The $^8\text{RH}_2$ Process for Producing Clean Hydrogen with Autothermal Reforming and Carbon Capture
Project Objectives

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

- 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 (H₂) 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 CO₂ per year in Class 6 wells.
Project Objectives

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

- The proposed effort will deliver a sufficiently detailed engineering package to deliver an AACE Class III estimate for the CO₂ 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 CO₂ capture rises from 90%-99%.

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

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

- Zero-Emissions Power from Gas
- Zero-Emissions Power from Solid Fuels
- Zero-Emissions Hydrogen and Ammonia
- Direct Air Capture of CO₂ (DAC)
- H₂S Sour Gas to Sweet Gas
- Post-Combustion Capture of CO₂
Technip Energies at a glance

TE
Euronext Paris listing ticker
ADRs for US investors

€6.7B
Full year 2021 adjusted revenue

~15,000
Employees in 34 countries

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

Headquarters in Paris
Registered in The Netherlands

60+
Years of operations

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

25+
Leading proprietary technologies

450 projects
under execution
Leader in hydrogen, syngas, CC
Ready for the hydrogen wave

<table>
<thead>
<tr>
<th>270+</th>
<th>5 to 220 MMSCFD</th>
<th>20+</th>
<th>3B SCFD &amp; 40+ plants for Air Products since 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂ plants &amp; reformer</td>
<td>H₂ plants</td>
<td>H₂ plants</td>
<td>H₂ plants 120 to 220 MMSCFD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>24+</th>
<th>9+</th>
<th>1st</th>
<th>50+</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂ plants with pre-reformer</td>
<td>H₂ plants with parallel reformer</td>
<td>Polybed PSA unit in a H₂ plant</td>
<td>CO₂ Capture plants</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Comparison 8 Rivers H₂ Production with Cryogenic CO₂ Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
</tr>
<tr>
<td>Technology</td>
</tr>
<tr>
<td>H₂ Production, MMSCFD</td>
</tr>
<tr>
<td>Thermal Efficiency, HHV</td>
</tr>
<tr>
<td>CO₂ Capture Efficiency</td>
</tr>
<tr>
<td>O₂ Consumption kg/kg-H₂</td>
</tr>
</tbody>
</table>
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
Northshore Energy Project Site

**Key Features**

- Proximity to western markets
- Rail / trucking access
- CO₂ 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 H₂ 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
Regional Hydrogen Demand

Exploring pathways for H₂ 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 H₂ Truck Transport

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

Exploring pathways for H₂ transport and utilization

3. Liquid Hydrogen Pathway

- Trucking via Liquid H₂ 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

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

https://www.energy.gov/eere/fuelcells/liquid-hydrogen-delivery
## Upcoming Project Milestones

<table>
<thead>
<tr>
<th>#</th>
<th>Milestone</th>
<th>Planned Completion Date</th>
<th>Verification Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kick-off meeting</td>
<td>May 2022</td>
<td>Kick-off meeting attended and completed</td>
</tr>
<tr>
<td>2</td>
<td>Basis of Design completed</td>
<td>Jan 2023</td>
<td>Submittal of the document judged sufficient to start technical work on H&amp;MB and PFD</td>
</tr>
<tr>
<td>3</td>
<td>PFD and H&amp;MB completed</td>
<td>July 2023</td>
<td>Meeting to review each unit operation in the flowsheet. Technical work progressed sufficiently to support techno-economic comparison between cases.</td>
</tr>
<tr>
<td>4</td>
<td>Plot Plan produced based on layout studies</td>
<td>July 2023</td>
<td>Meetings to review equipment arrangement and layout confirm layout studies and optimizations have generated suitable plot plan</td>
</tr>
<tr>
<td>5</td>
<td>3D Model and P&amp;IDs submitted</td>
<td>Q4 2023</td>
<td>Meeting to review confirms 3D model suitability for design/operability/constructability reviews</td>
</tr>
<tr>
<td>6</td>
<td>Emissions and Waste Streams Analysis</td>
<td>Q4 2023</td>
<td>Submission of Environmental Impact Report with required elements including air/water emissions, solid wastes, toxicological effects, and regulatory implications</td>
</tr>
<tr>
<td>7</td>
<td>Cost Estimate for equipment and consumables complete</td>
<td>Q4 2023</td>
<td>Submittal of the Cost Estimate and Estimate Basis which allows for eventual Class III/IV capital cost accuracy level</td>
</tr>
<tr>
<td>8</td>
<td>Techno-Economic Analysis generates Levelized Cost of Hydrogen Production</td>
<td>Q4 2023</td>
<td>Submission of Techno-Economic Report with Levelized Cost of Hydrogen Production which meets the list of required elements from FOA Appendix S.1</td>
</tr>
<tr>
<td>9</td>
<td>Full Pre-FEED + TEA Report</td>
<td>Q4 2023</td>
<td>Submission of Final Non-Public Report receives DOE Approval</td>
</tr>
</tbody>
</table>
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 CO₂ sequestered from a point source or through DAC
- Construction must begin by 2033
- Direct pay for 5 years (12 if non-profit), transferability option

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

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Credit Value ($/mt CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point Source w/ geologic sequestration</td>
<td>$85</td>
</tr>
<tr>
<td>Point Source w/ utilization or EOR</td>
<td>$60</td>
</tr>
<tr>
<td>DAC w/ geologic sequestration</td>
<td>$180</td>
</tr>
<tr>
<td>DAC w/ utilization or EOR</td>
<td>$130</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carbon Intensity (kg CO₂e/kg H₂)</th>
<th>Credit Value ($/mt H₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.45</td>
<td>$3.00</td>
</tr>
<tr>
<td>0.45-1.5</td>
<td>$1.00</td>
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<tr>
<td>1.5-2.5</td>
<td>$0.75</td>
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<tr>
<td>2.5-4.0</td>
<td>$0.60</td>
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</tbody>
</table>
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% CO₂ 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 CO₂ stored in state.
- Provide best-in-class capital and operating cost data for CO₂ capture from autothermal reforming and for cryogenic CO₂ capture systems with up to 99% CO₂ 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 H₂ projects.
- Project deployment will store 639k MT of CO₂ per year and 19 MMT of CO₂ over 30 years, and provide clean H₂ for fertilizers in the region and/or for transportation fuels and the refining industry.