The $^{8}RH_2$ Process for Producing Clean Hydrogen with Autothermal Reforming and Carbon Capture

7b – Advanced CCUS Systems from Autothermal Methane Reforming Plants

DOE NETL Conference Presentation

September 1, 2023

8 RIVERS

Project Objectives

The 8RH2 Process for Producing Clean Hydrogen with Autothermal Reforming and Carbon Capture

Project Information	
Prime Performer: 8 Rivers Capital, LLC	**Location:** Durham, NC
Project Duration: 02/07/2022 - 12/31/2023	**Agreement Number:** FE0032127
Technology Area: Pre-Combustion Capture	**Total Award Value:** $1,802,863
Key Technology: Novel Concepts	**DOE Share:** $1,412,863
	Performer Share: $390,000

- This project aims to conduct a Pre-Front-End Engineering Design (Pre-FEED) study for a new build 8 Rivers Hydrogen (8RH2) plant

- 8RH2 is an autothermal reforming carbon capture technology which will be designed to produce 100 MMSCFD of clean hydrogen with 90-99% carbon capture for sequestration at the brownfield Painter Gas Complex in Evanston Wyoming. The hydrogen (H_2) product with 99.97% purity will be exported to western demand centers as hydrogen or as up to 440,000 MT of ammonia.

- The project when built would capture and store ≈600,000 MT of CO_2 per year in Class 6 wells.

Proposed Brownfield Site for Clean Hydrogen Production in Evanston, WY

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- The proposed effort will deliver a sufficiently detailed engineering package to deliver an AACE Class III estimate for the CO_2 capture process and an AACE Class IV estimate for the Balance of Plant, producing a levelized cost of hydrogen for three cases.

- Three 8RH2 designs will be advanced in the project, a base 8RH2 ATR case, an ATR with heat exchanging reforming, and then an ATR with heat exchanging reforming and an oxy fired heater. This will provide greater understanding of the characteristics and costs as CO_2 capture rises from 90%-99%.

- Project Partners:
  - 8 Rivers
  - Technip Energies
  - Northshore Energy
  - Wyoming Energy Authority
  - US DOE NETL

Proposed Brownfield Site for Clean Hydrogen Production in Evanston, WY

8 Rivers' Technology Portfolio

8 Rivers has a pipeline of energy transition technologies under development and a business model that supports continuous innovation.

NETPOWER

8 RIVERS ENERGY

8RH2

Calcite

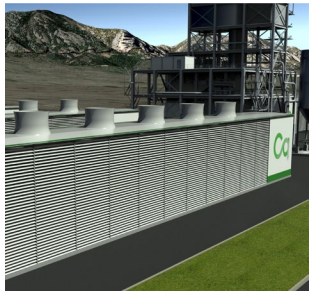
TarT

KC8

Zero-Emissions Power from Gas

Zero-Emissions Power from Solid Fuels

Zero-Emissions Hydrogen and Ammonia



Direct Air Capture of CO_2 (DAC)

H_2S Sour Gas to Sweet Gas

Post-Combustion Capture of CO_2

Technip Energies at a glance

TE
Euronext Paris listing ticker
ADRs for US investors

Headquarters in Paris
Registered in
The Netherlands

60+
Years of operations

€6.7B
Full year 2021 adjusted revenue

A leading Project, Engineering & Technology company for the Energy Transition

€16.4B
Backlog at end 2021
Order intake €9.8B

~15,000
Employees in 34 countries

25+
Leading proprietary technologies

450 projects
under execution

Leader in hydrogen, syngas, CC

Ready for the hydrogen wave

270+ H_2 plants & reformer	5 to 220 MMSCFD H_2 plants	20+ H_2 plants 120 to 220 MMSCFD	3B SCFD & 40+ plants for Air Products since 1992
24+ H_2 plants with pre-reformer	9+ H_2 plants with parallel reformer	1st Polybed PSA unit in a H_2 plant	50+ CO_2 Capture plants

