# Supercritical Carbon Dioxide (sCO<sub>2</sub>) Primary Power Large-Scale Pilot Plant

Award DE-FE0031585

Project kickoff May 22, 2018 Timothy J. Held



ECHOGEN power systems

#### **Outline**



- Background
- Technical approach
- Project objective(s)
- Project structure
- Project schedule
- Project budget
- Project Management Plan, including Risk Management

# Background and overview



- FOA objective: Design/build/operate large-scale pilots:
  - Transformational coal technologies
  - Step change improvements in performance, efficiency, cost of electricity
- Echogen project sCO<sub>2</sub> power cycle + atmospheric pressure pulverized coal-fired heater
  - Leverages Echogen commercial sCO<sub>2</sub> power cycle
  - Leverages DOE-funded study (DE-FE-0025959)
  - Complementary to STEP R&D project
  - Good lead-in to DE-FOA-0001931 RFI

# Echogen Background





Echogen Power Systems is the industry leader in development of supercritical CO<sub>2</sub> heat recovery systems.

Founded in 2007, EPS has progressed from small multi-kW demonstration units to the recent multi-MW heat recovery package, the EPS100.

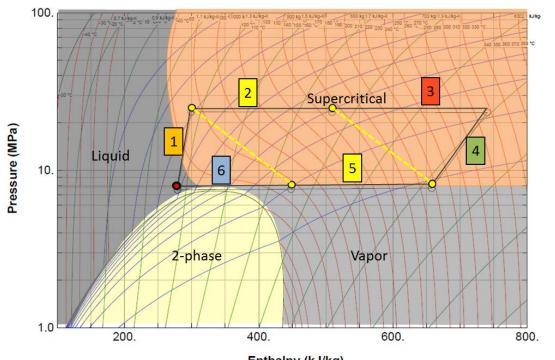
2007	Echogen founded
2011	Partnership with <i>Dresser-Rand</i> for oil & gas market; development of EPS100 7.5 MW engine begins
2013	Partnership with <i>GE Marine</i> ; development of EPS30 1.35 MW engine begins
2014	EPS100 completes factory testing
2016	EPS30 testing commences with high-speed alternator subsystem test
2018	Pursuing commercial pilot sites for all EPS products

Plans for the future...

- Introduce additional EPS engine sizes
- Progress to primary power & combined cycle
- Industrial and nuclear applications

### The Echogen supercritical CO<sub>2</sub> Cycle





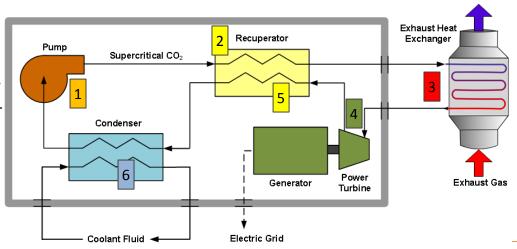
- Pump
- Recuperator
- 3 WHX
- 4 Turbine
- 5 Recuperator
- 6 Condenser

CO<sub>2</sub> becomes supercritical above 31°C, 74 bar, and has properties of both liquid and gas. There is no distinct phase change when moving in/out of supercritical region.

- Enthalpy (kJ/kg)
- 2. CO<sub>2</sub> preheated at recuperator
- 3. Recovered waste heat added at waste heat exchanger
- 4. High energy CO<sub>2</sub> expanded at turbine drives generator
- 5. Expanded CO<sub>2</sub> is pre-cooled at recuperator

1. Liquid CO<sub>2</sub> compressed to supercritical state

6. CO<sub>2</sub> is condensed/cooled to a high-density fluid



# sCO<sub>2</sub> Technology Benefits



#### Water-Free

- Totally dry, water-free, closed-loop process
- Air cooled condenser (water cooled condenser optional)

#### Compact

- No exhaust bypass stack required
- 25-40% smaller footprint than steam; minimally invasive retrofit

#### Flexible

- Suitable for remote operation; no boiler operator required
- 20-30 minutes to full load

#### **Efficient**

- Simple heat transfer, no boiling process (supercritical)
- Direct in-stack WHX, no intermediate fluid required

#### Competitive

- Lower LCOE than other heat recovery alternatives
- Competitive OPEX and LTSA

#### Clean

- Produces electricity without incremental emissions
- Working fluid is stable, benign and non-flammable

# Echogen EPS100









EPS100 power skid



The EPS100 is the largest sCO<sub>2</sub> power loop in the world and first commercially available sCO<sub>2</sub> system

