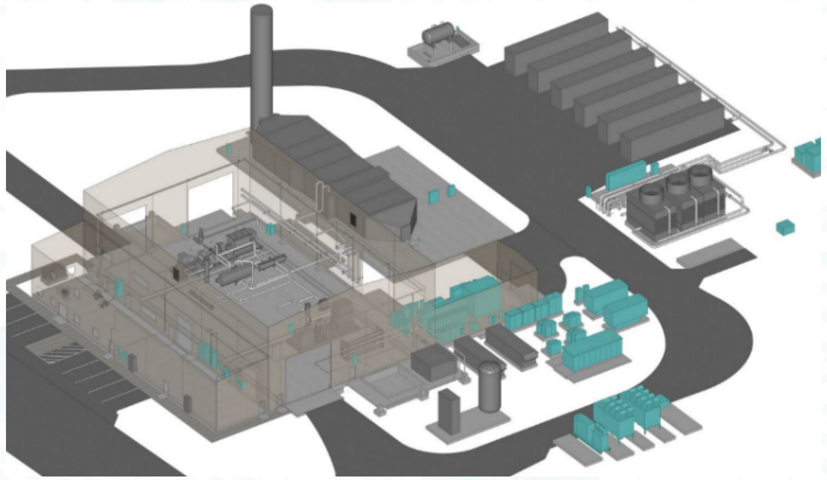
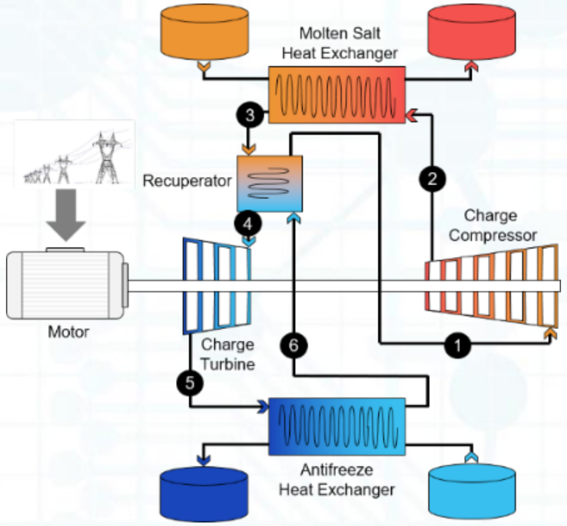
Optimizing the Size and Duration of LDES in Distributed Energy Systems

Tim Allison, Ph.D.
Director, Machinery Department
Southwest Research Institute



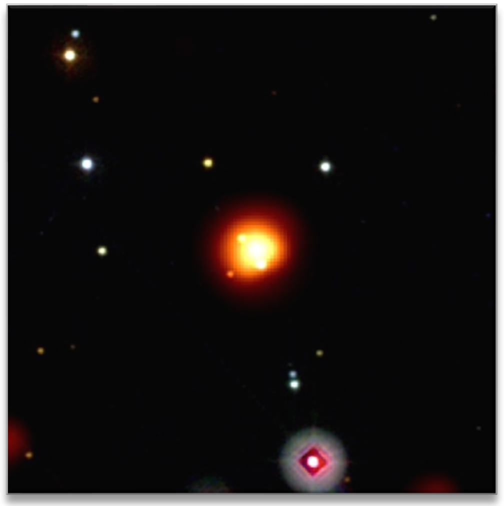


July 30, 2026
TMCES Workshop
Charlotte, NC

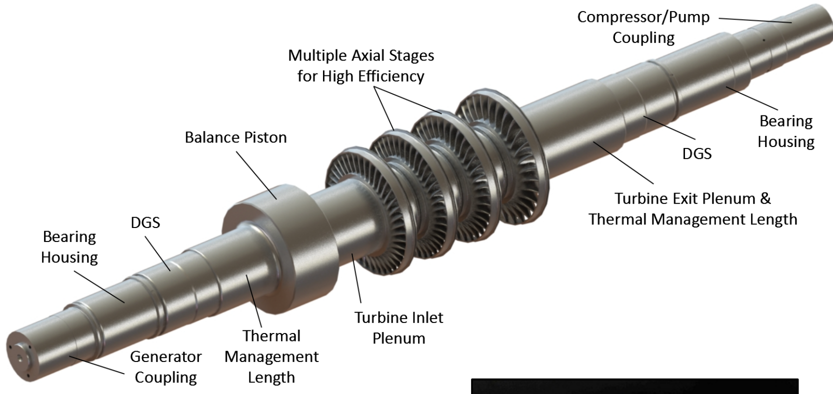
SwRI Matures Technology Through Applied Research & Development Projects

- Founded in 1947, based in San Antonio, Texas
- 501(c)(3) nonprofit corporation
  - Internal Research
  - New Laboratories
- $915M FY25 revenue from contract work for industry and government clients
- Over 3,200 employees
- 1,500-acre facility; 2.3 million square feet of laboratories & offices
- Customer-centric IP policy
- Core values of integrity, innovation, people, stewardship

Deep Sea to Deep Space®…

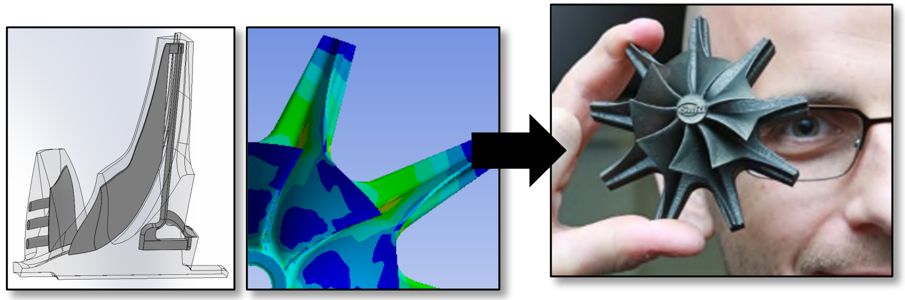


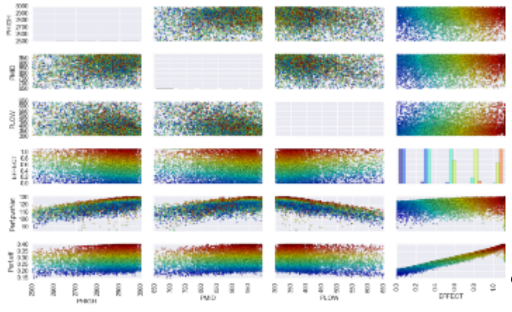
SwRI Machinery Department

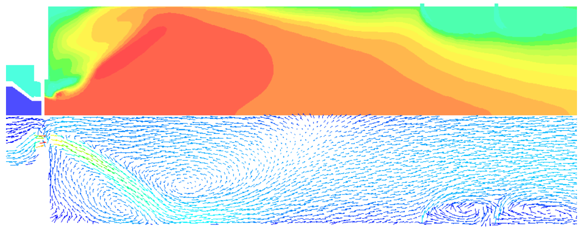


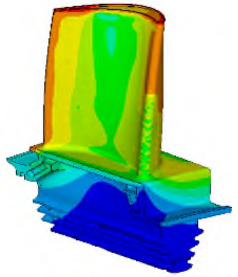
Applied Research centered around Rotating Machinery and associated systems for

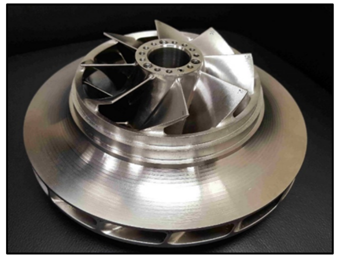
- Oil & Gas Compression Systems
- Aviation & Liquid Propulsion
- Power Generation
- Industrial Machinery





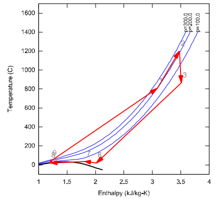


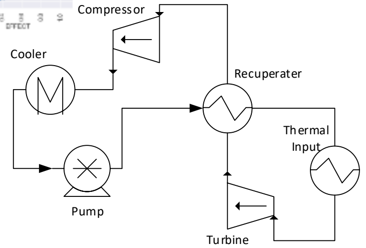


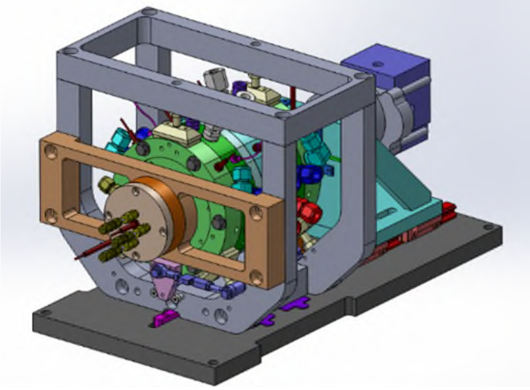


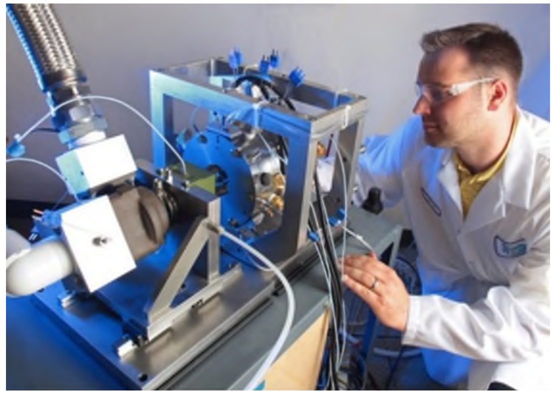
Expertise including developing technologies, prototype demonstration, and mature products and systems

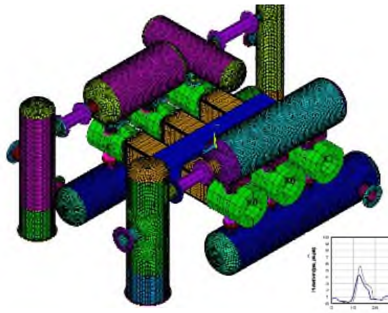
- 90 Staff
- 6 labs; open/closed-loop test facilities; powertrains up to 15 MW shaft power
- New flammable gas test facility
- Field testing and troubleshooting
- Support OEMs in transitioning new technologies to products

