Energy & Environmental Research Center (EERC)

SCALE-UP OF COAL-BASED SUPERCRITICAL CO_2 CYCLE TECHNOLOGY

DE-FOA-0001788 Technical Kickoff Meeting

EERC

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Energy Systems Development

Critical Challenges. Practical Solutions.

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PROJECT OVERVIEW

- The EERC was awarded $700K under DE-FOA-0001788, Fossil Fuel Large-Scale Pilots, Phase I
- The team will use $175K from of nonfederal funds as matching cost share.

	Period of Performance	Maximum DOE Funding Share	Cost Share	Number of Awards	Objective
Phase I	1 year	$1,000,000	Minimum 20%	8–10	Project scoping, site selection
Phase II	1 year	$3,000,000	Minimum 20%	4–5	FEED (front-end engineering and design)
Phase III	5 years	$80,000,000	Minimum 20%	1–2	Construction and operation
Total Available Funding: $100,000,000					

BACKGROUND

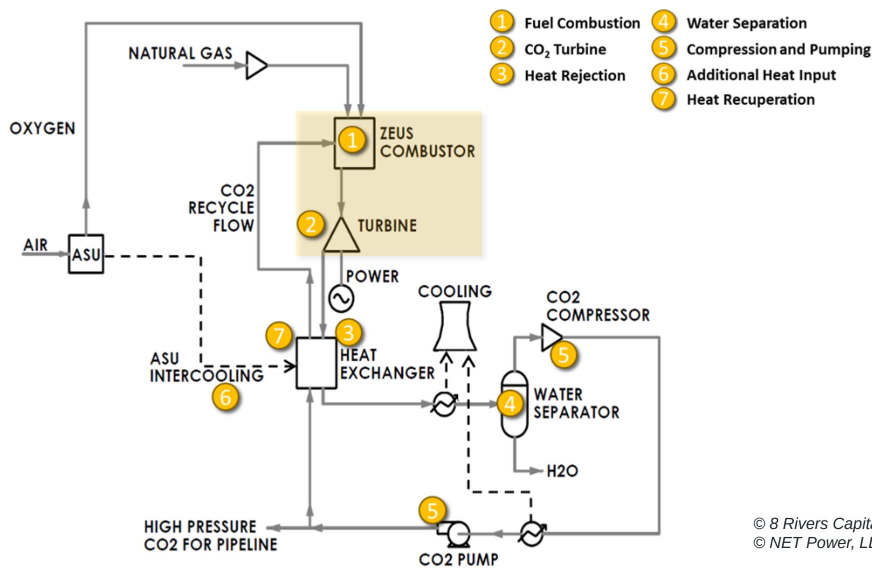
- Industry is seeking a solution for next-generation coal-fired power systems.
  - CO_2 as a useful product.
- Allam Cycle – promising technology.
  - Integrated CO_2 capture = high efficiency.
  - CO_2 ready for enhanced oil recovery (EOR) applications.
  - Developed by 8 Rivers Capital.
- Can benefit North Dakota industries.
  - Oil and gas industry.
  - Lignite power generation.

PATHWAY TO LOW-CARBON LIGNITE UTILIZATION

WHAT IS THE ALLAM CYCLE?

The Allam Cycle is any supercritical CO_2 Brayton cycle that:

- Is oxy-fueled and direct-fired.
- Recuperates turbine exhaust heat via a recycle stream.
- Is able to use a heat source in addition to the turbine exhaust.
- Uses a turbine inlet temperature above 800°C (1000°–1200°C optimal) and inlet pressure above 80 bar (200–400 bar optimal).



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CORE NATURAL GAS ALLAM CYCLE DEMONSTRATION BY NET POWER

- 50-MW_{th} natural gas demonstration plant located in La Porte, Texas.
  - Mirrors design of commercial plant to ensure scalability.
  - Includes all components of the Allam Cycle.
  - Oxygen will be pulled from a pipeline as opposed to a dedicated air separation unit (ASU).

