Decreasing the Cost and Risk of Decarbonization Pathways Through Technology Development

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4th IERE Webinar: Towards a Carbon Neutral Energy Future

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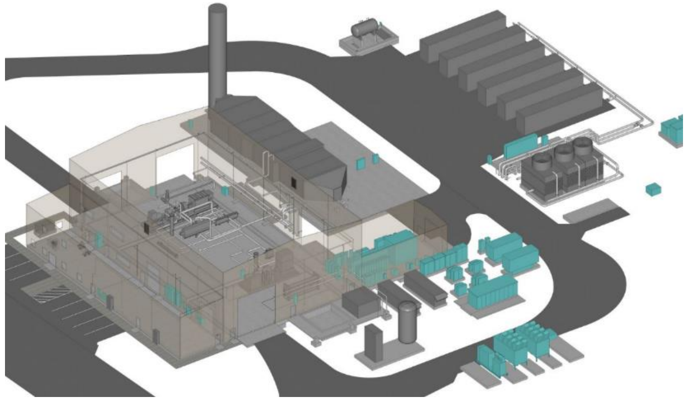
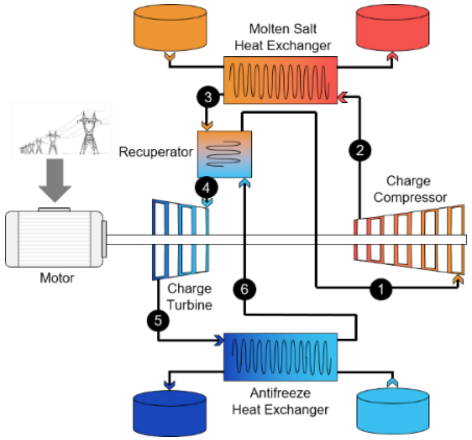
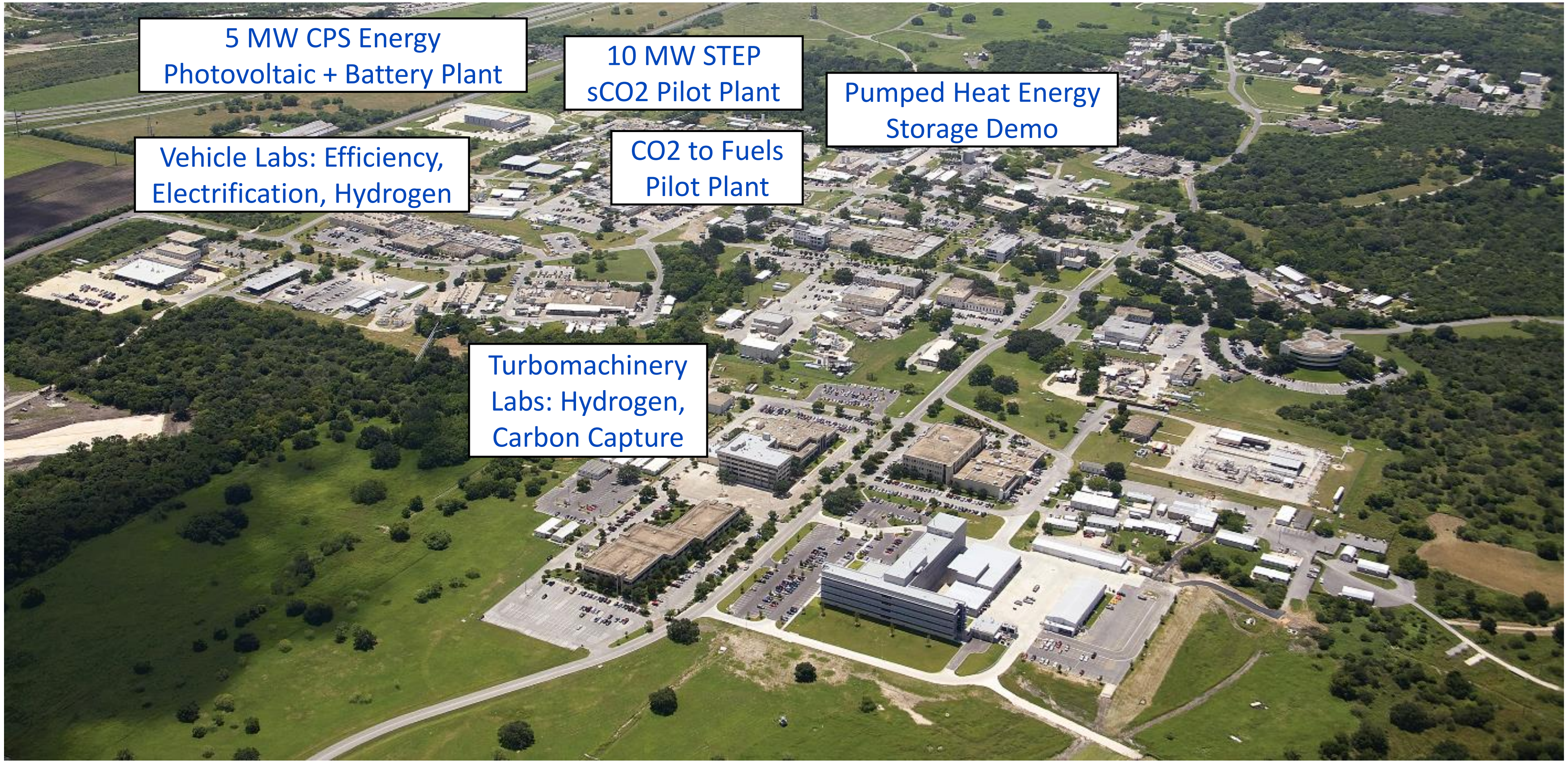




SwRI Performs Applied Research & Development Supporting Clean Energy

- Founded in 1947
- San Antonio, Texas
- Not-for-Profit Contract R&D
- 2,800 employees
- 1,500-acre facility
- 300 labs and office buildings