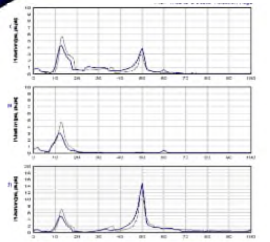






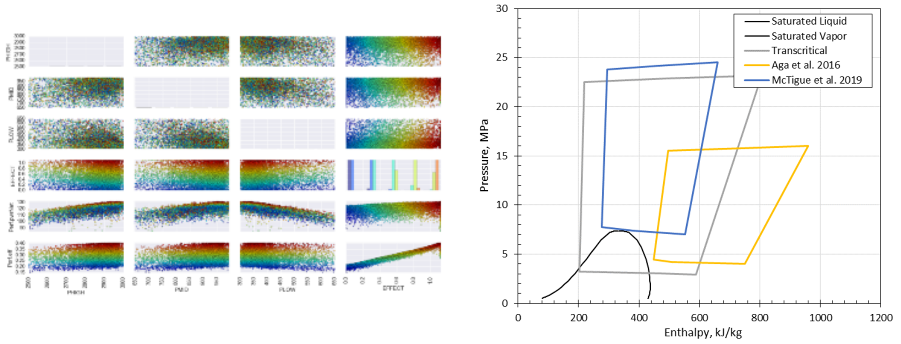




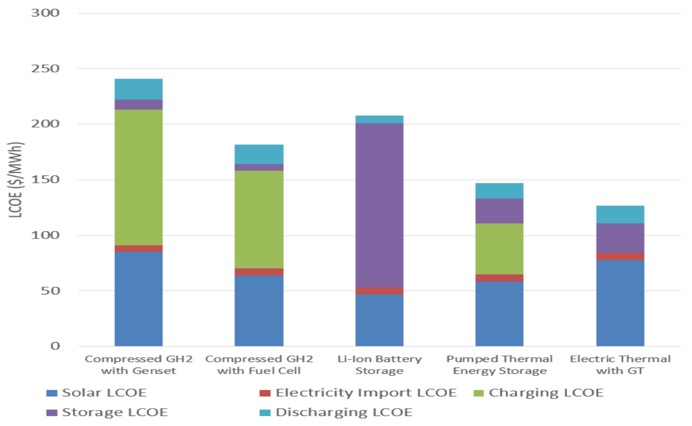


Research Capabilities for Energy Storage Technology Development

Thermodynamic and Techno-economic Analyses

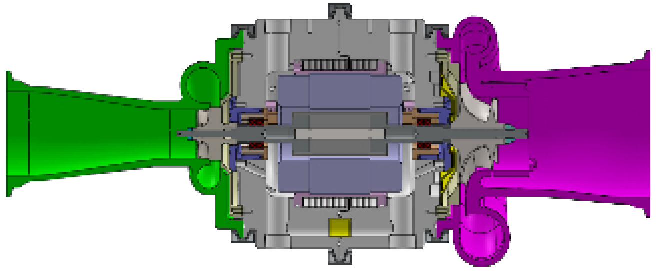


Parameter Studies and Optimization of Heat Pumps and Power Cycles

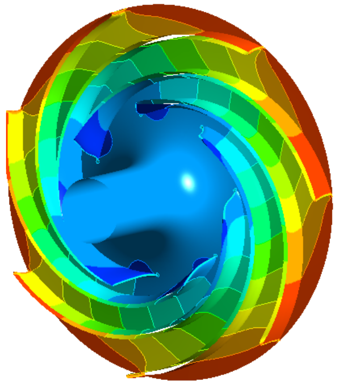


Techno-economic Analysis of Net-Zero Pathways for a 25 MW Microgrid

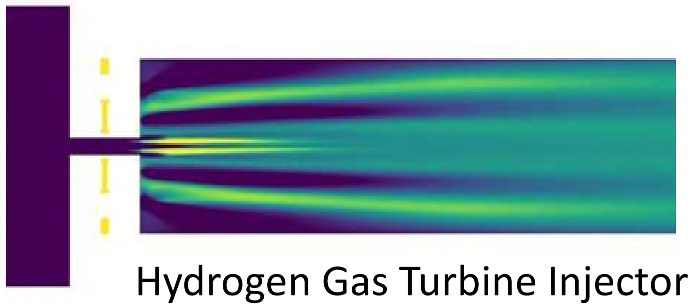
Mechanical Design, Analysis, Fabrication



Turbo-Compressor Development for Pumped Thermal Energy Storage Demo



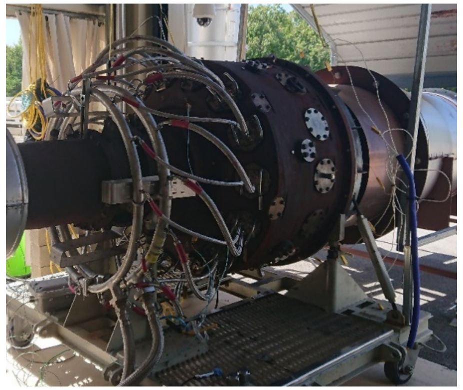
Pump-as-Turbine Simulation



Hydrogen Gas Turbine Injector Design

715°C 255 bar sCO_2 Turbine Rotor

Component and Pilot-Scale Testing

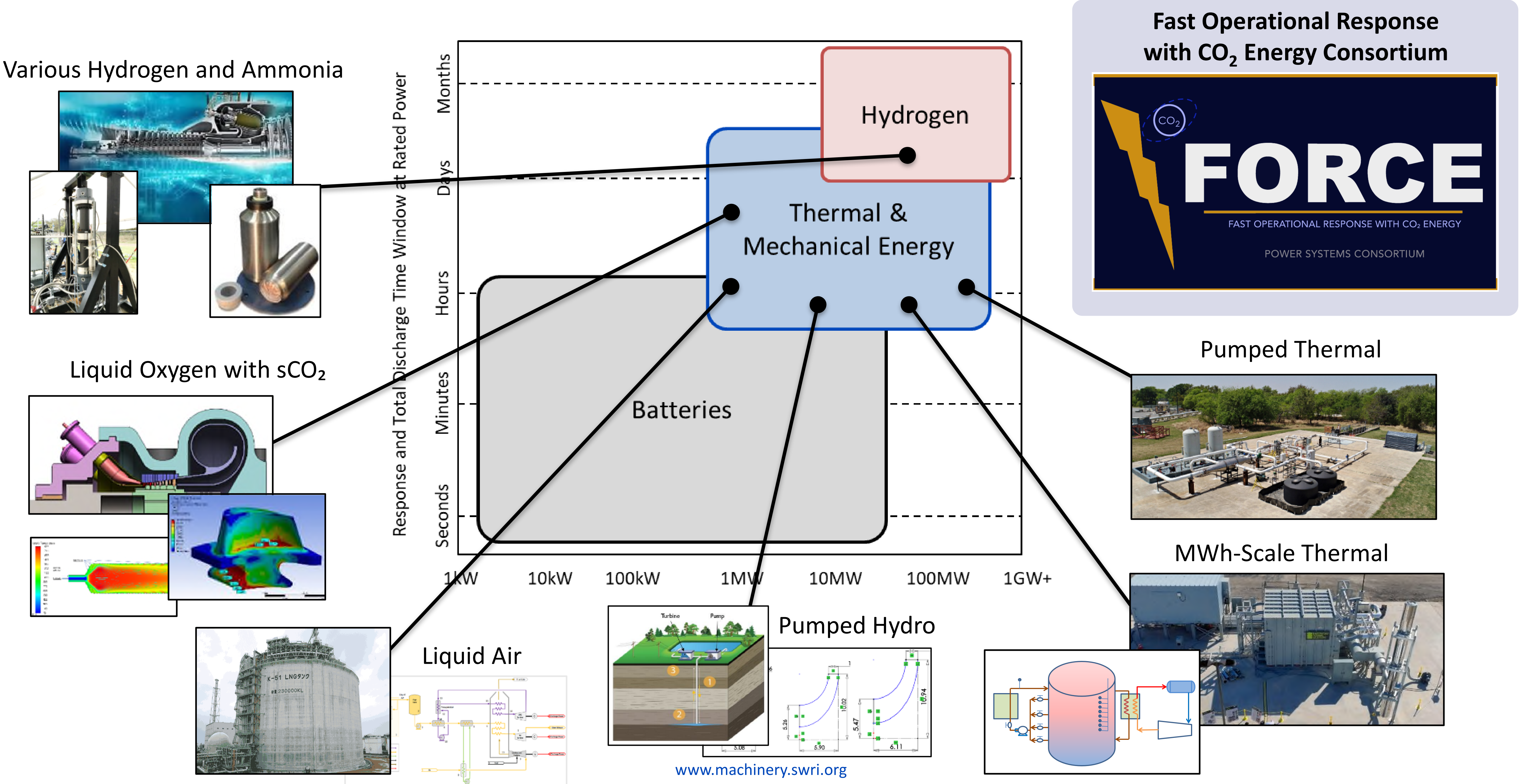


Hydrogen and Ammonia Combustion

MWh-Scale Thermal Energy Storage

10 MWe STEP sCO_2 Pilot Plant

Energy Storage Technology Experience



www.machinery.swri.org

Distributed Energy Systems and LDES

- Many data center / industrial use cases, including 10-100+ MW scale
- Streamlines ownership of emissions targets, tax credits
- Minimize/eliminate transmission & distribution costs, typically 40-50% of purchased electricity
- Frequently behind-the-meter framework
- May include combined heat and power
- Typically maintain grid connection as source of additional/backup power and frequency stability.

