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The ARPA-E DAYS Program

Update on new long-duration storage technologies

Scott Litzelman, Ph.D.

Program Director

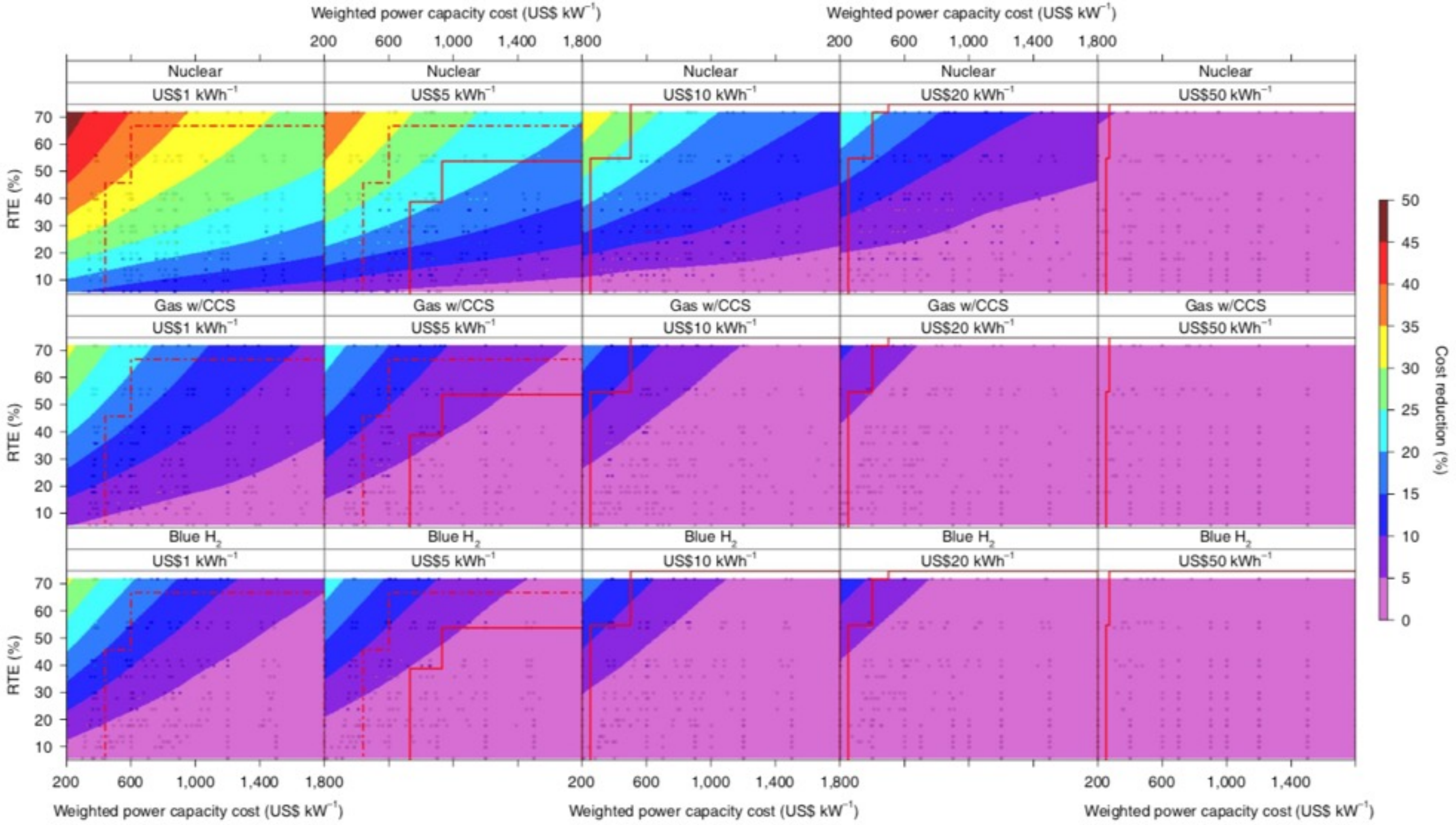
SERDP • ESTCP SYMPOSIUM
2021 • Enhancing DoD's Mission Effectiveness

Outline

The value of long-duration energy storage (LDES) and some early applications

Technology updates from the ARPA-E DAYS program

LDES can reduce the cost of decarbonized systems



N.A. Sepulveda, et al., Nature Energy 6, 506-516 (2021)

LDES applications coming into focus

Capacity Resource for LSEs

Central Coast Community Energy | CleanPowerSF | MCE My community. My choice. | PENINSULA CLEAN ENERGY

REDWOOD COAST Energy Authority | SAN JOSE CLEAN ENERGY | SILICON VALLEY CLEAN ENERGY | Sonoma Clean Power

Seeking 500 MWs for long duration storage

The eight joint CCAs are seeking to acquire up to 500 MWs of capacity, energy and any associated ancillary products, and resource adequacy ("Full Toll") and/or simply Resource Adequacy ("RA Only".)

Interconnection Maximization for Developers

gtm:

L.A. Looks to Break Price Records With Massive Solar-Battery Project

The cheapest U.S. solar PPAs have been coming out of places like West Texas, but developer 8minute Solar has put the spotlight back on California.

JEFF ST. JOHN | JULY 01, 2019

*8minute's project with LADWP will include about 65 MW of **additional solar PV beyond its nameplate capacity** to serve the battery storage to be added to the project, because the Kern County transmission corridor, already the home of about 1 GW of solar PV, has a maximum capacity for how much power it can carry to Los Angeles.*

Risk Management for Energy Marketers

Large Scale, Long Duration Energy Storage, and the Future of Renewables Generation

White Paper

form energy | enel Foundation

*Through this analysis, we provide a quantitative framework to demonstrate the ability of storage to manage risk and return for wind farms exposed to volume and basis risk factors… The results are persistent across the wind farms modeled and demonstrate the impact of bulk energy storage technologies to **effectively manage risks and maximize returns**.*