- CUSTOMIZED SOLUTIONS
- SINGLE-SOURCE RESPONSIBILITY
- STATE-OF-THE-ART DESIGNS
- EXTENSIVE REFERENCE BASE

T.EN TECHNIP ENERGIES

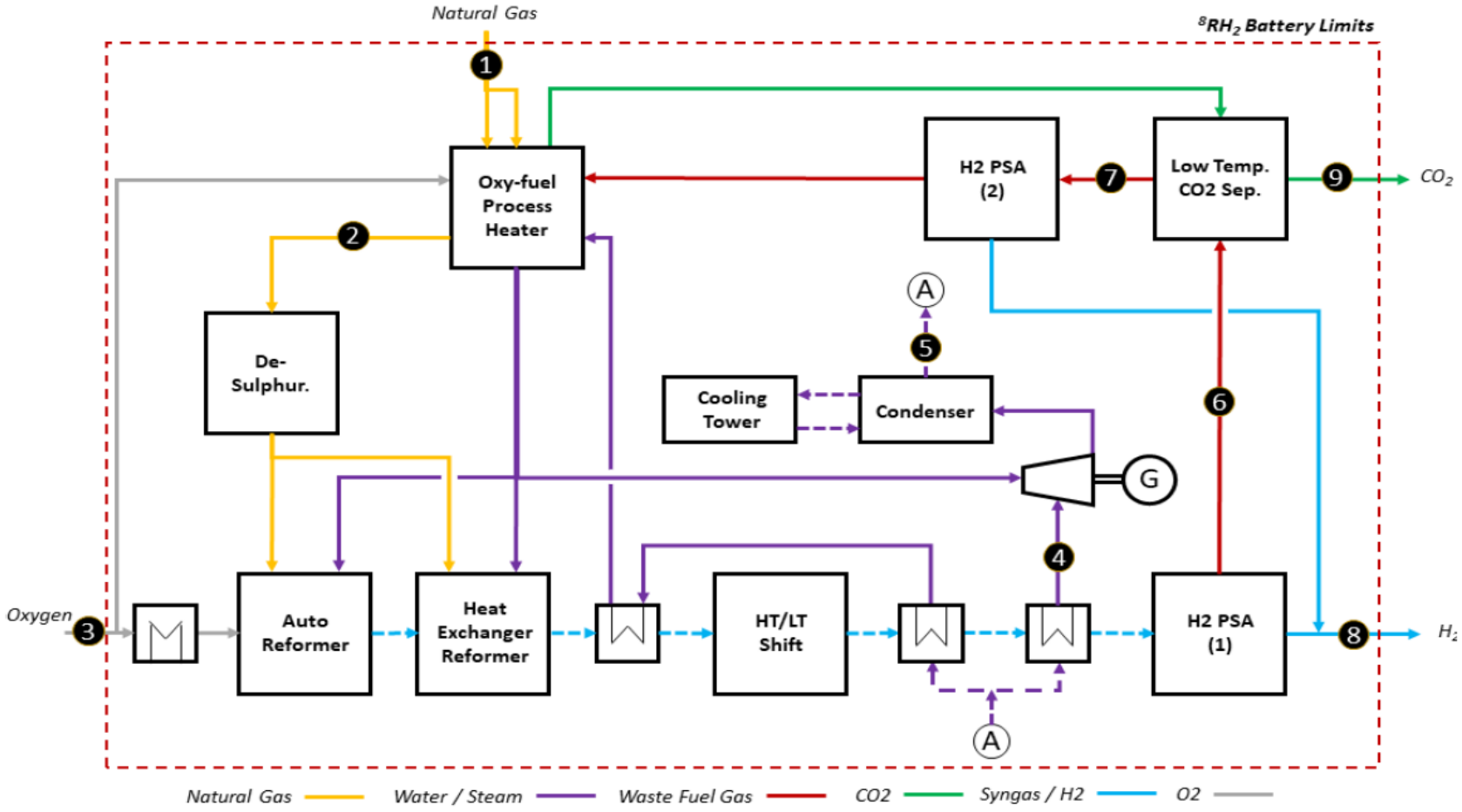
Three Cases Evaluated in Pre-FEED

High nitrogen content in Wyoming natural gas decreased capture rate in cases 1 and 2, and increased oxygen consumption in case 3

