U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

Enabling the Hydrogen Value Chain Using Natural Gas Resources and Infrastructure (FWP-1022467 (2, 5, 7, 8))

Research & Innovation Center

NATIONAL ENERGY TECHNOLOGY LABORATORY

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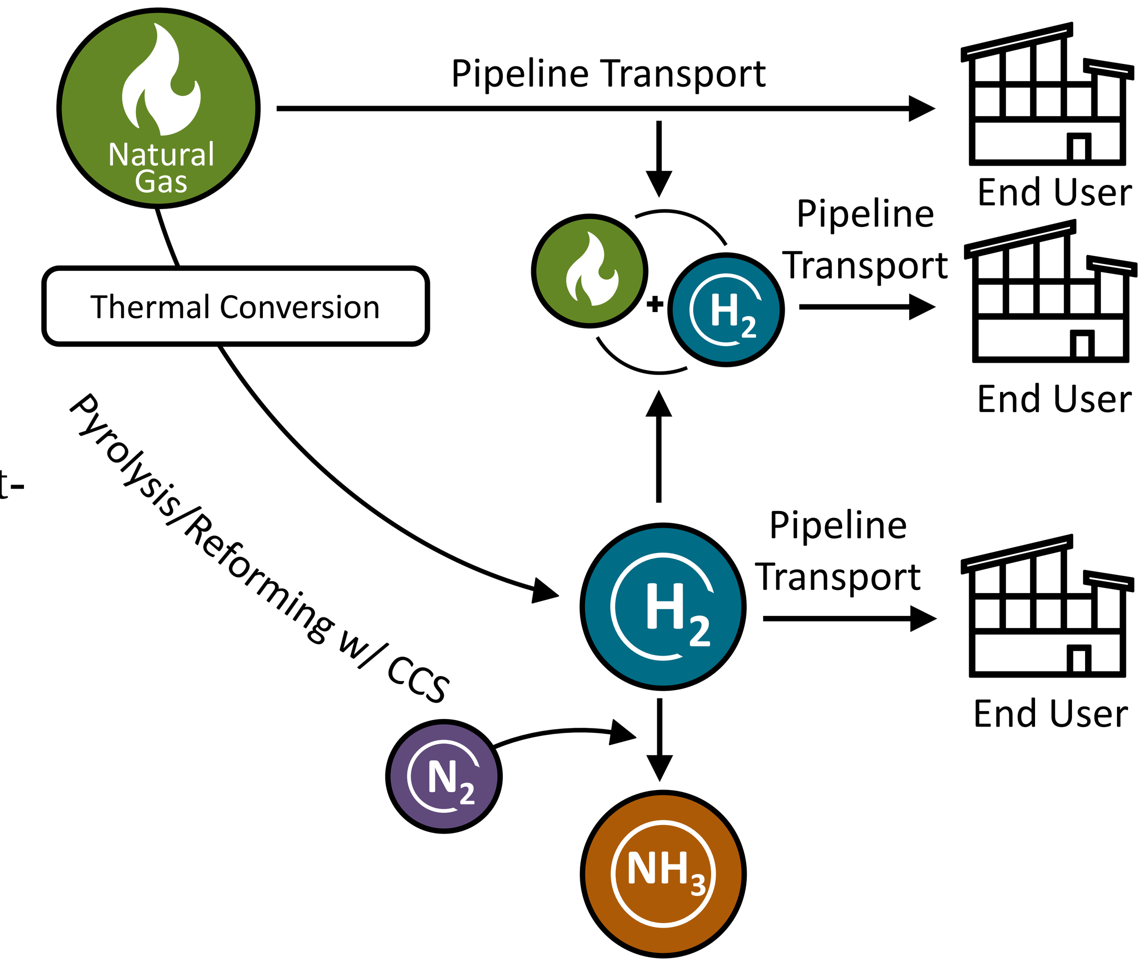
PROGRAM OVERVIEW

The Fossil Energy and Carbon Management (FECM) Natural Gas Decarbonization and Hydrogen Technologies Program supports technical solutions for:

1) Transformative production of clean hydrogen from natural gas.
2) Leveraging the existing natural gas pipeline infrastructure as a cost-effective near-term solution to enable decarbonization through hydrogen and blended gas transport.
3) Modeling and producing sustainable chemicals and fuels, such as ammonia, from natural gas resources.



