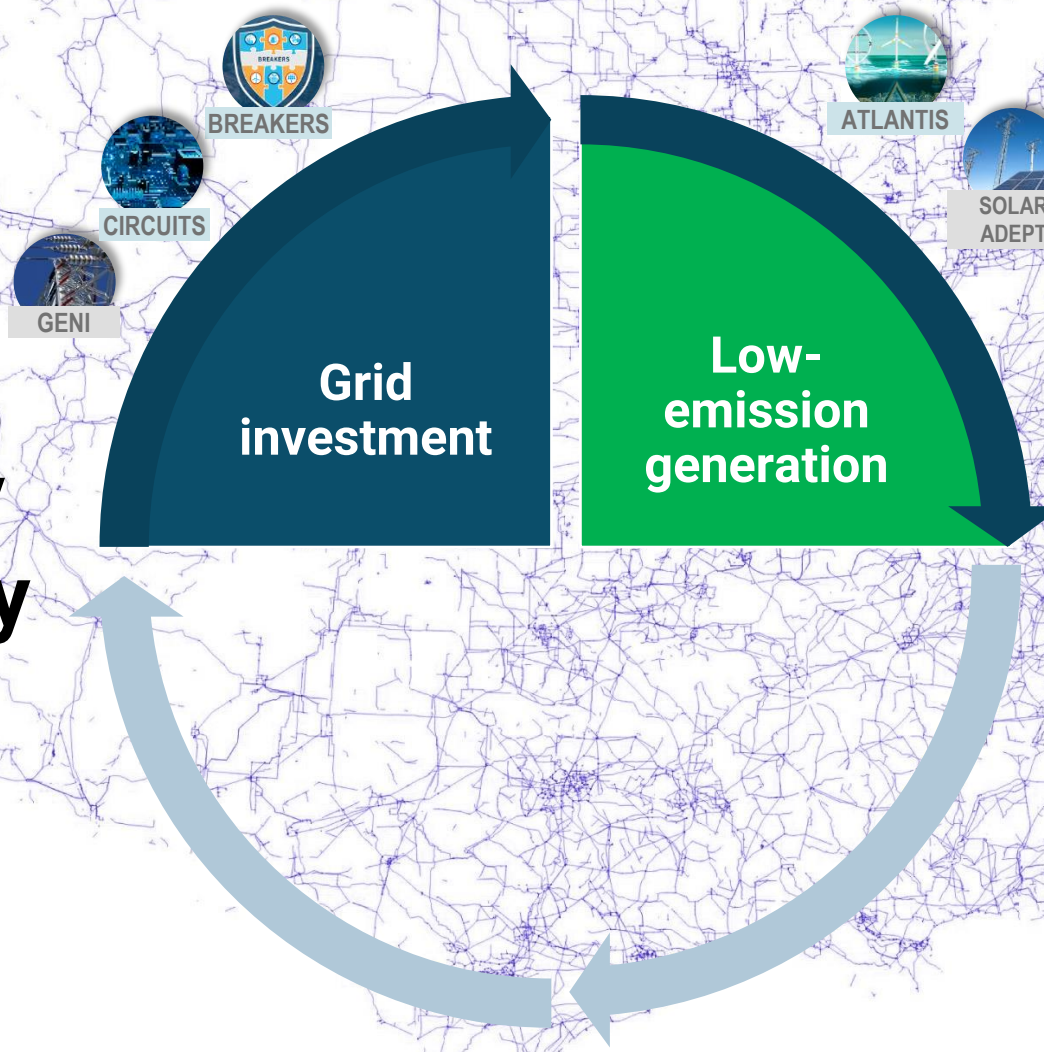
Maintain affordability and reliability

+

Transition to clean, sustainable power

Two key elements…

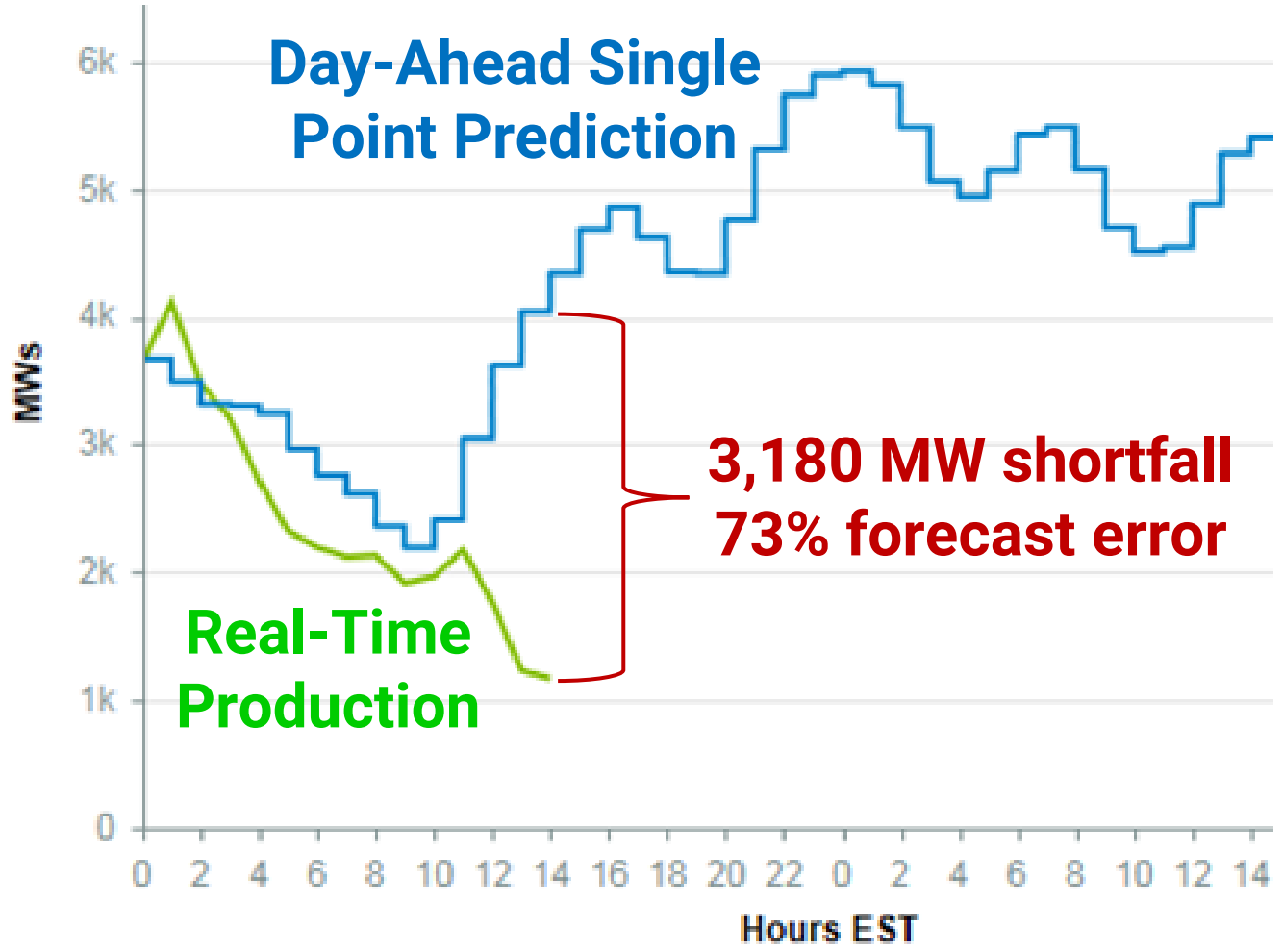
Maintain affordability and reliability



Transition to clean, sustainable power