Plant will undergo full performance evaluation.
  - Construction completed, testing underway.
  - Will test performance, reliability, controllability, and safety.
  - $140 million raised for engineering, construction, and testing.

300-MW_e commercial plant under development.
  - Pre-FEED study completed on 300MWe natural gas plant.
  - Beginning FEED and early development work.
  - Toshiba well progressed on commercial turbine design.
  - Working with customers in power, oil, and gas industries on development opportunities.

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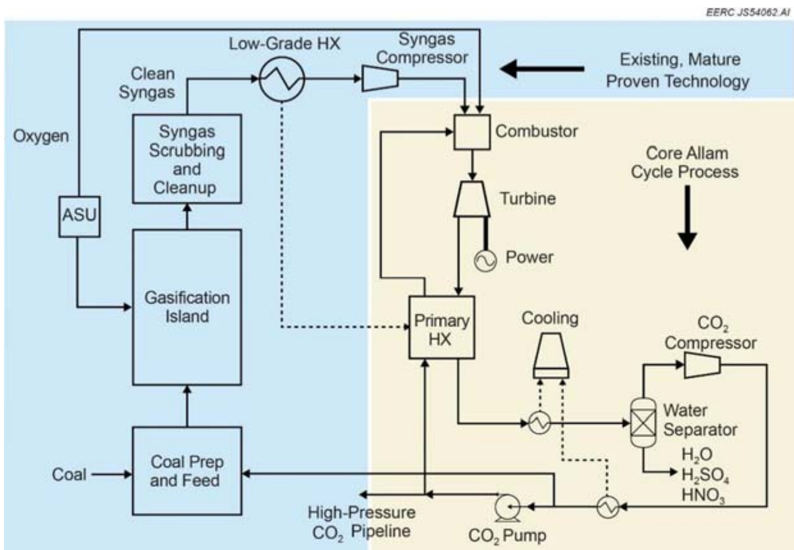
COAL-BASED ALLAM CYCLE



Efficiency	HHV
Gross Turbine Output	72.5%
Coal Prep & Feed	-0.2%
ASU	-9.7%
CO_2, Syngas Comp.	-8.7%
Other Auxiliaries	-6.1%
Net Efficiency	**47.8%***

*Based on preliminary studies with bituminous coal.

- High efficiency with **existing gasifier technologies.**
- **Minimal gasifier integration required**, low complexity.
- **Near-zero emissions.** No additional capture or compression equipment needed.

KEY AREAS REQUIRED TO MITIGATE ADDITIONAL RISKS FOR COAL

- Metallurgy/corrosion
  - Evaluation tolerance of downstream system to potential impurities.
  - Dependent on gas cleanup system and coal type.
- Gasifier selection
  - Optimized system selection based on site and fuel.
  - Select for lowest LCOE, lowest-risk system. Consider downstream implications.
- Gas cleanup
  - Evaluation of existing vs. proposed cleanup systems.
  - Coal- and gasifier-dependent.
- Syngas combustor
  - Key equipment development.
  - Dependent on gasifier output, fuel type, and required flexibility.
- Pilot-scale demonstration

TECHNICAL APPROACH

Goal: Determine the most appropriate scope, scale, and location for an Allam Cycle coal-based demonstration.

- Scope
  - Components of the system that must be demonstrated in the large pilot.
- Scale
  - Determine size of the large pilot (notionally 5–50 MW).
- Location
  - Supporting infrastructure available to reduce the overall investment across a wide range of potential scope.

SCOPE

- Ensure that key aspects of the coal-based Allam Cycle are addressed.
  - Syngas combustion
  - Impact of impurities
- Final scope will be informed by results of ongoing efforts.
- Sourced syngas versus generated syngas.

