ALLAM CYCLE ZERO EMISSION COAL POWER

US Department of Energy Coal FIRST Phase 2

Project Execution Plan Presentation

March 9th 2020

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Potential Project Schedule

Task	Timing
Wyoming Pre-FEED Completion	Q2 2020
Coal FIRST Syngas Combustor Test Start	Q4 2020
Coal FIRST Design and FEED Funding Start	Q1 2021
Negotiate Wyoming Project Offtake Contracts	2021-2022
Project Permitting	2021-2023
Commercial NET Power Plant Commissioned on Gas	2022
Wyoming FEED Completion	H2 2022
Combustor Test Completion	Q4 2022
Project Financial Close & Commence Construction	Q1 2023
Wyoming Allam Cycle Project COD	2025-2026

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Syngas Combustor And Turbine

The Syngas Combustor Test Plan is still under development schedule is thus still open for modification.

The test is expected to take roughly two years and finish in 2022.

Multiple potential turbine vendors will be prepared to supply the commercial turbine for the coal system by well before the 2023 FID date.

This includes turbines specifically designed for coal syngas and repurposing turbines designed for natural gas but that can be repurposed due to the operational flexibility of the Allam-Fetvedt cycle

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Commercial Gasifier Suppliers

All commercial gasifiers can be integrated with the Allam Cycle for power and chemical production

Entrained flow gasifier:

- **Sinopec-ECUST (SE gasifier)**
  - Vendor selected in current Pre-FEED
- **ECUST OMB gasifier**
- **Air Product**
- **E-gas**

Fluidized bed gasifier:

- **KBR Transport**
- **SES**
- **U-gas**

Moving bed gasifier:

- **BGL**
- **Lurgi Dry-Ash**

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Advanced Gasifier Technology

- R-GAS™ Advanced Gasification Technology 800TPD Demo unit is being commissioned in China
- 90% smaller reactor volume allows for factory integration and enables modularization
- High CGE: 2-4% > than other dry feed, 7%-9% > than slurry
- Lower capex: ~15-25% plant cost reduction vs. lowest cost entrained flow technology
- 15%-25% reduction in cost of product (power, chemicals, liquids)

R-GAS™ Timeline:-

Year	2008	2012	2014	2016	2017	2018	2019	Jun-20	Dec-20	Jun-21	Dec-21	Jun-22
Pilot Plant Testing with >1300 hr of operation												
Testing of China Coal												
PRE-FEED Study												
MOU for 800 TPD Demo Unit												
PDP Package Development												
Detailed Engineering												
Completion of Construction												
Start up and Commisisoning												
Operational testing												
Technology Commerically Available												

Economics of China-base Plant

Parameter	TECHNOLOGY R-GAS™	Dry Feed (Western)	Dry Feed (PRC Domestic)	Slurry	Units
Capex	377689	500058	347291	426377	10,000 RMB
Annual Revenue	517106	513031	511404	511404	10,000 RMB/yr
Annual Cost	270280	372212	370093	319734	10,000 RMB/yr
Annual Profit	151438	83245	84540	115795	10,000 RMB/yr
Syngas Cost	318.3	445.5	437.7	373.3	RMB/kNm³
Payback	3.65	5.41	4.52	4.3	yr
FIRR	48.26	24.7	33.02	35.95	%

Study performed by East China Engineering Science and Technology Co.

15%-29% Cost Of Syngas Advantage

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NET Power To De-Risk The Core Allam Cycle

Commissioning of the first commercial scale plant is targeted for 2022

POWER

News & Technology for the Global Energy Industry

News

300-MW Natural Gas Allam Cycle Power Plant Targeted for 2022

Testing continues at NET Power for a much-watched project that is demonstrating production of low-carbon natural gas power. The project is using a supercritical carbon dioxide (sCO_2) cycle, and its developer is confident that the technology will be commercially deployed in 2022.

