ALLAM CYCLE ZERO EMISSION COAL POWER

US Department of Energy Coal FIRST Phase 2

Project Execution Plan Presentation

March 9th 2020
## Potential Project Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming Pre-FEED Completion</td>
<td>Q2 2020</td>
</tr>
<tr>
<td>Coal FIRST Syngas Combustor Test Start</td>
<td>Q4 2020</td>
</tr>
<tr>
<td>Coal FIRST Design and FEED Funding Start</td>
<td>Q1 2021</td>
</tr>
<tr>
<td>Negotiate Wyoming Project Offtake Contracts</td>
<td>2021-2022</td>
</tr>
<tr>
<td>Project Permitting</td>
<td>2021-2023</td>
</tr>
<tr>
<td>Commercial NET Power Plant Commissioned on Gas</td>
<td>2022</td>
</tr>
<tr>
<td>Wyoming FEED Completion</td>
<td>H2 2022</td>
</tr>
<tr>
<td>Combustor Test Completion</td>
<td>Q4 2022</td>
</tr>
<tr>
<td>Project Financial Close &amp; Commence Construction</td>
<td>Q1 2023</td>
</tr>
<tr>
<td>Wyoming Allam Cycle Project COD</td>
<td>2025-2026</td>
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</table>
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.
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
Advanced Gasifier Technology

- R-GAS™ Advanced Gasification Technology 800 TPD 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:

- 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 Commissioning
- Operational testing
- Technology Commerically Available

Economics of China-base Plant

<table>
<thead>
<tr>
<th>Parameter</th>
<th>R-GAS™</th>
<th>Dry Feed (Western)</th>
<th>Dry Feed (PRC Domestic)</th>
<th>Slurry</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>Capex</td>
<td>377689</td>
<td>500058</td>
<td>347291</td>
<td>426377</td>
<td>10,000 RMB</td>
</tr>
<tr>
<td>Annual Revenue</td>
<td>517106</td>
<td>513031</td>
<td>511404</td>
<td>511404</td>
<td>10,000 RMB/yr</td>
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<tr>
<td>Annual Cost</td>
<td>270280</td>
<td>372212</td>
<td>370909</td>
<td>319734</td>
<td>10,000 RMB/yr</td>
</tr>
<tr>
<td>Annual Profit</td>
<td>151438</td>
<td>83245</td>
<td>84540</td>
<td>115795</td>
<td>10,000 RMB/yr</td>
</tr>
<tr>
<td>Syngas Cost</td>
<td>318.3</td>
<td>445.5</td>
<td>457.7</td>
<td>375.3</td>
<td>RMB/kNm³</td>
</tr>
<tr>
<td>Payback</td>
<td>3.65</td>
<td>5.41</td>
<td>4.52</td>
<td>4.3</td>
<td>yr</td>
</tr>
<tr>
<td>FIRR</td>
<td>48.26</td>
<td>24.7</td>
<td>33.02</td>
<td>35.95</td>
<td>%</td>
</tr>
</tbody>
</table>

15%-29% Cost Of Syngas Advantage
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 (sCO₂) cycle, and its developer is confident that the technology will be commercially deployed in 2022.
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.

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”
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 CO₂ infrastructure.

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

<table>
<thead>
<tr>
<th>Coal thermal input (MW LHV)</th>
<th>676</th>
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<tbody>
<tr>
<td>Gross output</td>
<td>468.15</td>
</tr>
<tr>
<td>ASU load</td>
<td>-72.19</td>
</tr>
<tr>
<td>Compression/pumping load</td>
<td>-86.29</td>
</tr>
<tr>
<td>Gasification utility</td>
<td>-5.23</td>
</tr>
<tr>
<td>Cooling tower</td>
<td>-4.35</td>
</tr>
<tr>
<td>Miscellaneous BOP</td>
<td>-6.2</td>
</tr>
<tr>
<td>Net power output</td>
<td>286.7</td>
</tr>
<tr>
<td>Net efficiency (% LHV)</td>
<td>42.40%</td>
</tr>
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</table>
Project Revenue Streams

CO₂ 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.

Commodity pricing:
- Coal: $0.72/MMBtu
- Oil: $70/bbls
- Electricity: $0.04/kWh
- Ar: $331/MT
- N₂: $9/MT
- CO₂: $15/MT
- CO₂ (45Q): $35/MT

85% Capacity Factor

Allam-Fetvedt Cycle Coal Revenue Flow Chart

- Air Separation Unit (ASU) necessary to service the plant (interconnections inside box not shown)
- 287 MW AC Coal Plant
- $15M Coal
- $71M 45Q
- $85M e⁻
- $24m CO₂
- $95M CO₂
- $37M N₂
- $21M Ar
- $7M 45Q
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.
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.

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

CO₂ emissions represent the uncontrolled discharge from the process.

N₂ from the fuel which makes it into the system is converted to NOx in the combustor and removed as HNO₃ in the water separator.

### Plant Emissions

<table>
<thead>
<tr>
<th></th>
<th>kg/GJ</th>
<th>lb/MMBtu</th>
<th>Tonne/year</th>
<th>kg/MWh</th>
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<tbody>
<tr>
<td>SO₂</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>NOₓ</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Particulate</td>
<td>0.0005</td>
<td>0.0012</td>
<td>9.515</td>
<td>0.0027</td>
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<tr>
<td>Hg</td>
<td>9.22941E-11</td>
<td>2.14615E-10</td>
<td>0.002</td>
<td>4.82614E-10</td>
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<tr>
<td>HCl</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>CO₂</td>
<td>5.72</td>
<td>13.31</td>
<td>104,310</td>
<td>29.92</td>
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### Start-Up Emissions

<table>
<thead>
<tr>
<th></th>
<th>tonne/year</th>
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<tbody>
<tr>
<td>SO₅</td>
<td>0.371</td>
</tr>
<tr>
<td>NOₓ</td>
<td>n/a</td>
</tr>
<tr>
<td>Particulate</td>
<td>n/a</td>
</tr>
<tr>
<td>Hg</td>
<td>1.80749E-05</td>
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<tr>
<td>HCl</td>
<td>n/a</td>
</tr>
<tr>
<td>CO₂</td>
<td>254</td>
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</table>

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

<table>
<thead>
<tr>
<th>Dry Cooling Water Use</th>
<th>Water Demand</th>
<th>Internal Recycle</th>
<th>Raw Water Withdrawal</th>
<th>Process Water Discharge</th>
<th>Raw Water Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gpm</td>
<td>gpm</td>
<td>gpm</td>
<td>gpm</td>
<td>gpm</td>
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<tr>
<td>Overall Balance</td>
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<td>6208.8</td>
<td>-414.9</td>
<td>0</td>
<td>-414.9</td>
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### Wet Cooling and Zero Liquid Discharge

<table>
<thead>
<tr>
<th>Wet Cooling Water Use</th>
<th>Water Demand</th>
<th>Internal Recycle</th>
<th>Raw Water Withdrawal</th>
<th>Process Water Discharge</th>
<th>Raw Water Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gpm</td>
<td>gpm</td>
<td>gpm</td>
<td>gpm</td>
<td>gpm</td>
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<tr>
<td>Overall Balance</td>
<td>7975.5</td>
<td>6806.0</td>
<td>1169.5</td>
<td>0</td>
<td>1169.5</td>
</tr>
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</table>
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
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
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.
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

- 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
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 CO₂ capture
- Strategic interest in turning coal into a zero emission fuel source
- Ability to hedge risk across commodities
- Focus on low-carbon infrastructure