

Gasification of Coal and Biomass: The Route to Net-Negative-Carbon Power and Hydrogen

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FY23 FECM Spring R&D Project Review Mtg

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Overall Project Objectives

- Meet the goals of DOE's 21st Century Power Plant Initiative by gasifying a mixture of PRB coal and biomass to yield a syngas, which can have CO₂ removed and then be used to produce hydrogen as well as an off-gas that can be used to flexibly produce power
- Concept would be carbon net-negative and readily meet the DOE targets of smaller scale MW generation, high ramp rates and turndown, feedstock flexibility, high efficiency
- Cost of hydrogen ~\$2-3/kg-H₂, with reasonable plant cost

Funding: \$11,742,350 (\$9,393,880 gov't, \$2,348,470 cost share)

Technical Objectives

- Perform a front-end engineering design (FEED) study on an oxygen-blown gasification system coupled with water-gas shift, pre-combustion CO₂ capture, and pressure-swing adsorption process using a coal/biomass mix to yield high-purity hydrogen and a fuel off-gas that can generate power
- Evaluate capability of producing ~50 MW net from a flexible generator with 8,500 kg/hr of hydrogen, achieve net-negative CO₂ emissions, and an overall efficiency of ~50% net HHV
- Finalize host site selection, and gasifier type (GTI fluid bed, HMI moving bed)
- Update gasifier designs for corn stover as primary biomass (locally available), to be mixed with domestic coal (and waste plastics), and to support flexibility for other types of fuels



Project Team

Project Team Organizations

Electric Power Research Institute (EPRI)

- Prime, lead organization, overall project management and administration (Task 1)
- Leading Investment Case (Task 3, 7), Host Site Selection (Task 5)

Bechtel

- Engineering, Procurement and Construction (contractor)
- Lead on the FEED Study (Task 6)

NexantECA

- Technology analysis, screening and selection (contractor)
- Lead Design Development (Task 2)

Project Team Organizations

GTI Energy (GTI)

- Gasification technology developer (subrecipient)
- Participate in Design Development (Task 2) and potentially FEED Study (Task 6)

Hamilton Mauer International (HMI)

- Gasification technology developer (contractor)
- Participate in Design Development (Task 2) and potentially FEED Study (Task 6)

Nebraska Public Power District (NPPD)

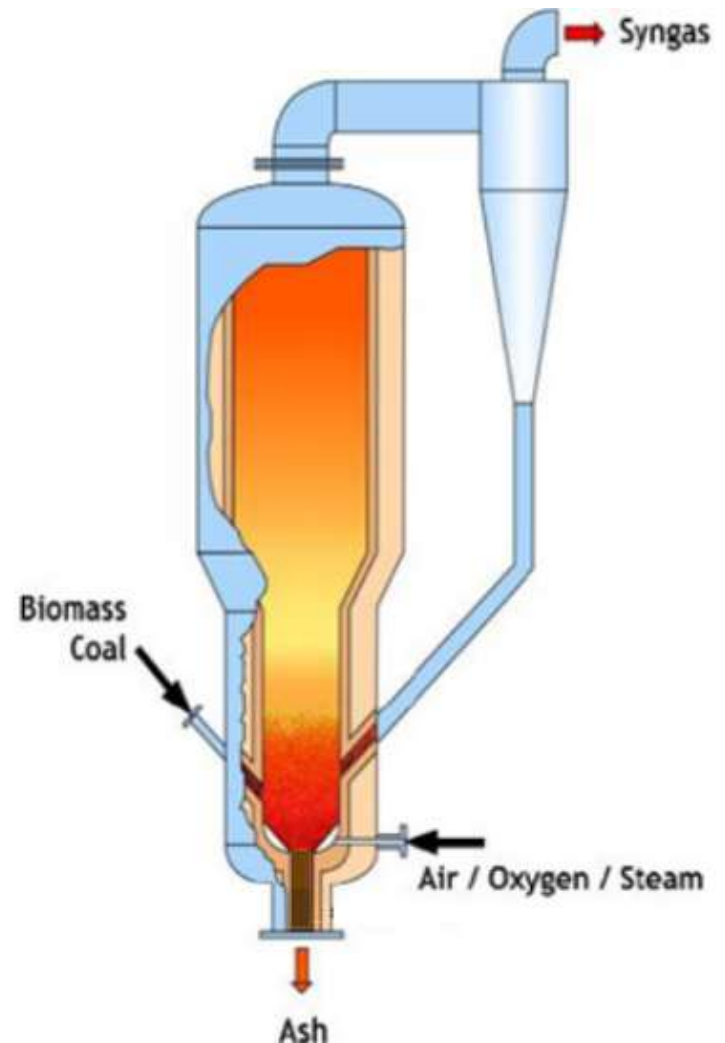
- Host site owner (subrecipient)
- Participate across all tasks