Comparison 8 Rivers H_2 Production with Cryogenic Co_2 Capture			
Case	**1**	**2**	**3**
Technology	**ATR / Air-Fired**	**ATR+HXR / Air-Fired**	**ATR+HXR Oxy-Fired**
H_2 Production, MMSCFD	100	100	100
Thermal Efficiency, HHV	81%	88%	85%
CO_2 Capture Efficiency	87%	85%	99%
O_2 Consumption kg/kg-H_2	3.44	2.55	3.91

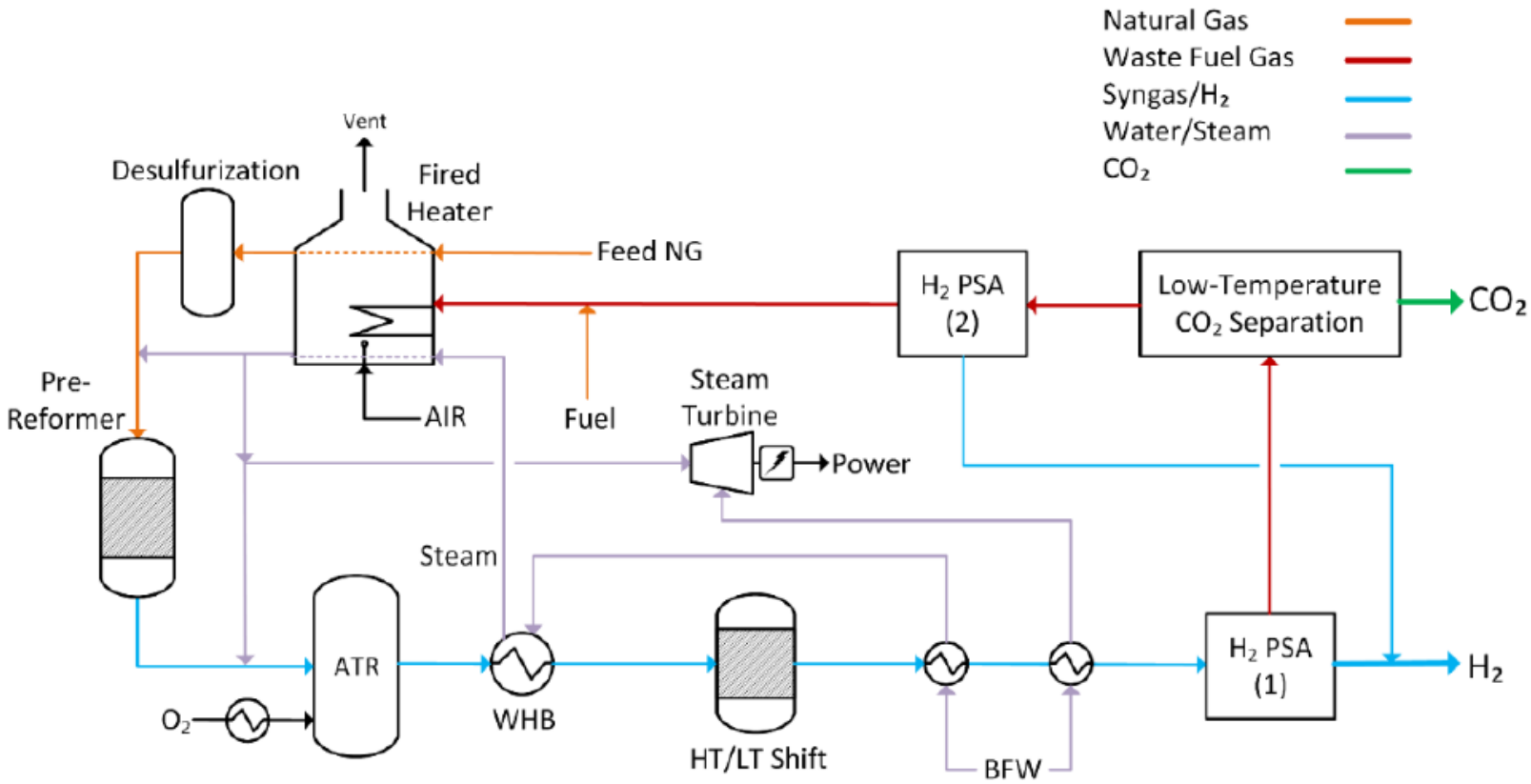
Technical Approach: 8RH2 Process Flow Diagram, Case 3