Production of H_2 and Valuable Carbons with Novel NETL Pyrolysis Catalyst

Task Goals: 1) Develop a thermo-catalytic H_2 production process that is more economical than steam methane reforming by producing a valuable carbon co-product with no CO_2 emissions.
2) Understand current and potential global markets for different types of carbon products.

Approach: Develop patented Iron (Fe)-based pyrolysis catalyst beyond bench scale.

- Optimize catalyst composition and reaction parameters at larger scales (5 kg of catalyst).
- Generate reactivity data for process economic and lifecycle assessments.
- Evaluate carbon purification, processing, and separation procedures.

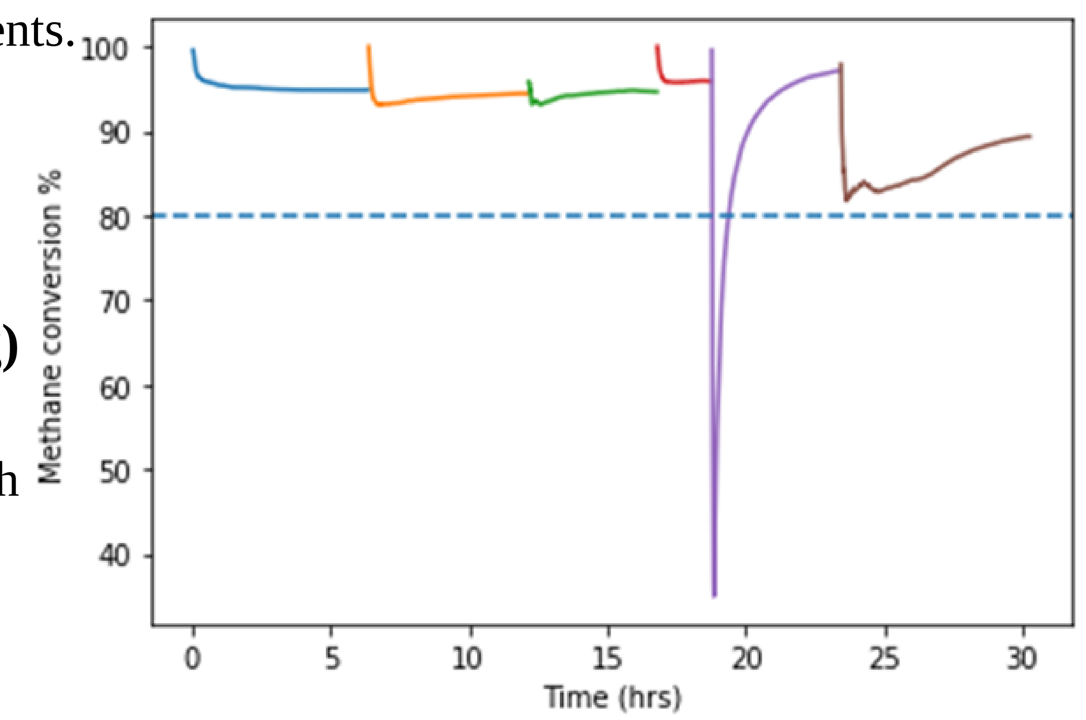
Key Accomplishments:

Catalyst Performance:

- **The team demonstrated scaling the catalyst 10 times (4.5 kg) compared to previous testing (500 g).**
- Initial scoping tests showed catalyst to be robust for over 40h producing CH_4 conversions to H_2 >80%

Carbon Product Analysis and Separation:

- Using surfactants to separate mixtures of the carbon allotropes produced from methane pyrolysis.
- Achieved carbon allotrope separation by selecting the right surfactant for dispersing one type of carbon.



Demonstration of methane conversion to H_2 at 700 C In scaled fluidized bed reactor (4.5 kg catalyst)