Decarbonization Pathways

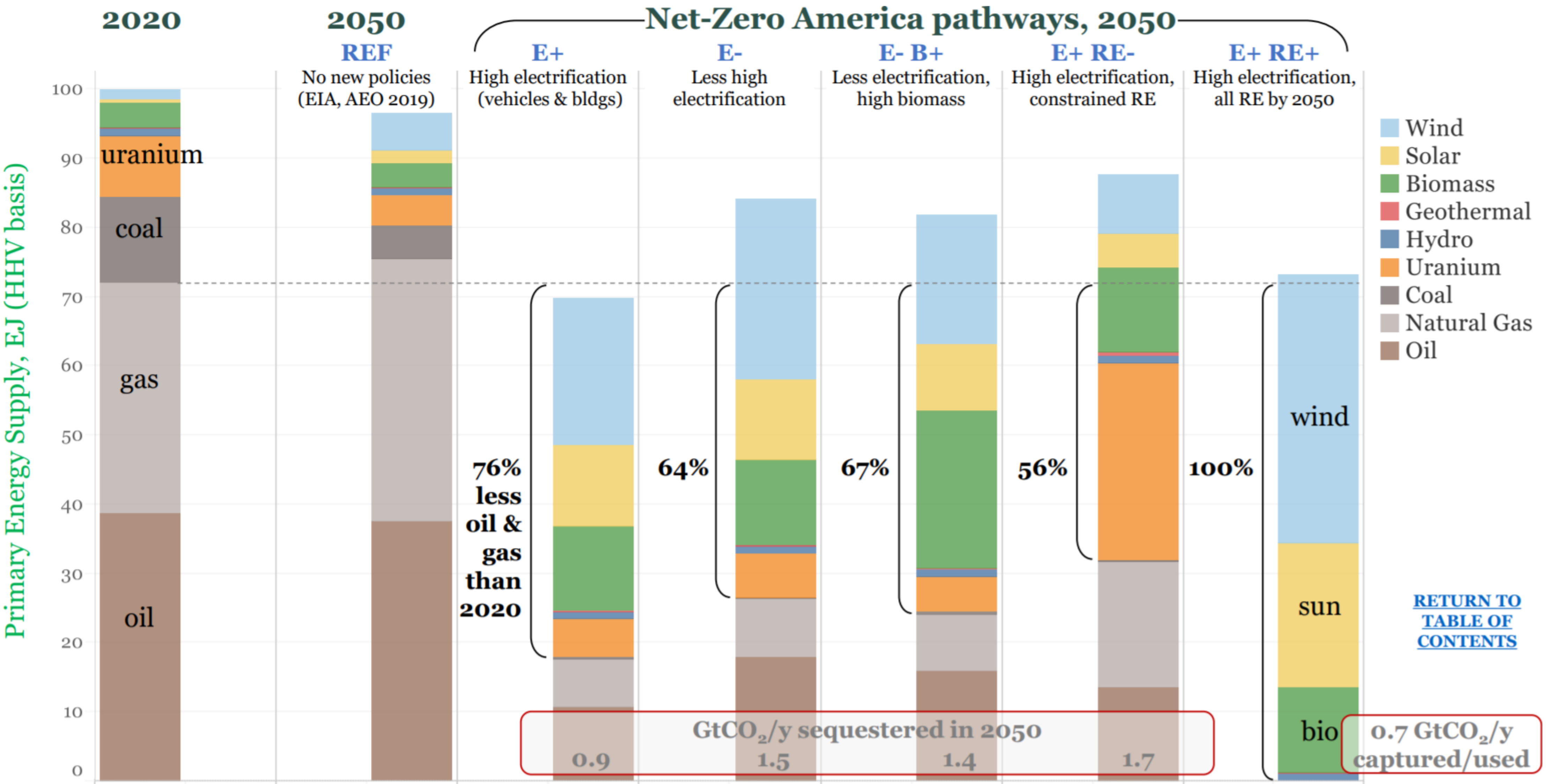


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Image Source: Princeton University

U.S. Department of Energy Initiatives

- Energy Storage Grand Challenge and roadmap addresses all energy storage technologies, targeting domestic solutions for all 2030 U.S. market demands
- Earthshots Initiative aims for clean energy breakthroughs in a decade:
  - Hydrogen Shot: $1/kg
  - Long Duration Storage Shot: 90% cost reduction vs. batteries for 10+ hours duration
- Pending $1.2T Infrastructure Bill allocates $73B for clean energy investments
  - Electric grid, vehicle charging, advanced reactors, carbon capture, hydrogen, long-duration storage

ENERGY STORAGE GRAND CHALLENGE
U.S. DEPARTMENT OF ENERGY

ENERGY earthshots
U.S. DEPARTMENT OF ENERGY

Enabling Firm Renewables

Firming Renewables with Long Duration Energy Storage

- Variability, demand mismatch of wind and solar
  - Typical hourly, daily, seasonal variability is ~50-100% of rated power
- Studies show that storage on the order of ~1x daily energy production or more may be needed[1]
  - U.S. Natural gas storage is 1420 TWh vs. annual electricity use of 3800 TWh (total gas use of 9230 TWh), i.e. ~2-3 months of storage.
- Visualizing storage needs:
  - 10 hours storage in Phoenix = 125 GWh
  - U.S. natural gas store = 1420 TWh

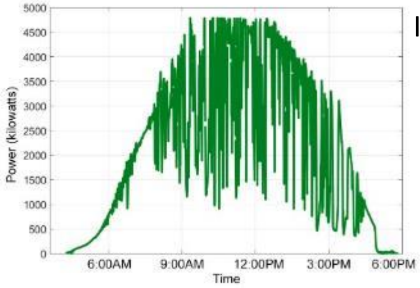


Image Source: EPRI 2018

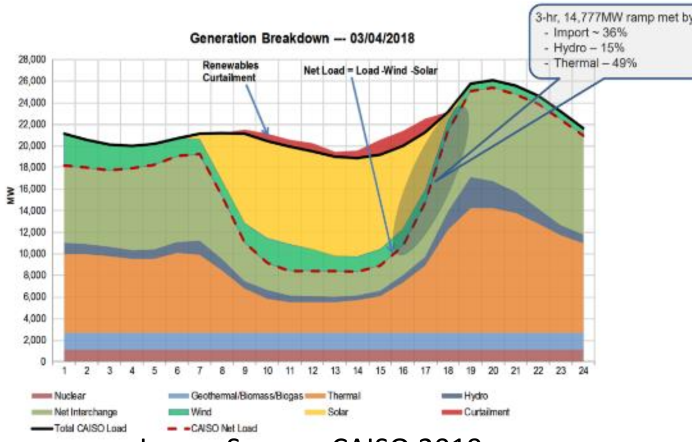


Image Source: CAISO 2019

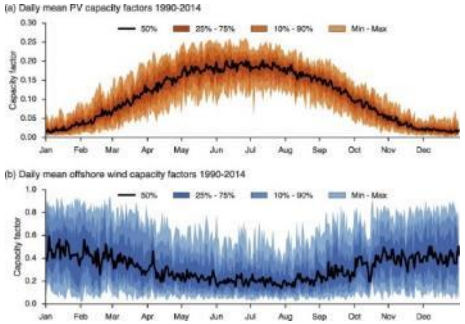


Image Source: Pfenninger 2017

5-56,800 of the world's largest pumped hydro systems

...or 114-1,290,909 of these molten salt tanks

[1]Solomon, A.A. *et al*, 2017.

Why Not Batteries?