Representative, not exhaustive, ARPA-E programs

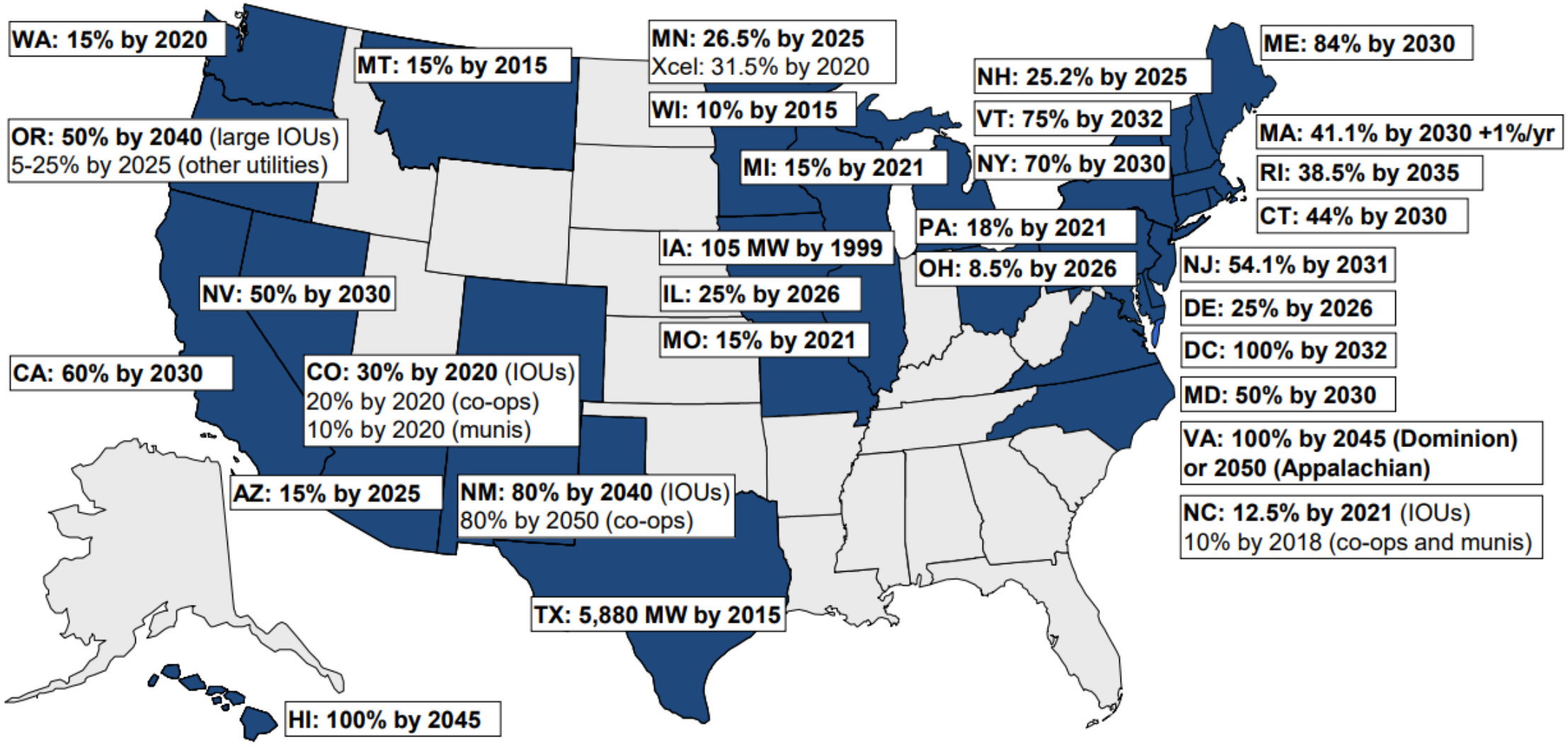
… but then this happens



MISO Renewable Day-Ahead Forecast and Real-Time Production for June 26, 2019

And it doesn't get easier

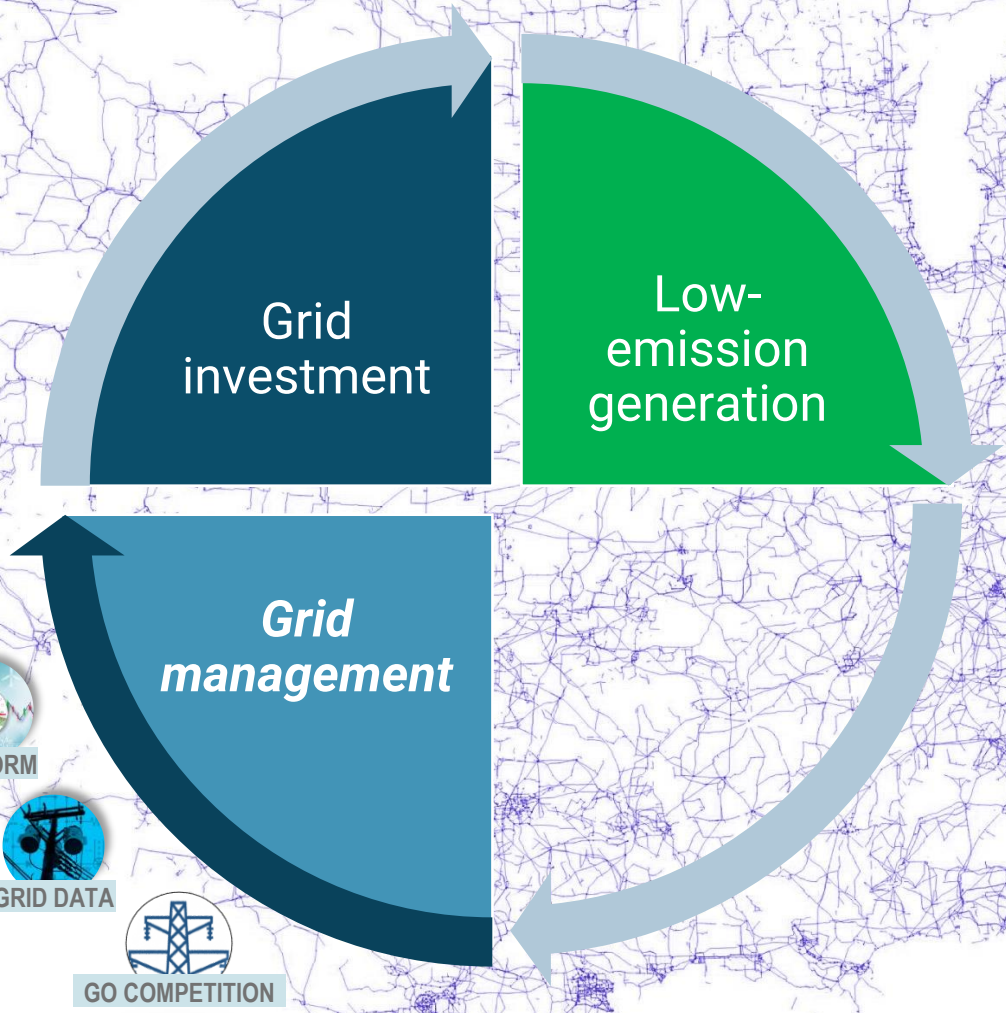
RPS Policies in 30 States + DC



