Decarbonization of the Existing Gas Turbine Fleet: SwRI Perspective

SOUTHWEST RESEARCH INSTITUTE®

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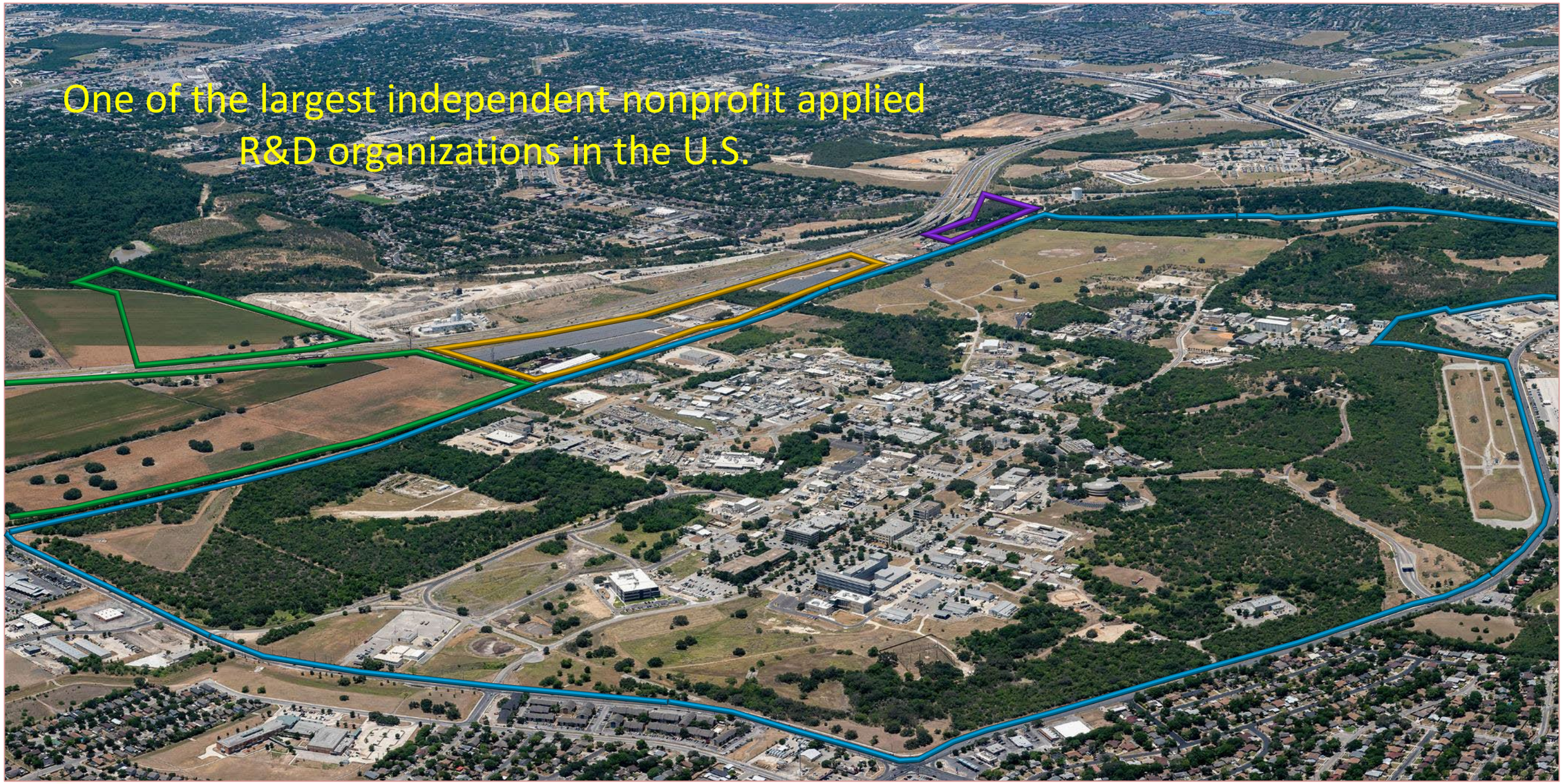

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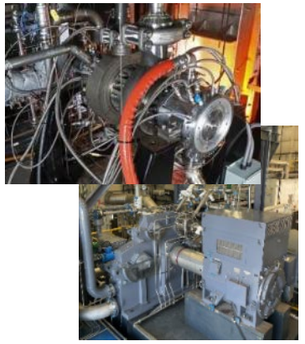
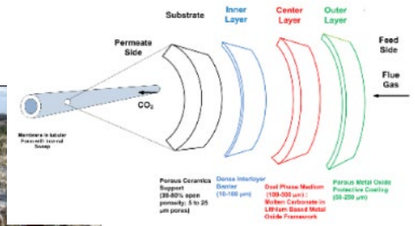
Decarbonization R&D Technologies at SwRI

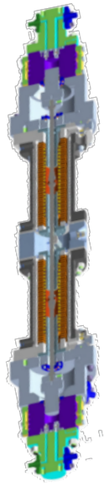



Supercritical CO_2 Power Systems

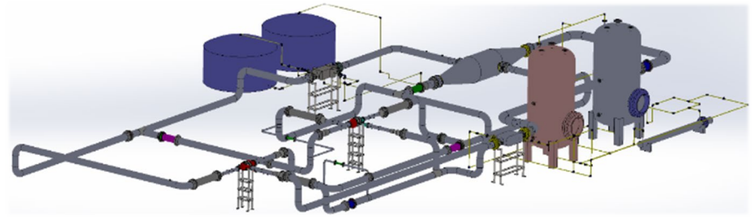
Carbon Capture & Utilization



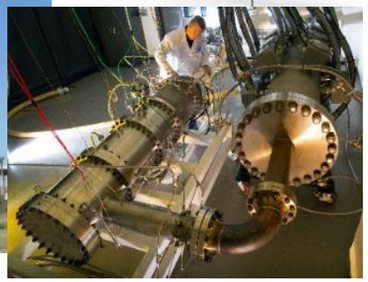
Low-Carbon Fuels (Hydrogen, Ammonia)