SYSTEM SCALE

- Starting point: 5–50 MW
- Scaled to match La Porte Facility?
- Flexibility of scale at larger host sites
- Salable end products?
  - CO_2
  - Electricity

SYSTEM LOCATION

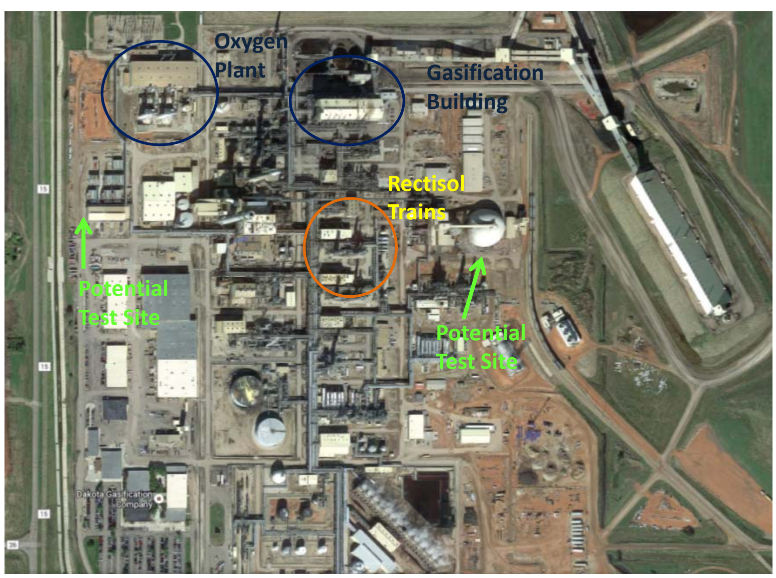
- Two primary sites currently being considered.
  - Dakota Gasification
  - La Porte
- Other sites are being evaluated as backup sites, but detailed investigations are not planned.

SYSTEM LOCATION

Attributes of Various U.S.-Based Host Sites

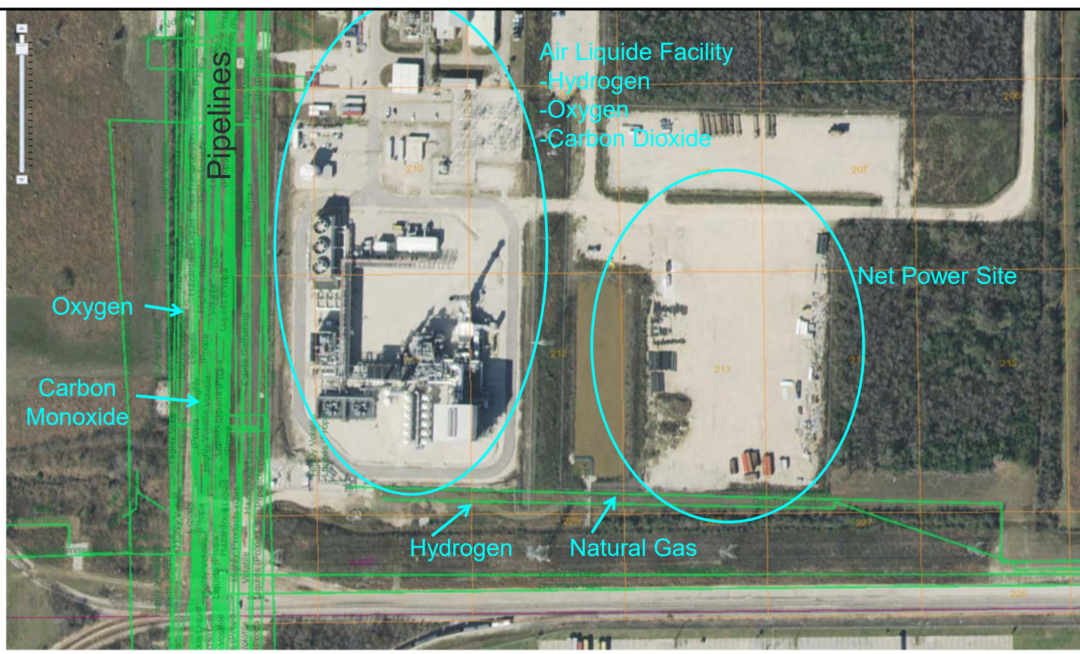
Site	Gasifier Type	Size, MWth	Fuel Type	AGR Type	H_2S Conc., ppm	Product(s)
DGC	Lurgi	1900	Lignite	Rectisol	<0.1	SNG, CO_2, $(NH_4)_2SO_4$
La Porte, TX	TBD				0	
TECO	GE/radiant	451	Bit./pc	MDEA	280	Power, H_2SO_4
Wabash	E-Gas	591	Petcoke	MDEA	<70	Power, S
Eastman	GE/quench	219	Bit. coal	Rectisol	<0.1	Chemicals, S
Edwardsport	GE/radiant	1150	Bit. coal	Selexol	0.014 lb/MMBtu	Power, S
Coffeyville	GE/quench	293	Petcoke	Selexol	<1	NH_3, UAN, S

