Systems Analysis Perspectives of Methane Pyrolysis, Fossil-Based Ammonia Production, and H_2 and NG/H_2 Transport (FWP-1022467 (5, 7, 8))

Alana Sheriff[1,2], Shannon McNaul[1,2], Dale Keairns[1,2], Mark Woods[1,2], Travis Warner[1,2], Eric Lewis[1], Robert Stevens[1], and David Morgan[1]

[1]National Energy Technology Laboratory (NETL), Pittsburgh, PA; [2]NETL Support Contractor, Pittsburgh, PA 15236, USA

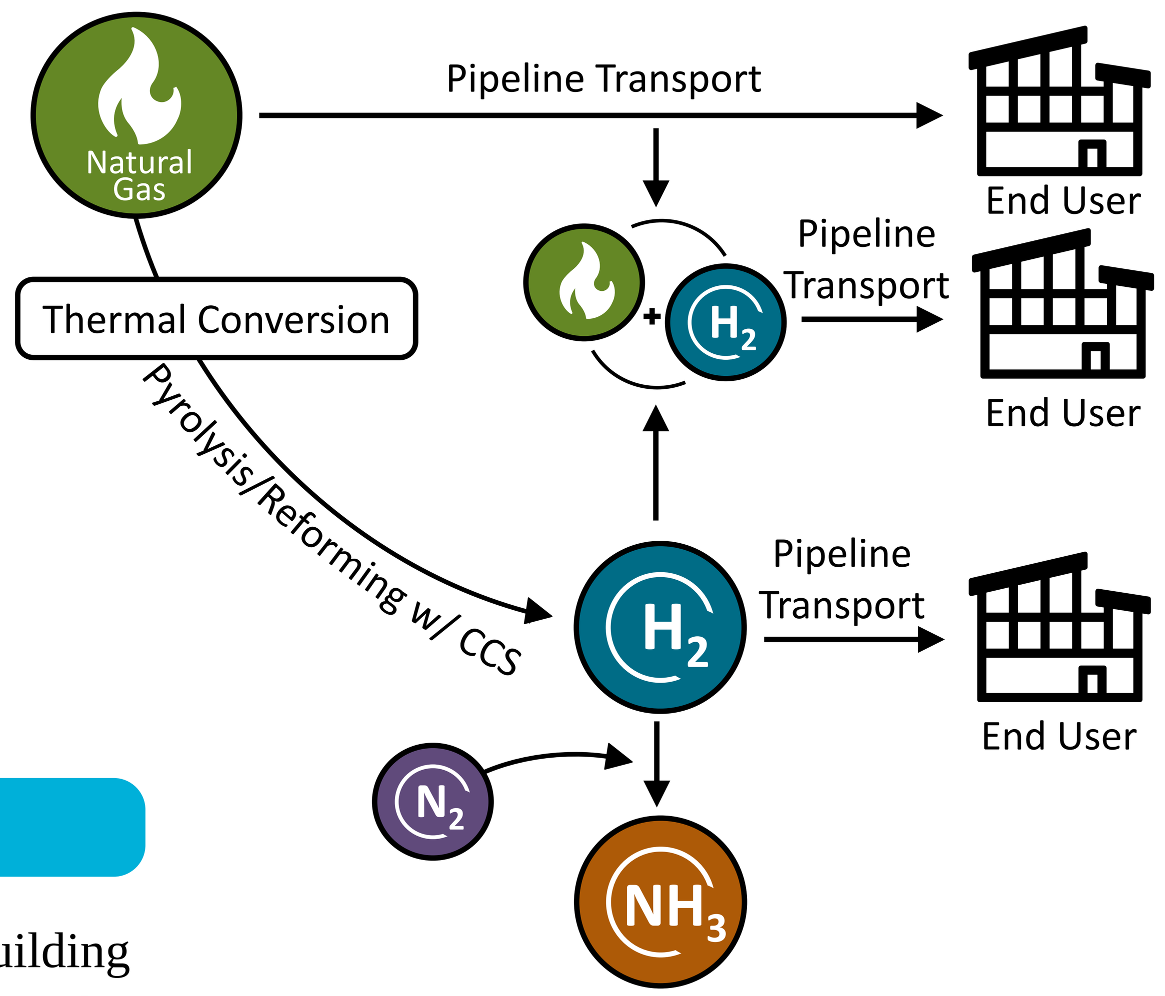
Research & Innovation Center

NATIONAL ENERGY TECHNOLOGY LABORATORY

PROGRAM OVERVIEW

The program supports the development of technical solutions to:

1) Produce economical and low-carbon hydrogen from natural gas
2) Develop advanced hydrogen sensing technologies for the existing natural gas pipelines and new infrastructure to be used to transport hydrogen safely at a large scale
3) Produce sustainable chemicals and fuels, such as ammonia, from natural gas resources