Backup Power for Critical Loads

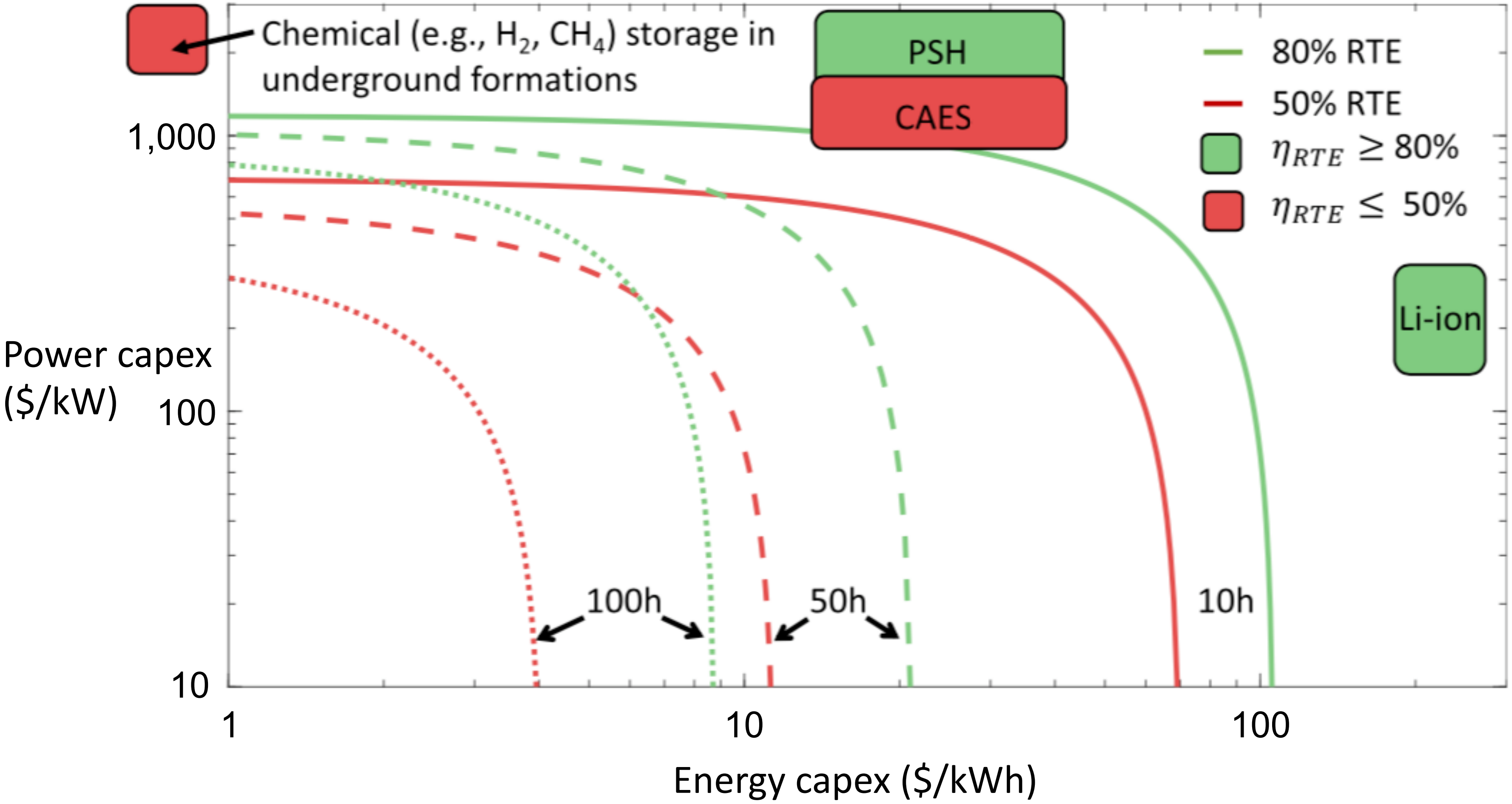
ESTCP

The Value of Battery Storage in Military Microgrids:

An Assessment for ESTCP

Jeffrey Marquesee, Dan Olis, William Becker, and Sean Ericson
National Renewable Energy Laboratory
Craig Schultz
ICF
Design and production by Noblis, Inc.
July 2020

Desired technology cost structure

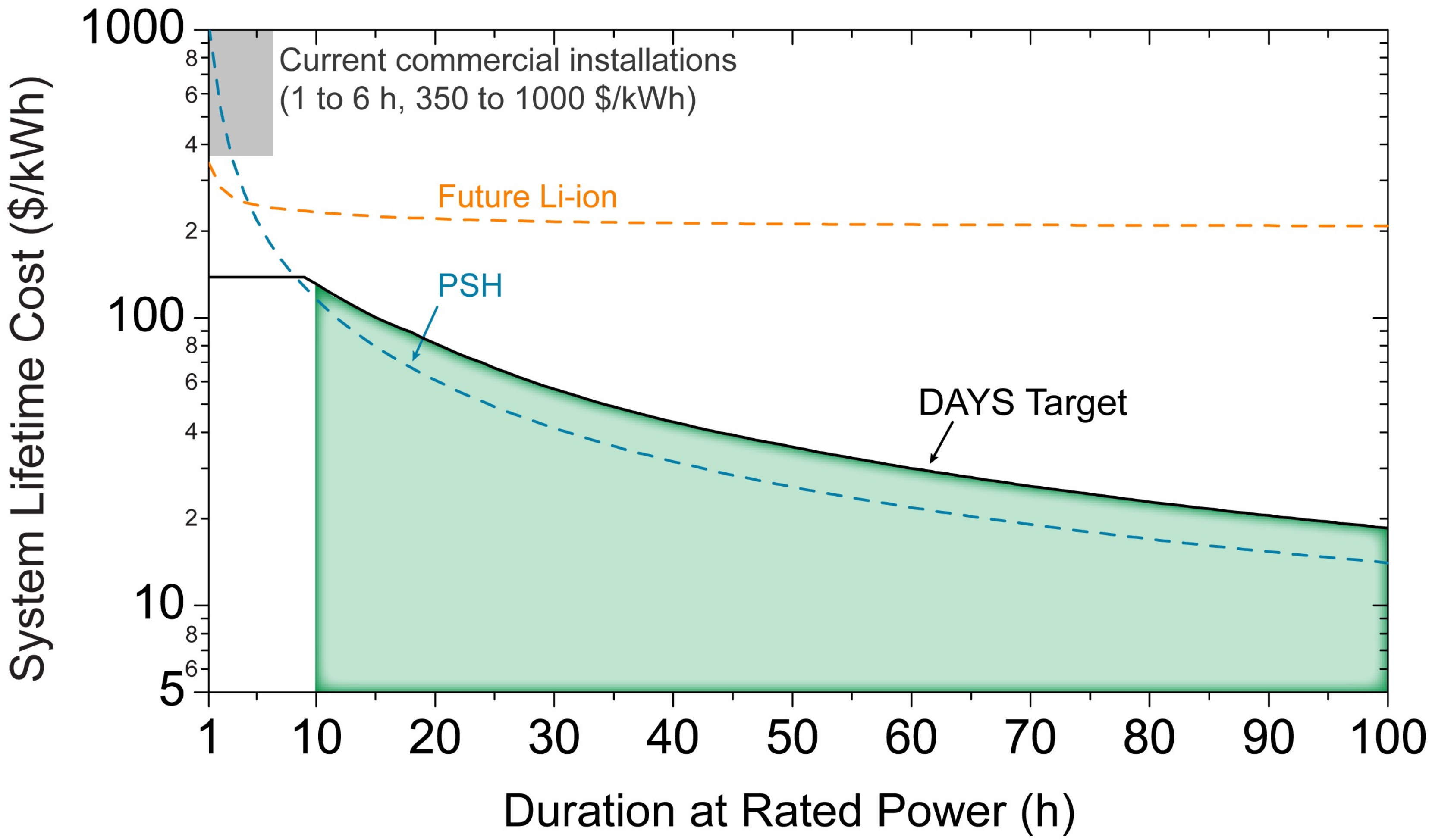


<u>Assumptions</u>

- $0.05/kWh differential per cycle
- Certain duty cycle
- $25/kW-yr capacity payment