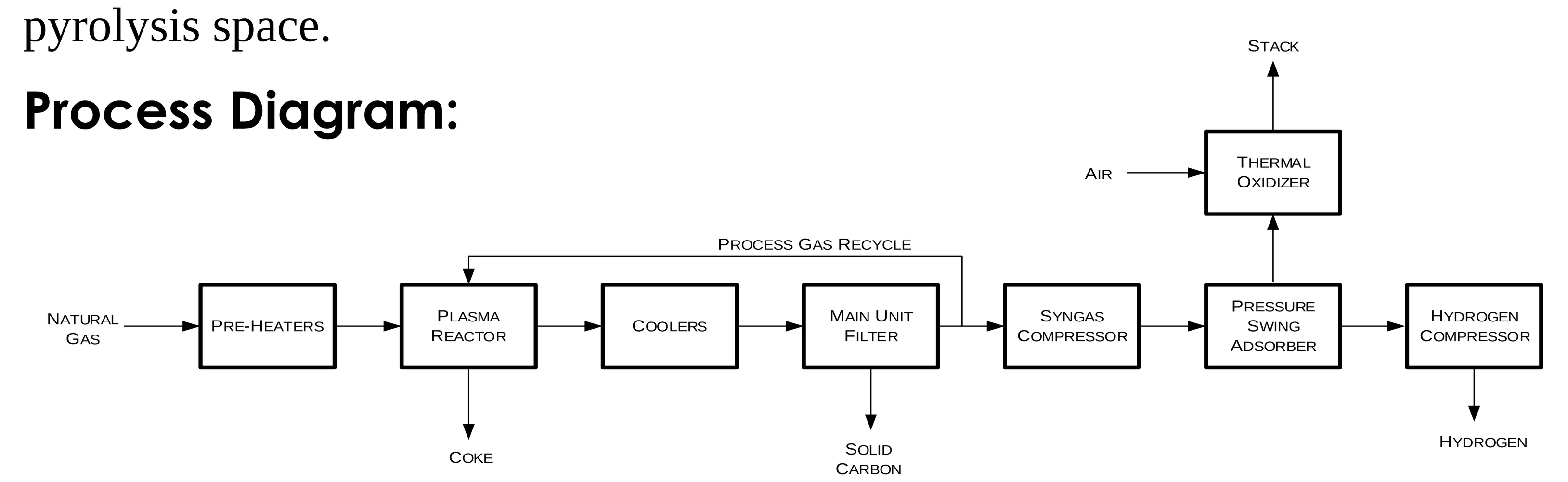
Next Steps: Demonstrate a reduction of H_2 cost through improved system performance and selectivity to valuable carbons.

METHANE PYROLYSIS

Task Goal: To provide a techno-economic analysis and life cycle assessment of different pyrolysis technologies for industrial clean hydrogen production. The project evaluates natural gas pyrolysis technologies including catalytic and plasma, and it identifies system-level challenges that affect cost and emissions to inform R&D priorities. Key study metrics include the levelized cost of hydrogen ($/kg H_2) and global warming potential (kg CO_2e/kg H_2).

Key Accomplishments: A literature review has been conducted on thermal, catalytic, and plasma pyrolysis technologies. A process diagram and design basis for a plasma pyrolysis concept has been developed. A preliminary thermodynamic model and life cycle assessment has been developed and results have been reviewed by leaders in the pyrolysis space.

Process Diagram:



Design Basis:

Pyrolysis Type	By-Products
TRL 8-9 Plasma	Carbon ($254/tonne) Coke ($47/tonne) Steam ($0/tonne)
H_2 Plant Capacity	**H_2 Product**
58,000 tonne/yr @ 85% CF (Vendor Commercial Plant)	Pipeline Ready (99.9 vol% purity, 925 psig)

Next Steps: Conduct economic evaluation to determine the capital and operating costs of the plasma system. The solid carbon by-product is considered salable as a carbon black feedstock and provides revenue to the plant. Finally, sensitivity studies will analyze how parameters such as capacity factor, sales prices, and financial factors impact the levelized cost of hydrogen. The study will be summarized in a technical publication for public release.