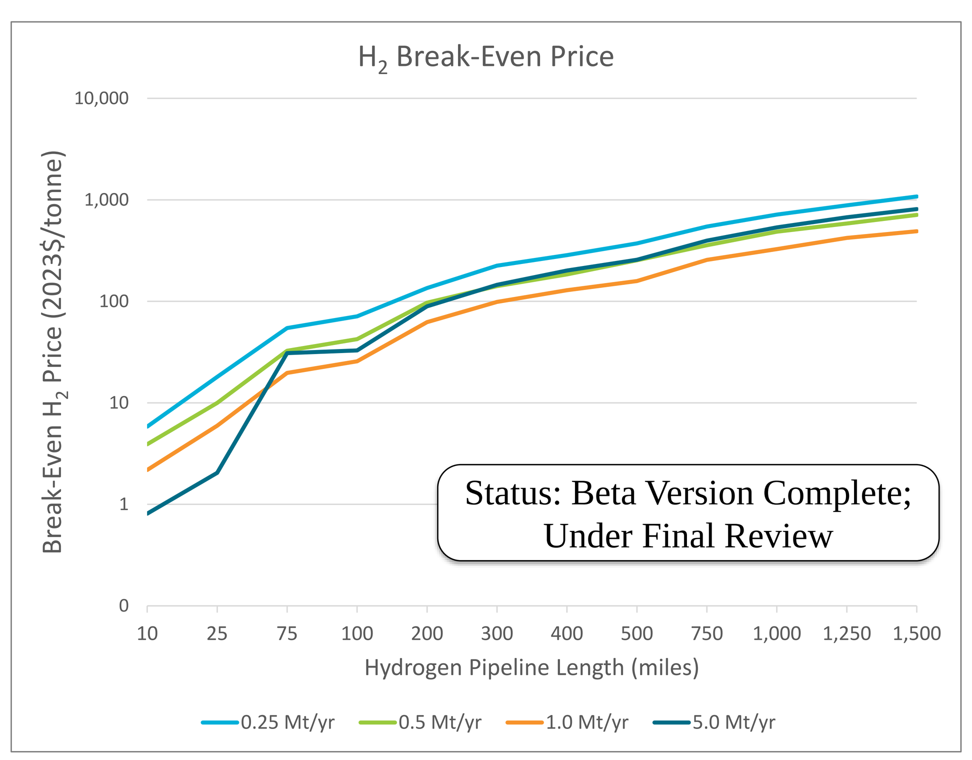


H_2 and NG with H_2 PIPELINE TRANSPORT COST MODELS

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.

FECM/NETL Hydrogen Pipeline Cost Model (H2_P_COM)

The H2_P_COM is an Excel based techno-economic model that estimates the cost of transporting pure gaseous H_2 by a newly built point-to-point pipeline based on the hydrogen mass flow rate, pipeline length, and number of compressor stations.

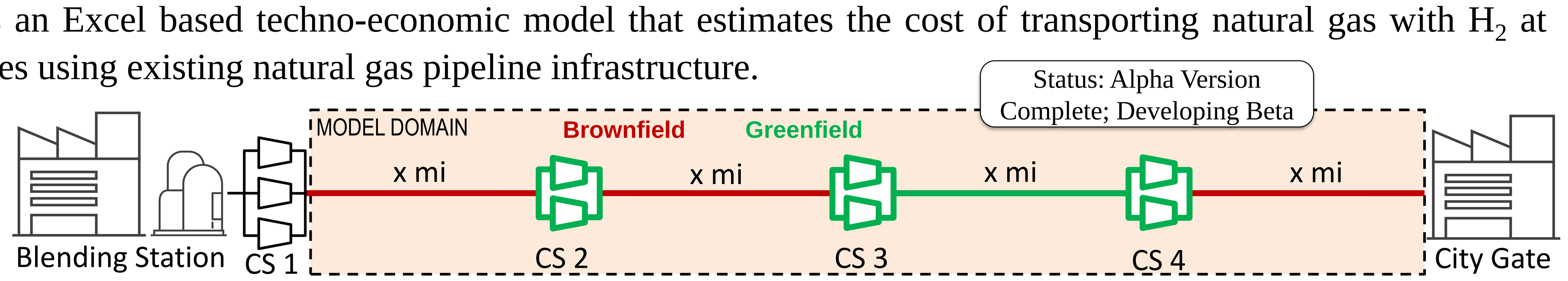


Preliminary Results:

- A single-source (0.25 – 1 Mt/yr) benefits from economies of scale with H_2 break-even price decreasing for each pipeline length given an increase in transport capacity.
- A trunkline transporting H_2 from multiple industrial sources (5 Mt/yr) benefits from economies of scale when pipeline length is less than 25 miles. At 5 Mt/yr, distances over 25 miles require significantly more compressor stations to maintain the operating pressure.
- Costs increase significantly with increased pipeline length – The first-year break-even price for a 100-mile dedicated pipeline transporting 0.25 million tonnes (Mt) per year is $71.16/t ($0.071/kg) compared to $715.61/t ($0.72/kg) for a 1,000-mile pipeline.