DAKOTA GASIFICATION SITE



DAKOTA GASIFICATION SITE

- Advantages
  - Lignite-derived syngas
  - Precombustion impurity removal
  - Gases available:
    - ♦ Oxygen
    - ♦ CO_2
    - ♦ Syngas (H_2, CO, CH_4)
- Challenges
  - Rebuild core cycle or ship from Texas?
  - Elevated H_2/CO ratio
  - Methane in syngas
  - Can we test a wide variety of U.S.-based feedstocks?



NET Power La Porte, Texas, demonstration site.
Green lines represent existing pipeline infrastructure.

LA PORTE SITE

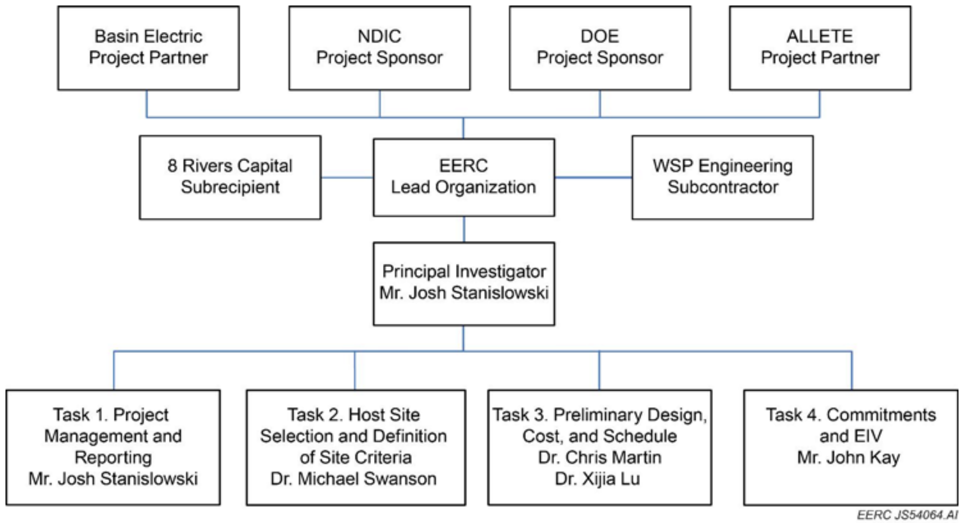
- Advantages:
  - Proximity to gas production facility.
  - Proximity to pipeline infrastructure.
  - Blended syngas enables precise control of composition.
  - Existing equipment on-site from NG demonstration.
  - Gases available:
    - Hydrogen
    - CO
    - CO_2
    - Oxygen
- Challenges
  - Options for syngas supply
  - Timing of site/equipment availability.
  - May have to boost CO pipeline pressure.

PROJECT OBJECTIVES

The objective of this project by the Energy & Environmental Research Center (EERC), upon completion of Phase III, is to design, build, and operate a direct-fired, supercritical CO_2 cycle pilot plant operating on syngas. Specifically, this project will further the technology development of the coal-based Allam Cycle.

Broad Project Partner Objectives:
Develop enough data, information, and experience to give project partners confidence that new options exist for next-generation coal-based power systems.