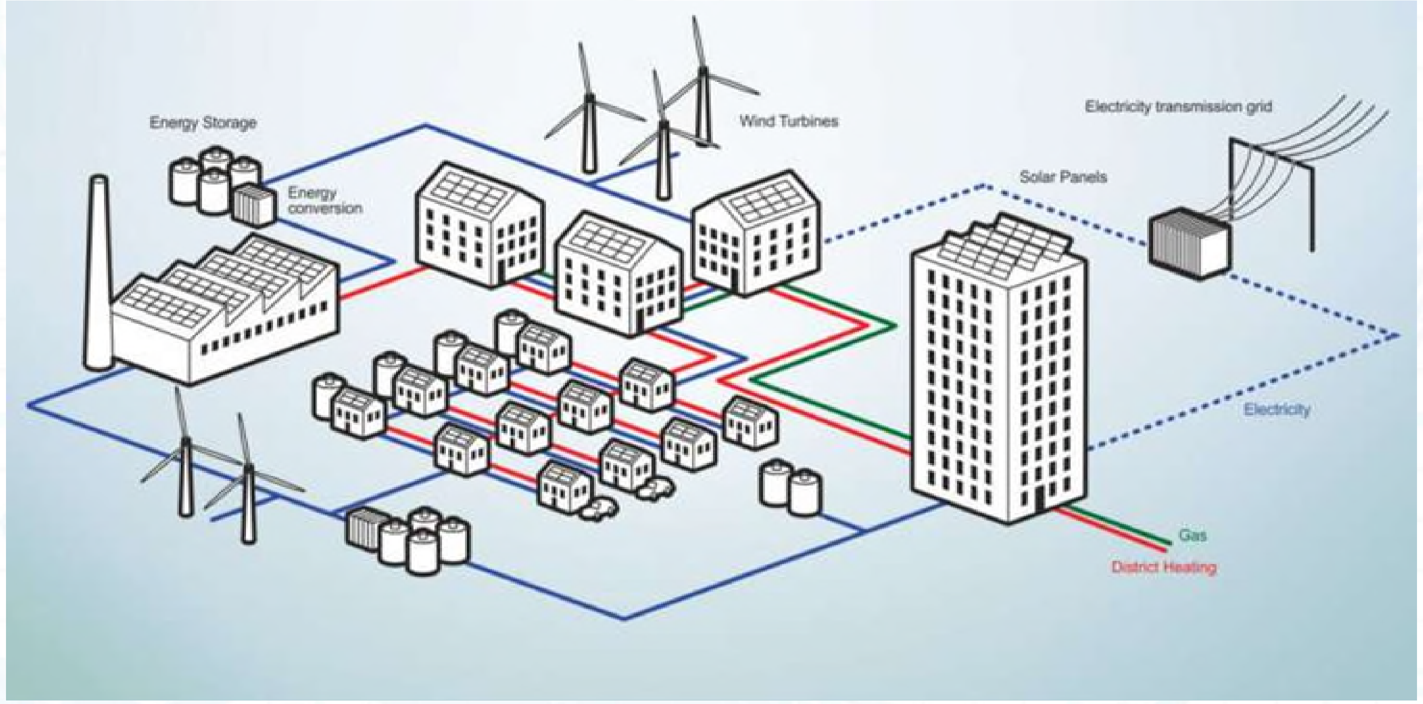
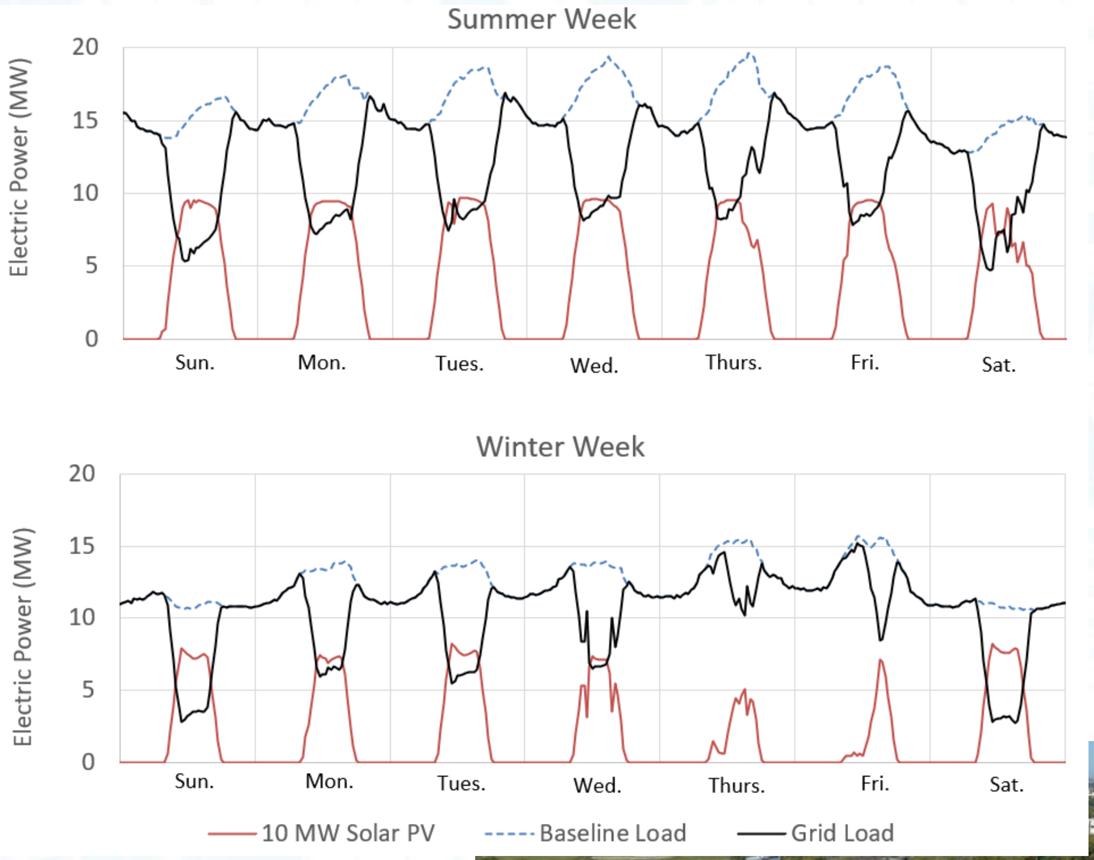


Image Courtesy ETH Zurich

SwRI as Case Study: 22 MWe System

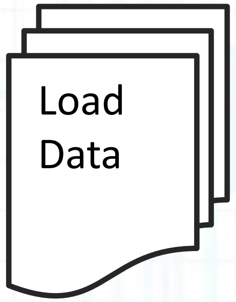
- ~22 MW peak load and good solar irradiance
- "Buffer" land available for solar PV
- Existing natural gas supplies for ~200 MWth
- No additional land cost
- Combined use case of R&D opportunity, electricity decarbonization, and cost savings
- Already have a 10 MW power plant with grid tie-in



Typical SwRI load and impact of 10 MW Solar PV

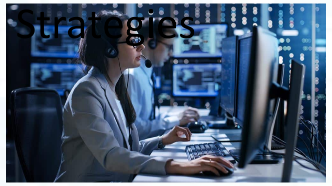
STEP 10 MW Supercritical CO2 Pilot Plant at SwRI

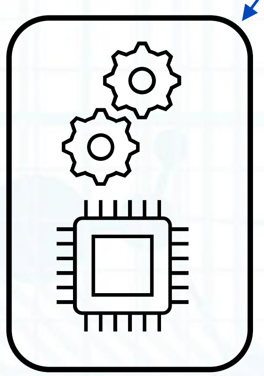
Energy Storage Modeling Tool



Federal Tax Incentives

Custom Dispatch Strategies





PyZ Model

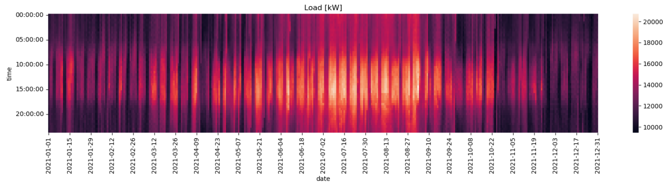
Generalized toolset developed under SwRI IR&D Project Z