P. Albertus, J.S. Manser, S. Litzelman, *Joule* **4**, 1-12 (2020)

DAYS: pumped hydro-like costs but sited anywhere



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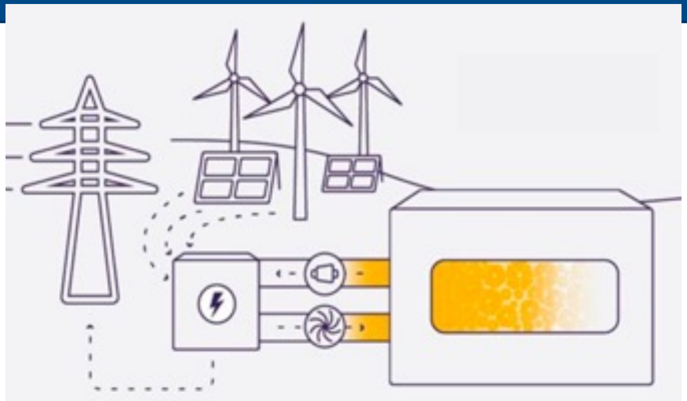
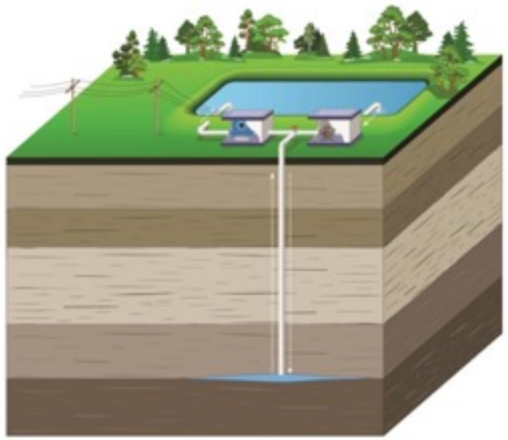
The DAYS portfolio

Thermal energy storage

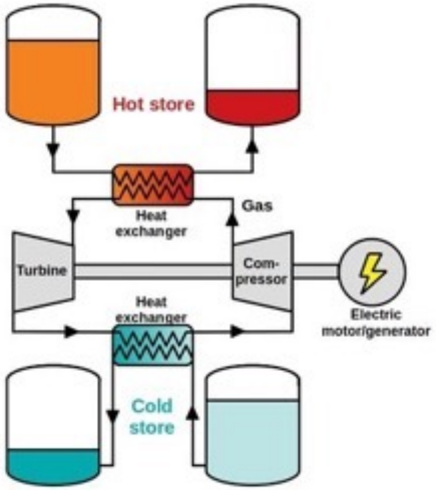


Thermophotovoltaic (TPV) storage

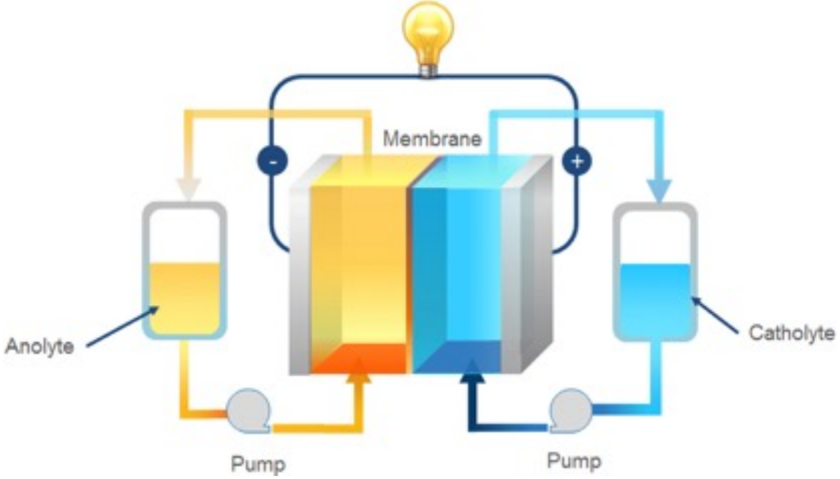
Geomechanical storage



Pumped thermal energy storage (PTES)



Electrochemical storage



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The DAYS portfolio

Thermal energy storage

MICHIGAN STATE UNIVERSITY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Thermophotovoltaic (TPV) storage

Antora Energy

Massachusetts Institute of Technology

Geomechanical storage

Quidnet Energy

Pumped thermal energy storage (PTES)