#### EPS100 Testing at Dresser-Rand – Key Accomplishments





**EPS100 Process Skid** 



EPS100 Power Skid

#### Testing

- Phase I: Validation of components completed
- ✓ Phase II: Full speed no load completed
- ✓ Phase III: Durability completed
- ✓ Phase IV: Endurance Run completed
- System control and stability fully demonstrated
- Component performances meet or exceed expectations
- Turbopump run to max conditions
- Generator speed control stability demonstrated
- Power turbine electrical output = 3.1 MWe (max power at test stand conditions, limited by steam available)
- 330 hours turbo-pump run time
- 170 hours power turbine run time

### **TECHNICAL APPROACH**



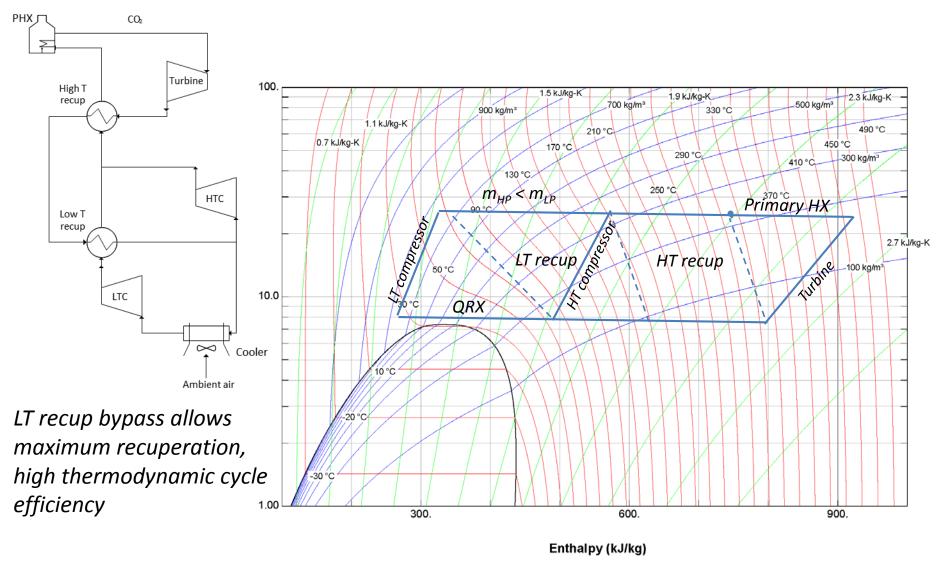
# Technical approach



- sCO<sub>2</sub> power cycle
  - "RCB" configuration
  - Low-temperature supplemental heat recovery option
  - Turbine-driven variable speed compressors
- Air-fired pulverized coal combustion
  - Leverage existing infrastructure if possible
  - Advanced combustion technology integration beyond budget
  - Integration of advanced combustion (CLC and oxycombustion) and post-combustion CO<sub>2</sub> capture possible with sCO<sub>2</sub> power cycle

# RCB cycle overview





# sCO<sub>2</sub>/RCB vs steam



#### Advantages:

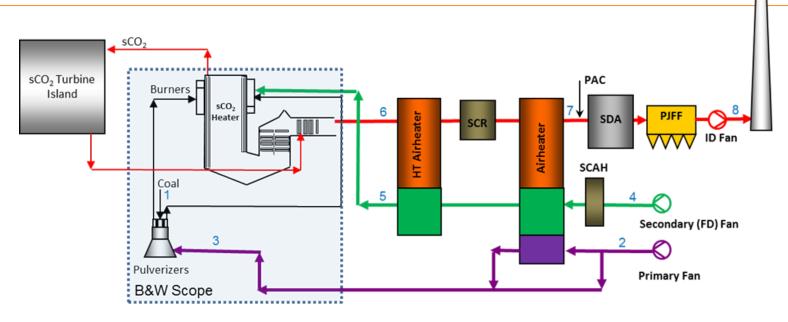
- Efficiency
- Capex
- Opex

### Disadvantages

- Large volumetric flow rate
- Limited temperature rise
- Performance sensitivity to pressure drop

# Baseline configuration





- Based on 90 MWe Test Case 5/6 from -25959 study
  - Steam base case: TIT 538°C, 33% HHV efficiency
    - Adjusted to 593°C, ~ 34%
  - sCO<sub>2</sub> cases: 593°C/730°C, 36%/41% HHV efficiency
- Scaled to ~ 10MWe
  - TIT expected to be 600-650°C, dependent on cost/performance optimization

#### **PROJECT OBJECTIVES**



# Project objectives



- Select primary and alternate host sites
- Complete preliminary design of
  - Power cycle
  - Fired heater
  - Balance of plant equipment
- Complete site Environmental Information Volume (EIV)
- Secure Phase II cost share commitments
- Develop Phase III cost share plan
- Complete Techno-Economic Analysis (TEA) of pilot- and full-scale systems