Background & Technical Approach

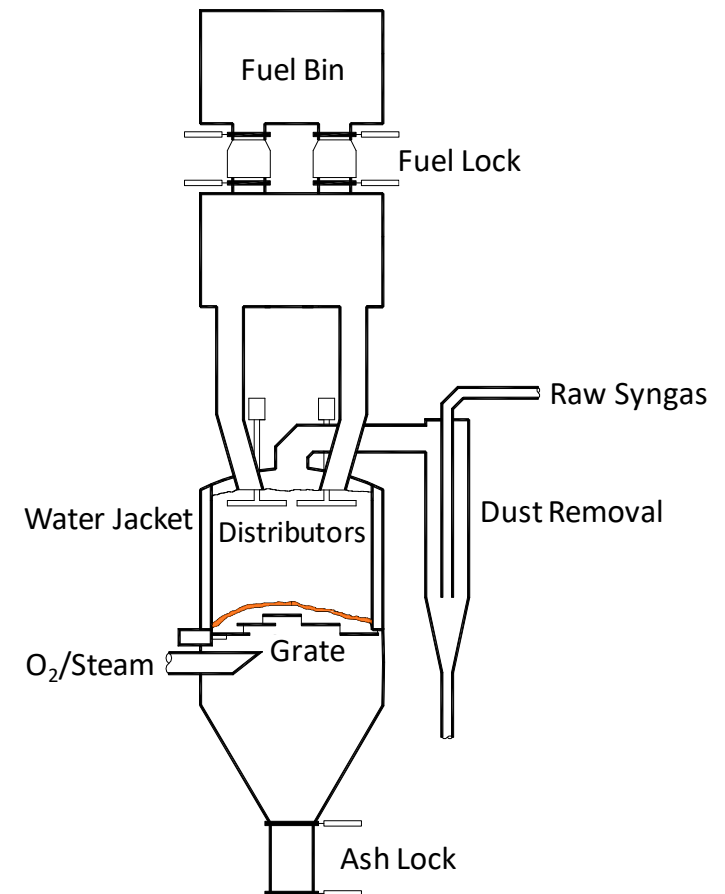
GTI U-GAS® Fluidized-Bed Gasifier

- Gasifier, based on a single-stage, bubbling, fluidized-bed technology to produce low-to-medium heating value syngas from an array of coal and biomass feedstocks
- Oxygen-blown system was chosen to reduce nitrogen in the syngas and make it easier to produce high-purity hydrogen
- Higher operating pressure of 450 psia selected
- Syngas is free of tars
- History of gasifying biomass at pilot and demonstration scale
- Corn stover gasification at lab and bench scale