Generation

Energy Storage

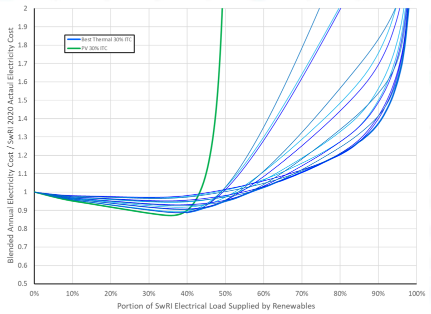
Electricity Pricing

Hourly energy balance against load

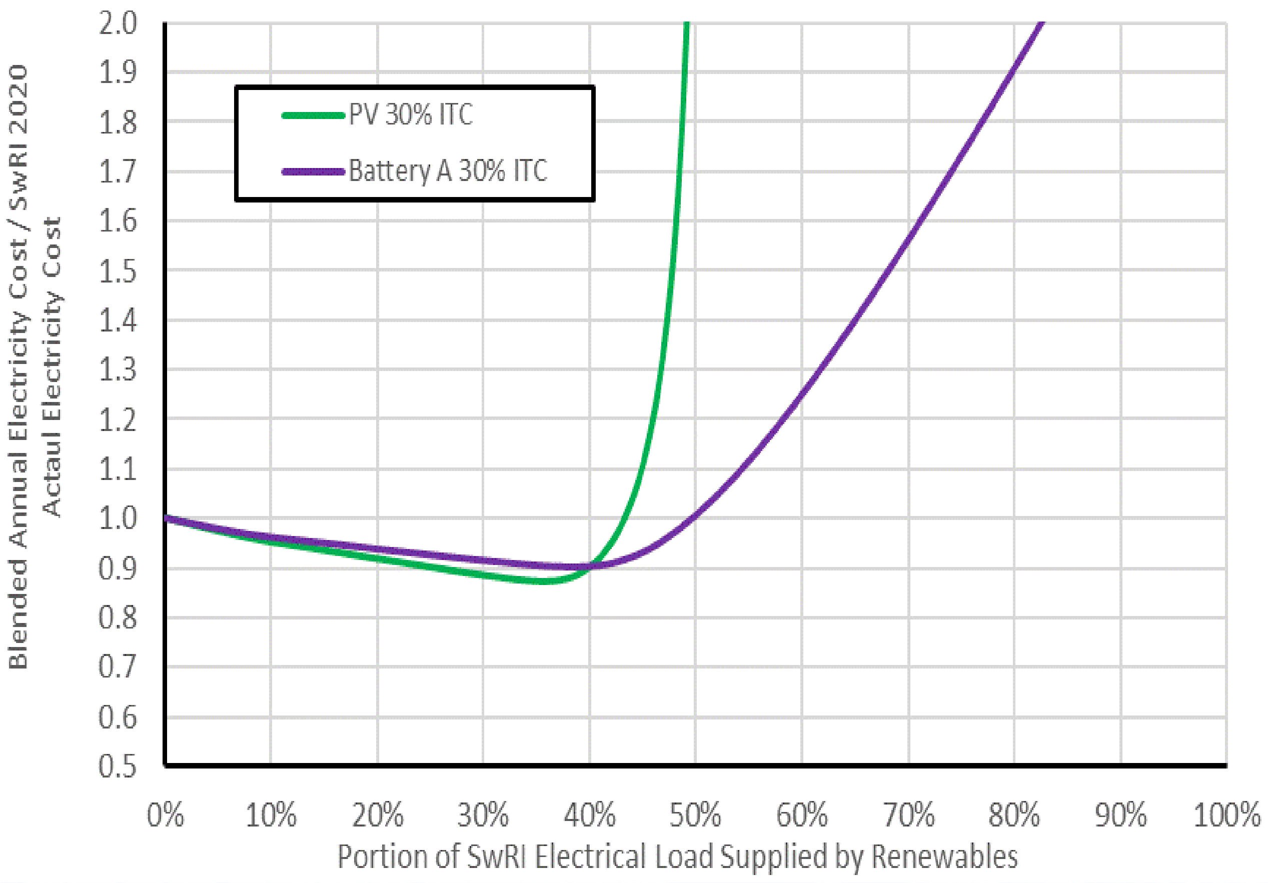


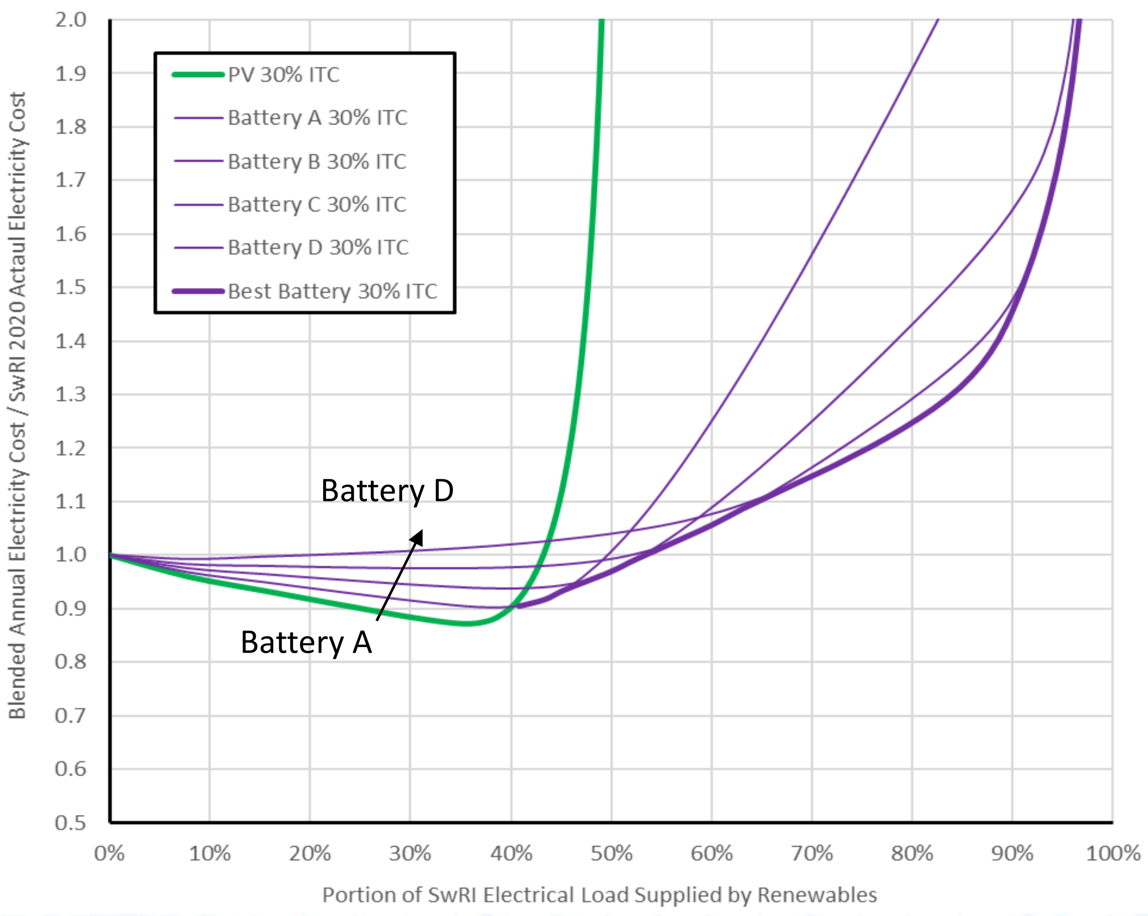
Techno-Economic Analysis of

- On-site generation
- Storage Options



Example Battery Results with Swept Parameters

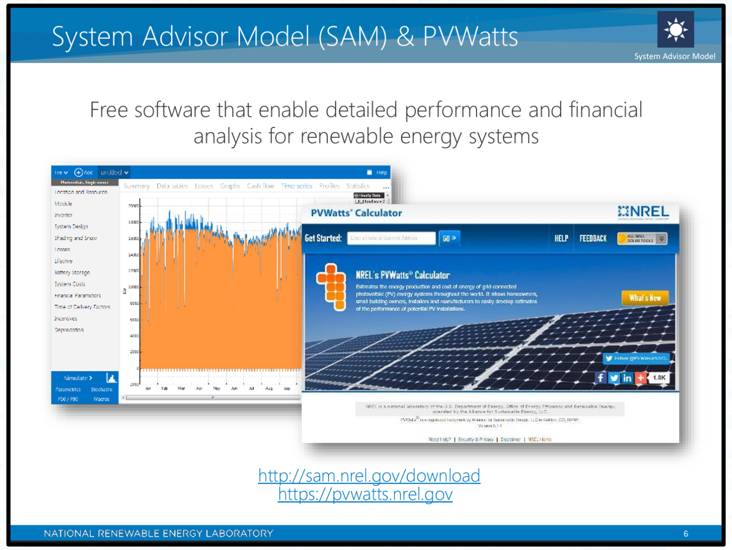


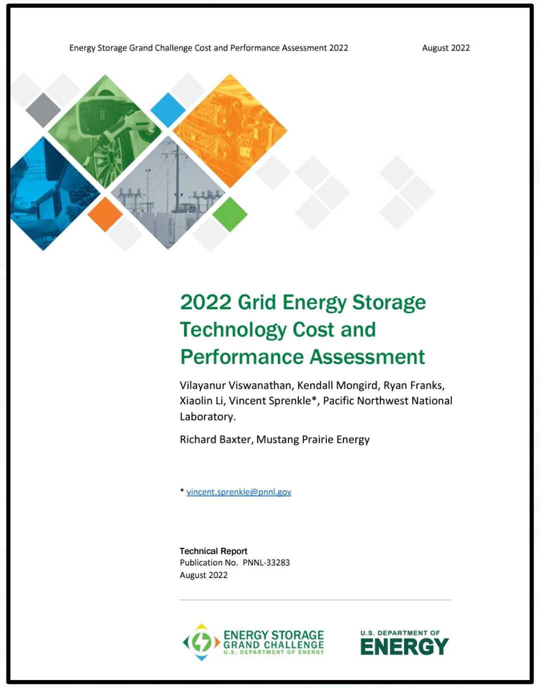


- Battery size relative to PV size is swept
- Range from 0.5 to 2.0 MWh of storage per MW PV capacity
- Creates a lowest cost curve that is used going forward

SwRI Study: Techno-Economic Inputs

- Public studies from reputable sources
  - NREL for renewable generation costs, performance
  - PNNL 2022 Grid Energy Storage Assessment
- Detailed cost breakdowns that separate major costs, like charging, storage, discharging, and EPC costs
- Utilizing 30% ITC Tax Credit in U.S.





Energy Storage Grand Challenge Cost and Performance Assessment 2022 August 2022

2022 Grid Energy Storage Technology Cost and Performance Assessment

Vilayanur Viswanathan, Kendall Mongird, Ryan Franks, Xiaolin Li, Vincent Sprenkle*, Pacific Northwest National Laboratory.

Richard Baxter, Mustang Prairie Energy

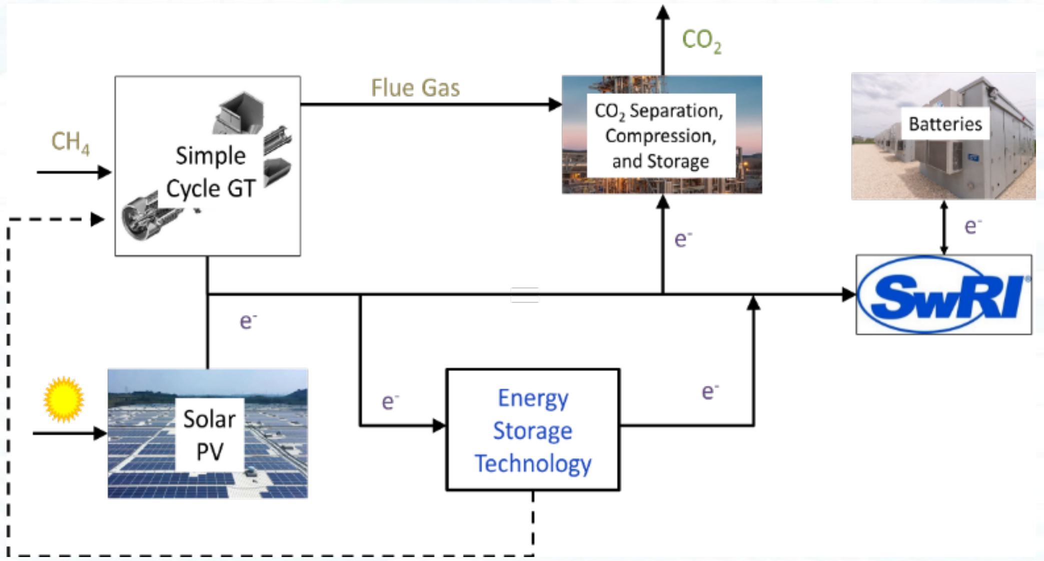
* vincent.sprenkle@pnnl.gov

Technical Report
Publication No. PNNL-33283
August 2022

ENERGY STORAGE GRAND CHALLENGE U.S. DEPARTMENT OF ENERGY

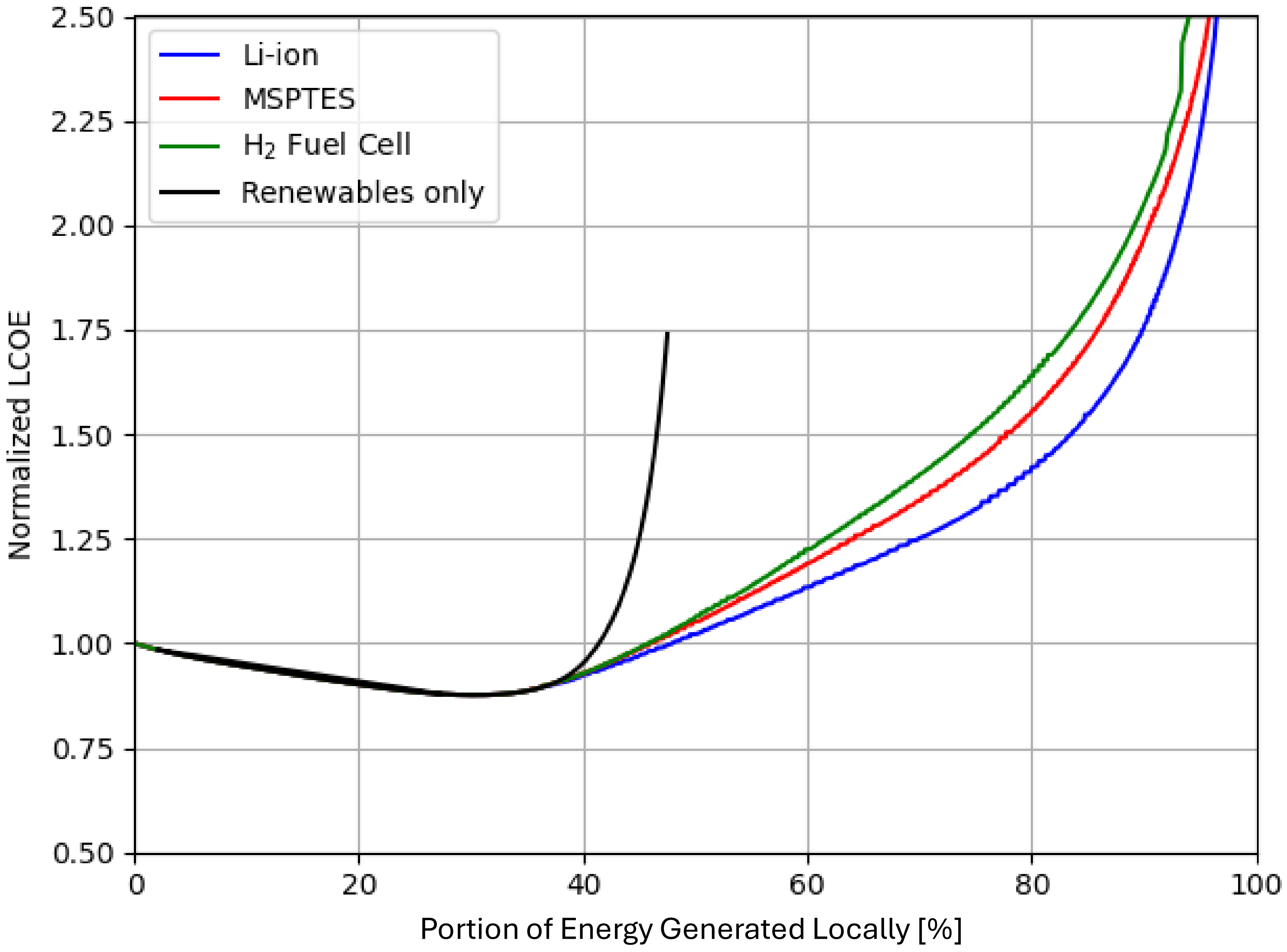
U.S. DEPARTMENT OF ENERGY

	Li-ion BES	Molten Salt PTES	H_2 Fuel Cell
Charge / Discharge CAPEX, $/kW	53 / 53	935 / 597	1485 / 1408
Energy CAPEX, $/kWh	384	127	122
Round Trip Efficiency	85%	50%	35%