Energy Storage





Industrial Processes / Onsite Power and Heat

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H2 Combustion in Gas Turbines

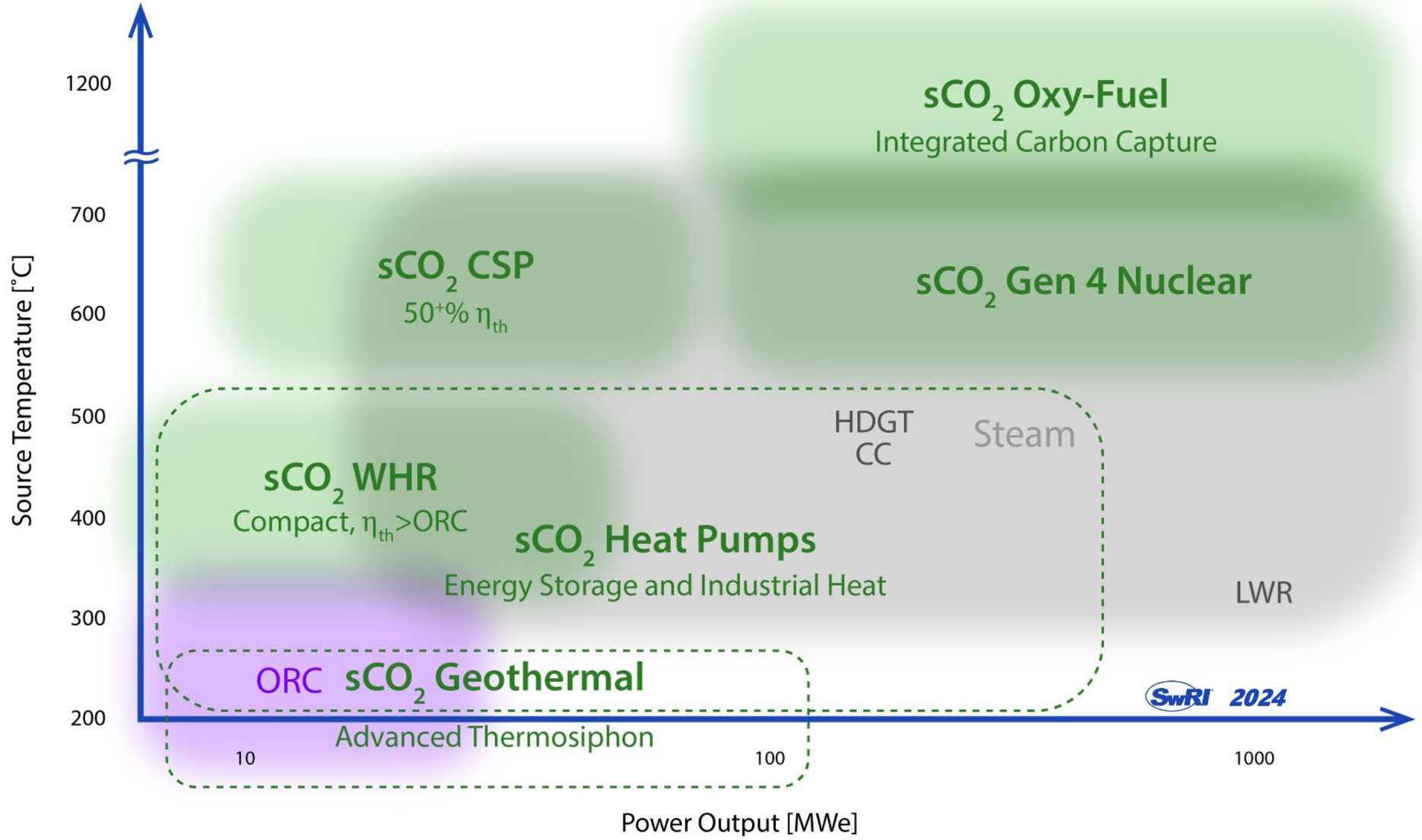
Challenges:

- Increased NOx emissions and performance/ reliability issues in premixed combustors
- Existing combustor emissions/performance limits
- New H_2 combustor designs for high H_2 concentrations

Our Solution:

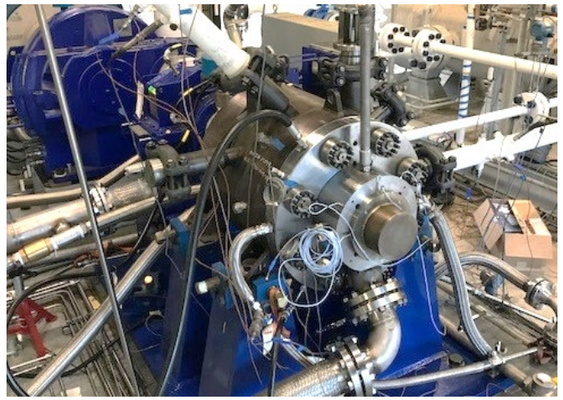
- SwRI operates several combustion test rigs and can test up to 100% H_2 fuel for large-scale tests, injector rigs, and annular rig tests
  - Rotating detonation engine combustor testing and component development
  - Develop and test prototype injectors and combustors, including development of an additively manufactured injector
  - Develop and test microturbine prototypes
  - Operate two microturbine test rigs and a P&W JT15D engine test stand
  - 6 kg/s at 20 bar air supply

sCO_2 Power System Application Space

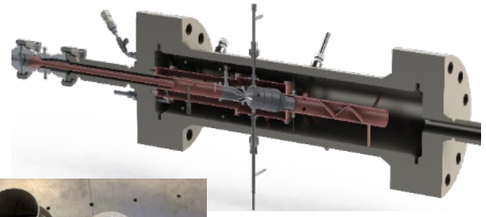
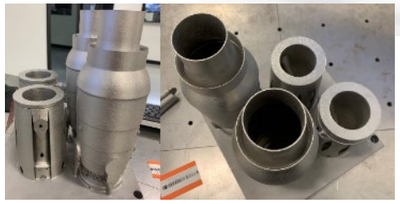