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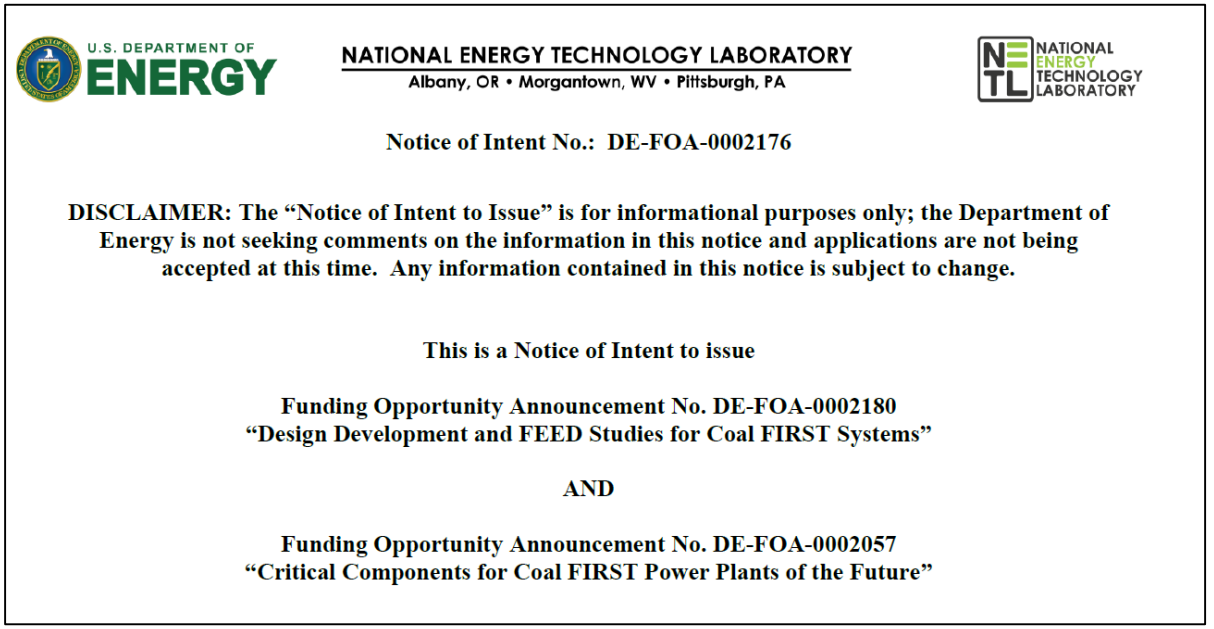
Detailed Design: FEED Study

The next phase of engineering after Pre-FEED for this project would be a detailed site-specific FEED study.

An upcoming FOA could potentially provide the funding for this FEED.



U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY
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Notice of Intent No.: DE-FOA-0002176

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This is a Notice of Intent to issue

Funding Opportunity Announcement No. DE-FOA-0002180
"Design Development and FEED Studies for Coal FIRST Systems"

AND

Funding Opportunity Announcement No. DE-FOA-0002057
"Critical Components for Coal FIRST Power Plants of the Future"

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Site Selection

This Pre-FEED has been sited at Peabody's North Antelope Rochelle Mine (NARM) to enable access to mine mouth coal near transmission and CO_2 infrastructure.

Selection of the exact site would occur after completion of Pre-FEED.

Peabody's North Antelope Rochelle Mine

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COMMERCIAL DEVELOPMENT

Project Outputs

The project has 3 main revenue streams: power, CO2, and industrial gases.

CO2

- 1.6 MMT CO2 output per year at 150 BAR

Industrial Gases

- 64,000 MT Argon output. Up to 4.2 MMT N2 output

Power:

- 287 MW net output
- 369 MW peak output using stored oxygen

Coal thermal input (MW LHV)	676
Gross output	468.15
ASU load	-72.19
Compression/pumping load	-86.29
Gasification utility	-5.23
Cooling tower	-4.35
Miscellaneous BOP	-6.2
Net power output	286.7
Net efficiency (% LHV)	42.40%