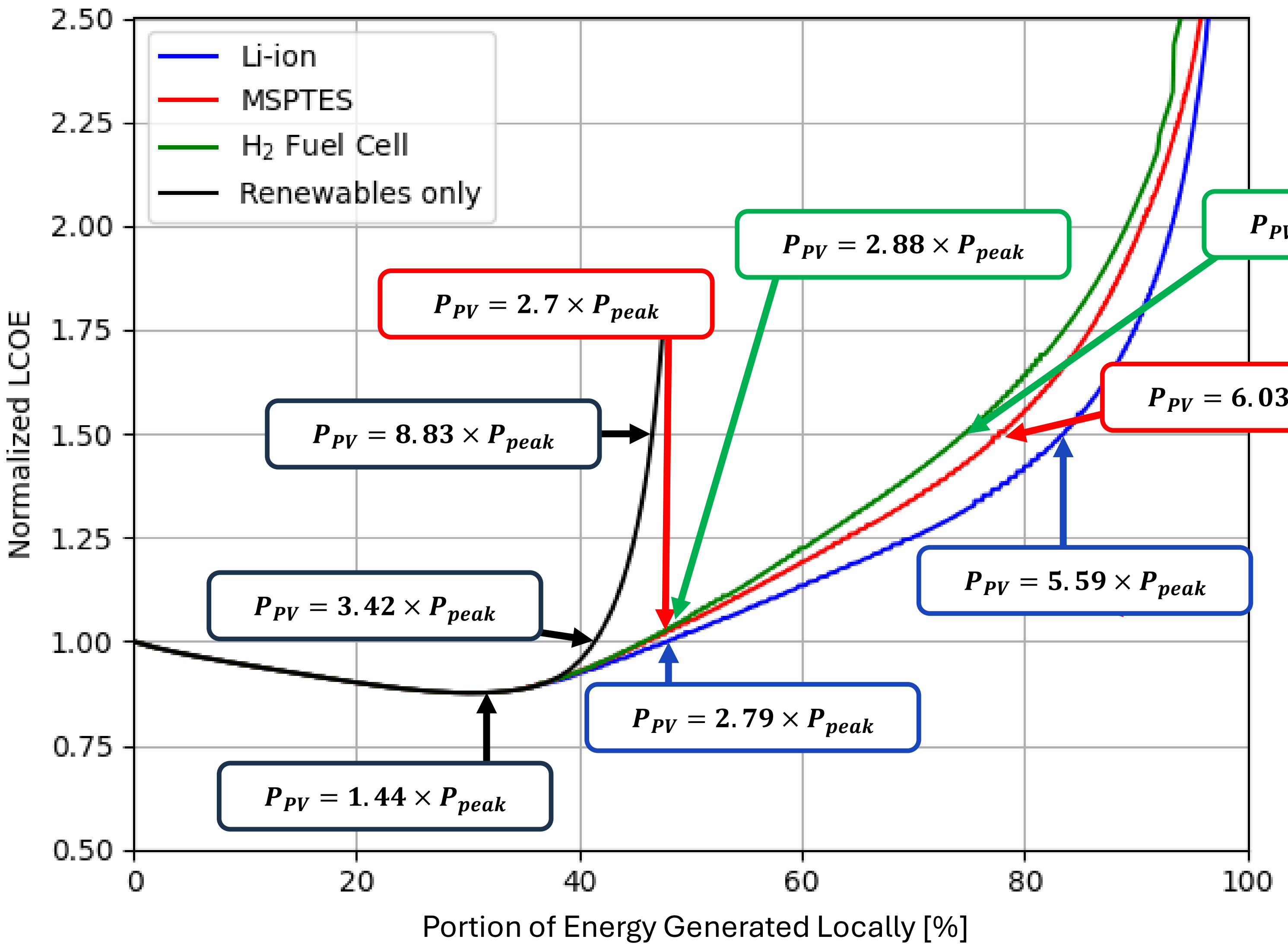


SwRI Study: Pathways to Onsite Generation

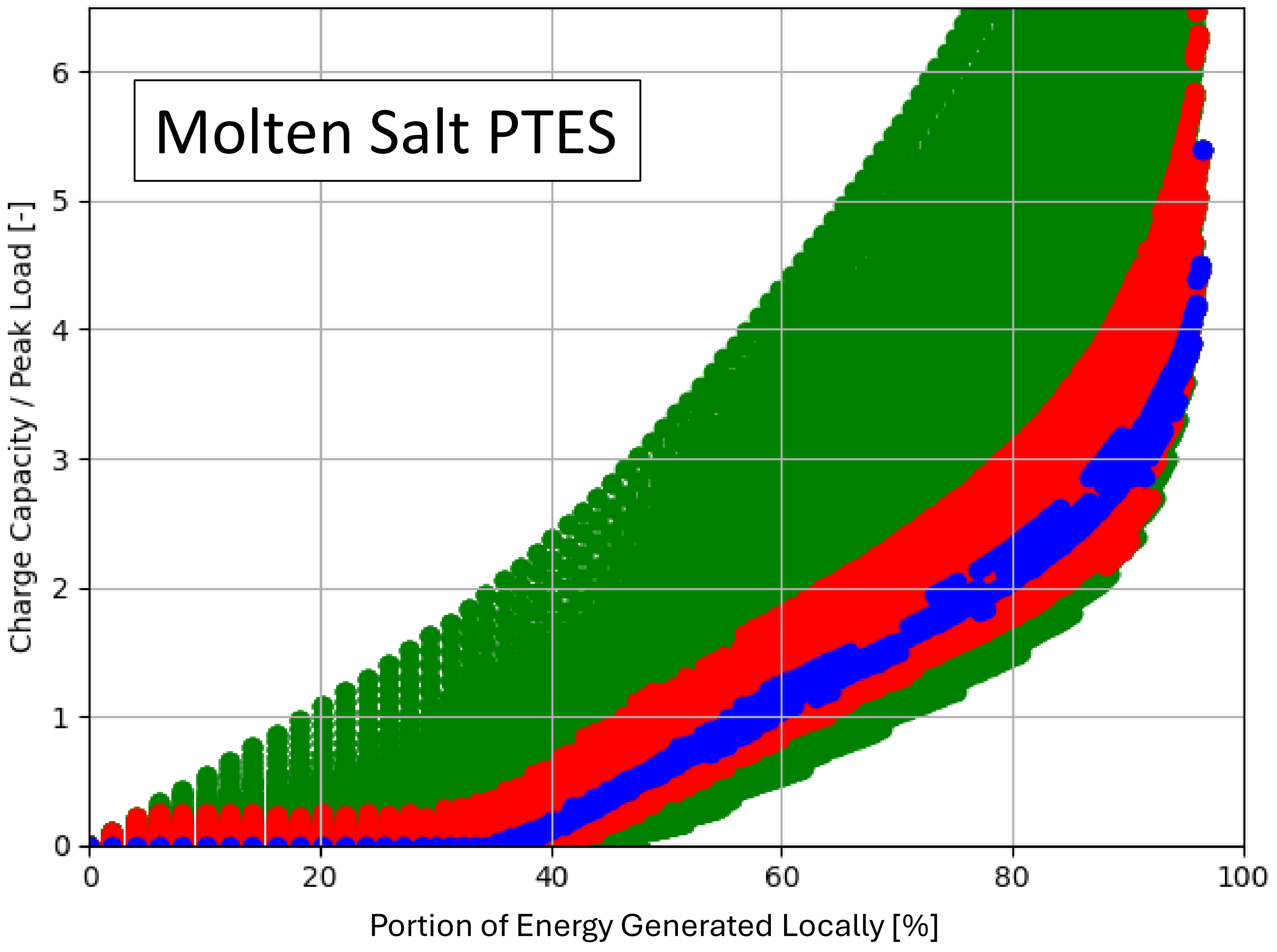
- Solar PV only (not storage):
  - Initially decreases electricity costs but cannot generate past ~40% at cost parity
  - Cannot generate beyond ~45% due to low capacity factor
- Storage technologies:
  - Extend cost parity point to ~45%
  - Can generate past ~90% at ~2x costs
- Batteries are lowest cost option, but narrow spread
- What do these optimal systems look like?