SwRI Project Experience & Capabilities in sCO_2 Cycles, Components, Systems

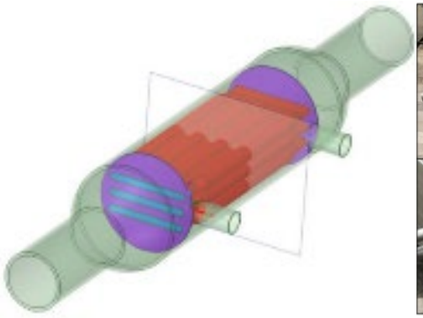




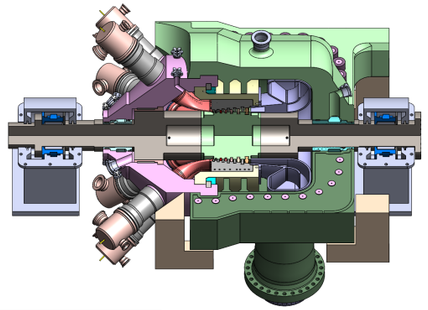
Design, Fabrication, Testing of 10 MWe-Scale Machinery

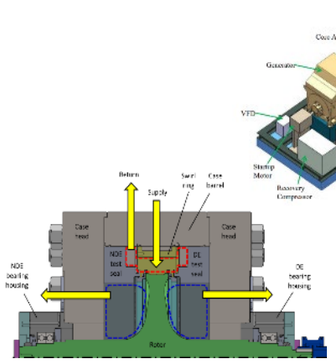



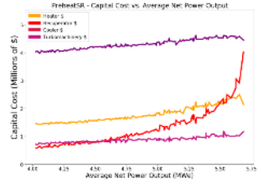
Oxy-Combustor and Turbine Development and Testing

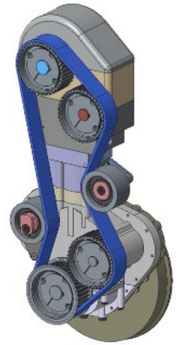
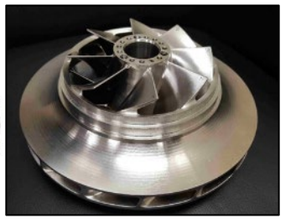
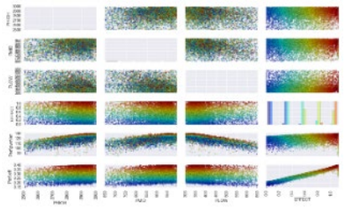



Heat exchanger Development and Testing





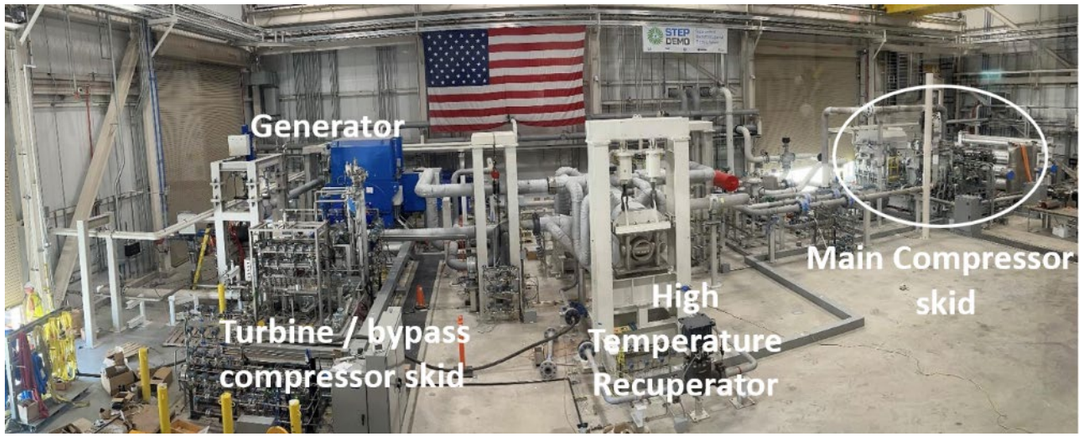


…and More Design, Analyze, Optimize, and Test Projects

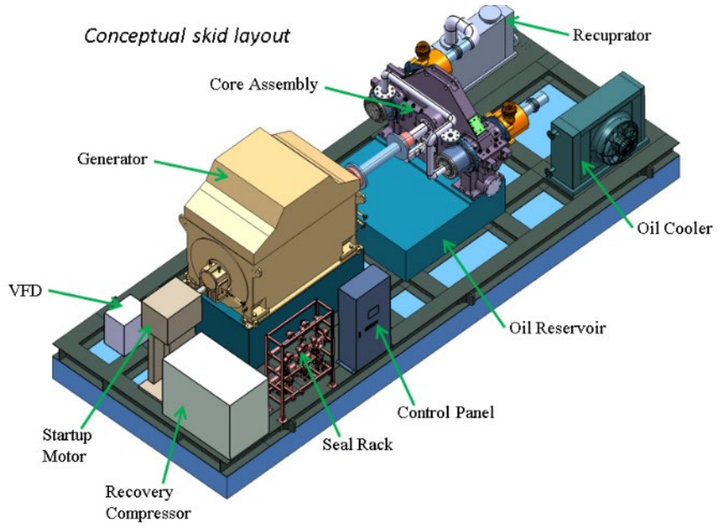
STEP Pilot Plant Project

- The STEP Demo is a project funded by DOE NETL and led by GTI Energy in partnership with SwRI and GE Vernova
  - 10 MWe sCO_2 Pilot Plant,
  - TRL3 to TRL7
  - $158 million budget over 7 Years
- Mechanical completion Oct 2023
- Full turbine speed and first electric power generated May 2024
- Net positive power achieved September 2024
- Simple Cycle testing continuing