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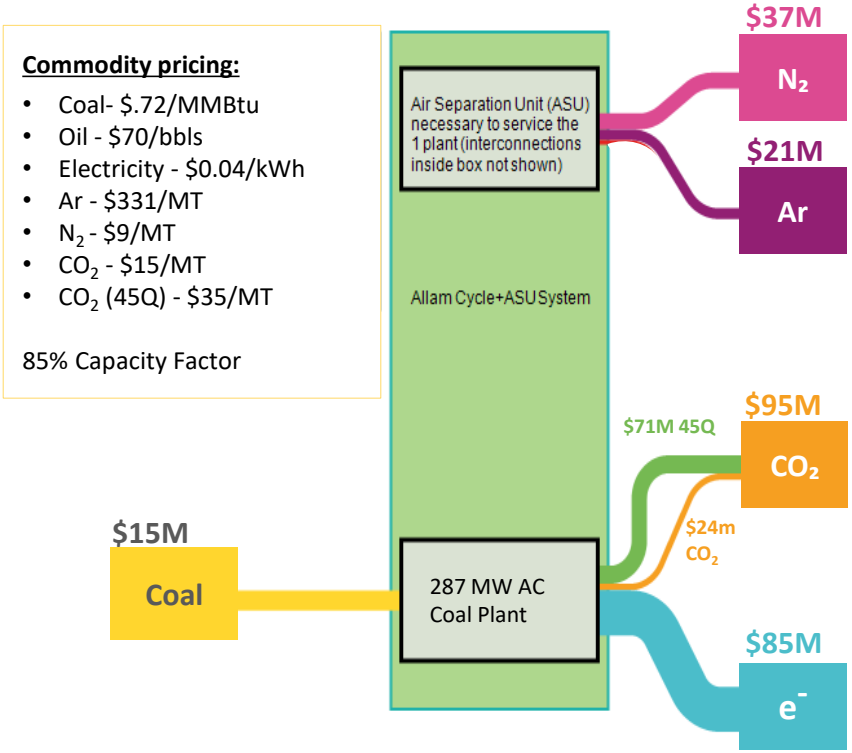
Project Revenue Streams

CO_2 and Electricity are the dominant revenue streams, and together will hedge the risk of the project, as oil and CO2 prices are not strongly correlated to power prices

Allam-Fetvedt Cycle Coal Revenue Flow Chart



Power Offtake

Finding customers for the power and suitable transmission to deliver it will be one of the key aspects of development to enable the raising of funds for the project.

Sending the power west will reach markets with higher power prices, higher power demand, and higher premiums for zero-emission power.

Review of Existing Transmission Infrastructure

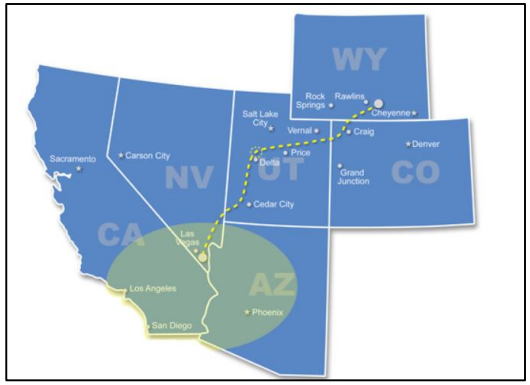
115 kV existing transmission line at NARM

230 kV transmission lines owned by Basin Electric / PacifiCorp connect to Dave Johnston Power Station in Glenrock and Dry Fork Station in Gillette, each of which has transmission infrastructure for regional distribution.

The TransWest Express wind transmission project can reach the California market. It has received its permits and is scheduled to be online in 2023. This project could utilize any spare transmission capacity as well as balanced out wind farms by utilizing the transmission when the wind isn't blowing.

California's SB 100 bill targets 100% zero emission power by 2045.