Source: Berkeley Lab, February 2021

So, new operational tools are needed…

Maintain affordability and reliability

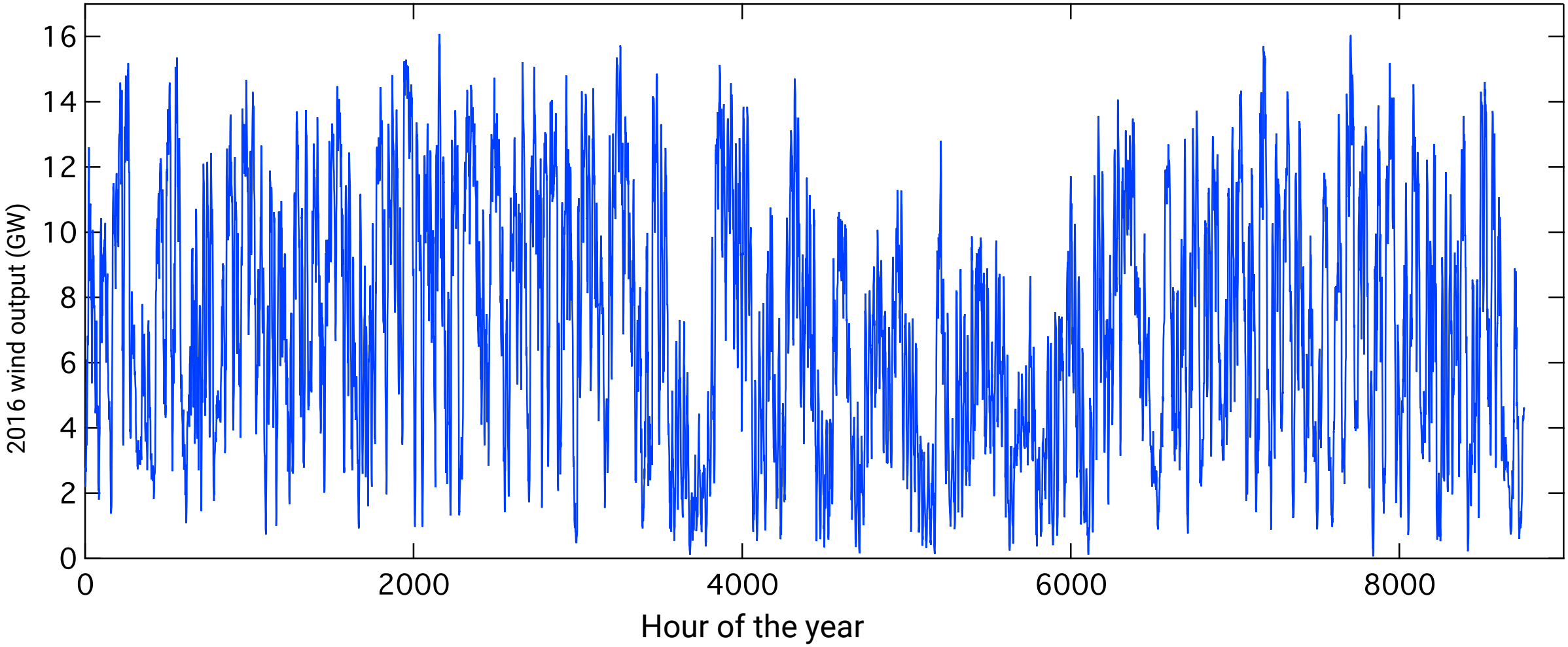


Transition to clean, sustainable power

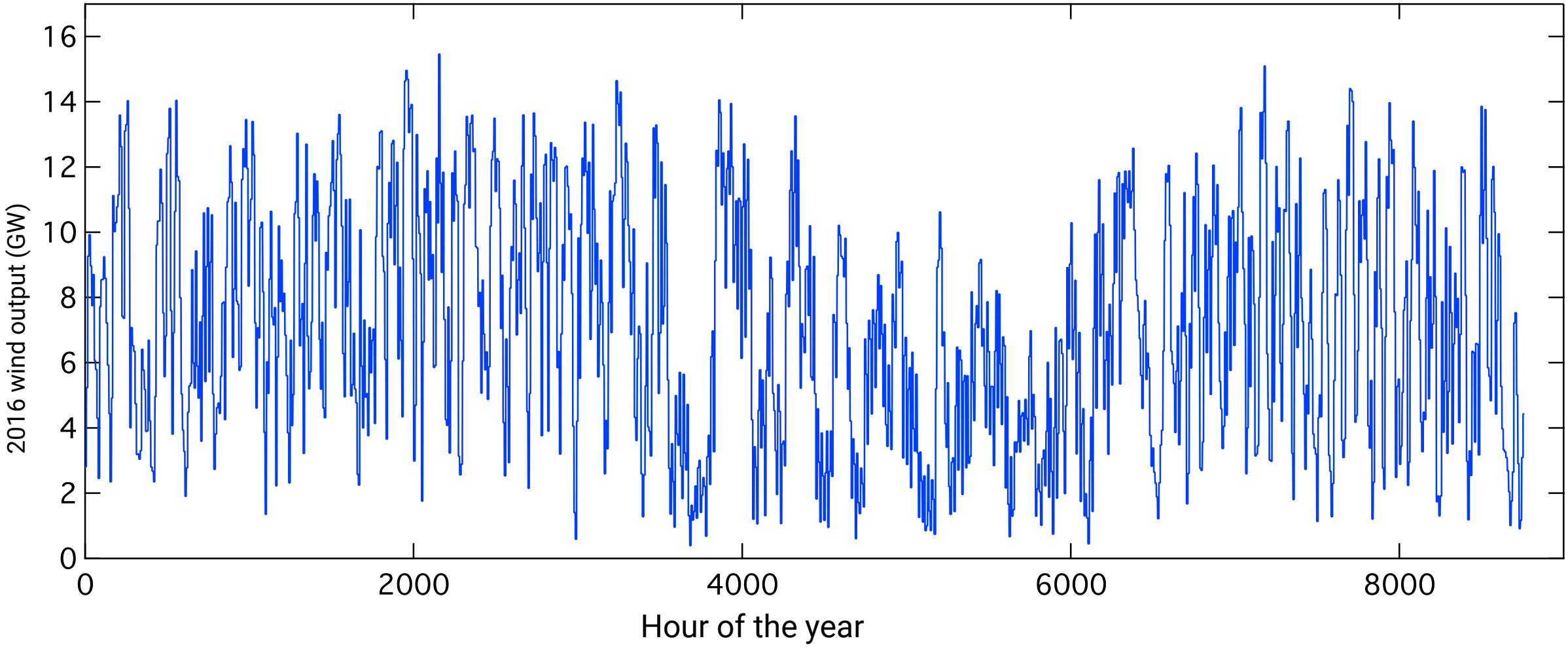
Representative, not exhaustive, ARPA-E programs