PROJECT STRUCTURE



TASK STRUCTURE

- Task 1 – Project Management and Reporting
  - Project coordination
  - DOE reporting requirements and presentations
- Task 2 – Host Site Selection and Definition of Site Criteria
  - Determine scope, scale, and candidate locations
  - Select host site
- Task 3 – Preliminary Design, Cost, and Schedule
  - Design system based on Task 2 results
  - Develop Class 5 cost estimate, WSP engineering
- Task 4 – Commitments and Environmental Information Volume (EIV)
  - Develop project team and additional partners
  - Complete an EIV for DOE.

TASK 3 – PRELIMINARY DESIGN, COST, AND SCHEDULE

- Once the host site is selected, the team will undertake a preliminary design effort based on site-specific characteristics and requirements.
- A Class 5 cost estimate will be prepared for the facility, with the costing effort let by WSP engineering.
- Preliminary schedule for Phase II and Phase III.

TASK 4 – COMMITMENTS AND EIV

- The team will work to secure commitments for Phases II and III:
  - FEED contractor.
  - NEPA contractor.
  - Host site.
  - Cost-share partners.
  - Other interested entities.
- Development of design basis document
  - Bids from engineering firms in Phase I?
- EIV
  - EERC to produce the EIV.
  - Will be included in the Phase II application.

EIV

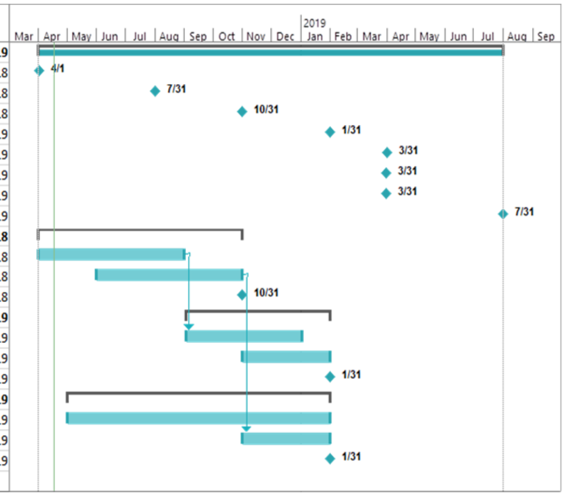
- Introduction
  - Background
  - Summary of impacts
- Proposed action and alternatives
  - Site description
  - Existing operations
  - Engineering descriptions of the proposed action
  - Alternatives
- Existing environment and consequences of the project
  - Atmospheric resources (climate, ambient air quality)
  - Land resources
  - Water resources (surface, ground)

EIV, CONT.

  - Ecological resources (wildlife, vegetation, threatened species)
  - Socioeconomic resources
  - Aesthetic/cultural resources
  - Energy and material resources (coal, water, power)
- Regulatory compliance
- Preparers and professional qualifications
- Agencies and persons contacted

PROJECT SCHEDULE

ID	Task Name	Start	Finish
1	**Task 1.0 – Project Management and Planning**	**4/1/2018**	**7/31/2019**
2	Project Start Date	4/1/2018	4/1/2018
3	Quarterly Report 1	7/31/2018	7/31/2018
4	Quarterly Report 2	10/31/2018	10/31/2018
5	Quarterly Report 3	1/31/2019	1/31/2019
6	Quarterly Report 4	3/31/2019	3/31/2019
7	Milestone 4 – Final Project Report	3/31/2019	3/31/2019
8	Phase II Application	3/31/2019	3/31/2019
9	Phase II Notification Date	7/31/2019	7/31/2019
10	**Task 2.0 – Definition of Site Criteria and Host Site Selection**	**4/1/2018**	**10/31/2018**
11	Subtask 2.1 – Definition of Site Criteria	4/1/2018	8/31/2018
12	Subtask 2.2 – Host Site Selection	6/1/2018	10/31/2018
13	Milestone 1 – Select Host Site for the Large Pilot Demonstration	10/31/2018	10/31/2018
14	**Task 3.0 – Preliminary Design, Cost, and Schedule**	**9/3/2018**	**1/31/2019**
15	Subtask 3.1 – Preliminary Design	9/3/2018	1/1/2019
16	Subtask 3.2 – Preliminary Cost and Schedule	11/1/2018	1/31/2019
17	Milestone 2 – Preliminary Cost and Schedule Estimate	1/31/2019	1/31/2019
18	**Task 4.0 – Commitments and EIV**	**5/1/2018**	**1/31/2019**
19	Subtask 4.1 – Commitments from 3rd Parties	5/1/2018	1/31/2019
20	Subtask 4.2 – Environmental Information Volume	11/1/2018	1/31/2019
21	Milestone 3 – Completion of Environmental Information Volume	1/31/2019	1/31/2019
22			