TransWest Express Route



Wyoming Transmission Map

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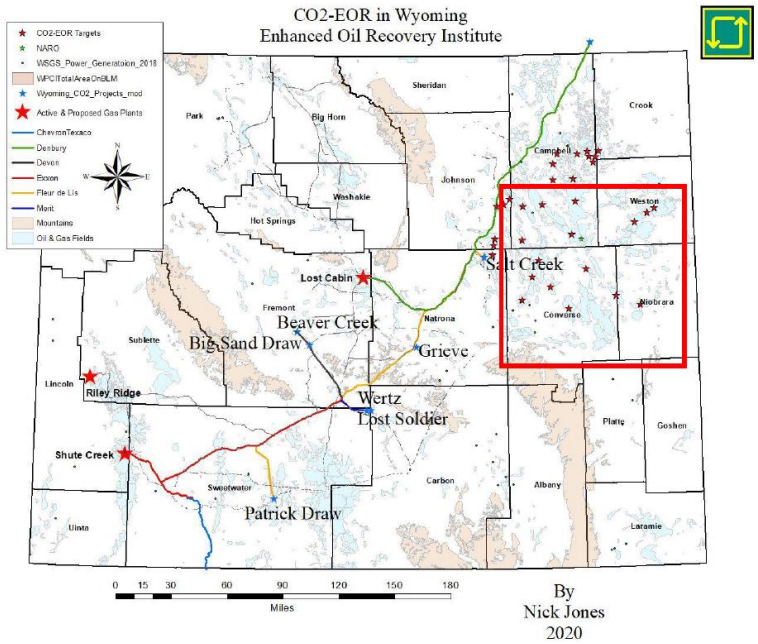
CO2 Offtake

20+ oil fields in <50 mile radius that can utilize and store the project's CO2.

Field selection and CO2 offtake contracts would be put together during the development period from 2021 up to FID.

CO2-EOR Field Map



CO2-EOR Field List

Distance Miles	Field Name	Reservoir Name	Cumulative Oil mmbo	CO2 Demand Bcf
25	Porcupine	Turner	4.9	26.22
25	Highlight	Muddy	81.7	261.37
25	Steinle Ranch	Muddy	4.3	23.60
50	Big Hand	Minnelusa	8.1	25.35
50	Bone Pile	Minnelusa	9.4	29.72
50	Clareton	Turner	7.4	23.60
50	Donky Creek	Minnelusa	17.3	46.33
50	Dry Gulch	Minnelusa	5.5	17.48
50	Halverson	Minnelusa	17.5	55.95
50	Hartzog Draw	Shannon	120.2	382.88
50	Hawk Point	Minnelusa	4.7	25.35
50	Heldt Draw	Shannon	7.9	20.98
50	Hornbuckle	Sussex	14.1	76.05
50	House Creek	Sussex	65.7	208.92
50	Jepson Draw	Shannon	1.9	6.99
50	Kaye	Teapot	10.1	32.34
50	Lance Creek	Leo	121.2	393.37
50	Meadow Creek	Minnelusa	35.7	96.16
50	Meadow Creek North	Frontier	9.5	51.57
50	Mush Creek	Muddy	14.8	48.08
50	Mush Creek West	Muddy	4.2	22.73
50	Pine Tree	Frontier	11.4	60.32
50	Powell	Frontier	29.4	156.47
50	Raven Creek	Minnelusa	47.7	154.72
50	Reel	Minnelusa	10.6	34.09
50	Salt Creek East	Tensleeep	13.6	43.71
50	Sand Dunes	Frontier	27	142.49
50	Scott	Parkman	22.7	72.55
50	Slattery	Minnelusa	14.8	47.20
50	Spearhead Ranch	Sussex	9.4	49.83
50	Table Mountain	Shannon	6.3	20.98
50	Timber Creek	Minnelusa	22.9	73.43
			Totals	2,730.84

Citation: Enhanced Oil Recovery Institute (EORI); 2020; www.eoriwyoming.org

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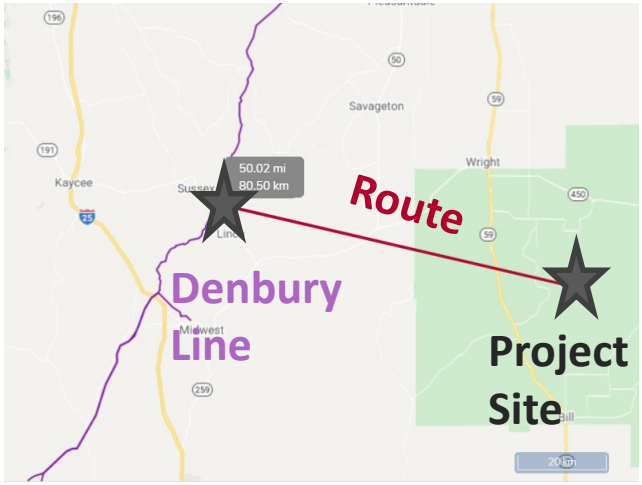
Sample CO2 Pipeline to Denbury CO2 Pipeline