#### Potential host sites

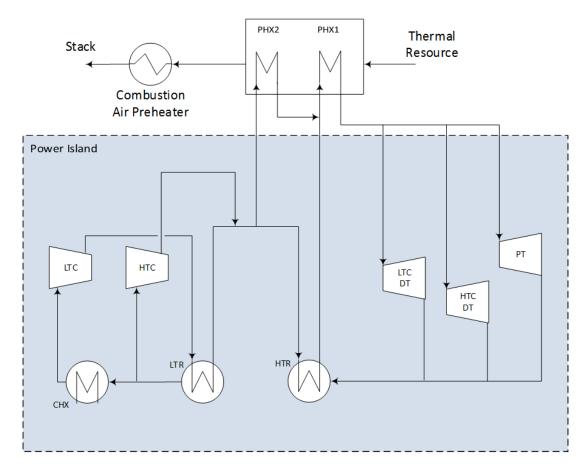


- Have identified 5 potential host sites/partners that we will evaluate during program
  - Southern Company
    - National Carbon Capture Center
    - Plant Barry
  - University of Missouri CHP plant
  - Greene County, PA (waste coal site)
  - Eastern Kentucky power cooperative

# Power cycle design



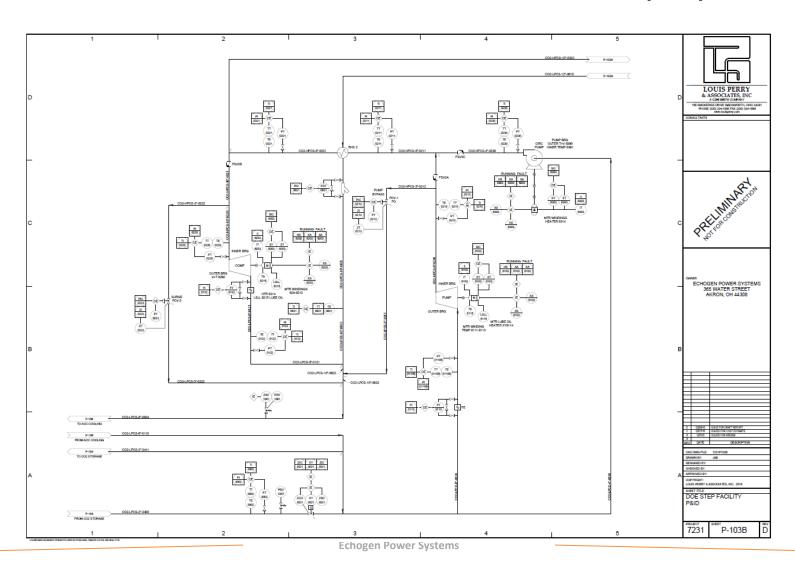
• Building off flow sheets from -25959 project Case 5/6:



# Power cycle & BOP design



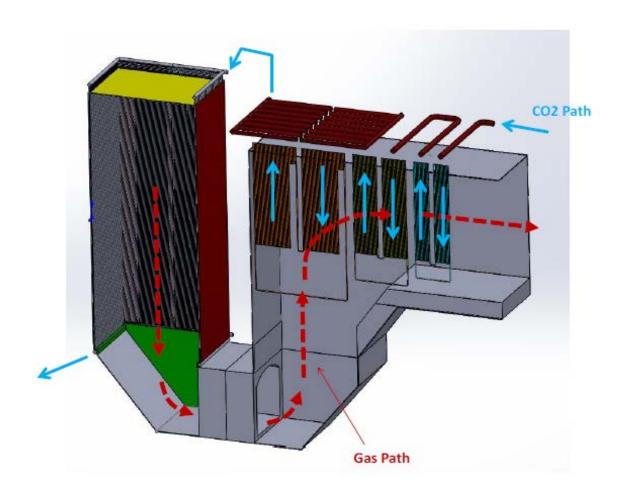
Initial P&IDs, SLDs from DE-FOA-0001457 proposal