But you still have this…

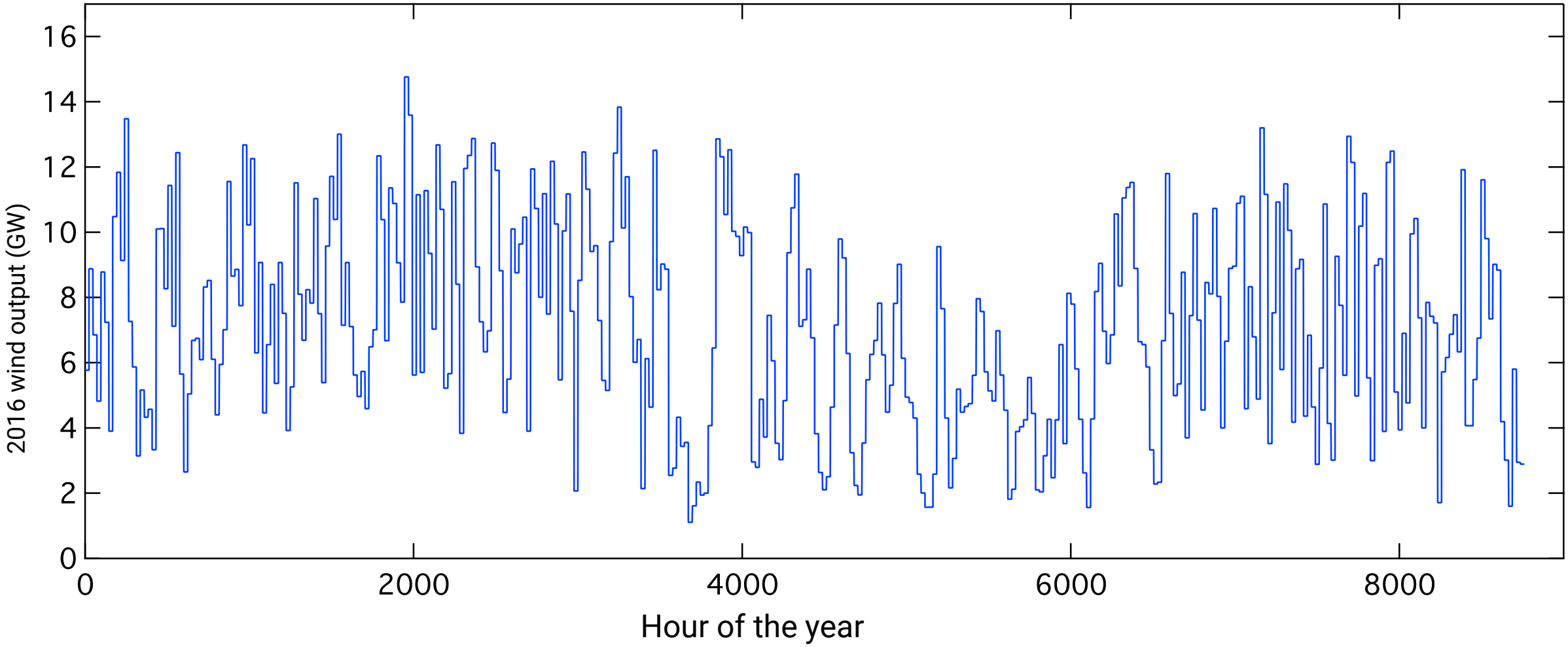
One-hour time blocks for Texas wind



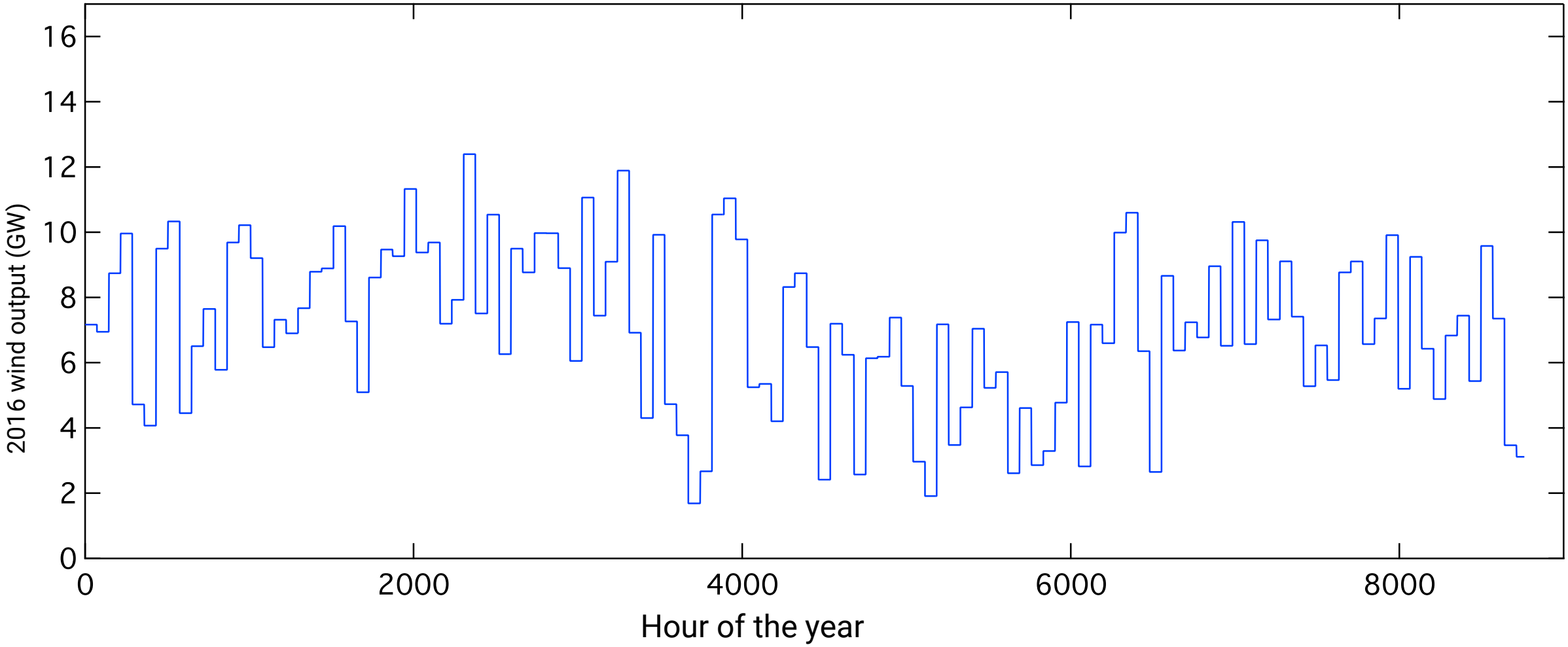
8-hour time blocks for Texas wind