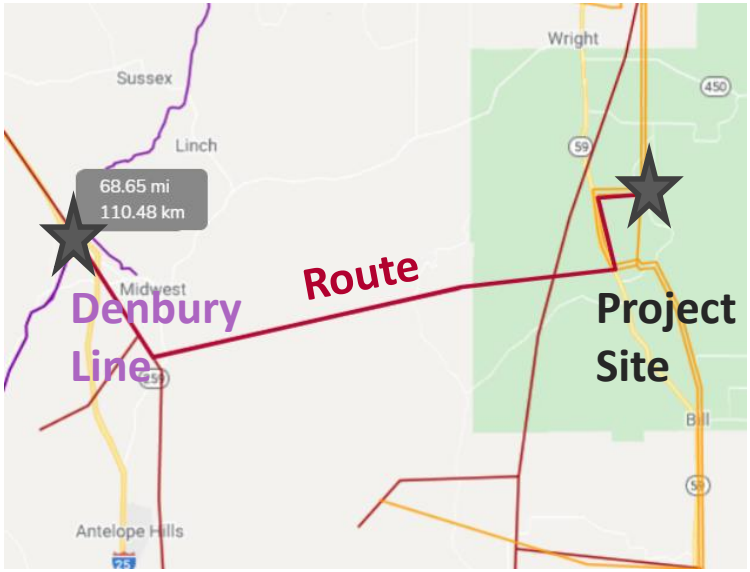
Denbury's Greencore 20 inch pipeline delivers CO2 to the Bell Creek EOR field in Montana, and it runs west of NARM.

A 50 mile straight line pipeline could connect to the existing Denbury line, or a longer 68 mile route that follow existing pipelines for 53 miles, with 15 miles of new route required.

50 mile straight line route



68 mile route to minimize permitting



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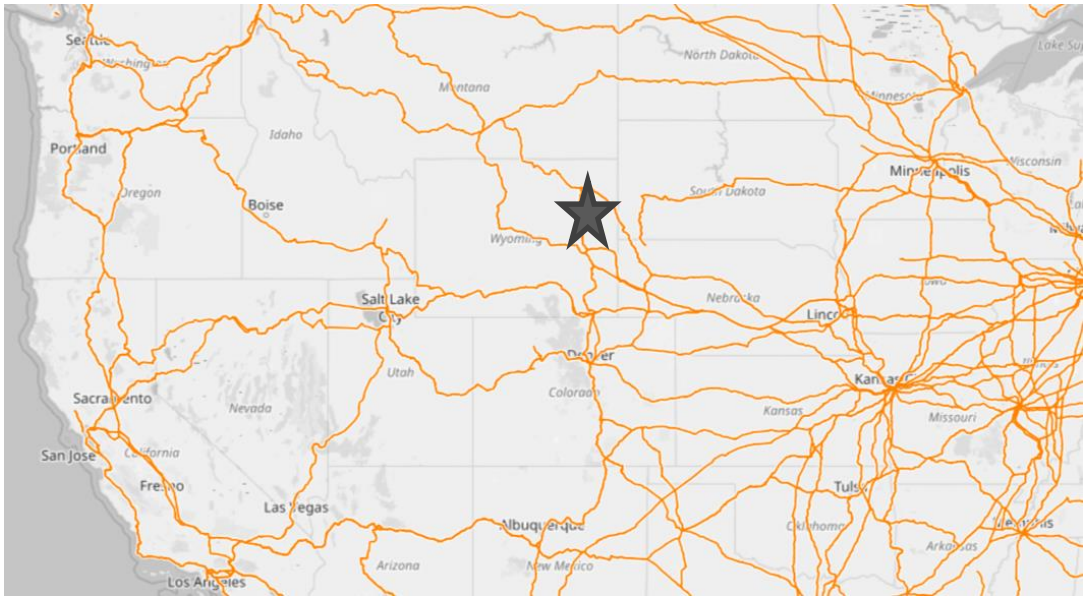
Industrial Gas Offtake

The NARM mine is already connected to a BNSF rail-line with a rail terminal that can hold >300 rail cars. This allows access to all key regional markets.