Autothermal Reformer and Heat Exchanger Reformer, Oxy-Fired



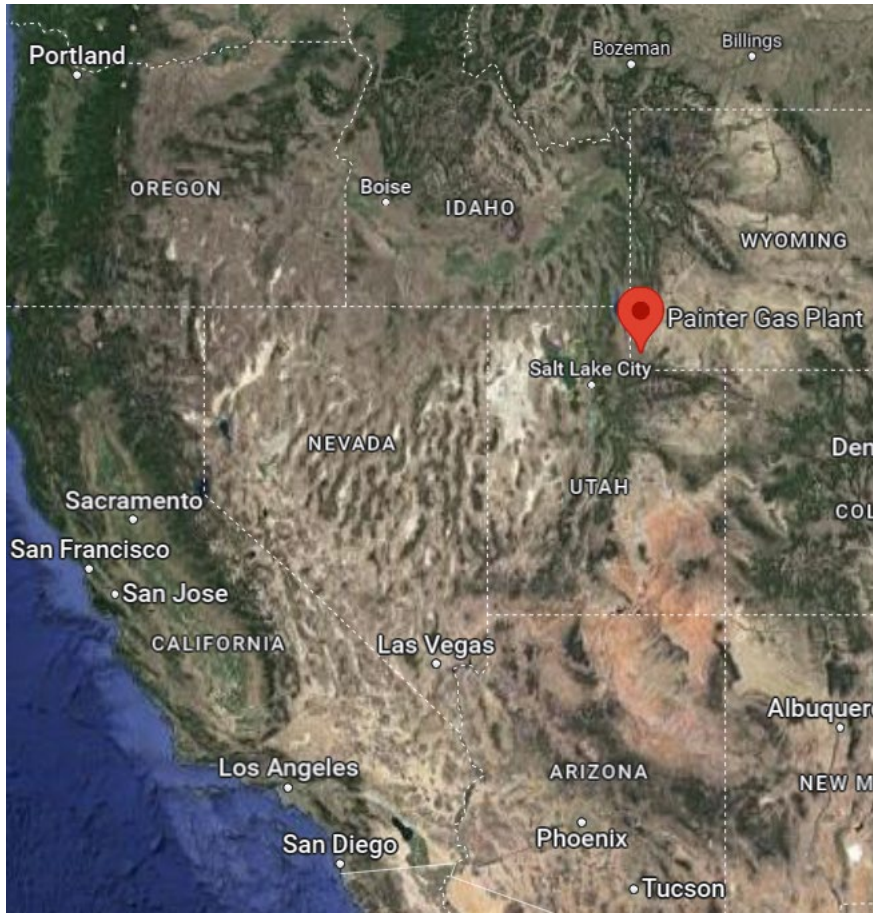
Technical Approach: 8RH2 Process Flow Diagram, Case 1