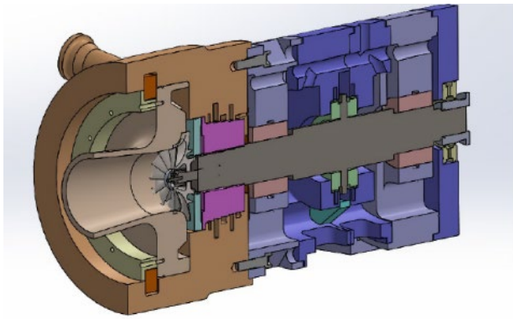


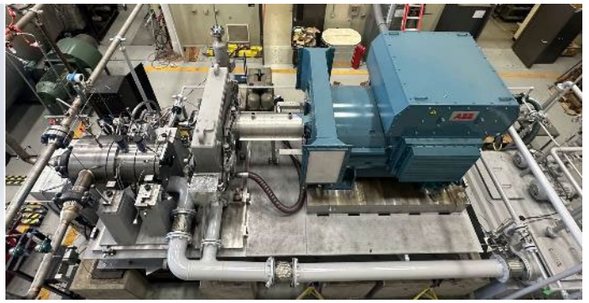
sCO_2 For CSP, Waste Heat, and Geothermal

- Turbomachinery and component / system design and development
- Mechanical and performance testing at full inlet pressures temperatures, and speeds
- Gas turbine waste heat recovery package design and optimization w/ Hanwha Power Systems
- Geothermal turbine design and testing for Sage Geosystems



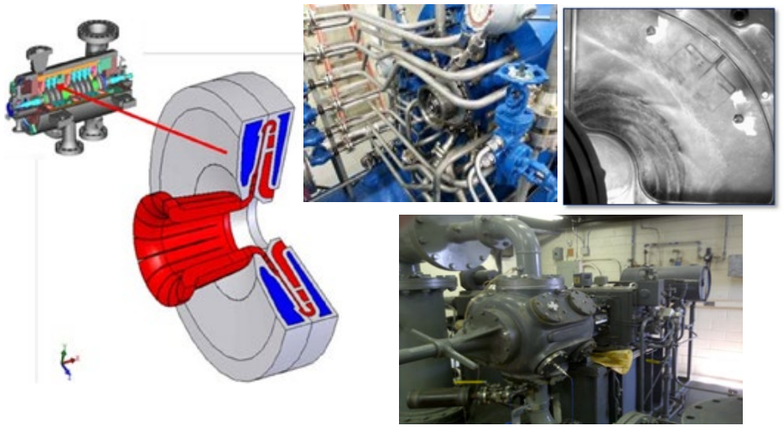
5.6 MW sCO_2 system and turbomachinery prototype (DOE, Hanwha)



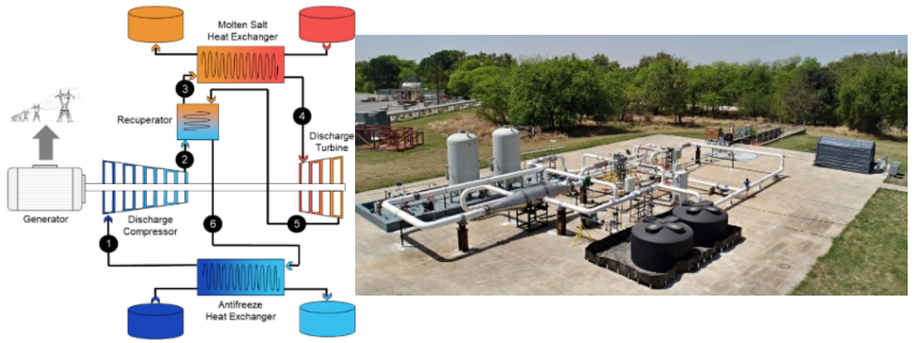


Geothermal Turbine Development with Modular Aero Design, Oil Seals

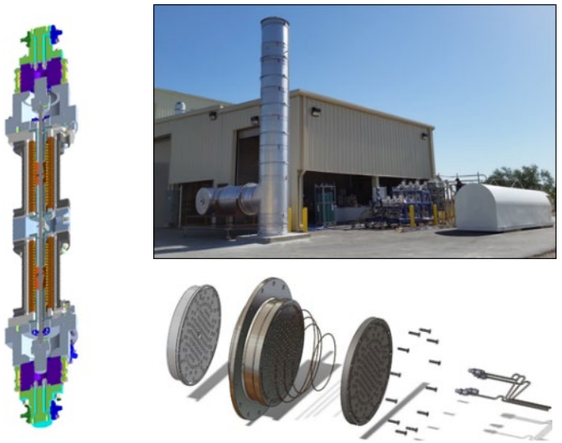
Long-Duration Energy Storage Projects at SwRI