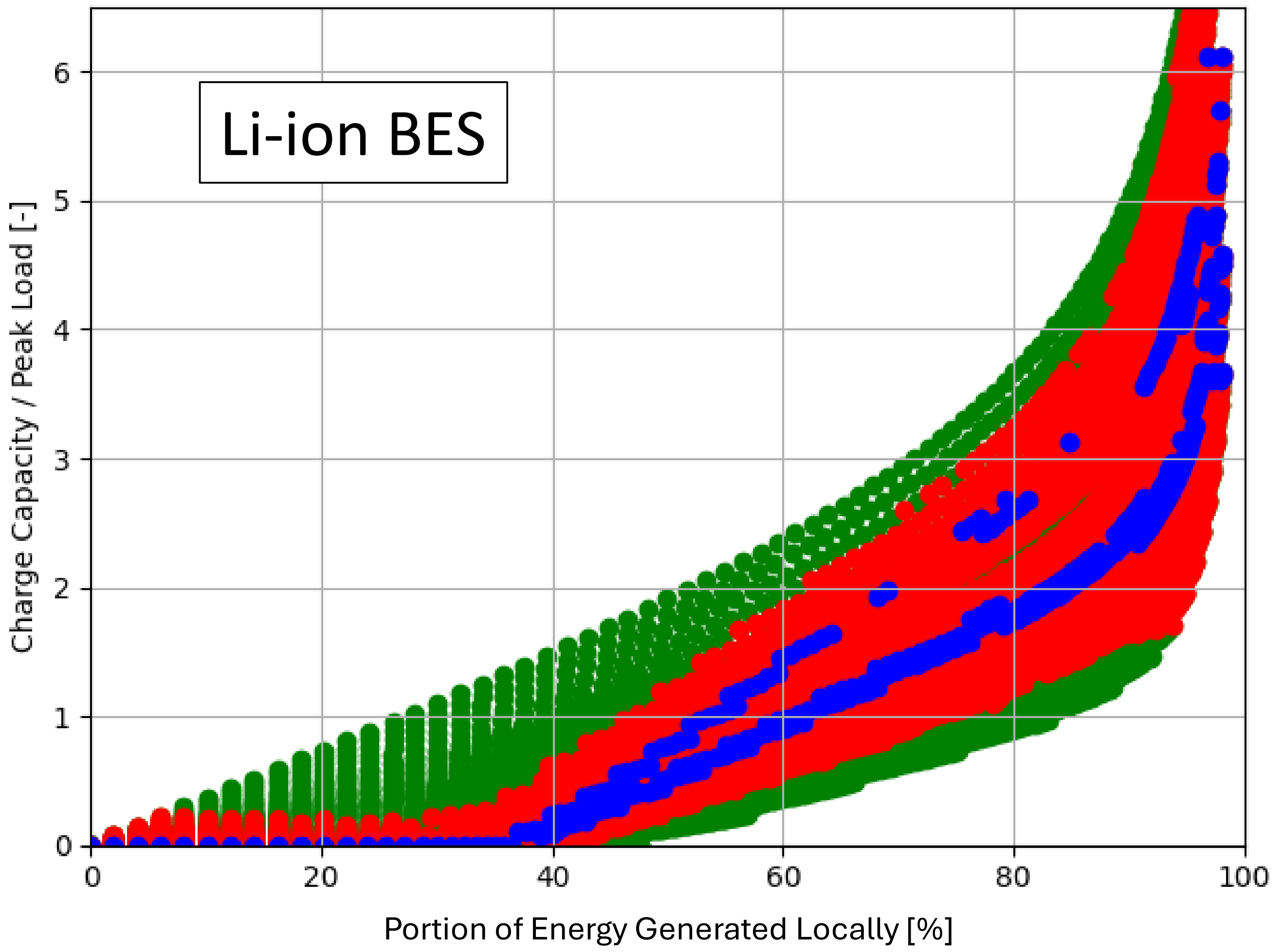


SwRI Study: Solar PV Capacity Requirements



Charge Capacity vs. Local Generation %

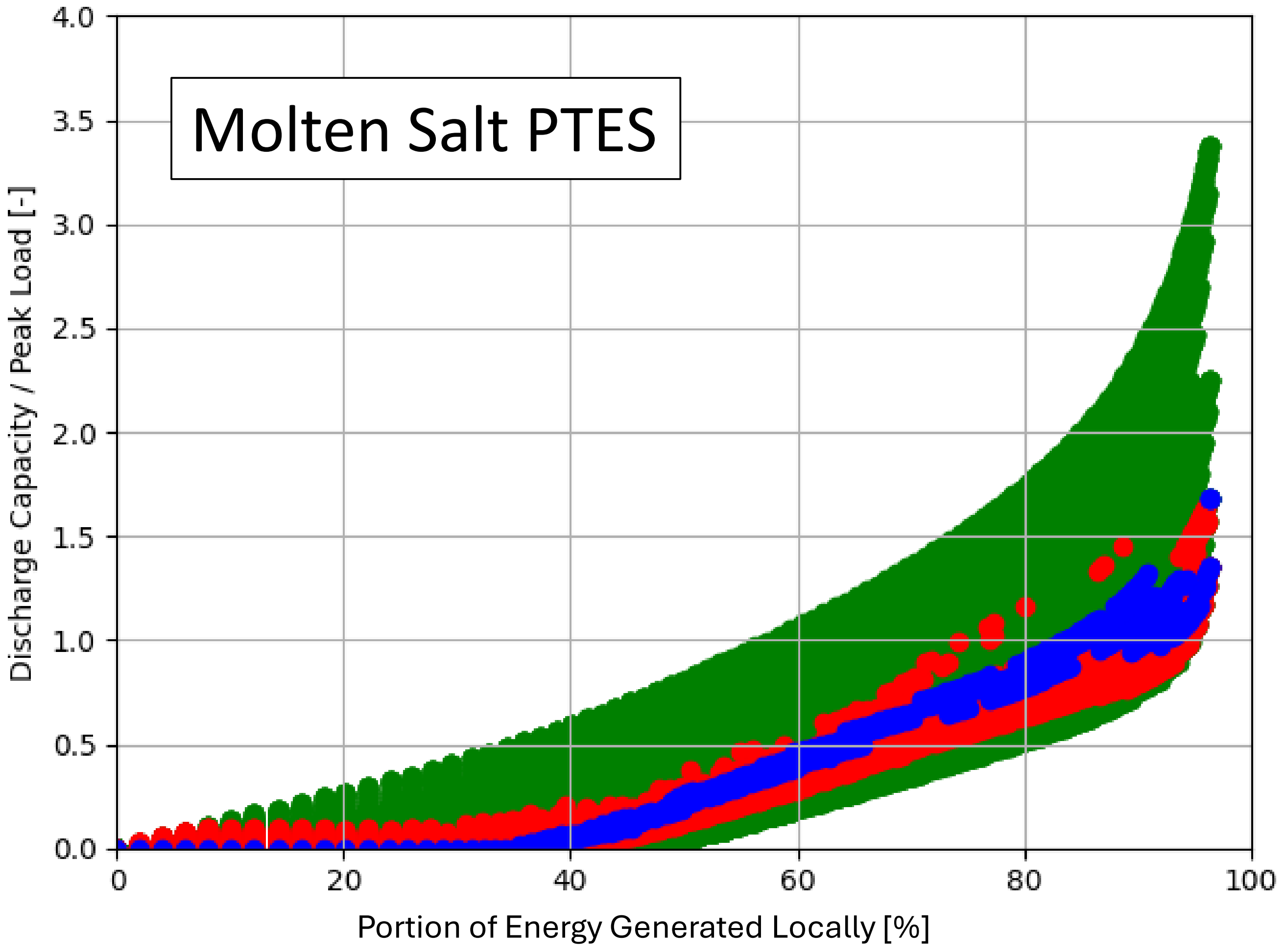


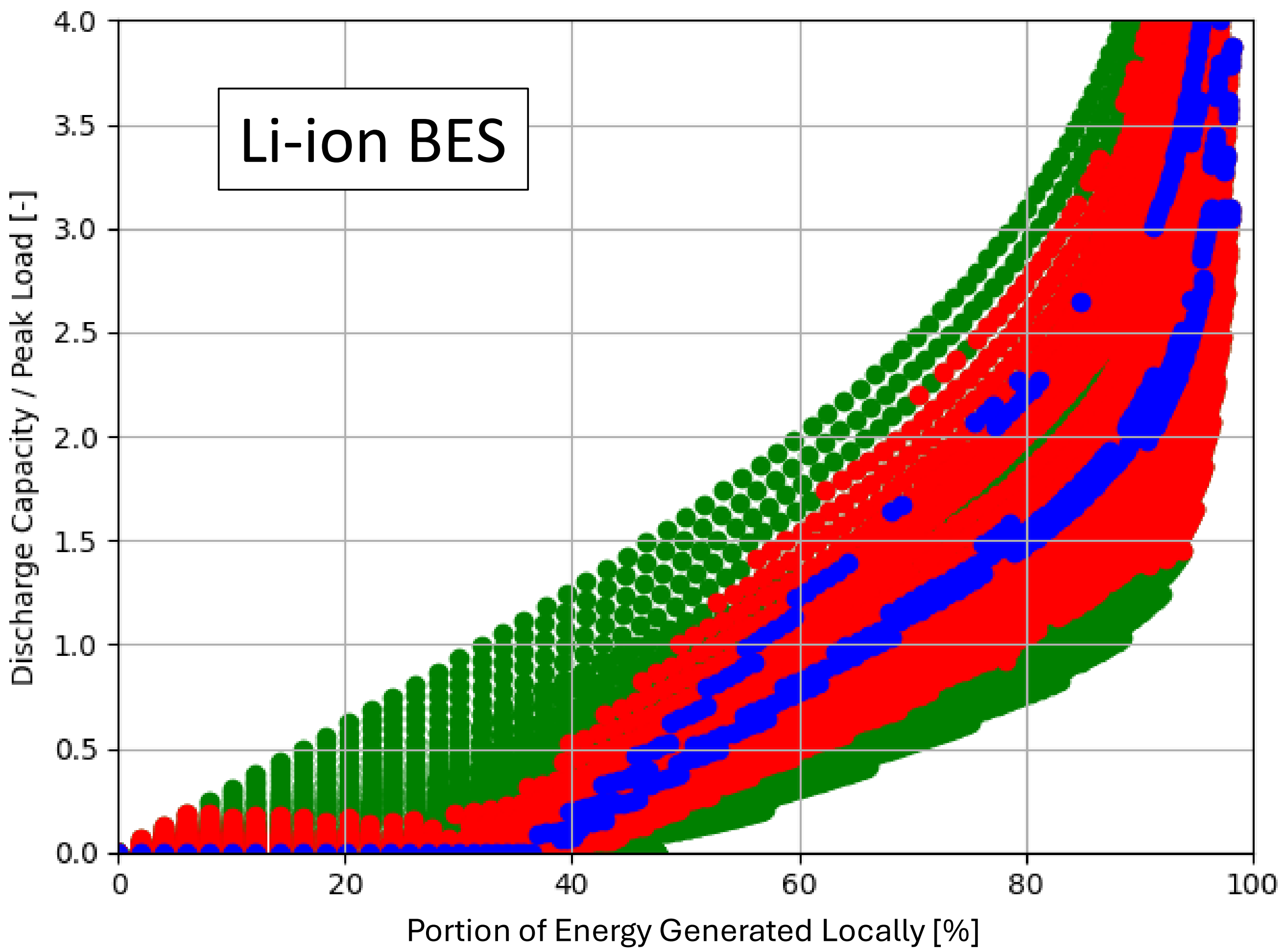


Lowest LCOE
Within 5% of Lowest LCOE
All Swept System Designs

- Optimal charge power capacity increases linearly → exponentially with local generation
- At 90% local generation, increases to ~3x peak load for MSPTES and ~2.5-3.5x peak load for Li-ion batteries