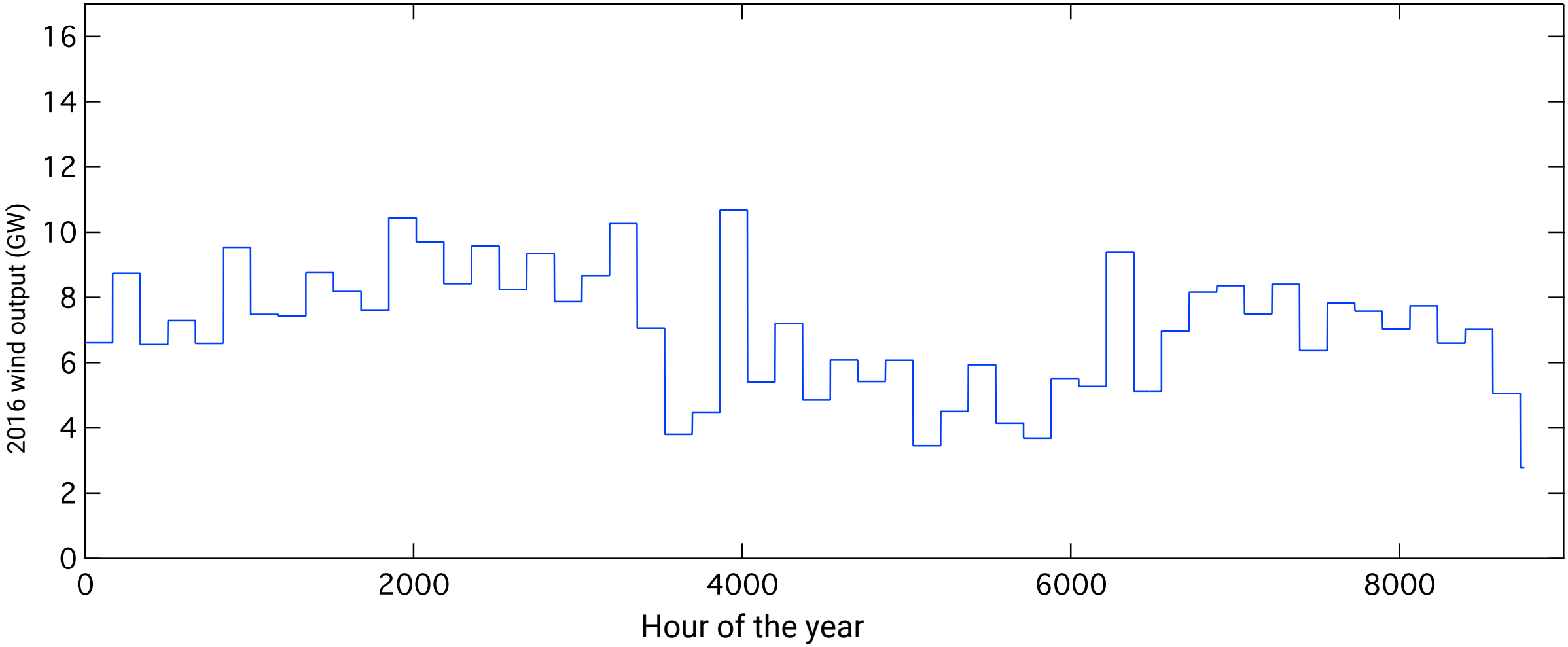
24-hour time blocks for Texas wind



72-hour time blocks for Texas wind

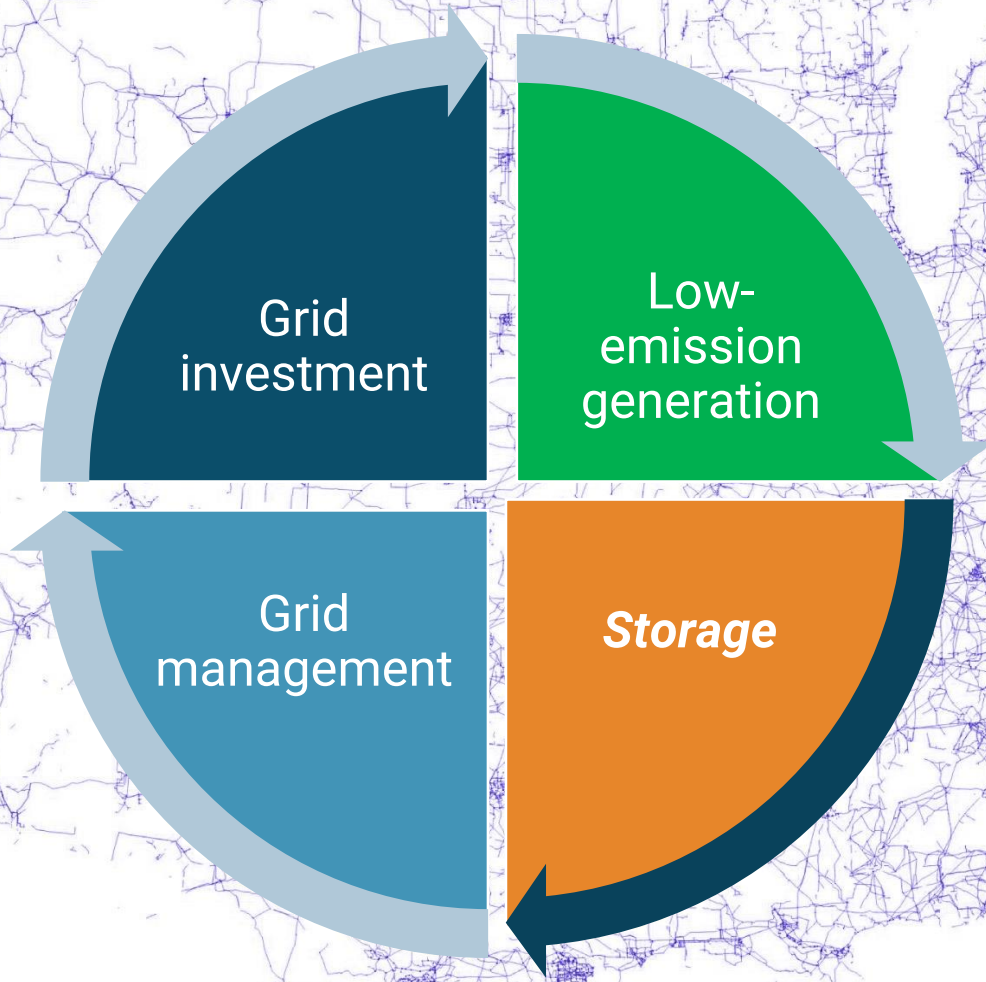


168-hour time blocks for Texas wind



So, what's missing?