- Batteries offer low $/MW but high $/MWh for significant durations above 2-6 hours
  - Energy and power both scale by adding cells
- Other concerns:
  - Rare-earth material sourcing (lithium, cobalt)
  - Degradation
  - No viable recycling option
  - Thermal management/runaway
- Other technologies offer promise of decoupling power with low-cost energy storage

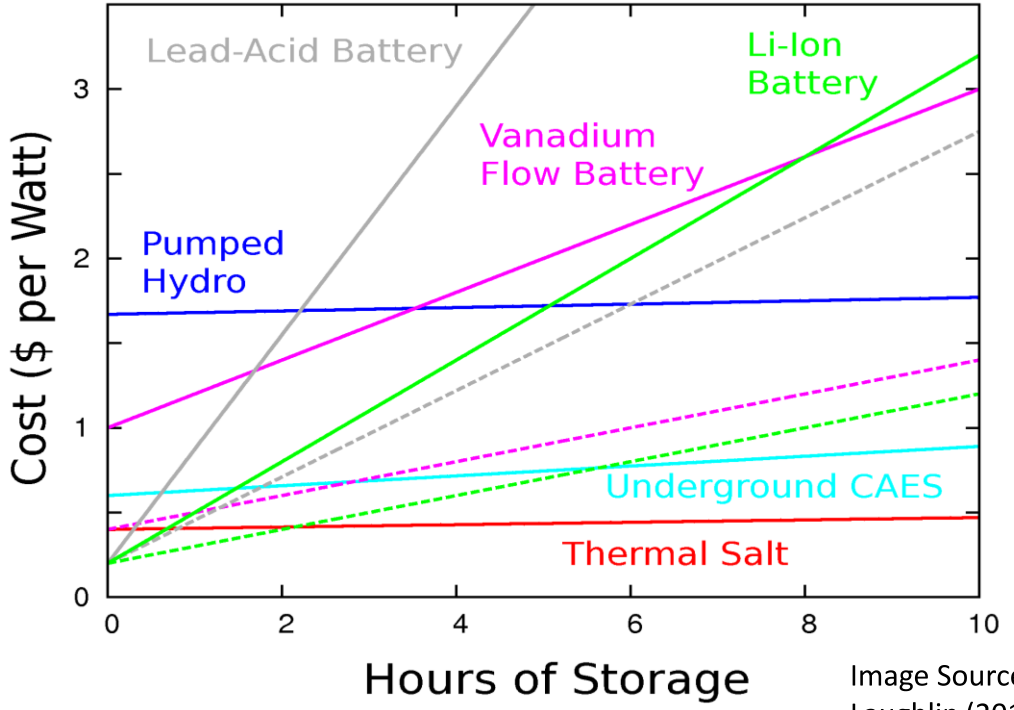
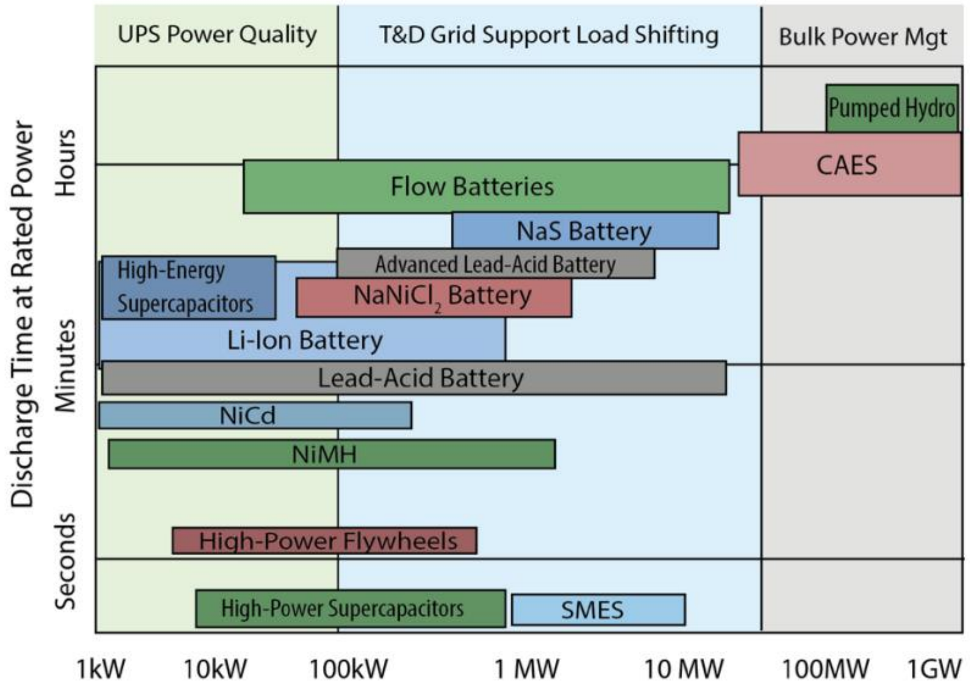


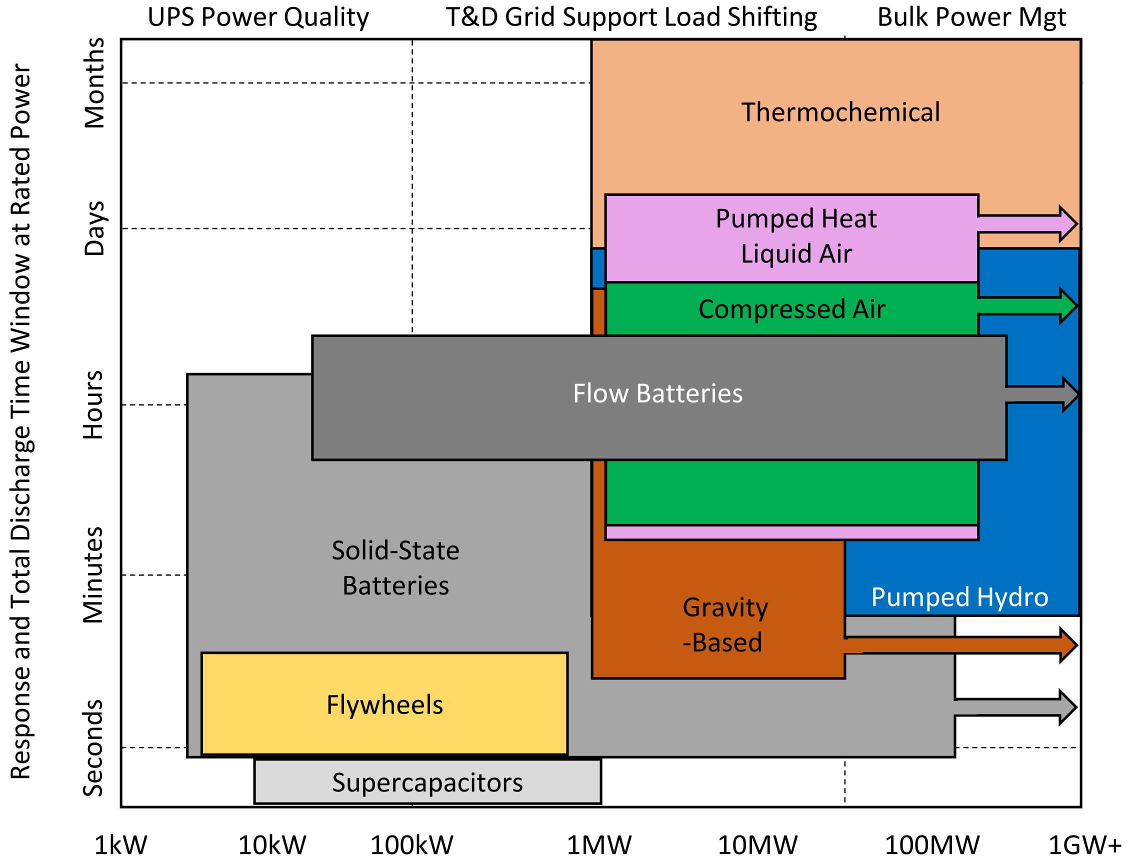
Image Source: Laughlin (2019)