Nearest competitor Air Separation Units are located in Salt Lake City and Denver.

Trucking is also a potential mode of transport for nearby customers and distributors.

Rail Access For Industrial Gas Export



Cryogenic Argon Rail Car

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Project Permitting

Permitting will be a key workstream to enable the project to rapidly advance to both Final Investment Decision and then to start construction and reach COD.

Key Permitting Items

- Air Permits
- Water Permits
- Power Infrastructure
- Intrastate CO2 Pipeline Permit
- Class 2 CO2-EOR Permits

Permitting and Compliance Strategies

- Permitting considerations for startup, shutdown, and malfunctions emissions will be considered
- Includes Basic Available Control Technology (BACT), air dispersion modeling, and other permitting considerations
- EPA Approved Regulations in the Wyoming SIP
- All necessary permits shall be obtained prior to the initiation of construction
- A local, state, and federal permitting matrix shall be created, with timelines to track long lead permits.

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Accelerated Air Permitting

The Project is expected to have a reduced permitting burden due to the low emissions rate, potentially qualifying as a Minor Source of Emissions.

Approximately 97 percent of the mercury is captured from the syngas by dual activated carbon beds.

CO_2 emissions represent the uncontrolled discharge from the process

N_2 from the fuel which makes it into the system is converted to NOx in the combustor and removed as HNO_3 in the water separator

Plant Emissions

	kg/GJ	lb/MMBtu	Tonne/year	kg/MWh
SO2	n/a	n/a	n/a	n/a
NOx	n/a	n/a	n/a	n/a
Particulate	0.0005	0.0012	9.515	0.0027
Hg	9.22941E-11	2.14615E-10	0.002	4.82614E-10
HCl	n/a	n/a	n/a	n/a
CO2	5.72	13.31	104,310	29.92

Start-Up Emissions

	tonne/year
SOx	0.371
NOx	n/a
Particulate	n/a
Hg	1.80749E-05
HCl	n/a
CO2	254

- 2 start-ups per year are considered while utilizing a lower coal feed rate.
- The start-up will last for 2 hrs

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Water Permitting and Design Decisions

Water and Wastewater Permits required will depend on if Zero Liquid Discharge is selected, as well as if Wet Cooling or Dry Cooling is utilized.

With Zero Liquid Discharge and Dry Cooling, there would be both no process water discharge and no water withdrawal to permit.

Dry Cooling and Zero Liquid Discharge

Dry Cooling Water Use	Water Demand	Internal Recycle [1]	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	gpm	gpm	gpm	gpm	gpm
Overall Balance	5793.9	6208.8	-414.9	0	-414.9

Wet Cooling and Zero Liquid Discharge

Wet Cooling Water Use	Water Demand	Internal Recycle	Raw Water Withdrawal	Process Water Discharge	Raw Water Consumption
	gpm	gpm	gpm	gpm	gpm
Overall Balance	7975.5	6806.0	1169.5	0	1169.5

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Gasifier Impact on Permitting

Emissions from the gasification island will be a key part of the permitting analysis

Coal Drying and Feed System

- Particulate Emissions

Gasifier

- Emissions sources typically include gasifier startup vents (CO and NOX), gasifier feed system vents (CO, VOC, and HAPs), and equipment leak components (CO , VOC, and HAPs)
- Off-specification raw syngas may be vented to the flare during startup, shutdown, and malfunction events

Gas Clean Up

- Sour syngas may be vented to the flare during startup, shutdown, and malfunction