ECHOGEN power systems

SwRI SOUTHWEST RESEARCH INSTITUTE

Brayton Energy LLC

Electrochemical storage

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

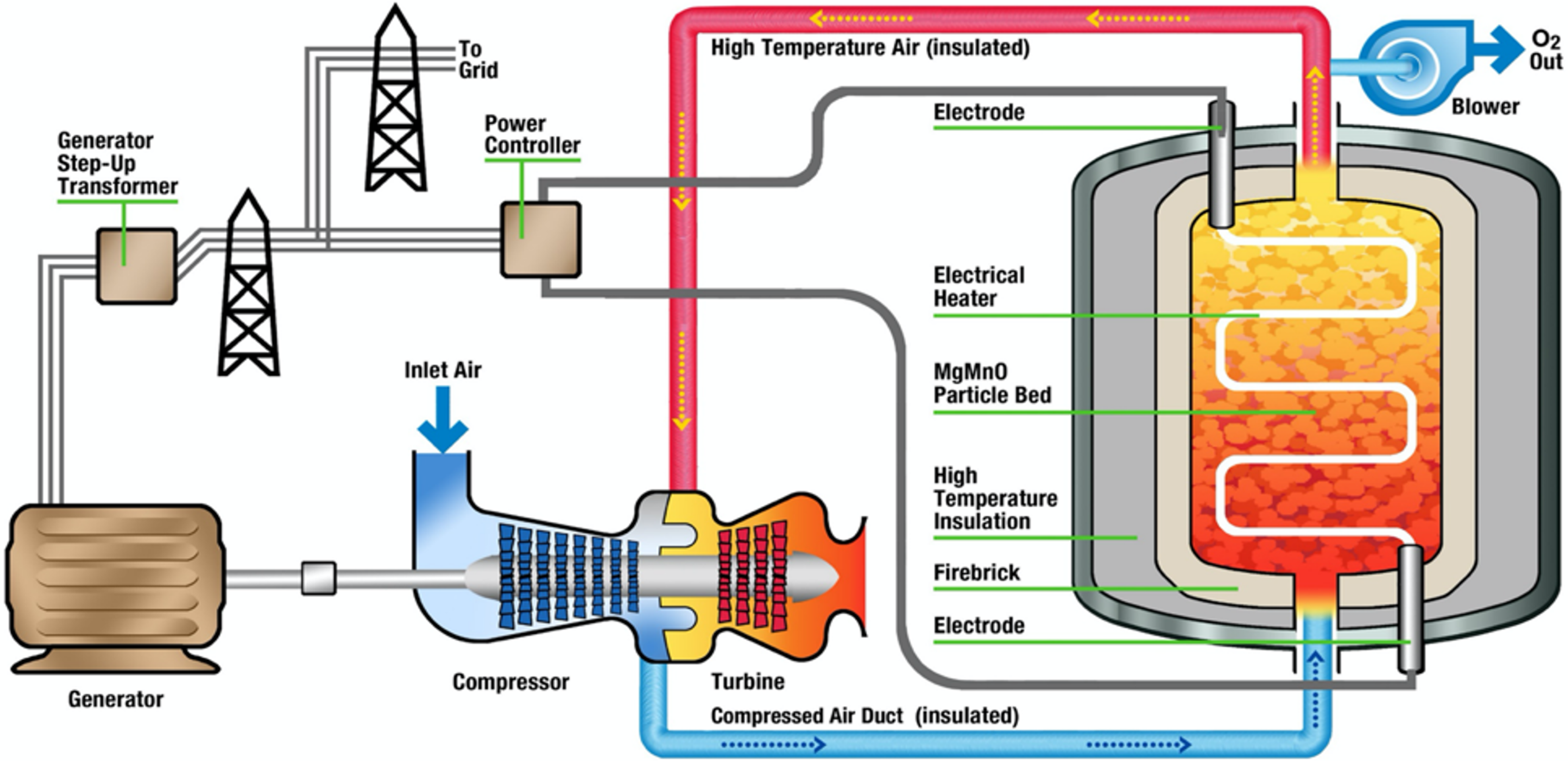
form energy

Raytheon Technologies

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Overview of the Technology: Thermochemical Storage

$$MgO + 2MnO + \frac{1}{2} O_2 \leftrightarrow MgMn_2O_4$$



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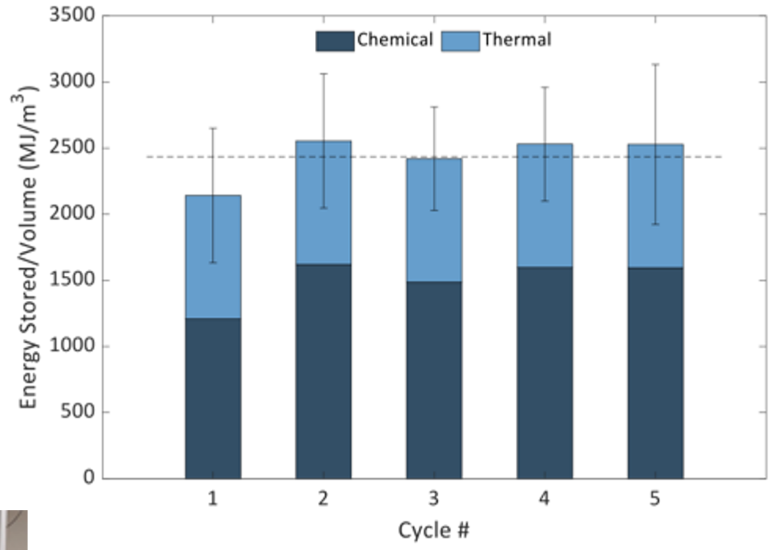
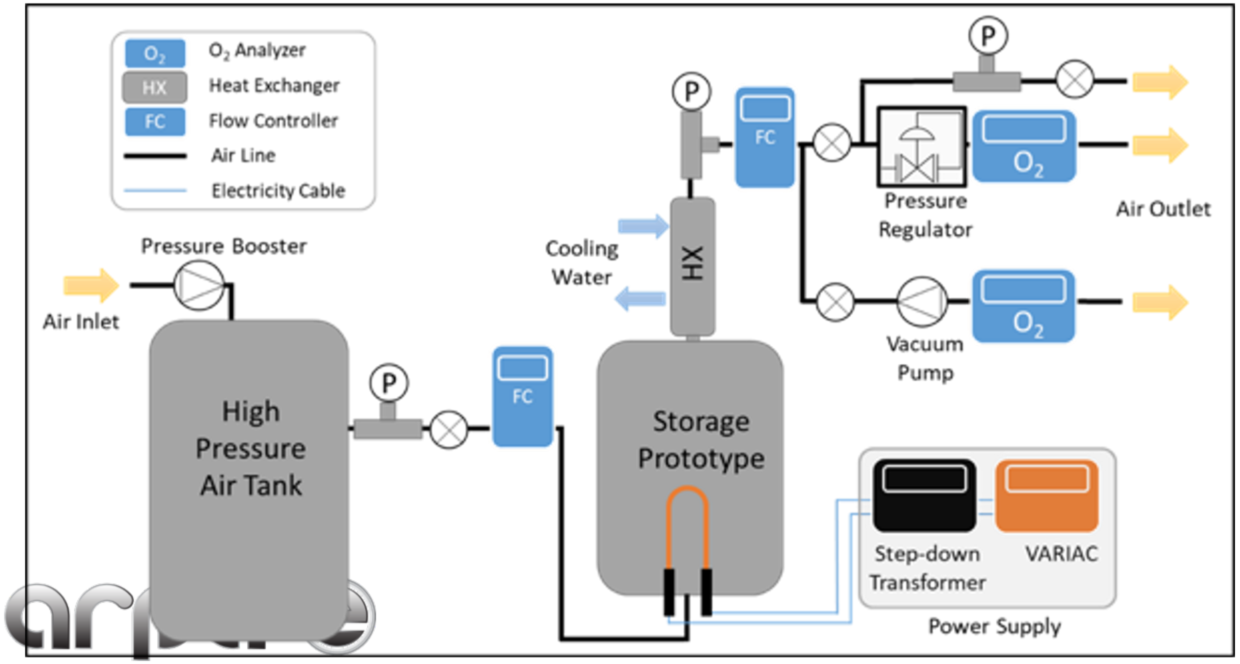
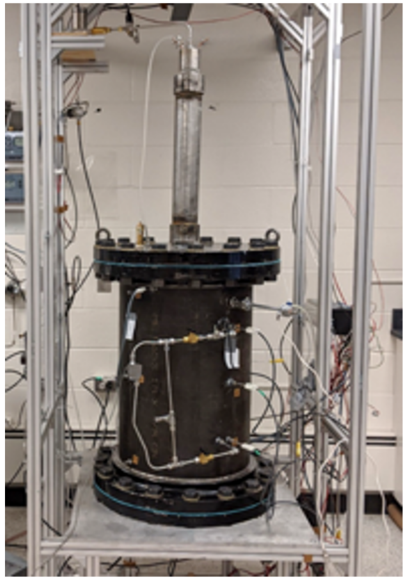
MICHIGAN STATE UNIVERSITY