Image Source: S&P Global (2019)

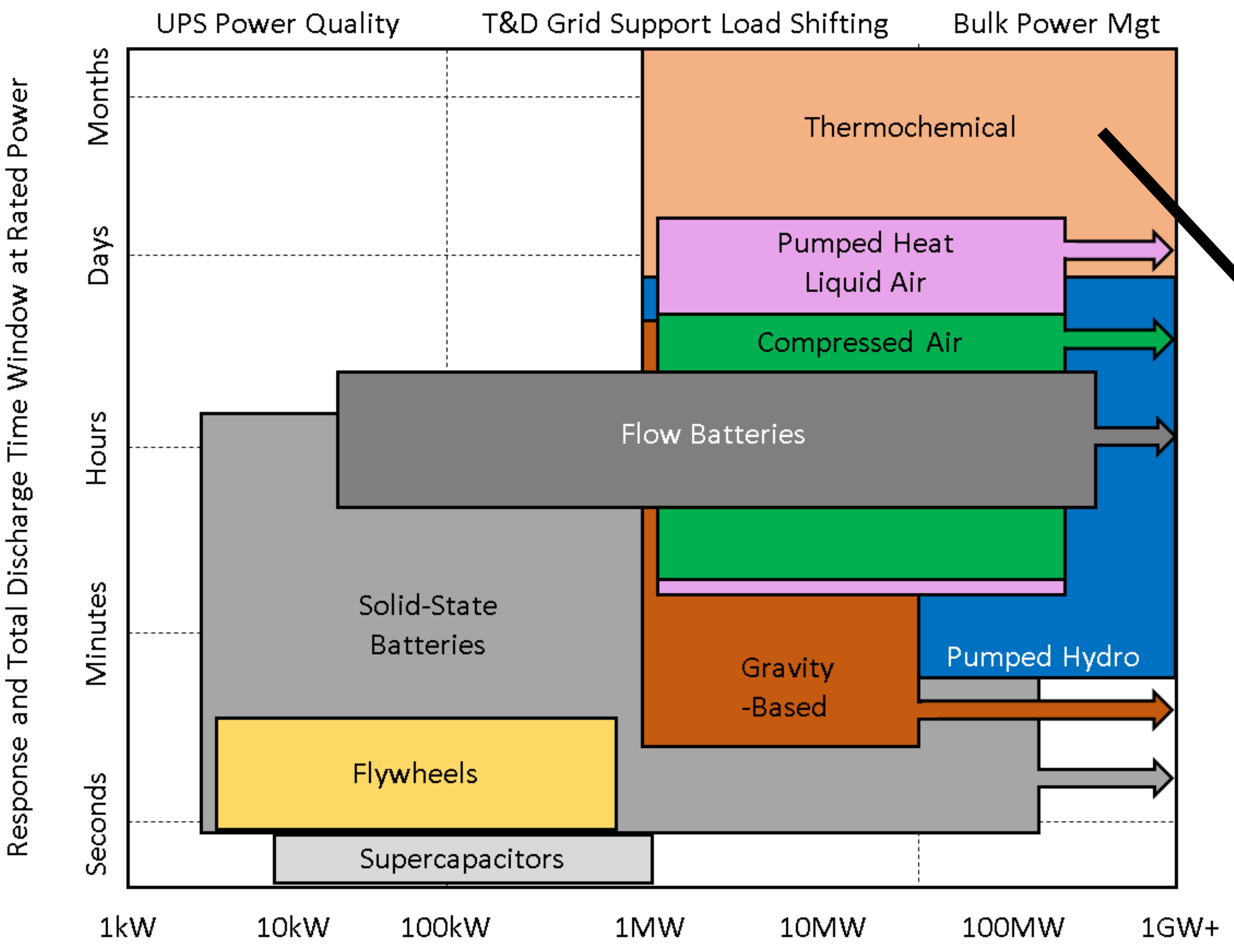
New Long-Duration Energy Storage Technologies are Needed

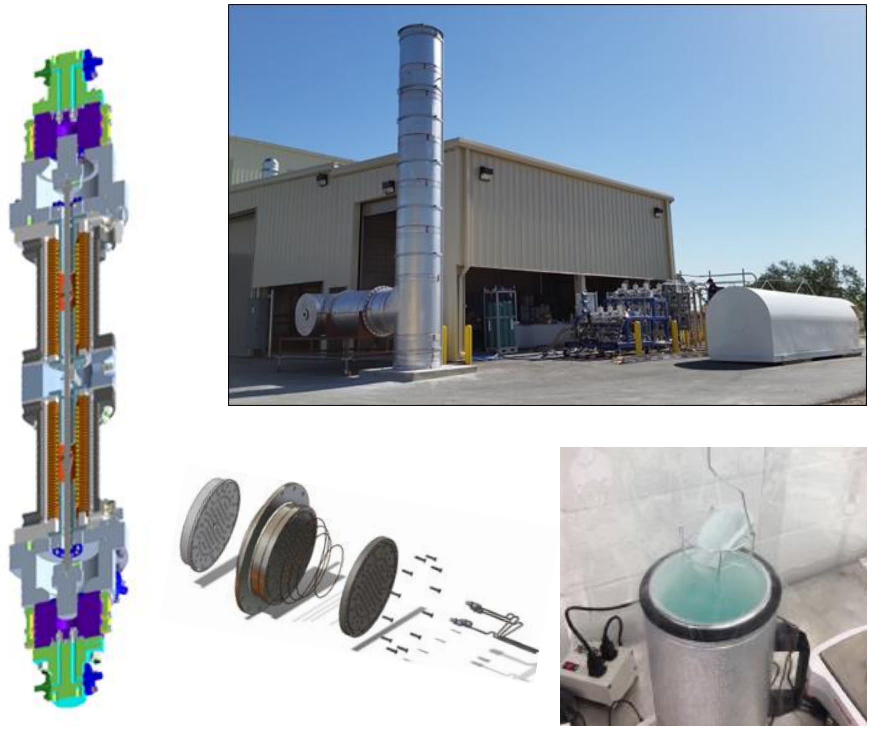


http://css.umich.edu/sites/default/files/U.S._Grid_Energy_Storage_Factsheet_CSS15-17_e2018.pdf