Autothermal Reformer, Air Fired

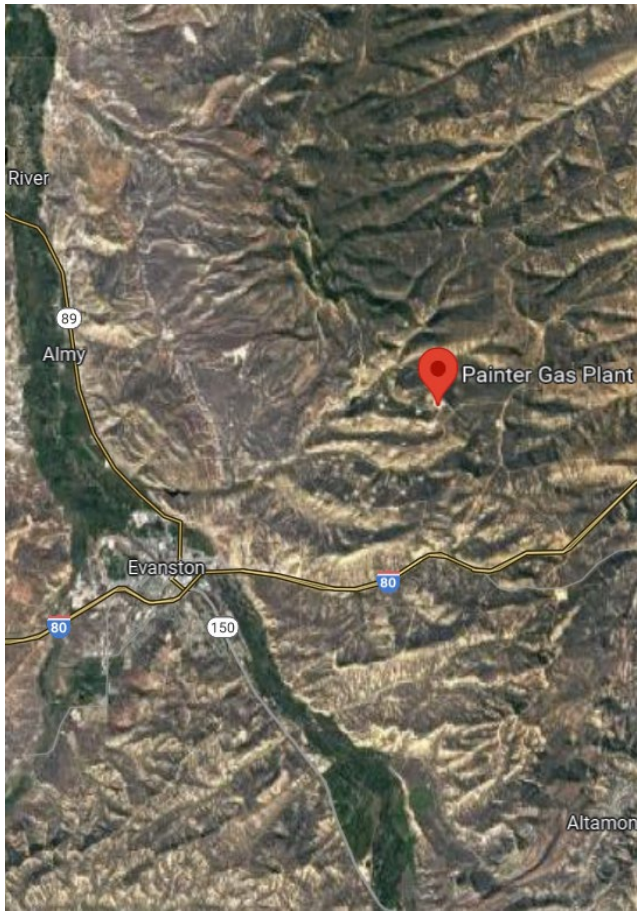


Northshore Energy Project Site

Site To Coast



Site to Town



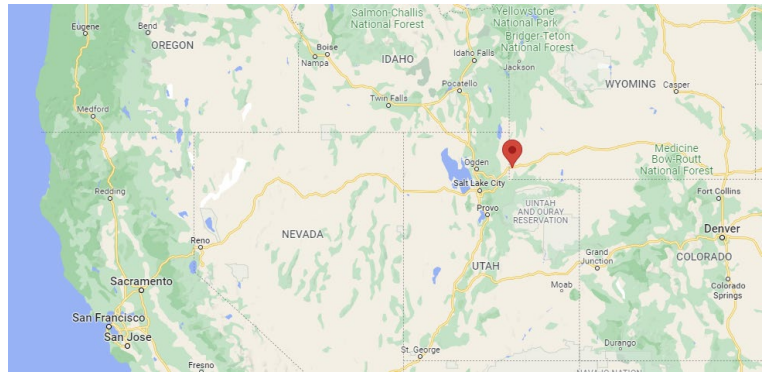
Brownfield Site

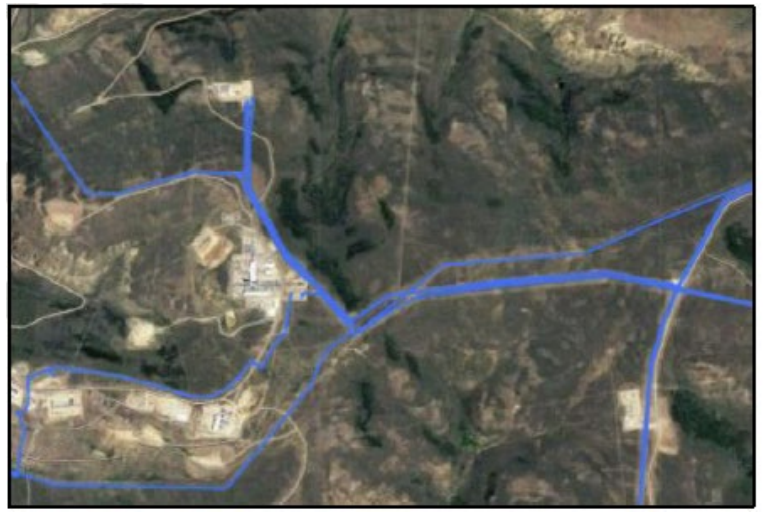
Northshore Energy Project Site

Key Features

- Proximity to western markets
- Rail / trucking access
- CO_2 Sequestration and Wyoming Class 6 Primacy
- Power infrastructure
- Gas supply