Mg-Mn-O Particles Successfully Operated in Small System

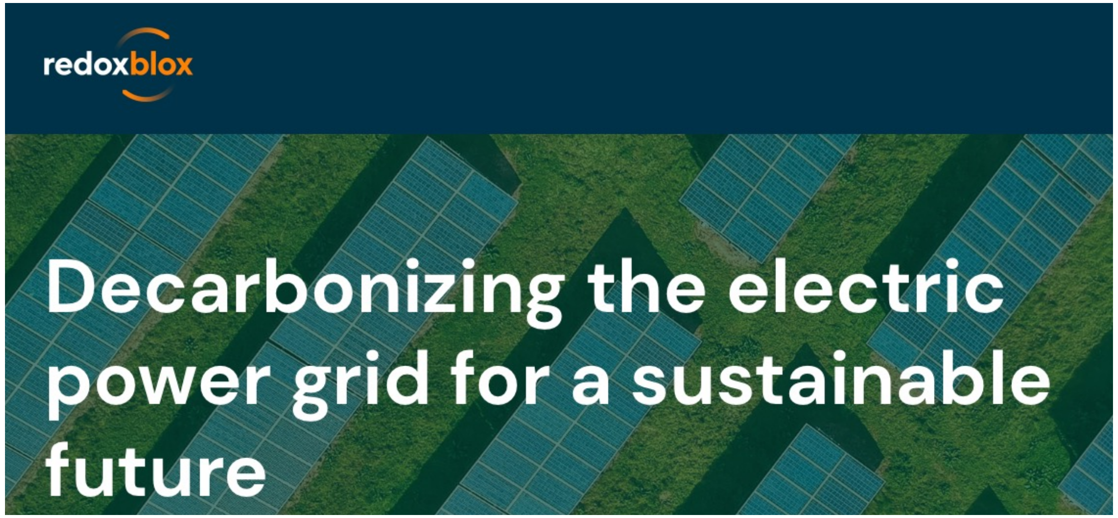
- Storage demonstrated in bench scale reactor
  - Real-world conditions
  - 1 kW/0.25 kWh, 1000-1500 ˚C, 0.2-11 bar
  - 5 continuous cycles
  - 2400 MWh/m^3
- Volumetric bed heating validated
- Started testing of scaled-up reactor with volumetric heating
  - 3 kW, 10 kWh







Spinout company: RedoxBlox



Partners

ANSALDO ENERGIA

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B&W BABCOCK & WILCOX

MICHIGAN STATE UNIVERSITY

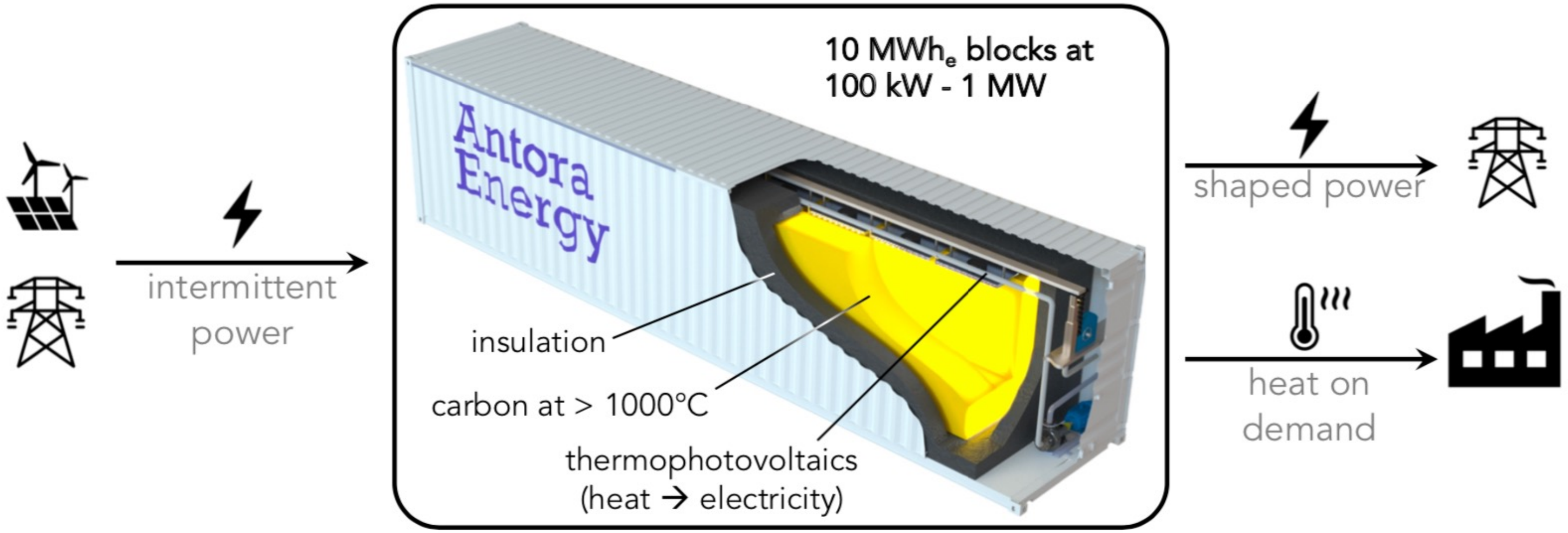
SIEMENS energy

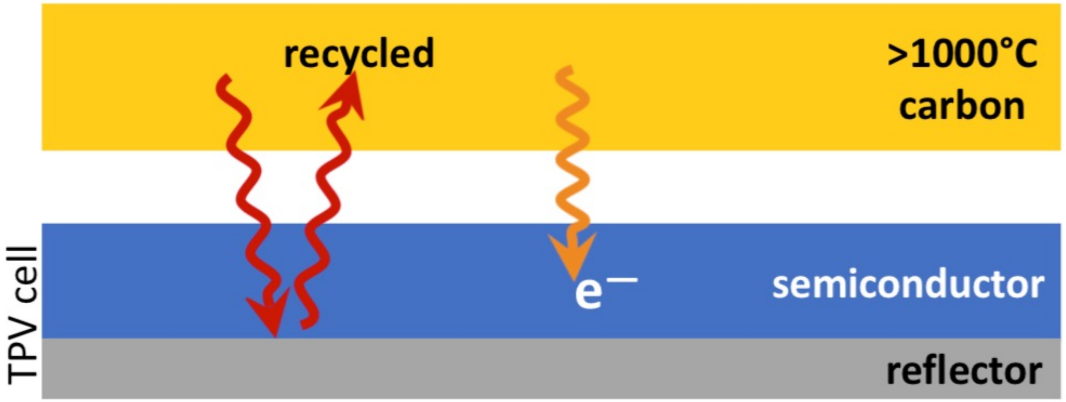
SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy