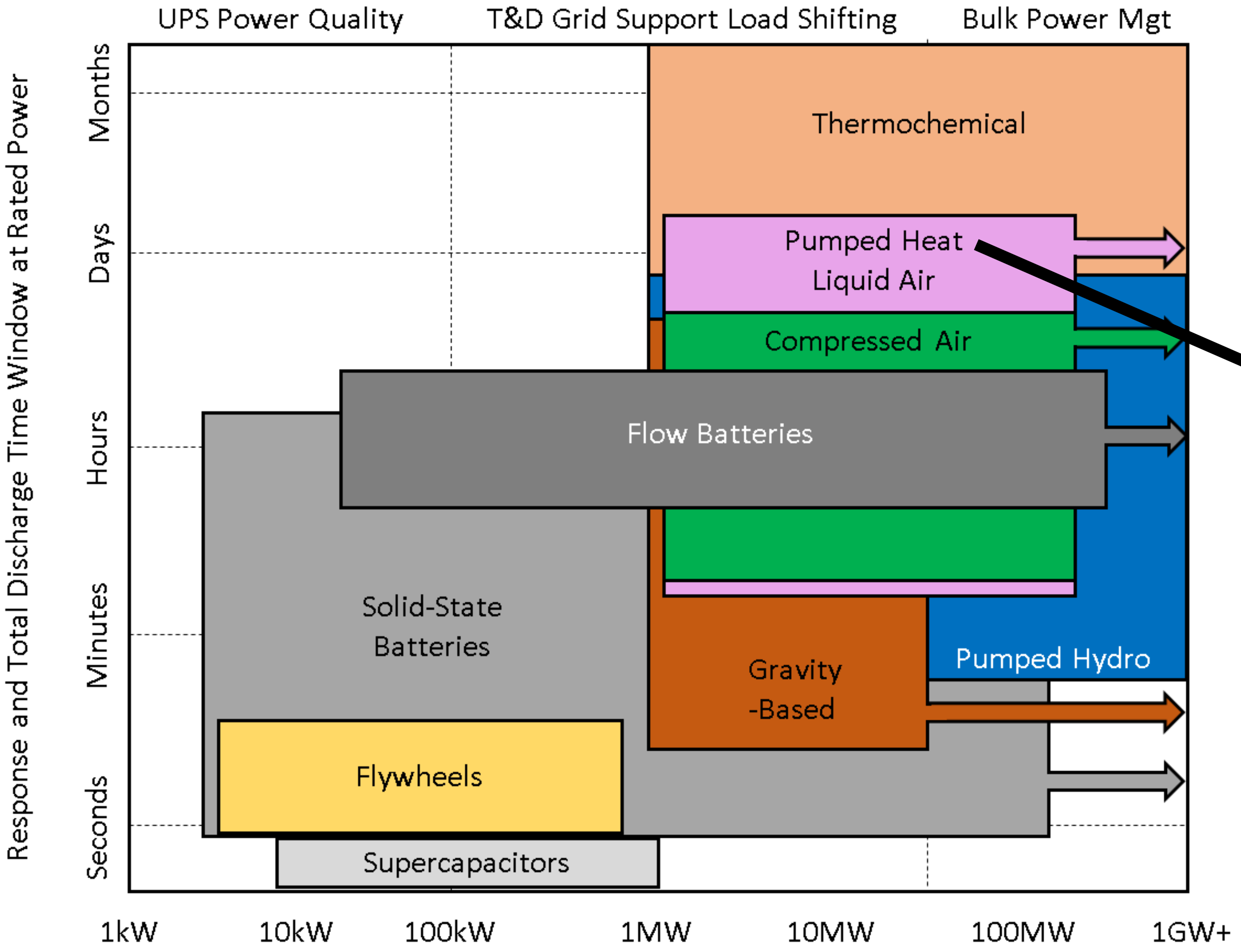
Enabling Renewables with Long-Duration Energy Storage