### Fired heater



Leveraging Case 5/6 designs from -25959



### PROJECT STRUCTURE



#### Team



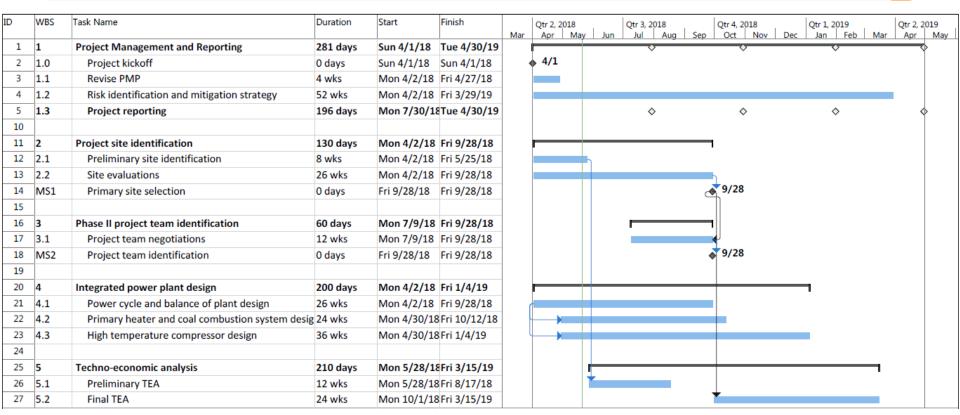
- Echogen Power Systems (EPS) Prime recipient
- Louis Perry Group (LPG) EPC
- Paul Weitzel Technical Consulting (PWTC) –
   Fired heater design
- Electric Power Research Institute (EPRI) –
   Utility liaison, TEA review
- Siemens Turbomachinery design
- EIV contractor (TBD)

#### **PROJECT SCHEDULE**



# Project Gannt chart





Phase II proposal date: March 31, 2019

#### PROJECT BUDGET



# Project budget



- Single budget period, mostly labor and subrecipient / subcontract costs
- Total \$932K (\$745 Federal, \$186K cost share (20%))
- Detailed breakdown:

	Tot	al	Со	st share
Echogen	\$	471,112	\$	126,845
LPG	\$	99,500	\$	19,900
PWTC	\$	72,360	\$	-
EPRI	\$	99,664	\$	19,933
Siemens	\$	98,787	\$	19,758
EIV	\$	90,757	\$	-
Total	\$	932,180	\$	186,436
				20%

### **RISK MANAGEMENT PLAN**



# Risk assessment and management plan



	Risk Rating				
Perceived Risk	Probability	Impact	Mitigation/Response Strategy		
	(Low, Med, High)				
Cost/Schedule Risks:					
The project team is unable to complete	Low	High	The members of the project team have worked closely		
the project within the expected budget and time frame			together on past projects and proposals and have a proven track record in putting together teams for proposals and estimates. Echogen, in its role as the prime will closely monitor status and budget with timely meetings and budget reports required from the subs.		
Program Risks:					
The project team is unable to identify a suitable host site for the demonstration project	Low	High	The project team has already identified four potential sites, with three site owners and is exploring additional possibilities. EPRI is available to act as a conduit to its member utilities, to explore other potential sites if none of the four identified sites are suitable for the pilot plant.		

# Risk assessment and management plan



	Risk Rating				
Perceived Risk	Probability	Impact	Mitigation/Response Strategy		
	(Low, Med, High)				
Cost/Schedule Risks:					
Program Risks:					
The project team is unable to secure agreements for the required cost share	Med	High	Echogen, EPRI and the Louis Perry Group have worked together on similar sized projects and have successfully pulled together cost share in the range needed to complete Phase II and Phase III of this program. The pool of potential cost share sources and there required amounts has been identified and will be tracked throughout Phase I.		
Planning and Oversight Risks:					
Project team has difficulty reaching consensus on project direction and process and technology choices	Low	High	There is a long work history between Echogen and the subs. Echogen will serve as the arbiter of any disagreements based on its position as prime along with its long history of developing and designing sCO2 power cycles.		
ES&H Risks:					
Site environmental issues not fully understood prior to site selection	Low	High	An environmental consulting firm is being brought onto the project to work the required environmental volume and to identify site environmental risks that could put future phases of the program at risk.		

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# Project milestones



Title	Plan Date	Verification method
Project Kick-Off	31-May-18	Kickoff meeting completed with NETL
Primary Site Identification	14-Sep-18	Q4FY18 Research Performance Progress Report
Team Commitments for Phase II Application Obtained	14-Sep-18	Q4FY18 Research Performance Progress Report
Pilot plant design and fabrication schedule and cost estimate updated	14-Sep-18	Q4FY18 Research Performance Progress Report
Project design review	04-Jan-19	Q1FY19 Research Performance Progress Report
Techno-economic analysis (TEA) review	01-Mar-19	Phase I Topical Report
Phase II Application Completed and Submitted	31-Mar-19	Phase II Application Package

### **PROJECT STATUS**



#### Current status



- DOE/Echogen negotiations completed in early April
- Contract "effective date" April 1, 2018
- Subcontract T&Cs agreed by LPG, PWTC
- Minor modifications requested by EPRI
- Siemens undergoing reorganization, small delay in response expected
- SOWs communicated to LPG, PWTC and EPRI
  - LPG and PWTC have been finalized
- Expect to have all but Siemens completed by 5/31
- Creating list of site selection criteria and questions