Discharge Capacity vs. Local Generation %

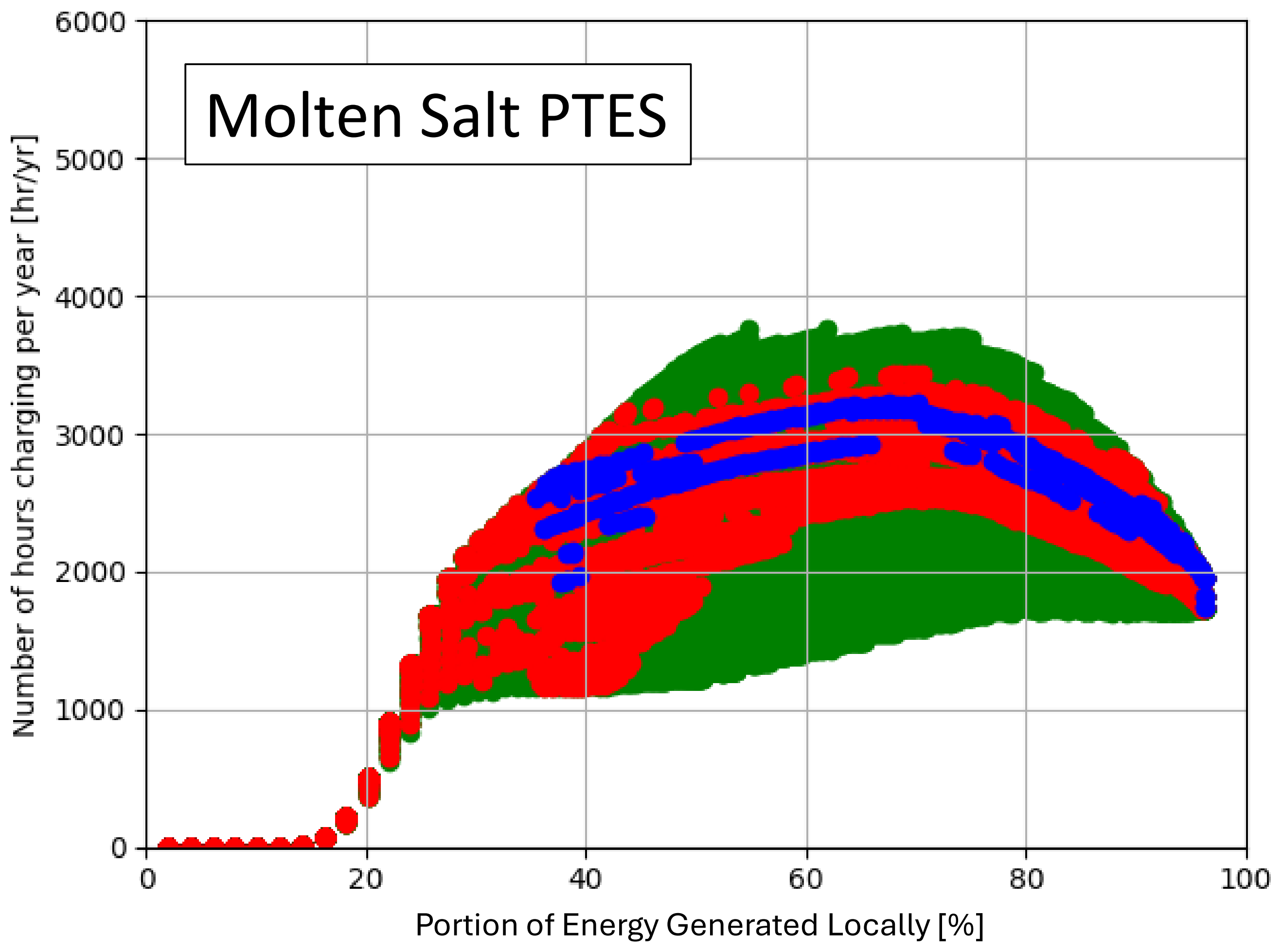


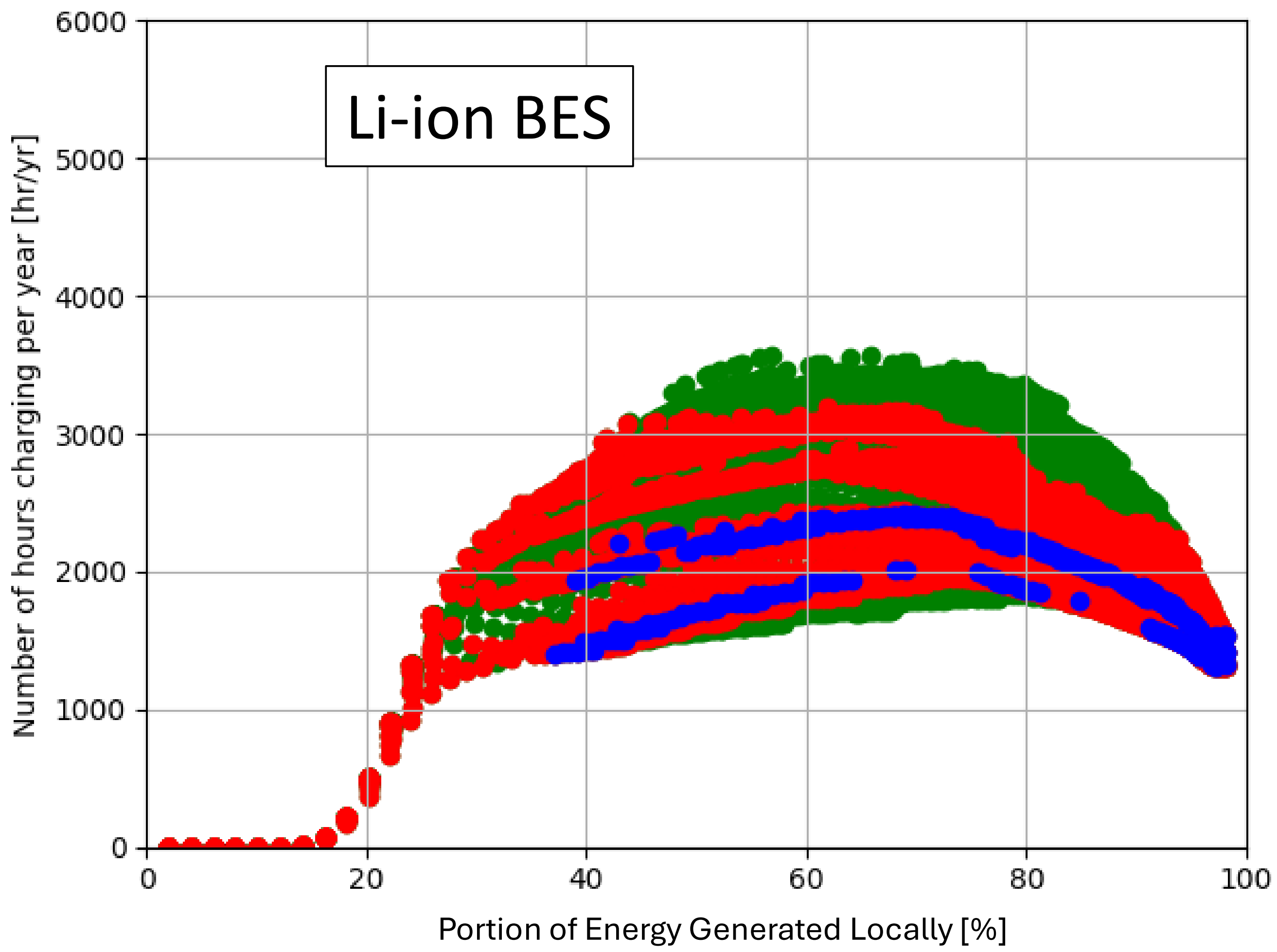


- Same linear → exponential trend as charge capacity
- At 90% local generation, increases to ~1-1.5x peak load for MSPTES and up to ~2-3x peak load for Li-ion batteries (oversized for charging requirements)
- Narrower optimal range than charge capacity for MSPTES (follows higher charge/discharge costs)

Lowest LCOE
Within 5% of Lowest LCOE
All Swept System Designs

Hours Charged vs. Local Generation %



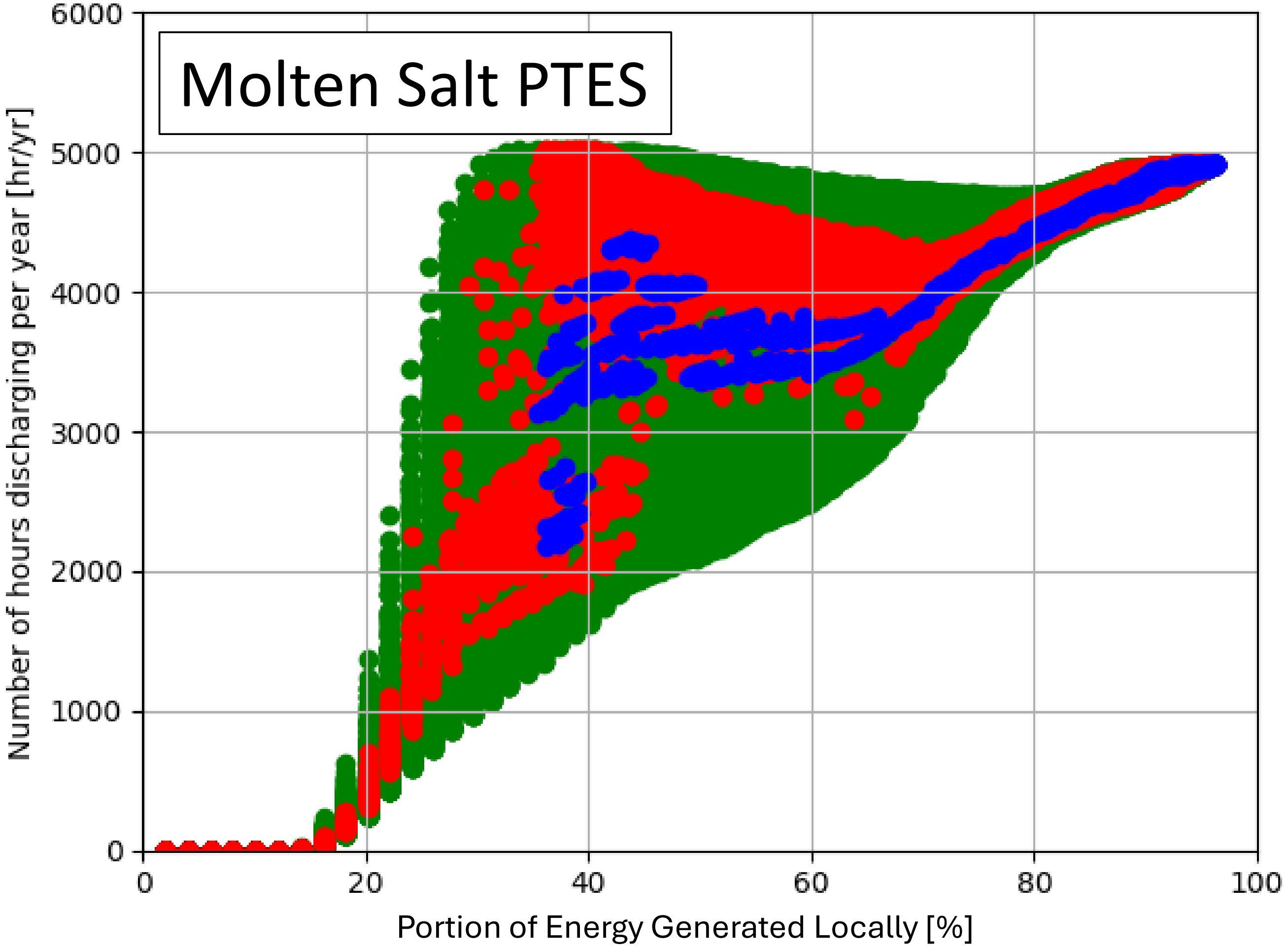


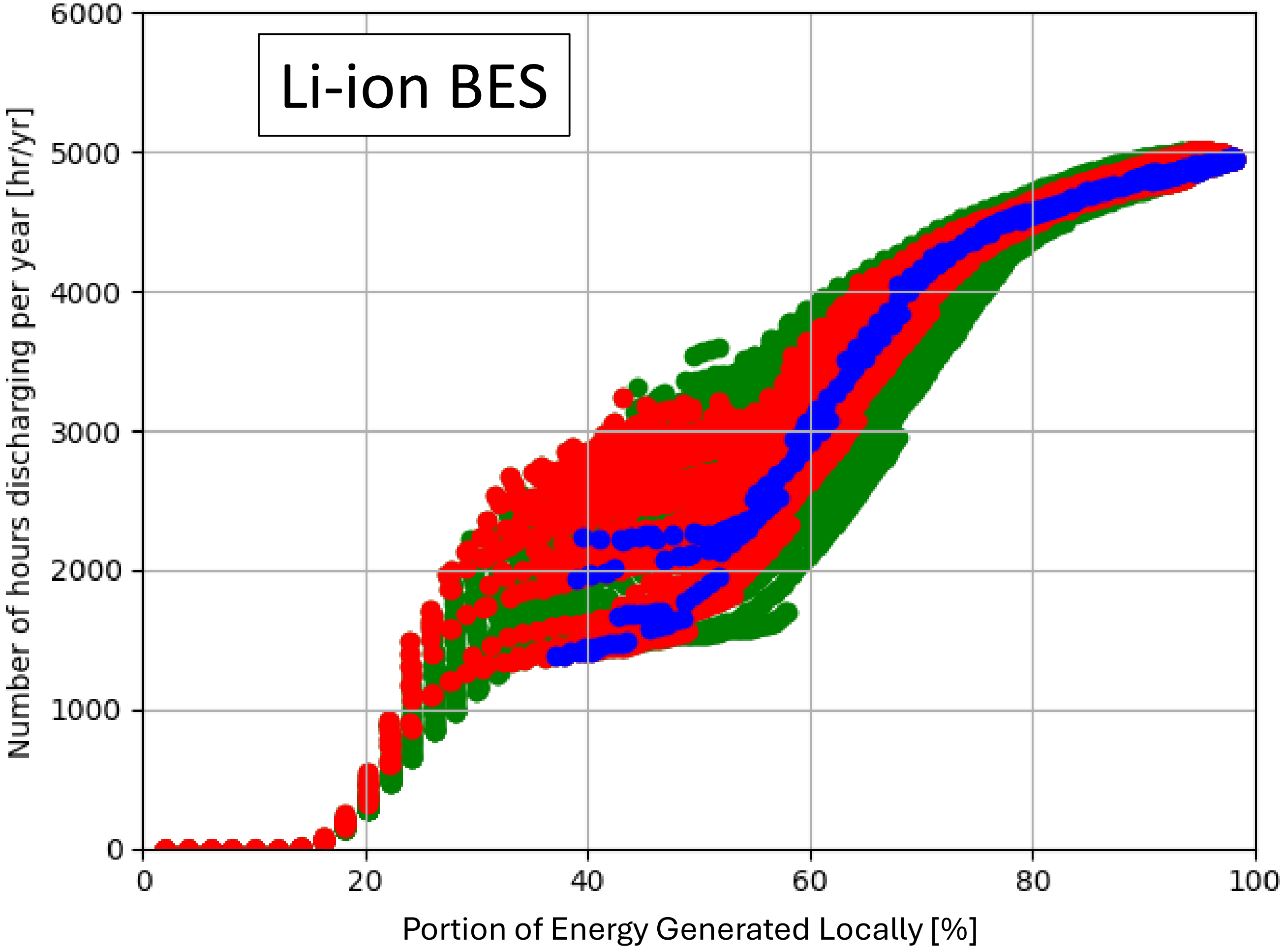
Lowest LCOE
Within 5% of Lowest LCOE
All Swept System Designs