SPARTAN INNOVATIONS Part of the MSU Innovation Center

Thermophotovoltaic (TPV) storage

Antora's solid state thermal battery





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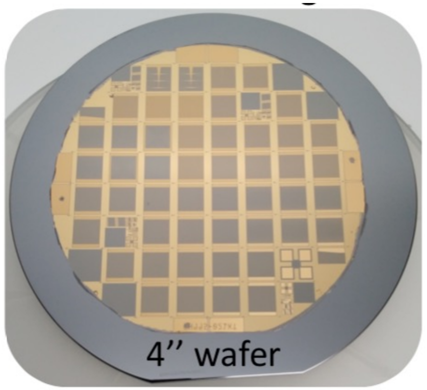
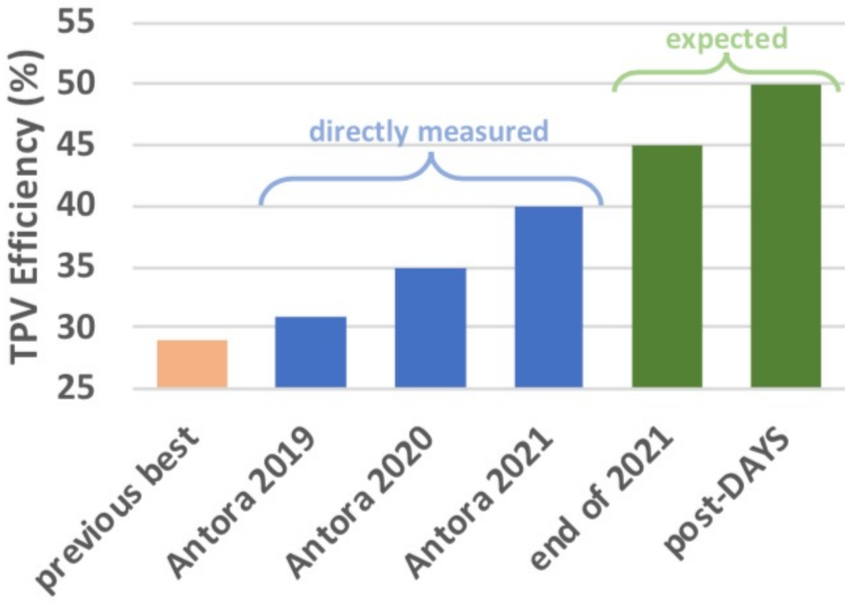
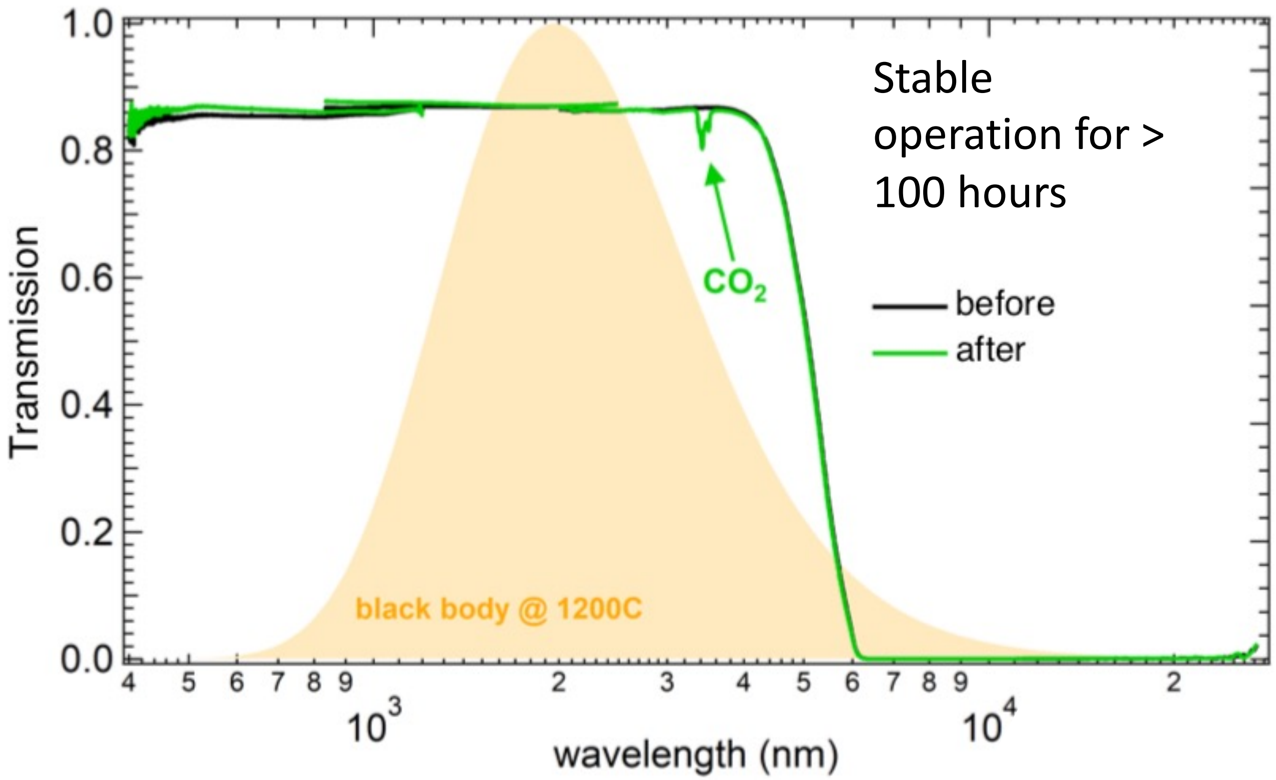
High efficiency and stability



Fabricated TPV cells in commercial manufacturing environment; tested in high-accuracy TPV setup