PROJECT BUDGET

	Budget Period 1	
	Government Funding	**Nonfederal Cost Share**
EERC-Prime	$396,168	$175,000
8 Rivers-subrecipient (Includes WSP)	$303,832	
Total	$700,000	$175,000
Cost Share, %	80%	20%

PROJECT BUDGET BY DOE FISCAL YEAR AS SHOWN IN PROJECT MANAGEMENT PLAN (PMP)

	FY 2018		FY 2019		Total	
	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share
EERC – Prime	$146,168	$146,000	$250,000	$29,000	$396,168	$175,000
8-Rivers – Subrecipient	$159,332		$144,500		$303,832	$0
Total ($)	**$305,500**	**$146,000**	**$394,500**	**$29,000**	**$700,000**	**$175,000**
Total Cost Share %	67.7%	32.3%	93.2%	6.8%	80%	20%

PMP – MILESTONES

Milestone No.: M1
Title: Select Host Site for the Large Pilot Demonstration
Planned Date: 10/31/2018
Verification Method: Q1FY19 Research Performance Progress Report

Milestone No.: M2
Title: Develop Preliminary Methodology Cost and Schedule Estimate
Planned Date: 1/31/2019
Verification Method: Phase I Topical Report

Milestone No.: M3
Title: Completion of Environmental Information Volume
Planned Date: 1/31/2019
Verification Method: Phase I Topical Report

Milestone No.: M4
Title: Submit Phase I Topical Report
Planned Date: 3/31/2019
Verification Method: Phase II Application Package

PMP – RISK MANAGEMENT

Perceived Risk	Risk Rating Probability	 Impact	 Overall	Mitigation/Response Strategy
	(Low, Med, High)			
Financial Risks:				
None identified.				
Cost/Schedule Risks:				
Development of notional cost and schedule estimate for the large pilot system within the Phase I budget.	Low	Med	Low	The EERC has experience in developing cost estimates of this nature and will also be bringing on a subcontractor with experience on the Allam Cycle technology to aid in cost estimating.
Technical/Scope Risks:				
Secure adequate host site for the large pilot demonstration.	Low	High	Low	The team is working with a strong industrial team and has already received two letters of interest from candidate host sites. Alternative sites beyond the two primary have also been identified.
Development of EIV within the period of performance.	Low	Med	Low	The EERC has extensive experience developing assessments of this nature and will use past experience to ensure success of this effort. Additionally, a subcontract will be awarded to the host site to aid in this assessment.

RISK MANAGEMENT, CONT.

Management Risks:				
None identified.				
Planning and Oversight Risks:				
None Identified.				
ES&H Risks:				
None identified.				
External Factor Risks:				
None identified.				
Management Risks:				
None identified.				

EXPECTED OUTCOMES/IMPACTS OF PHASE I

- Selection and commitment of host pilot site
- Completion of preliminary facility design and associated budget for construction and operation
- Completion of the EIV
- Selection of project team required to execute Phases II and III
- Estimated cost and schedule to complete Phases II and III

EXPECTED OUTCOMES/IMPACTS OF PHASE II AND III

- Demonstration of a transformational technology at the large pilot scale

- Addition of a new technology option for utilities to consider when making decisions on future power generation systems

- Options for utilities to deploy new coal-based power generation with CO_2 capture inherent

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