Evanston, Wyoming Site





Gas Pipelines

Regional Hydrogen Demand

Exploring pathways for H_2 transport and utilization

1. **Ammonia and Derivatives**
2. **Gaseous Hydrogen**
3. **Liquid Hydrogen**

Regional Hydrogen Demand

Exploring pathways for H_2 transport and utilization

1. Ammonia Pathway

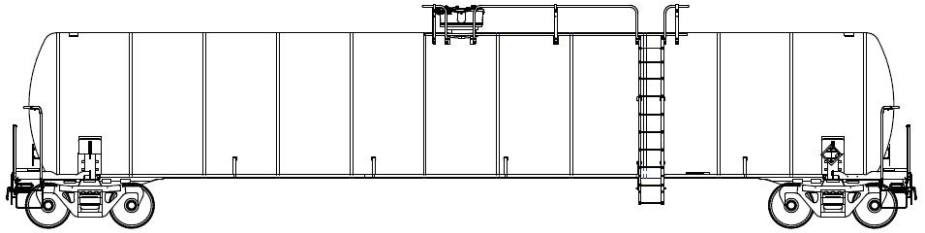
Transport

- Rail
  - Requires ammonia storage for loading/unloading.
- Trucking
  - Can serve regional market
- Pipeline Conversion

Upgrade Products

- Utilize as ammonia for fertilizer or industry
- Ammonia derivatives
- Need to balance product production to regional market supply and demand mix

Ammonia Rail Transport



https://www.gbrx.com/railcars/34300-gallon-anhydrous-ammonia-pressure-tank-car/

Ammonia Truck Transport

https://commons.wikimedia.org/wiki/File:Hazmatspotting_UN_1005,_%22Ammonia,_anhydrous%22.jpg

Regional Hydrogen Demand

Exploring pathways for H_2 transport and utilization

2. Gaseous Hydrogen Pathway

- Trucking via Compressed Tube Trailers
  - Traditional steel tubes: 380kg/trailer
  - New composite tubes: 560-900kg/trailer
- Limited radius of transport
- Pipeline blending

Compressed H_2 Truck Transport

https://www.energy.gov/eere/fuelcells/hydrogen-tube-trailers

Regional Hydrogen Demand

Exploring pathways for H_2 transport and utilization

3. Liquid Hydrogen Pathway

- Trucking via Liquid H_2 Trailers
  - 4,500 kg per truck load vs 8,000 kg per rail
  - Trucking is required to reach filling stations
- Liquefaction capital cost far exceeds hydrogen production cost
- Serving California heavy duty transport market
- Challenge in offtake contract duration

Liquid H_2 Facilities

https://www.energy.gov/eere/fuelcells/liquid-hydrogen-delivery

Liquid H_2 Truck Transport

https://www.energy.gov/eere/fuelcells/liquid-hydrogen-delivery

Upcoming Project Milestones

#	Milestone	Planned Completion Date	Verification Method
1	Kick-off meeting	May 2022	Kick-off meeting attended and completed
2	Basis of Design completed	Jan 2023	Submittal of the document judged sufficient to start technical work on H&MB and PFD
3	PFD and H&MB completed	July 2023	Meeting to review each unit operation in the flowsheet. Technical work progressed sufficiently to support techno-economic comparison between cases.
4	Plot Plan produced based on layout studies	July 2023	Meetings to review equipment arrangement and layout confirm layout studies and optimizations have generated suitable plot plan
5	3D Model and P&IDs submitted	Q4 2023	Meeting to review confirms 3D model suitability for design/operability/constructability reviews
6	Emissions and Waste Streams Analysis	Q4 2023	Submission of Environmental Impact Report with required elements including air/water emissions, solid wastes, toxicological effects, and regulatory implications
7	Cost Estimate for equipment and consumables complete	Q4 2023	Submittal of the Cost Estimate and Estimate Basis which allows for eventual Class III/IV capital cost accuracy level
8	Techno-Economic Analysis generates Levelized Cost of Hydrogen Production	Q4 2023	Submission of Techno-Economic Report with Levelized Cost of Hydrogen Production which meets the list of required elements from FOA Appendix S.1
9	Full Pre-FEED + TEA Report	Q4 2023	Submission of Final Non-Public Report receives DOE Approval