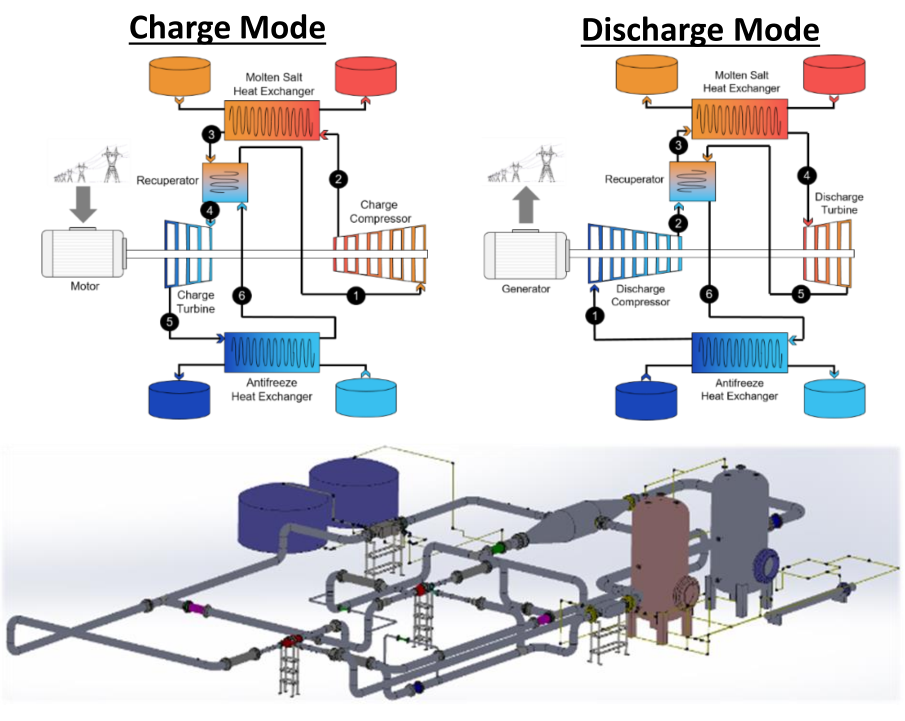




Hydrogen & Ammonia Storage, Compression, Combustion

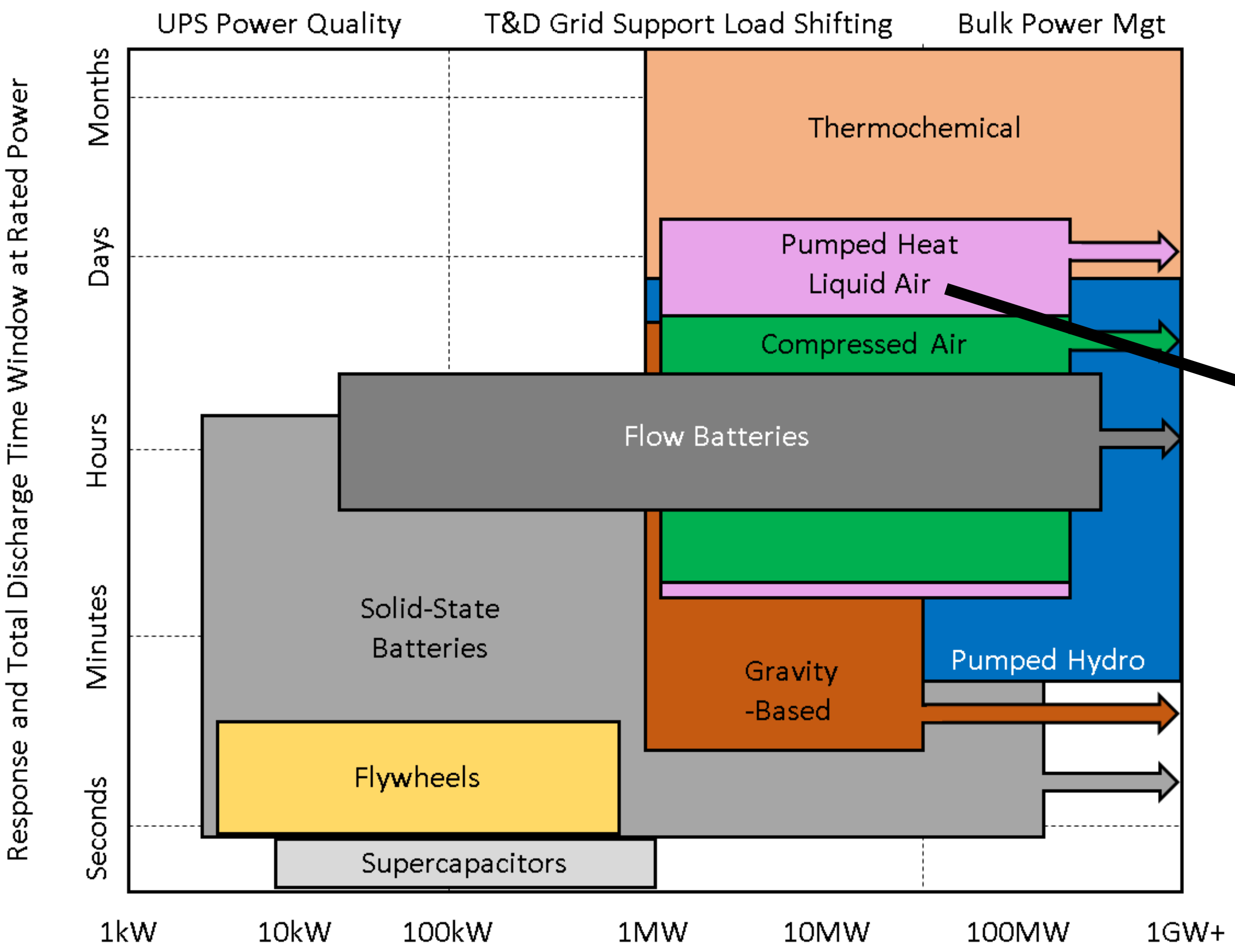
Enabling Renewables with Long-Duration Energy Storage

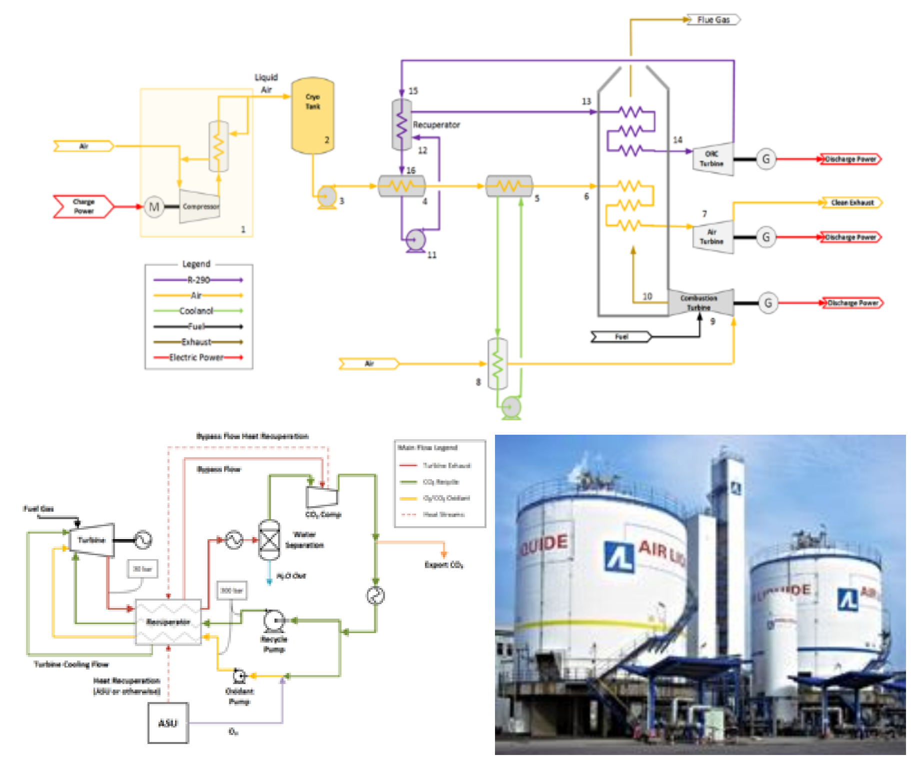




Pumped Thermal Energy Storage Demonstration with Malta, Inc. and Solar Turbines

Enabling Renewables with Long-Duration Energy Storage





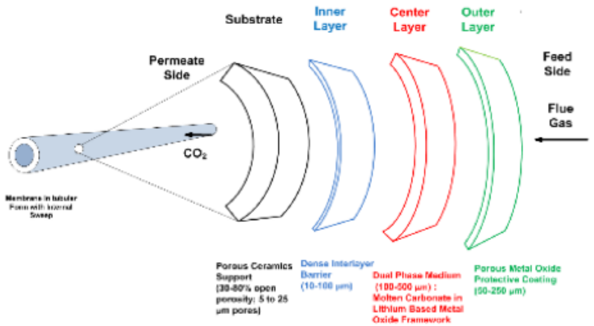
Liquid Air and Liquid Oxygen Storage for Time-Shifted Combined Cycle and Oxy-Combustion Applications

Decarbonizing Fossil Fuels

Carbon Capture & Utilization

- Post-combustion capture technologies include novel solvents, membranes
- Pre-combustion capture includes methane pyrolysis, gasification, other reactions
- Carbon utilization includes CO_2 to fuels, mineralization,
- Reducing the power penalty for CO_2 compression