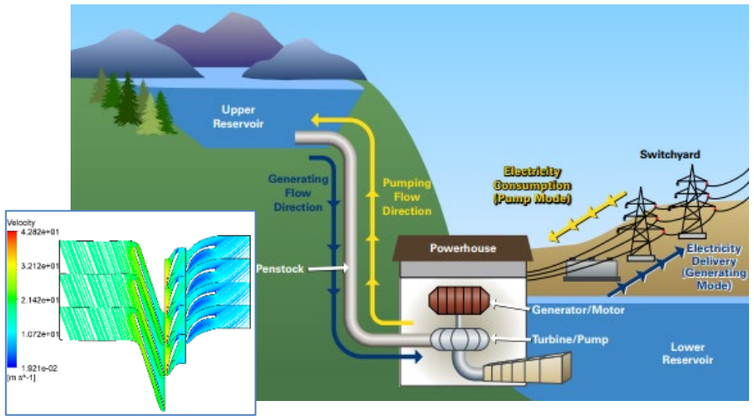
Isothermal and CAES Compressor Development



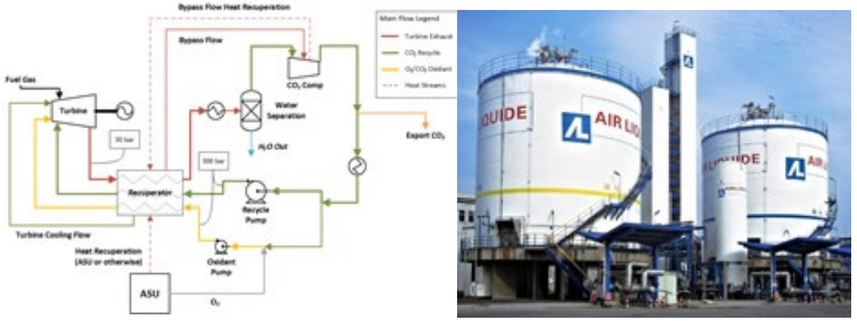
Pumped Thermal Energy Storage Demonstration and Pre-FEED Study



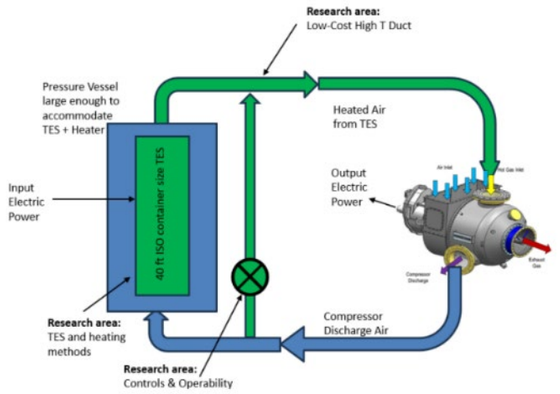
Hydrogen and Ammonia Storage, Compression, Combustion