Project Tasks, Statement of Project Objectives

B. Scope of Work:

The Recipient will conduct a Pre-FEED engineering, and levelized cost evaluation to deliver the Hydrogen and Plant at the Painter Gas Complex Site in Wyoming.

Task 1.0 Project Management and Planning

Task 2.0 - Initial Engineering

The initial engineering is broken down into 10 sub tasks to allow for easy evaluation of project progress. The Recipient will develop a process flow diagram (PFD), piping and instrument diagrams (P&ID's), a 3D model, a plot plan, and a heat and mass balance (H&MB) based on host sight integration data.

Task 3.0 - Techno-Economic Analysis (TEA)

The techno-economic analysis to be completed in Task 3.0 will contain several sub tasks and will conclude with the $/tonne CO2 capture and a levelized cost of production (LCOP) of hydrogen.

Task 4.0 - Environmental Health & Safety (EH&S)

Once the processes are fully defined through completion of Task 2-3 the environmental health and safety assessment will take place to ensure waste streams including air and water as well as toxicological effects and hazards of emission and waste streams are mitigated.

IRA Tax Credits Summary

45Q

- 12-year tax credit pay schedule
- Carbon capture and sequestration tax credit
- Based on volume CO_2 sequestered from a point source or through DAC
- Construction must begin by 2033
- Direct pay for 5 years (12 if non-profit), transferability option

Pathway	Credit Value ($/mt CO2)
Point Source w/ geologic sequestration	$85
Point Source w/ utilization or EOR	$60
DAC w/ geologic sequestration	$180
DAC w/ utilization or EOR	$130

45V

- 10-year tax credit pay schedule
- Clean hydrogen production tax credit (PTC)
- Based on process carbon intensity (CI) as calculated by the GREET model
- Construction must begin by 2033
- Direct pay for 5 years (10 if non-profit), transferability option

Carbon Intensity (kg CO_2e/kg H_2)	Credit Value ($/mt H_2)
0-0.45	$3.00
0.45-1.5	$1.00
1.5-2.5	$0.75
2.5-4.0	$0.60

Relevance, Outcomes, and Impact

- Accelerate project development and utilize Pre-FEED to complete a FEED at the same site
- Aim to finance and construct an 8RH2 plant in Wyoming to be operational within 5 years.
- Advance the 8RH2 design significantly, potentially accelerating the timeline for commissioning, enabling follow-on projects to reach commence construction before 45Q expiration.
- Create re-usable 8RH2 design with 99% CO_2 capture. Success of the project will create a repeatable project template for deployment in Wyoming and across the country to decarbonize industry.
- The deployment in Evanston will showcase a sustainable vision for the Wyoming economy where hydrocarbon resources are exported as clean hydrogen with the CO_2 stored in state.
- Provide best-in-class capital and operating cost data for CO_2 capture from autothermal reforming and for cryogenic CO_2 capture systems with up to 99% CO_2 capture and higher thermal efficiency.
- The Pre-FEED will be used by 8 Rivers in developing an export approach for hydrogen that demonstrates viable hydrogen transportation business model applicable to all H_2 projects.
- Project deployment will store 639k MT of CO_2 per year and 19 MMT of CO_2 over 30 years, and provide clean H_2 for fertilizers in the region and/or for transportation fuels and the refining industry.

8 RIVERS