FECM/NETL Natural Gas with Hydrogen Pipeline Cost Model (NG-H2_P_COM)

The NG-H2_P_COM is an Excel based techno-economic model that estimates the cost of transporting natural gas with H_2 at varying blend percentages using existing natural gas pipeline infrastructure.



Both Models:

- Output cashflows; NPV of project
- Determine first-year break-even price of H_2 ($/tonne H_2) when NPV is near $0

User Inputs:

- Existing (brownfield) NG pipeline specs: dimensions (length; diameter); flow rate; elevation change
- Percentage of existing NG pipeline that will need to be replaced (e.g., 25%)
- Existing compressor station count
- Existing NG composition; % H_2 to be blended into NG
- Financial parameters; project phase durations

Model:

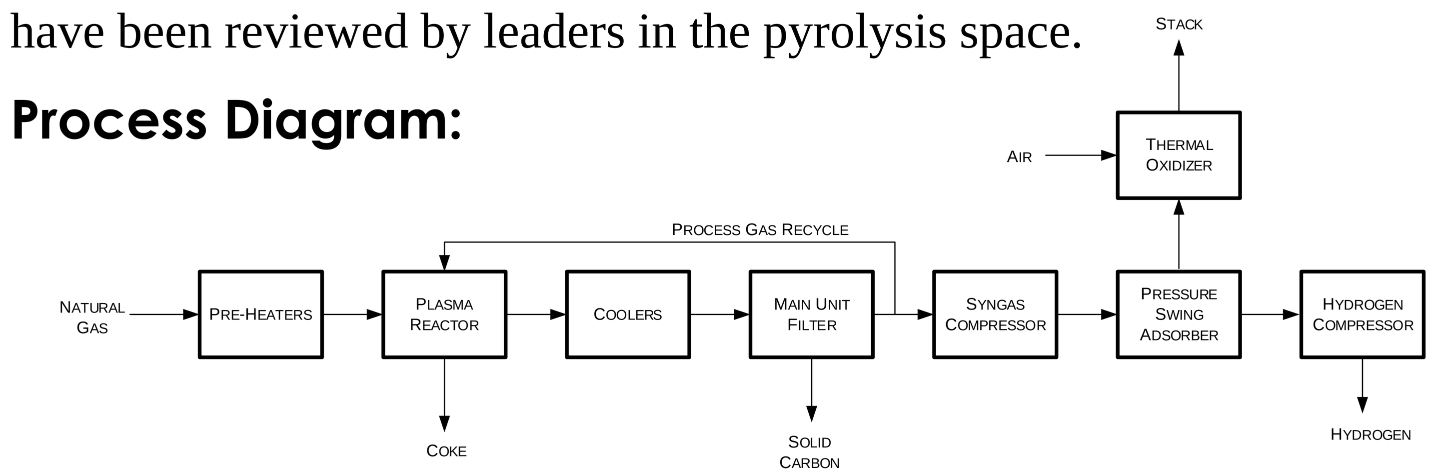
- Calculates NG-H_2 blend EoS; volumetric flow rate converted to Mt/yr and MMBtu/yr based on existing pipeline size
- Estimates CAPEX of replacing user input % of pipeline
- Estimates CAPEX of replacement compressors sized for 100% H_2 future potential (OPEX at user's input blend)

METHANE PYROLYSIS

Task Goal: To provide a techno-economic analysis and life cycle assessment of different pyrolysis technologies for industrial 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).

Work Completed to Date: 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: An economic evaluation will be conducted 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 note 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 ($/tonne NH_3).

Work Completed to Date: 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.

Design Basis:

Case	Reformer Type	Nitrogen Source	CO_2 Capture System	H_2 Purification	NH_3 Plant Capacity	NH_3 Grade	NH_3 Storage
1	SMR	Air	n/a	Pre-Combustion CO_2 Capture + Methanation	820,000 tonne/year @ 90% CF (Single-Train SMR Maximum)	C-grade (99.5% purity)	Atmospheric Insulated Cylindrical Tank (18.0 psia, -33 °C)
2		Air	Pre-Combustion (99%) and Post-Combustion (97%) CO_2 Capture	Methanation			
3	ATR	Air Separation Unit	Pre-Combustion (99%) CO_2 Capture	PSA	1,300,000 tonne/year @ 90% CF (Vendor Single-Train ATR)		

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 report for public release.