FOSSIL-BASED AMMONIA PRODUCTION

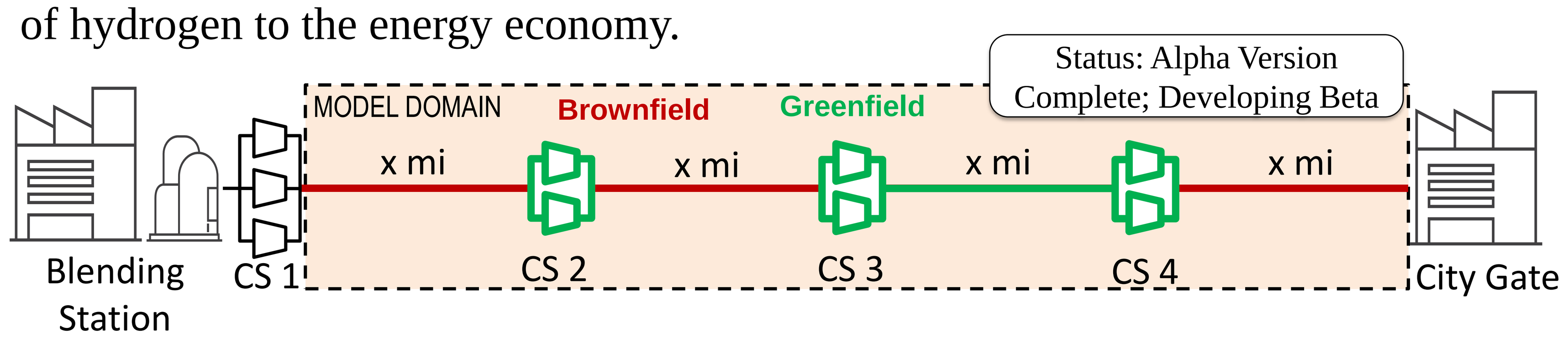
Task Goal: To provide baseline cost and performance estimates for current, industrial, fossil-based ammonia production technologies, including a determination of life cycle greenhouse gas emissions. The project focuses on ammonia produced from natural gas resources and informs decision makers of priority research areas. A key study metric includes the levelized cost of ammonia ($/kg NH_3).

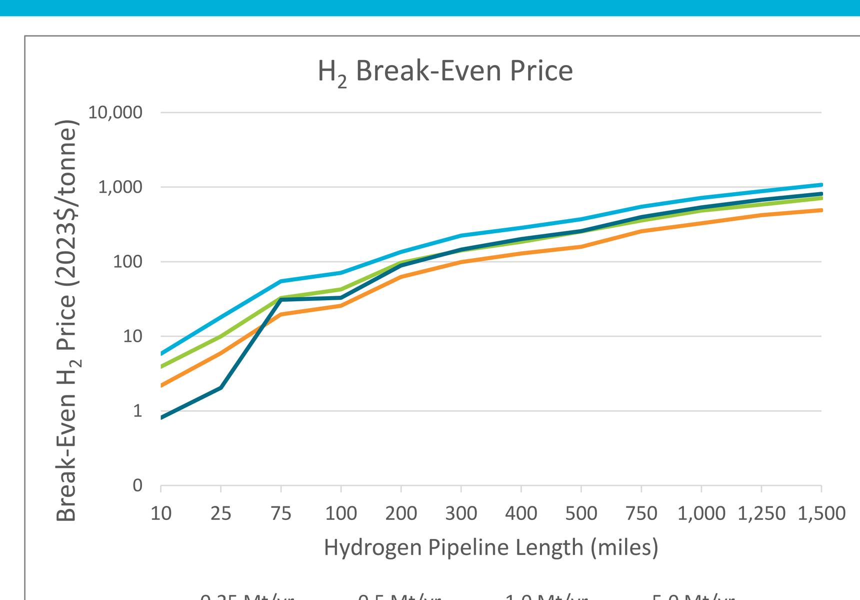
Key Accomplishments: A literature review has been conducted on current commercial ammonia plants. Three study cases have been selected and process diagrams have been created. A design basis has been developed that defines key study assumptions, such as plant capacity, technologies, and product purity.

Next Steps: Performance models and life cycle assessments will be developed for each study case. Next, an economic evaluation will be conducted to determine capital and operating costs. Finally, sensitivity studies will analyze how parameters such as capacity factor, natural gas price, and electricity price impact the levelized cost of ammonia. The study will be summarized in a technical publication for public release.

H_2 and NG with H_2 PIPELINE TRANSPORT COST MODELS

Task Goal: The H2_P_COM and NG-H2_P_COM models estimate the costs of building new pure hydrogen pipelines or reusing existing natural gas pipelines for transporting natural gas-hydrogen blends to facilitate the addition of hydrogen to the energy economy.





Key accomplishments:

- H2_P_COM and its users manual have been posted to the NETL website:
  Model: Energy Analysis | netl.doe.gov
  User's Manual: Energy Analysis | netl.doe.gov
- H2_P_COM results
  - For a fixed pipeline length, the greater the mass flow rate of hydrogen the lower the cost per tonne-mile
  - For a fixed mass flow rate, as the pipeline length increases, the cost per tonne-mile is relatively constant
- NG-H2_P_COM is undergoing internal review and will be finalized in spring/summer 2024

Both Models:

- Output cashflows; net present value (NPV) of project
- Determine break-even price of H_2 in $/tonne H_2 (i.e., H_2 price where NPV is $0)