Maintain affordability and reliability



Transition to clean, sustainable power

In 2018, ARPA-E launched DAYS

DURATION ADDITION TO ELECTRICITY STORAGE

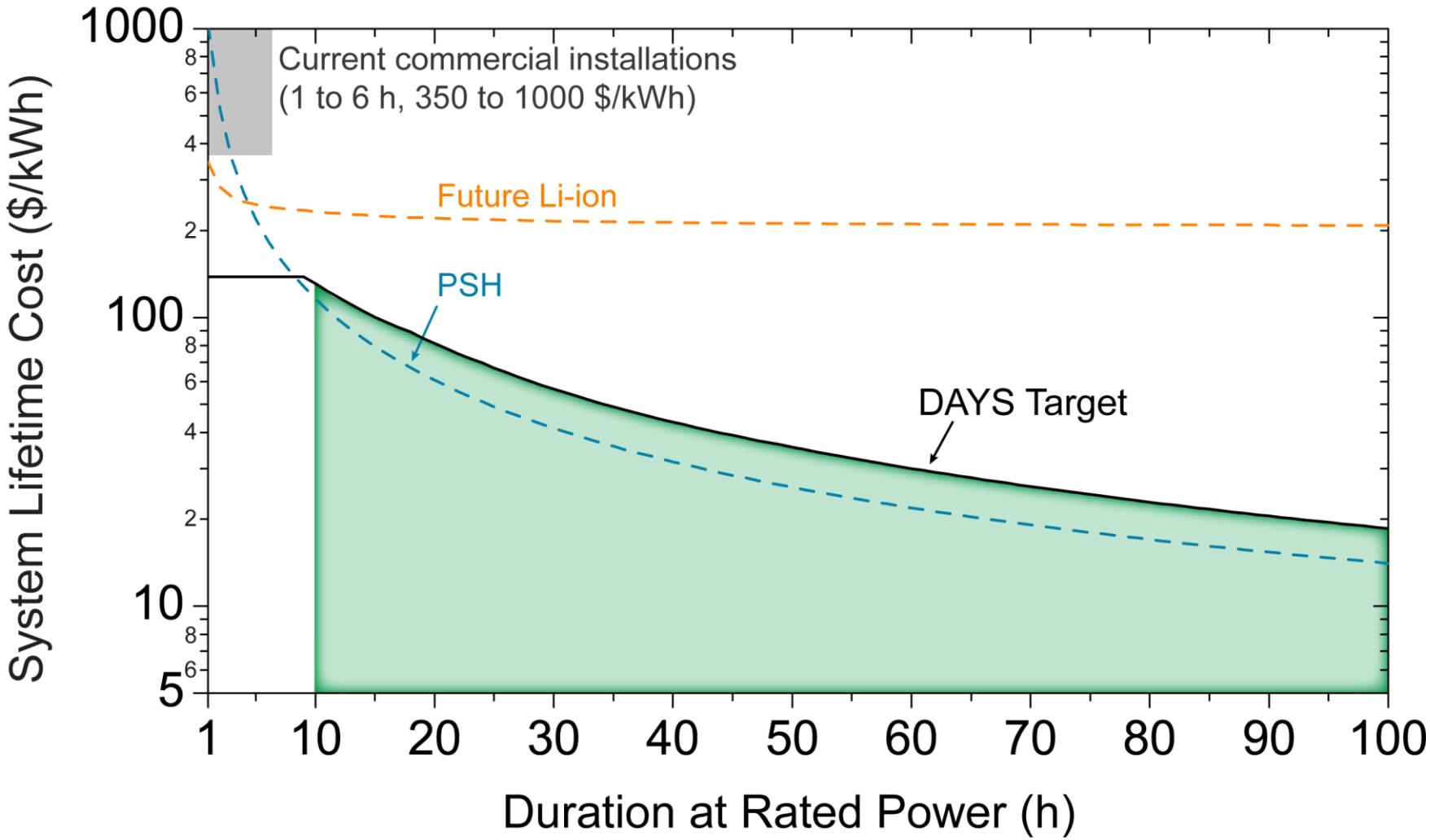
Our objective: Enable widespread adoption of long-duration storage

- <$0.05/kWh LCOS
- 10-100 hours duration
- 10-500kW demo → Multi-MW at scale
- No geographic constraints