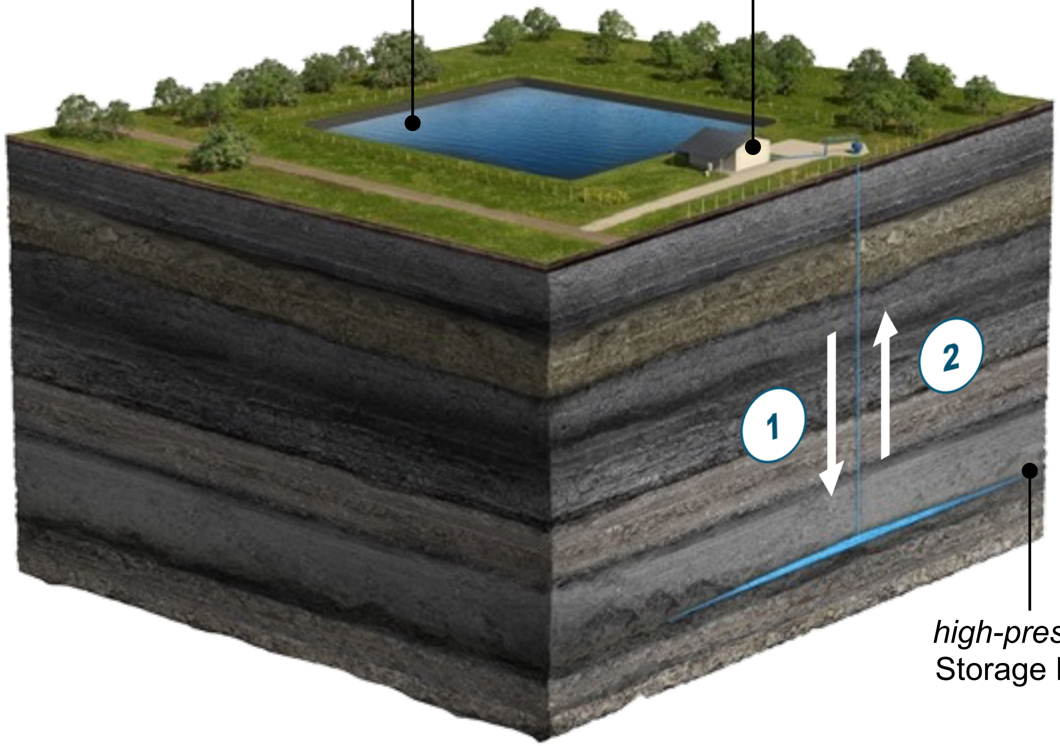
World-record TPV efficiency





Stable operation for > 100 hours

Quidnet stores energy as high-pressure water underground



Modular, long-duration storage

1-10 MW per well, 10+ hours

Structural cost position

<50% capex of battery & pumped hydro, <**$10 per** marginal kWh

Broad geological footprint

100+ TWh across multiple US basins

Mature execution supply chain

1. **Charge.** Water pumped down the well into high-pressure storage lens
2. **Discharge.** High-pressure water flows up the well to drive a turbine

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Quidnet Energy

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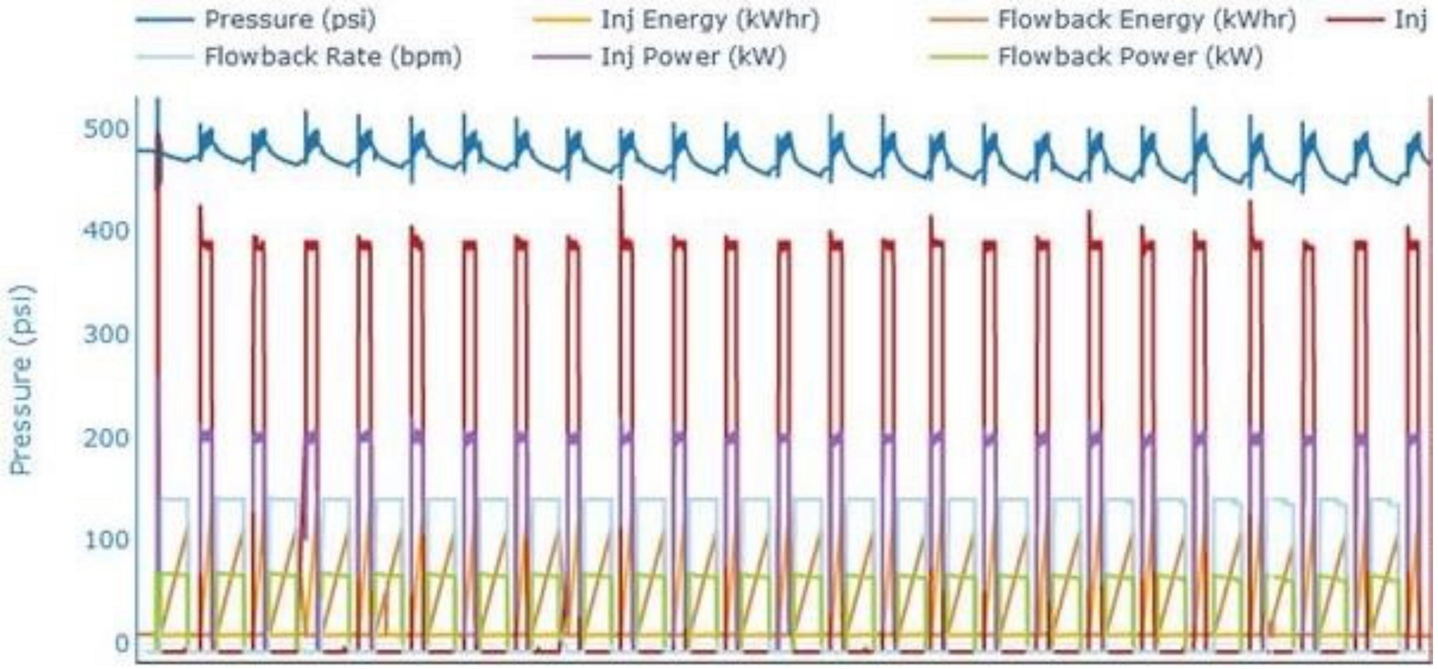
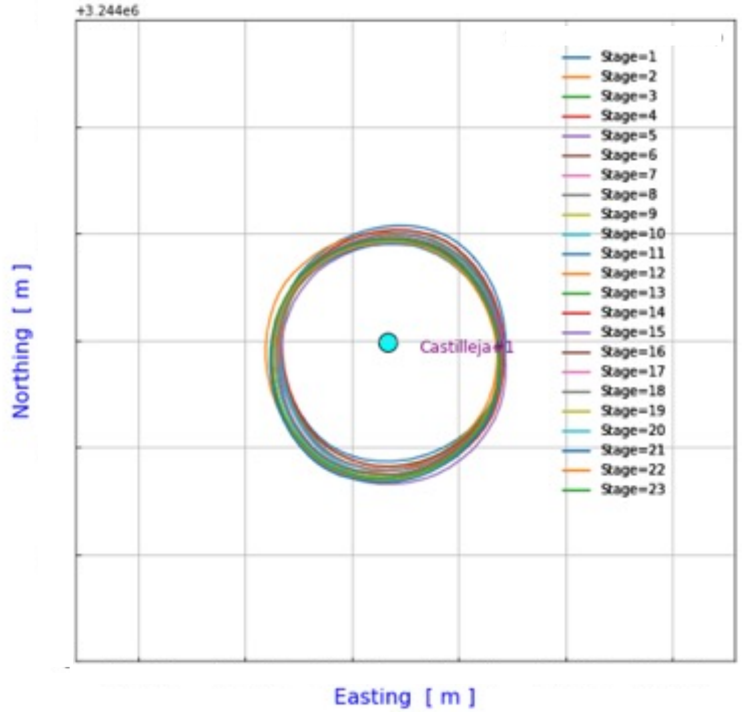
Texas results – repeated charge/discharge cycling





Pumped thermal energy storage (PTES)

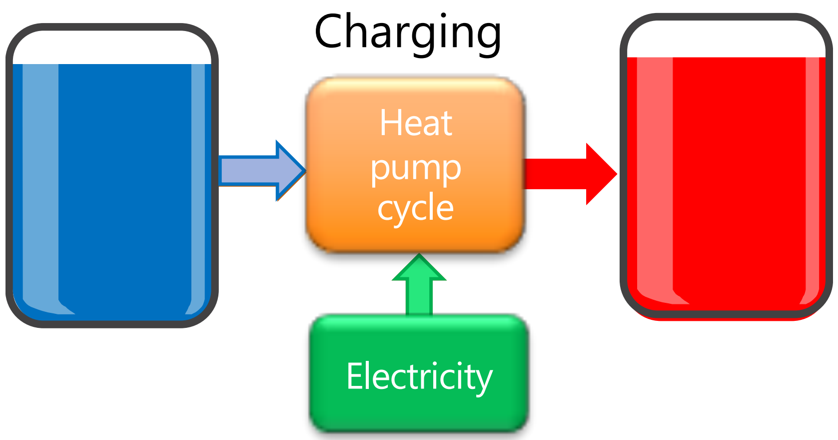
Thermodynamic cycles transform energy between electricity and heat