HAP- Hazardous Air Pollutants ; VOC-Volatile organic compounds

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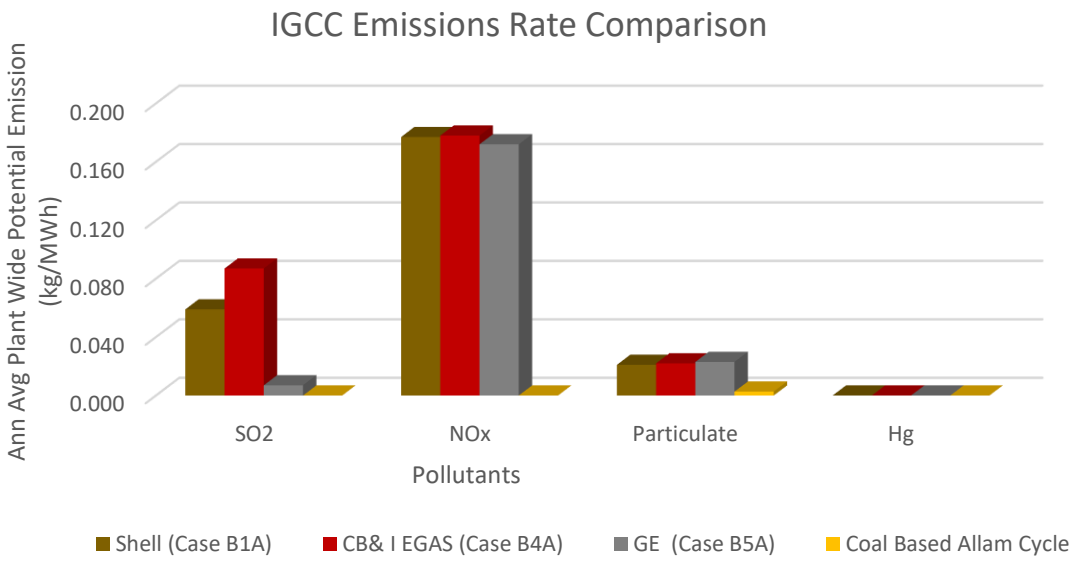
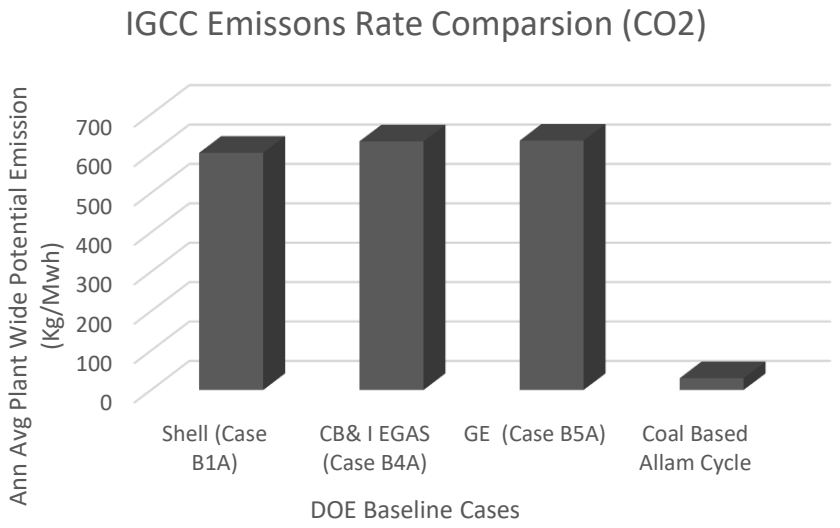
Emissions Comparison to IGCC

- **Comparison of Coal Based Allam cycle emissions with DOE baseline case studies.**
- **Emissions from DOE reports were compared to per MWh power generation**

Ref:- "COST AND PERFORMANCE BASELINE FOR FOSSIL ENERGY PLANTS VOLUME 1: BITUMINOUS COAL AND NATURAL GAS TO ELECTRICITY", NETL-PUB-22638 , Sept 24,2019





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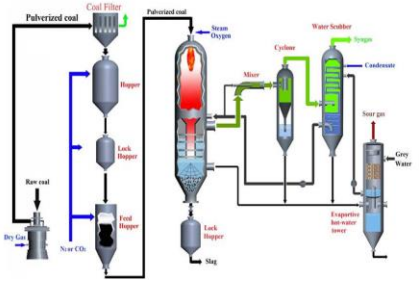
Partnering with Technology Providers

For key equipment items and packages, we are working in collaboration with selected, world-class technology providers during pre-FEED and FEED. This will ensure an optimum process configuration and minimize technology risk.