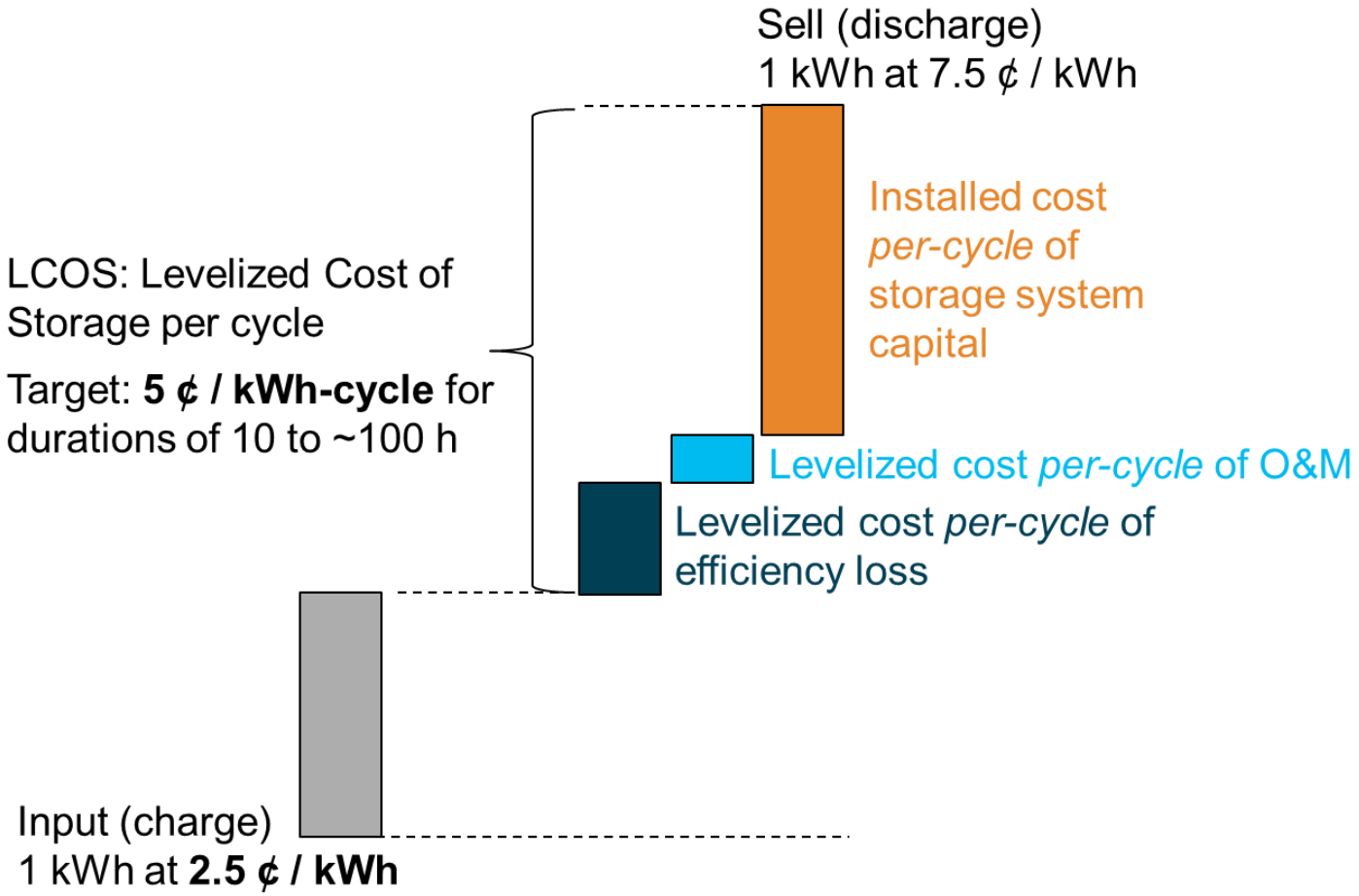
Long duration, today

Power (Watts)

It’ll be hard for Lithium ion to get there



Co-optimization of round trip efficiency, opex and capex required

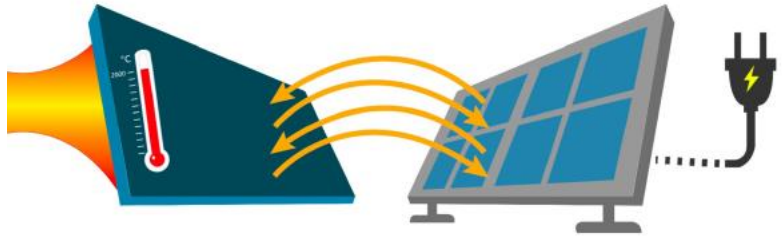


Note: Charge and discharge prices are assumptions, not market projections

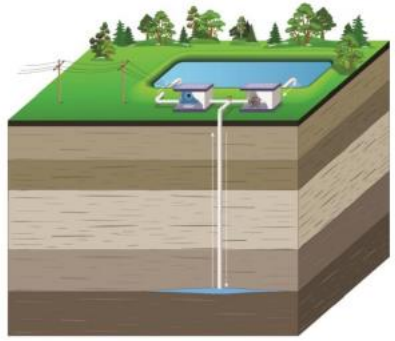
The DAYS technology portfolio

Thermal energy storage

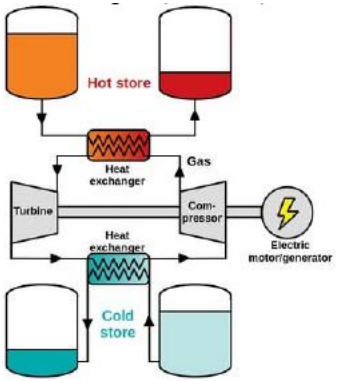
Thermophotovoltaic storage (TPV)



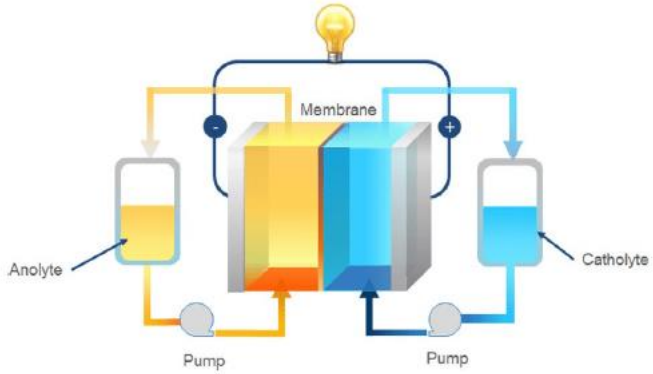
Geo-mechanical storage



Pumped heat energy storage (PHES)



Electrochemical storage



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The DAYS technology portfolio

Thermal energy storage

NREL

redoxblox *(Spinout from Michigan State University)*

Thermophotovoltaic storage (TPV)

ANTORA

THERMAL BATTERY *(Spinout from MIT)*

Geo-mechanical storage

Quidnet Energy

RENEWELL

Pumped heat energy storage (PHES)

ECHOGEN power systems

BraytonEnergy

SwRI SOUTHWEST RESEARCH INSTITUTE

Electrochemical storage

Form energy

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Washington University in St. Louis

UC San Diego

COLUMBIA UNIVERSITY *(2 projects)*

Raytheon Technologies

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Includes "cohorted" projects from IONICS, OPEN 2018 and OPEN 2021

The DAYS technology portfolio *(detail 1 of 2)*

Active | Ended

Program	Performer	Energy Storage System	Basic Proposition	Funding Amount	Project Finish
DAYS	Antora	Thermophotovoltaic	Heated carbon blocks that discharge as electricity or heat	$7.6MM	6/30/24
DAYS	Brayton	Pumped Heat Energy Storage	Reversible compressor turbo-machine for lower CAPEX	$3.0MM	3/31/23
DAYS	Columbia University	Electrochemical storage	Natural convection Zinc Bromine battery – no pumps or pipes	$3.4MM	5/31/23
DAYS	Form Energy	Electrochemical storage	Aqueous sulfur-air flow battery for low chemical costs	$2.9MM	8/31/23
DAYS	RedoxBlox	Thermal Energy Storage	Thermochemical storage based on MgMnO pellets combined with gas turbine	$4.9MM	5/31/24
DAYS → SCALEUP	Quidnet	Geo-mechanical Storage	Pump water under pressure into rock & expand fractures	$3.3MM	5/31/22
DAYS	Echogen	Pumped Heat Energy Storage	Sand-based heat storage with supercritical CO_2 as working fluid	$4.1MM	1/31/23
DAYS	NREL/Colorado School of Mines	Thermal Energy Storage	Hi-performance heat exchanger + Brayton cycle with inexpensive particles in silos	$2.8MM	9/30/22

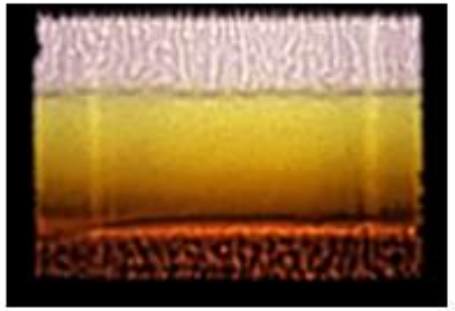
The DAYS technology portfolio *(detail 2 of 2)*