Commercial carbon capture demonstration

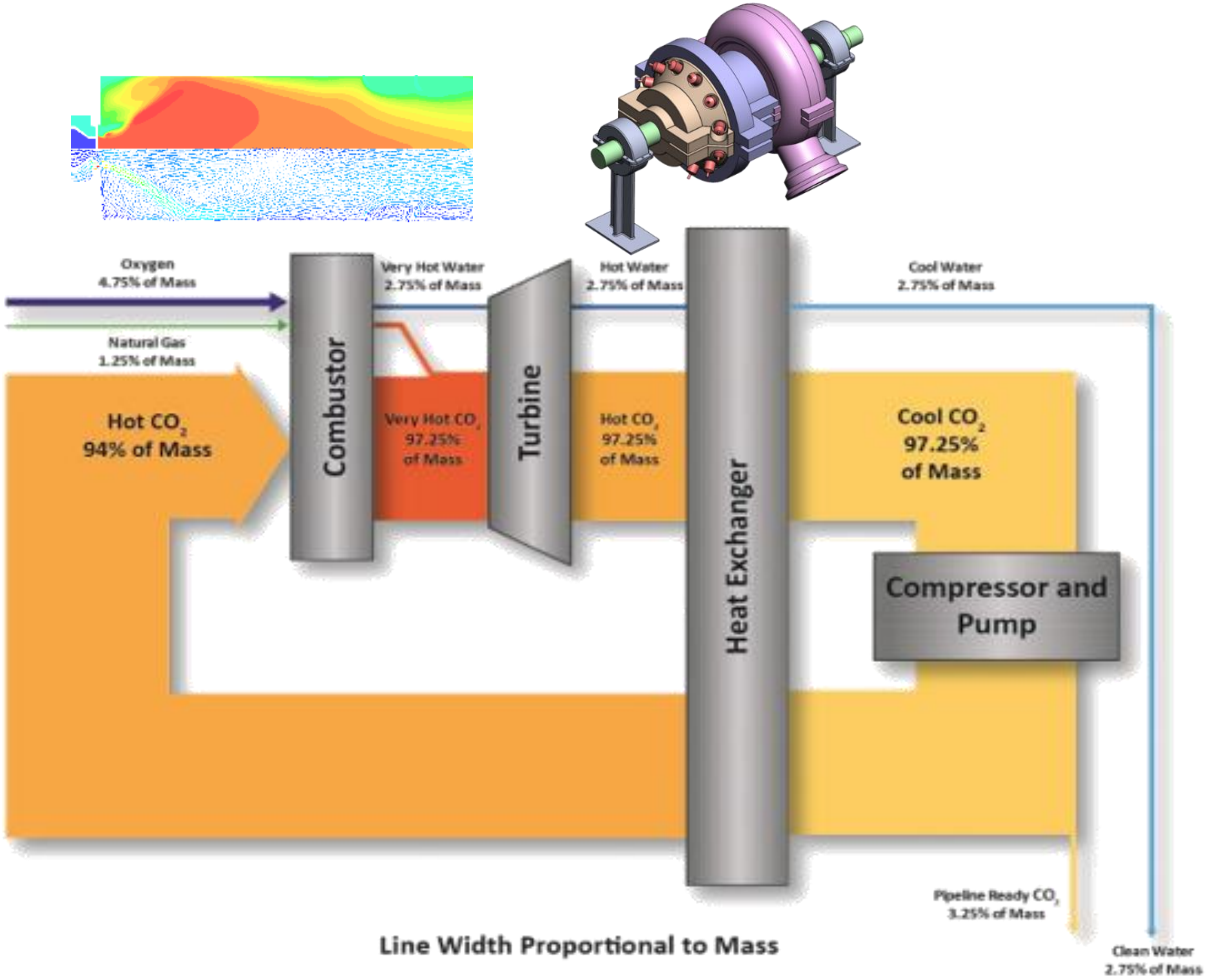


High-temperature CO2 separation membrane enables high CO2 flux, contamination tolerant with no regeneration requirements

CFB pyrolysis pilot plant

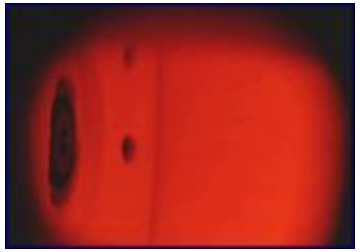
Isothermal CO2 compressor development

Net-Zero Fossil Fuel Technologies



Combustor and Turbine Development for Supercritical CO_2 Oxy-Combustion
[Allam-Fetvedt Cycle Image Courtesy 8 Rivers Capital]

Traditional Combustion with Flame Front



Flameless Pressurized Combustion

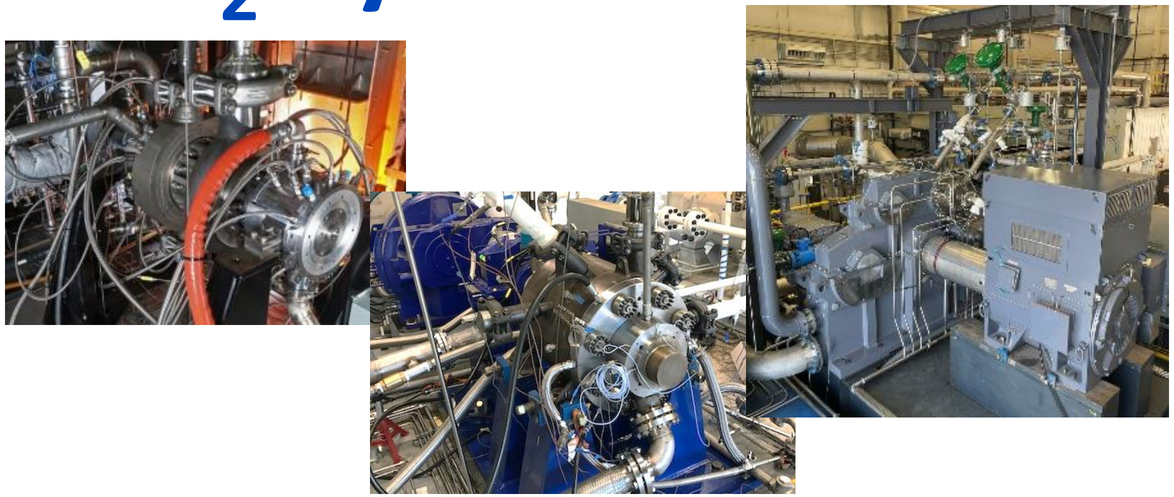
Traditional Combustor Products: Particulate