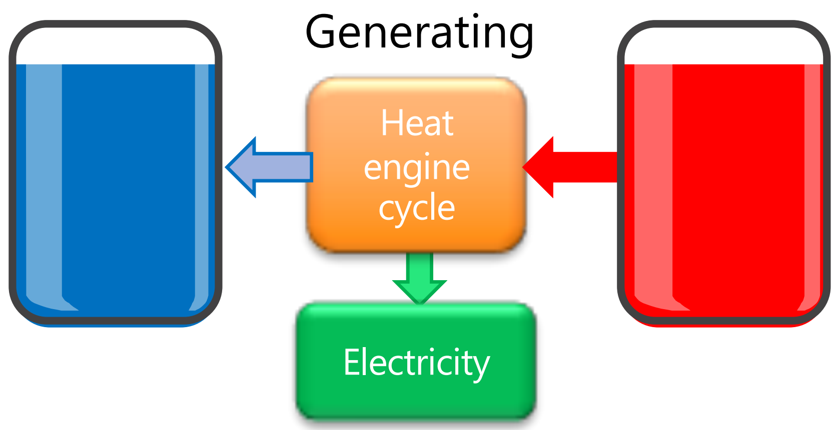
Charging cycle

- Heat pump cycle
- Uses electrical power to move heat from a cold reservoir to a hot reservoir
- Creates stored energy as both "heat" and "cold"

Generating cycle

- Heat engine cycle
- Uses heat stored in hot reservoir to generate electrical power
- "Cold" energy improves performance of heat engine





PTES proof of concept

~200 kWth system, including both charging and generating cycles

Low-Temperature Reservoir (LTR)

CO_2 heat pump & power cycle

High-Temperature Reservoir (HTR)

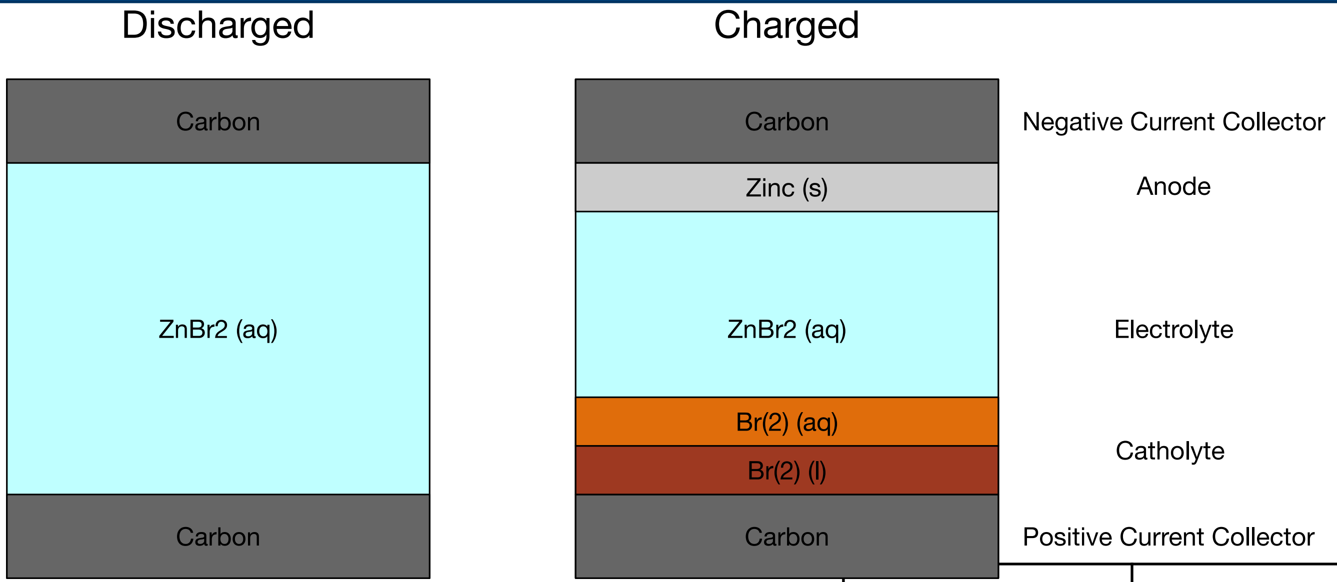
Initial build
- 2-tank heat transfer fluid HTR
- Ice slurry LTR
- Commissioning end of Sept 2020
- Complete testing October 2020

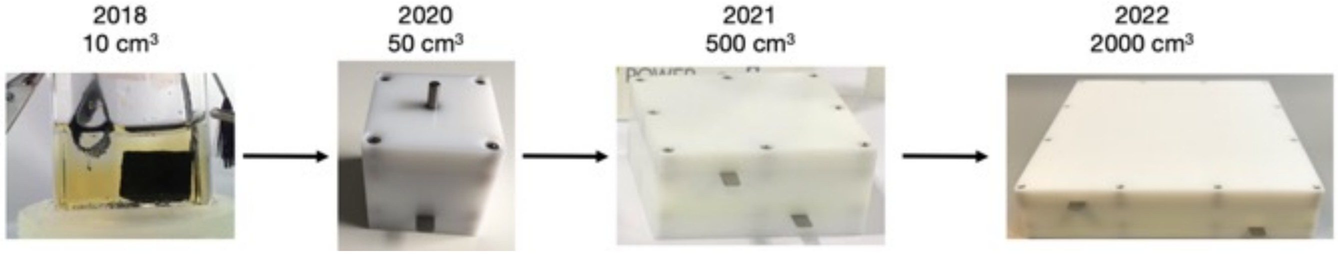
- Build and test sand HTR system
- Complete April 2022

Primary developmental focus:
- HTR and heat exchanger (TRL 4)
- LTR performance (TRL 4)
- Operation and controls

25 MW, 8–10-hour system in prelim design

$ZnBr_2$ battery: simple design, cheap materials





Metric	Before ARPA-E	Current	Target
Cell BOM	\$120/kWh	\$70/kWh	\$25/kWh
Energy Density	8 Wh/L	60 Wh/L	120 Wh/L
RTE	60%	68%	75%
Self Discharge	20% / day	10% / day	5% / day
Cell Size	50 mWh	20 Wh	200 Wh

Summary

- LDES assists in decarbonization
- To provide really long-duration storage for DoD applications, need much lower energy capex and high (enough) discharge efficiency
- The ARPA-E DAYS program and others (see right) are developing technologies to do this

Thank you!

https://arpa-e.energy.gov

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