Pumped Hydro Site Assessments and Geomechanical Pumped Storage Tech Development



Liquid Air/Oxygen Storage Coupled with Decarbonized Combustion

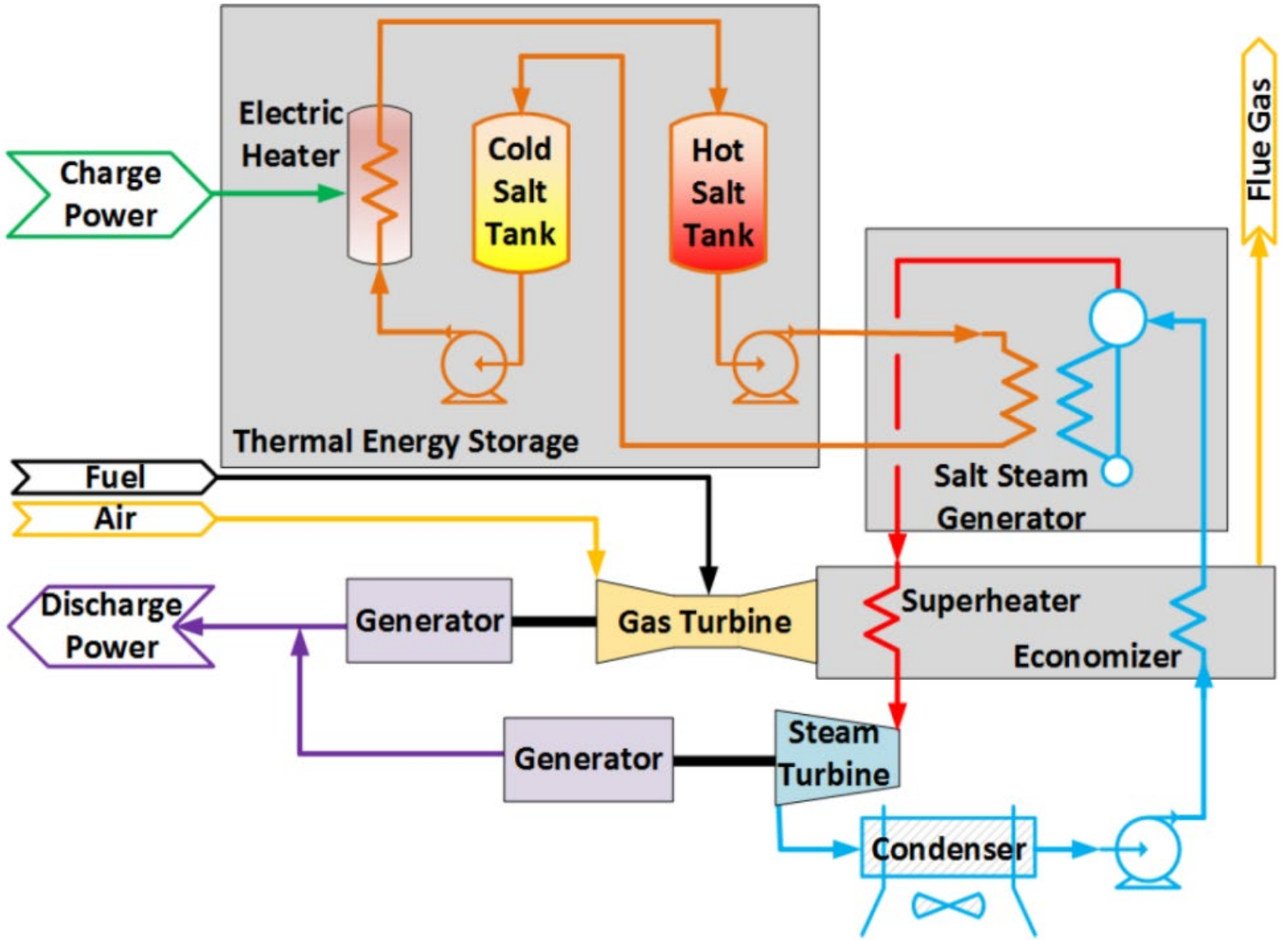


Thermal Energy Storage with Gas Turbines

Gas Turbine with Molten Salt Thermal Energy Storage

Liquid Salt Combined Cycle

- Hybridizes with existing open cycle gas turbine
- Renewable heating of molten salt
- Bottoming steam cycle leverages molten salt and gas turbine waste heat
- >3x typical combined cycle steam flow
- Targeting 5+ hours diurnal storage

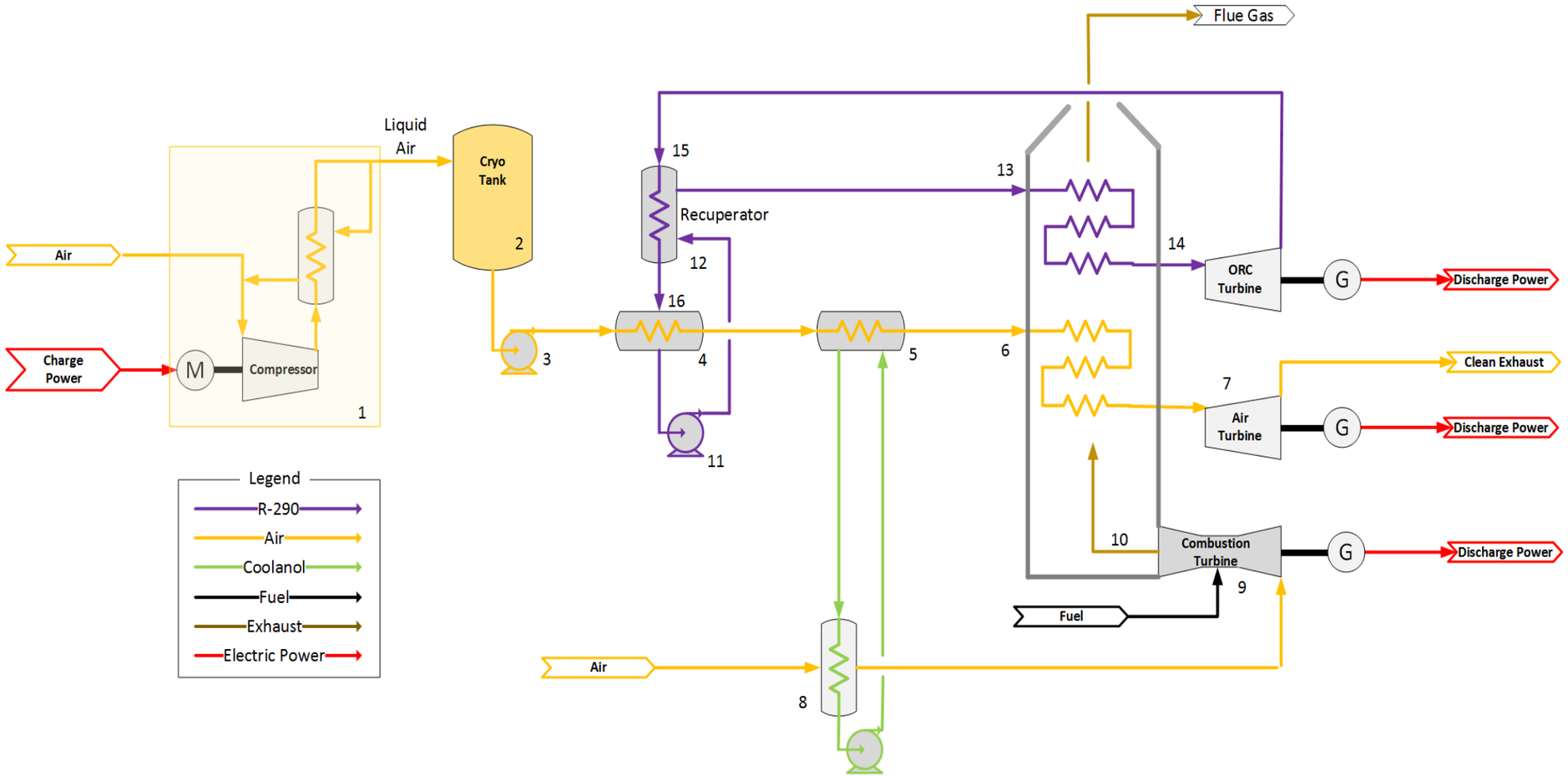


Data and Image Sources: Pintail Power (2020), Hume *et al* (2021)

Gas Turbine with Liquid Air Energy Storage

- Hybridizes with existing open cycle gas turbine
- Incorporates liquid air for energy storage
- Requires bottoming cycle component development
- System optimization for different cycles, fuel cost scenarios, hardware/permitting constraints
- Best at multi-day durations