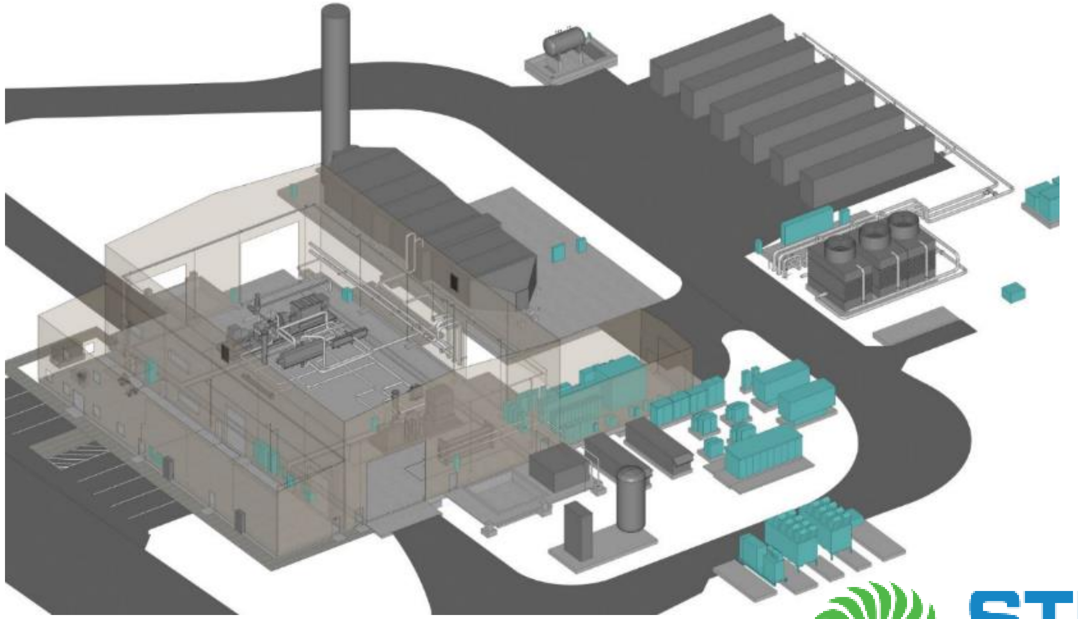
FPO Combustor Products: Near-zero slag

Cycle and Particle Separator Development for Flameless Pressurized Oxy-Combustion with Coal, Waste, Biomasss

Waste Heat Recovery with sCO_2 Cycles

- Improve efficiency of thermal generators by adding a bottoming cycle
- Supercritical CO_2 power cycle development has potential to exceed performance and economics of steam, ORC cycles
- Significant R&D in turbomachinery, heat exchangers, pilot-scale demonstration

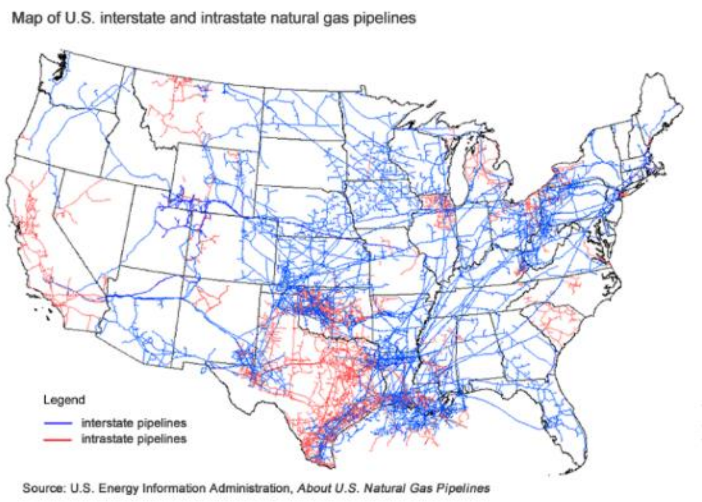




sCO_2 10 MW-Scale Turbine, Compressor Tests and 10 MW-Scale Pilot Plant Demonstration Facility

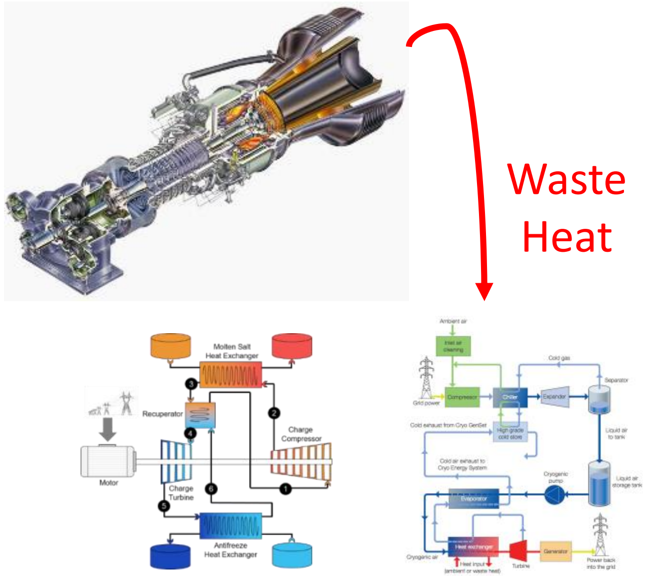
Opportunities for Synergy

Infrastructure



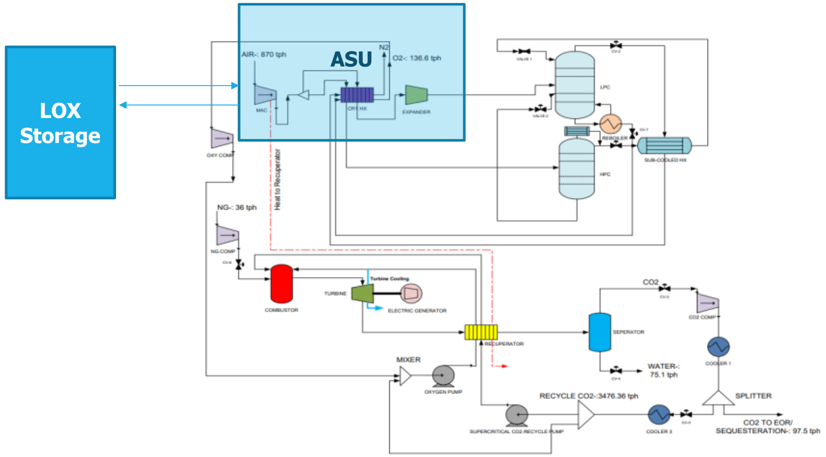
Hydrogen blending into natural gas pipeline infrastructure may allow low-cost phase-in of low-carbon hydrogen but requires significant research

Thermal Integration



Thermal generators coupled with low-cost thermal energy storage can hybridize with many long-duration storage technologies

Demand Response



Example of DOE ARPA-E FLExible Carbon Capture and Storage (FLECCS) Program: Oxygen storage enables time-shifting of ~20% air separation unit parasitic load for sCO_2 oxy-combustion.

Summary

- Technology development needed to achieve clean energy goals!
- Research and development activities focused on long-duration energy storage technologies (incl. Hydrogen) are enabler for deep renewable penetration with improved economics over Li-ion batteries
- Carbon capture and utilization / storage technology development can dramatically reduce carbon emissions while maintaining favorable economics
- Synergies exist coupling energy storage with existing energy transport infrastructure, thermal power plants (heat streams), and carbon capture (load shifting)

Questions?

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