For standard equipment packages we will adopt a competitive tendering approach from a range of approved suppliers to ensure minimum cost and ensure that alternative technology options are considered.

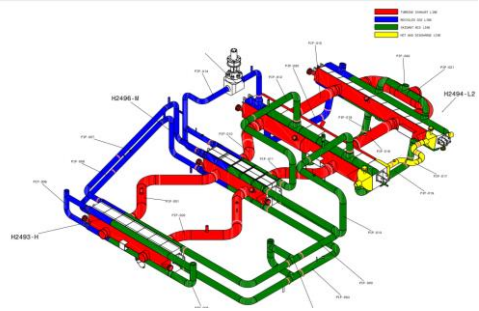
Key Partners for this Project:

Gasifier Island



Syngas Burner & CO_2 Turbine

Printed Circuit Heat Exchangers



Does not exclude engaging with alternative suppliers at later stage

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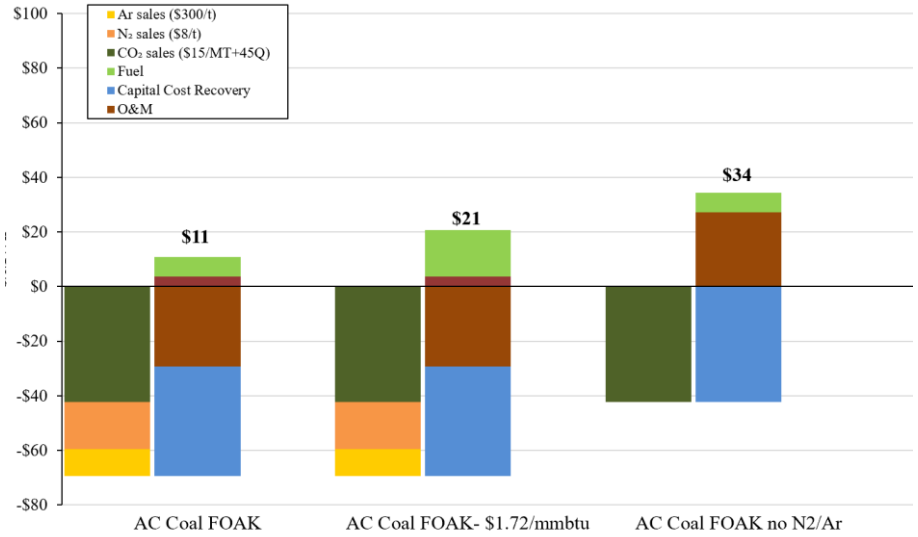
Financing

Keys to Successful Financing Include:

- **Project IRR**
- **Diversification of project risk**
- **Long term offtake contracts**
- **Lump Sum Turnkey EPC contract**
- **Low emissions profile**
- **Tax appetite**

Levelized Cost of Electricity Scenarios



- Wyoming Project can be competitive with a <$40 / MWH power price, both with and without industrial gas sales.
- To be financeable the project must commence construction before 45Q expiration at the end of 2023. 45Q
- 30% Investment Tax Credit from 48A could further improve project economics and allow for successful financing.
- Project may need to pay more for capital than the 5.15% Weighted Average Cost of Capital assumed In NETL Baselines

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Profile of Ideal Equity Investors

Target list will include:

- **Low Carbon Investment Funds**
- **Banks with Tax Equity Experience**
- **Independent Power Producers and Utilities**
- **Coal Industry**
- **Oil and Gas Majors**
- **Industrial power users**
- **Government entities**

Ideal Traits For Equity Investors

- >$50M annual tax appetite for 45Q and experience with tax equity structures
- Upfront tax appetite for potential 48A tax credit
- Power cycle and turbine expertise to appropriately judge technical progress and risk
- Long term strategic interest in CO_2 capture
- Strategic interest in turning coal into a zero emission fuel source
- Ability to hedge risk across commodities
- Focus on low-carbon infrastructure

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