Active | Ended

Program	Performer	Energy Storage System	Basic Proposition	Funding Amount	Project Finish
DAYS	U. Tennessee-Knoxville	Electrochemical storage	Reversible fuel cell/electrolyzer with hydrogen peroxide as storage medium	$1.5MM	9/5/21
DAYS	UTRC (Raytheon)	Electrochemical storage	Flow battery based on inexpensive Sulfur + Manganese	$3.8MM	5/31/22
IONICS	Washington U. St. Louis	Electrochemical storage	Flow battery with innovative anion exchange membrane	$4.0MM	9/30/23
OPEN 18	SW Research Institute	Pumped Heat Energy Storage	High-efficiency thermodynamic cycle utilizing hot and cold fluids	$2.6MM	12/19/22
OPEN 18	U. California San Diego	Electrochemical storage	Universal integration system to give second life to EV batteries for grid storage	$1.9MM	5/31/22
OPEN 18	Thermal Battery (MIT)	Thermophotovoltaic	Thermal energy storage system based on high efficiency multi-junction TPV cells	$1.5MM	2/3/22
OPEN 21	Columbia University	Electrochemical storage	Optimizing Li-ion materials in a bobbin cell format for 8+ hour discharge at <$0.05/kWh	$1.5MM	5/31/25
OPEN 21	Renewell / NREL	Geo-mechanical Storage	Repurposing inactive oil and gas wells as gravity-based energy storage systems	$2.7MM	6/30/25

Multiple demo sites and field pilots

Antora 5MWh pilot in Fresno, CA



Columbia Univ. natural diffusion zinc-bromine cell

South West Research Institute 5kW PHES demo unit San Antonio, TX

Quidnet Energy 1MW commercial pilot for CPS Energy in San Antonio, TX

RedoxBlox 100kWh demonstration unit in Bend, OR

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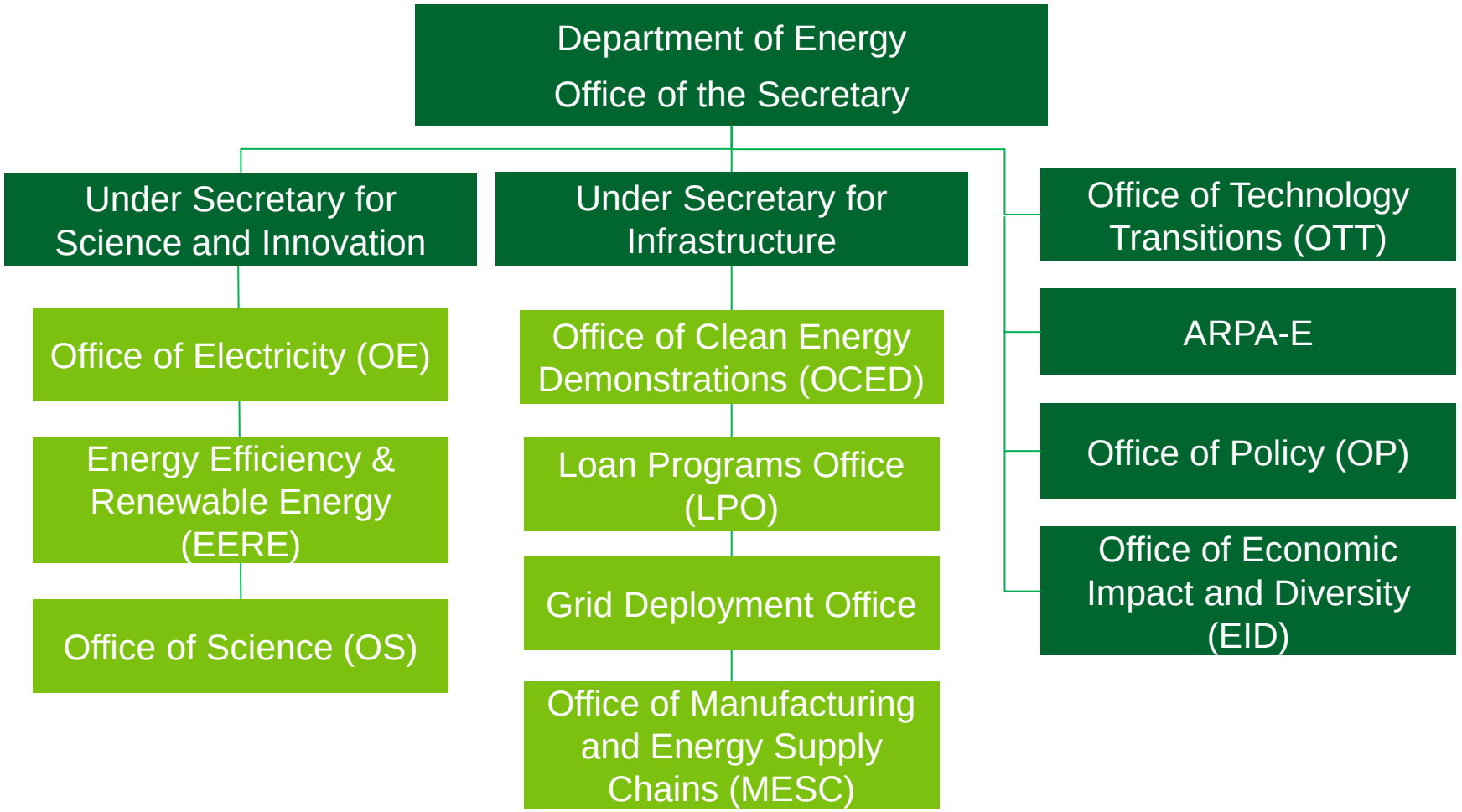
Part of broader energy storage initiatives across the DOE



"Deploy! Deploy! Deploy!" – Secretary of Energy, Jennifer Granholm

Additional DOE initiatives
(not exhaustive)

- **DOE awarded $2.8B in grants from BIL** to 20 battery projects
- BIL allocated **$505M to LDES for Everyone, Everywhere Initiative**
- **LPO issued $102M loan** to domestic graphite anode producer
- DOE and Dept. of Labor launched the **Battery Workforce Initiative** with $5M investment
- DOE's applied R&D programs invest **$300M+ per year in Energy Storage** including **Long Duration Storage Shot** and **Energy Storage Grand Challenge**
- DOE **Pathways to Commercial Liftoff** report on March 16

U.S. DEPARTMENT OF ENERGY

Long Duration Energy Storage (LDES) MOU & Partnership

Established March 2023 at CERA Week:

- DOE + 3 initial partners (EPRI, EEI, LDES Council), open to all companies interested in LDES.
- To convene a Collaboration to support collective and individual actions related to the LDES RDD&D continuum.
- To achieve faster commercialization of the LDES technologies.
- To amplify the Pathways to Commercial Liftoff Report on LDES, due out March 16, 2023.
- More details forthcoming.

For more information and to join, contact Anna Siefken
anna.siefken@hq.doe.gov

How to engage

Learn more

arpa-e.energy.gov/technologies/programs/days

Reach out

jonathan.glass@hq.doe.gov

Explore how to partner

Pilot projects, use case modeling, strategic supply, investment, EPC, …

U.S. DEPARTMENT OF ENERGY

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https://arpa-e.energy.gov