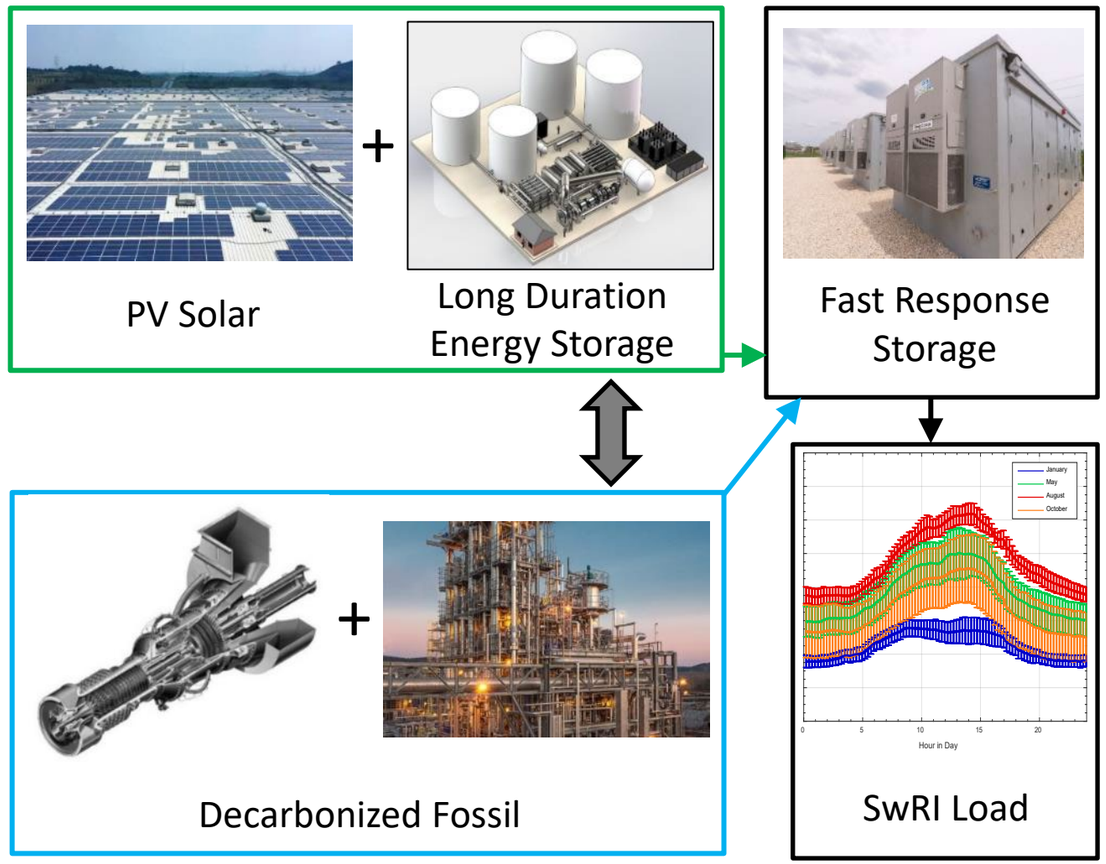
Liquid Air Combined Cycle



Data and Image Sources: Pintail Power (2020)

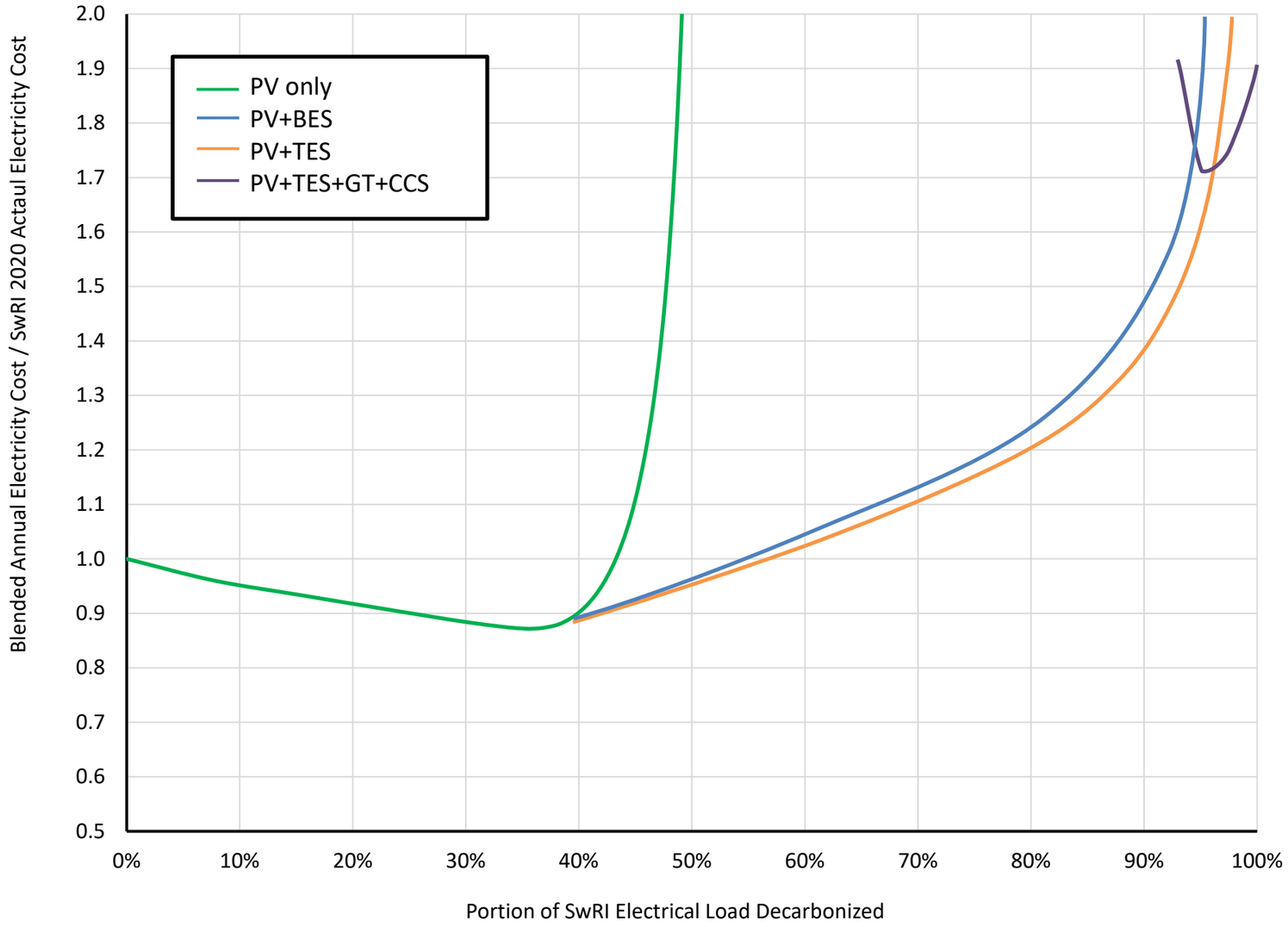
SwRI's "Project Z": Onsite Net-Zero Power