Note 10 hrs/day = 3650 hrs/year

- Optimal solutions hit peak hours charged at 60-70% local generation, ~5.5-6.5 hours/day for Li-ion batteries due to higher $/kWh and ~8.5 hours/day for MSPTES
- At higher local generation, energy storage charging hours reduce to align with just the peak of solar day as discharging hours increase

Hours Discharged vs. Local Generation %



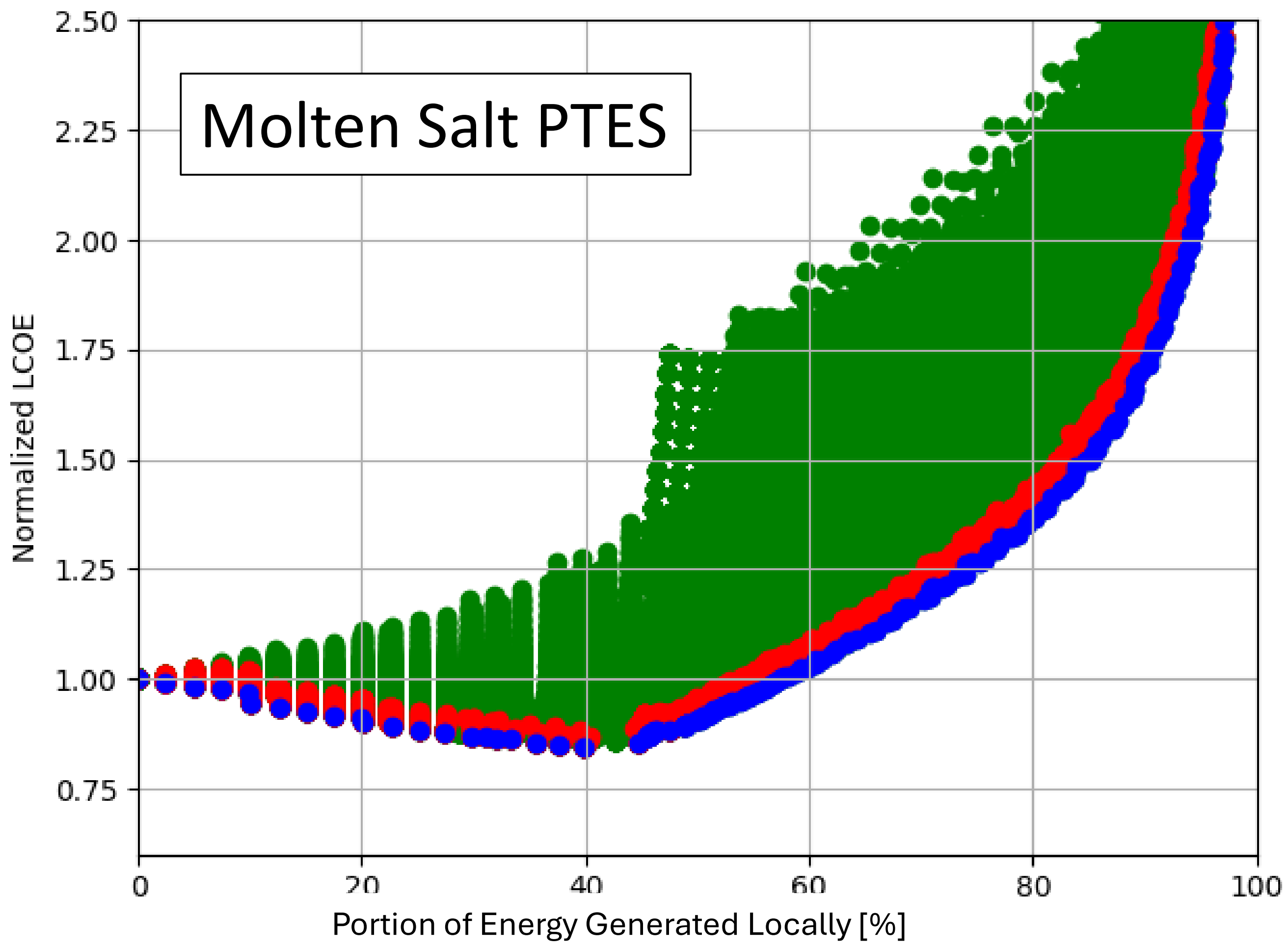


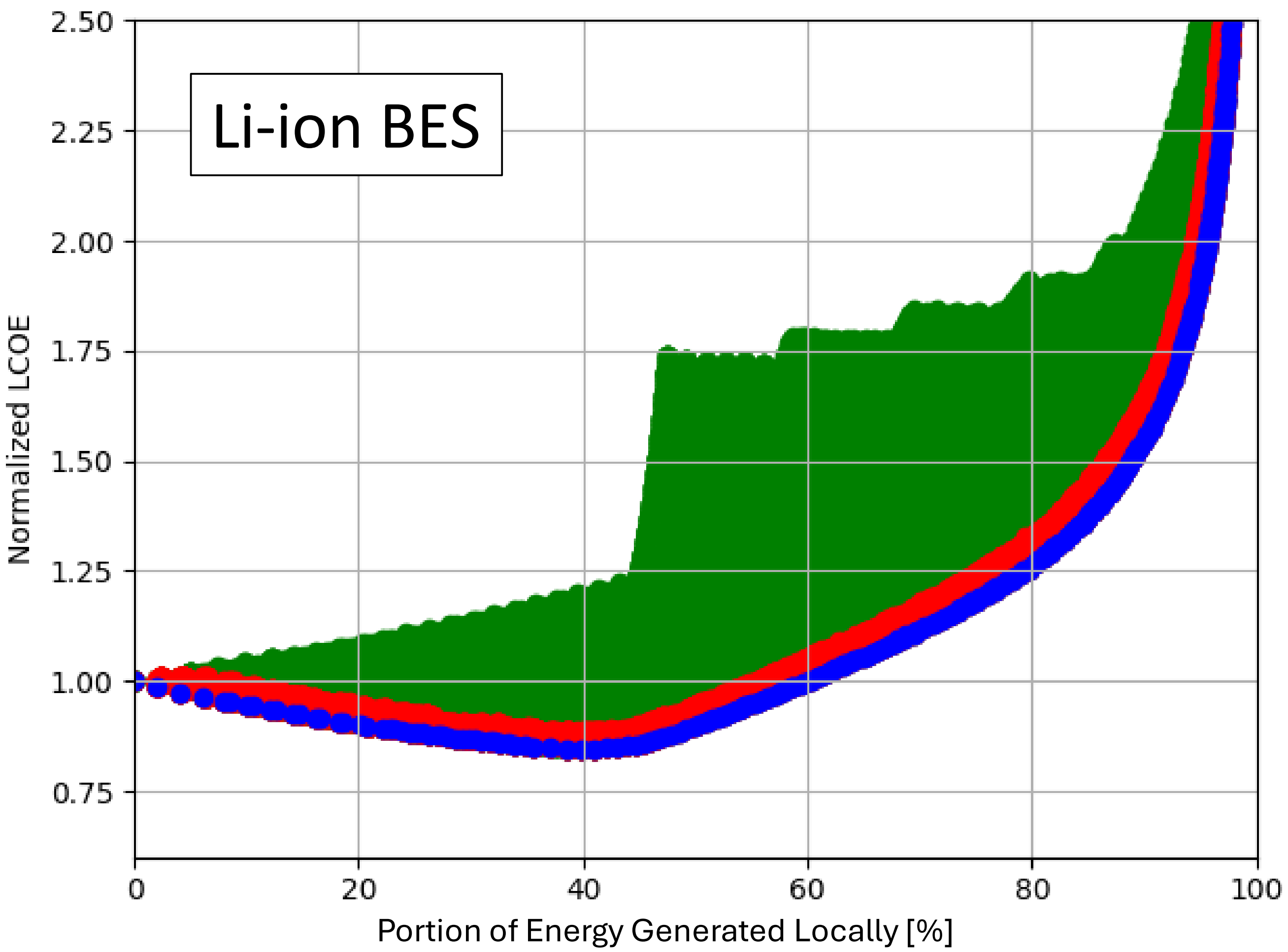
Lowest LCOE
Within 5% of Lowest LCOE
All Swept System Designs

Note 10 hrs/day = 3650 hrs/year

- Optimal solutions increase discharge hours when achieving greater local generation: ~4-6 hours/day initially increasing to ~13-14 hrs/day for Li-ion batteries; ~9-11 increasing to ~13-14 hours/day for MSPTES
- Wide range of optimal solutions at <60% local generation, narrows above that
- Inflections due to progressing role of storage from *partial supplement* to *daily energy shifting* to *powering rare weather / load events*

Adding in 10 MW of Wind Generation





- Similar trends overall; addition of wind generation (+ PV + Storage):
  - Pushes cost-parity point from ~45% to ~60% local generation
  - Reduces cost penalty for 90% local generation from ~2x to ~1.5-1.75x
  - Optimal charge/discharge capacity and hour curves are compressed to the right but peak values are essentially unchanged

Lowest LCOE
Within 5% of Lowest LCOE
All Swept System Designs

Note 10 hrs/day = 3650 hrs/year

Energy Storage: Sizing Summary

- Solar PV can cost-effectively generate up to ~**40%** of electricity use locally **(60+% with wind)**
- Energy storage buys you another **~5%** of local generation within existing costs
- Getting to 90-95% approximately **doubles** LCOE **(1.5x-1.75 increase with wind)**, and costs to further close the gap with storage increase dramatically
- At high local generation % the optimal (decoupled) storage solutions are typically **charged at 3-4x peak load** and **discharged at 1x peak load**
- The optimal storage solutions **charge for 5.5-8.5 hours/day** and **discharge up to 14 hrs/day**.
- The most cost-effective technology and architecture depends on local renewable resources, load profile, electricity market, etc.
- LDES technologies can be cost-competitive with batteries, although technology cost/efficiency improvements across the board are still necessary for cost-competitive deep minimization of purchased power
- *The above conclusions do not consider the expected increase in costs for utilities on the grid to provide remaining energy with infrequently-utilized equipment (peakers)*
- *Recent changes to tax credits and cost increases to Solar PV will affect these results*

Questions?

Tim Allison, Ph.D.
Southwest Research Institute
(210) 522-3561
tim.allison@swri.org