- Project Z: define a zero-carbon emission facility that will supply onsite electric generation and pilot-scale clean power research platform
- Operate as an onsite micro-grid, but use the local utility as a backup
- Pilot-scale clean energy R&D while reducing electricity costs and carbon emissions
- Develop analysis framework and toolset for technoeconomic and generation/load dispatch modeling to evaluate many onsite generation and energy storage technologies
- Define roadmap to net zero behind-the-meter electricity at SwRI



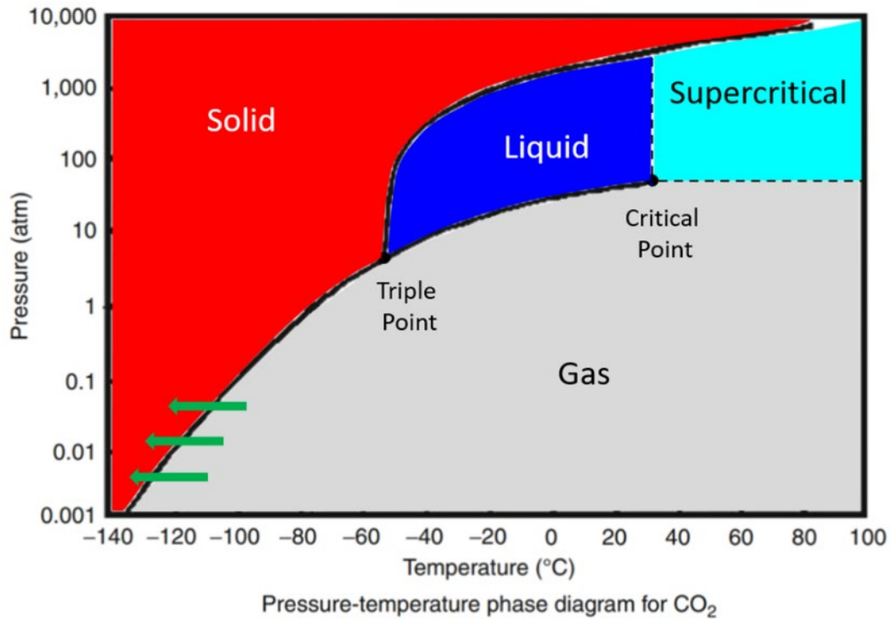
Pathway to 100% Decarbonized Electricity

- PV is modular and deployable but cannot meet full energy demand or advance decarbonization beyond 40-50%
- Adding battery energy storage (BES) and thermal energy storage (TES) improves results
  - Storage adds costs but advances decarbonization beyond 80%
  - A dramatic increase in cost is still seen with PV+ES beyond ~90%
- A PV+TES system supplemented by a gas generator with carbon capture can achieve full decarbonization

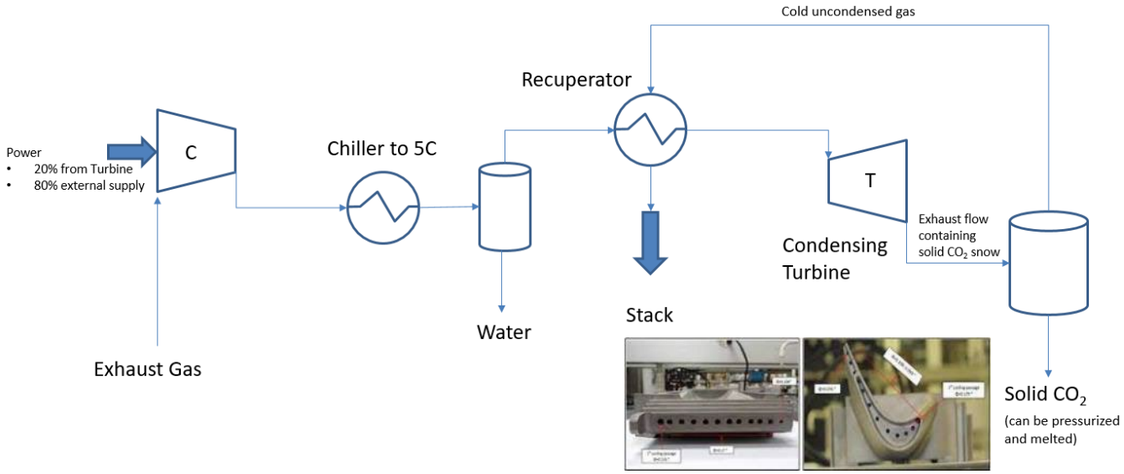


Turbomachine-Based Cryogenic Carbon Capture

- Capture CO_2 as solid below triple point pressure
  - Two ways to cool a fluid: heat transfer or work extraction
- Key advantages of turbomachine-based process
  - Condensing turbine
  - Scalability
- Current project defining cycle & turbine concept design, next step is system demo



Pressure-temperature phase diagram for CO_2



Questions?

Thank you!

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