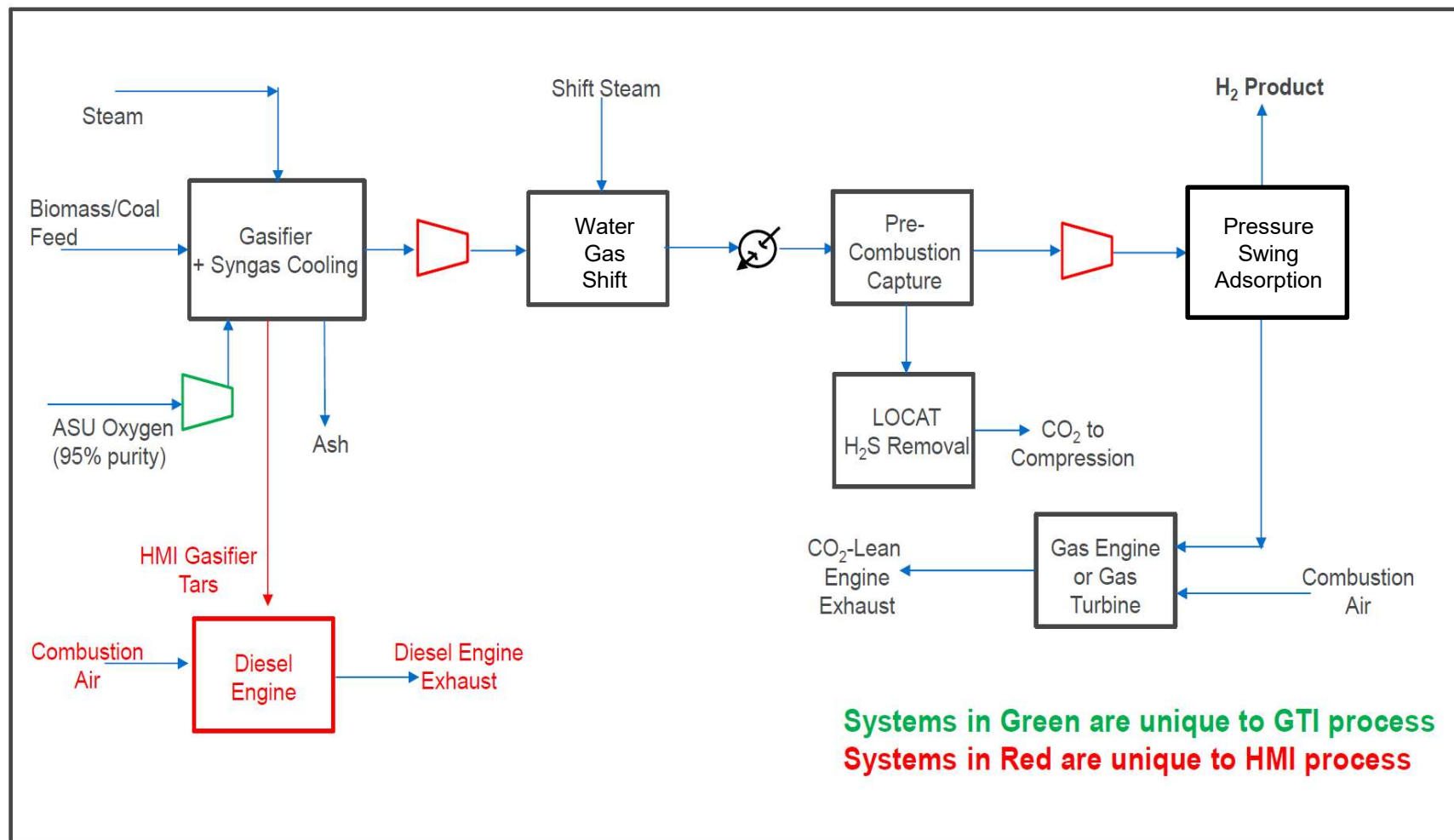


HMI Moving Bed Gasifier

- Moving-bed gasification has demonstrated gasifying many coal ranks as well as biomass. Testing suggests that it should be well suited for blends of coal, biomass, and plastic waste.
- As the fuel descends, it is dried, devolatilized, and the resulting char is gasified. Ash is removed through a grate and collected in a lock hopper.
- CO_2 produced by combustion and the steam from the blast react with the char in the gasification zone to produce CO and H_2
- Streams leaving are ash out the bottom and dry gas/tar/water vapor/dust out the top



Initial Block Flow Diagram (Proposed Configurations)





Project Tasks and Results

Statement of Project Objectives – Phase I Tasks

1. **Project Management and Planning:** Monitor and control of the project and project reporting and maintenance of the project management and technology maturation plans.
2. **Design Development:** Completion of design activities necessary to provide inputs for the FEED study. Multiple design cases will be assessed with the selection of the optimal one for the FEED.
3. **Investment Case Preparation:** Development of the draft investment case for the proposed process with business cases performed for the proposed host site and two other locations.
4. **Host Site Selection:** Evaluation of the two potential host sites within NPPD's portfolio to select the preferred candidate based on technical, economic, and environmental considerations.
5. **Environmental Information Volume (EIV) Development:** Completion of the EIV for the host site.

Statement of Project Objectives – Phase II Tasks

6. **FEED Study:** Completion of a FEED study based on the design selected in Phase I. A Greenhouse Gas (GHG) Life Cycle Analysis (LCA) will also be performed for the process.
7. **Update Investment Case:** Finalization of the investment case based on findings from the FEED.

Overall project schedule is ~36 months

Task 1 – Project Management and Planning

- Conducted kick-off meeting
- Updated Project Management Plan (PMP)
- Developed a Technology Maturation Plan (TMP)
- Prepared a Workforce Readiness Plan
- Conducted periodic meetings and submitted required financial and project reports

Technology Maturation Plan

- The proposed integrated gasification-hydrogen-production technology has advanced to TRL-6 (corn stover) using NETL's TRL guidelines
- This project will produce a detailed FEED study that will tee up a next-step commercial-scale demonstration project intended to advance the technology to TRL-8
- The scale of the proposed process is identical to the intended commercial scale
 - The next-step demonstration built off this FEED would advance the technology to commercial readiness, which could be accomplished by the 2027 timeframe
- Significant and timely funding from either public or private sources will be required to support the demonstration

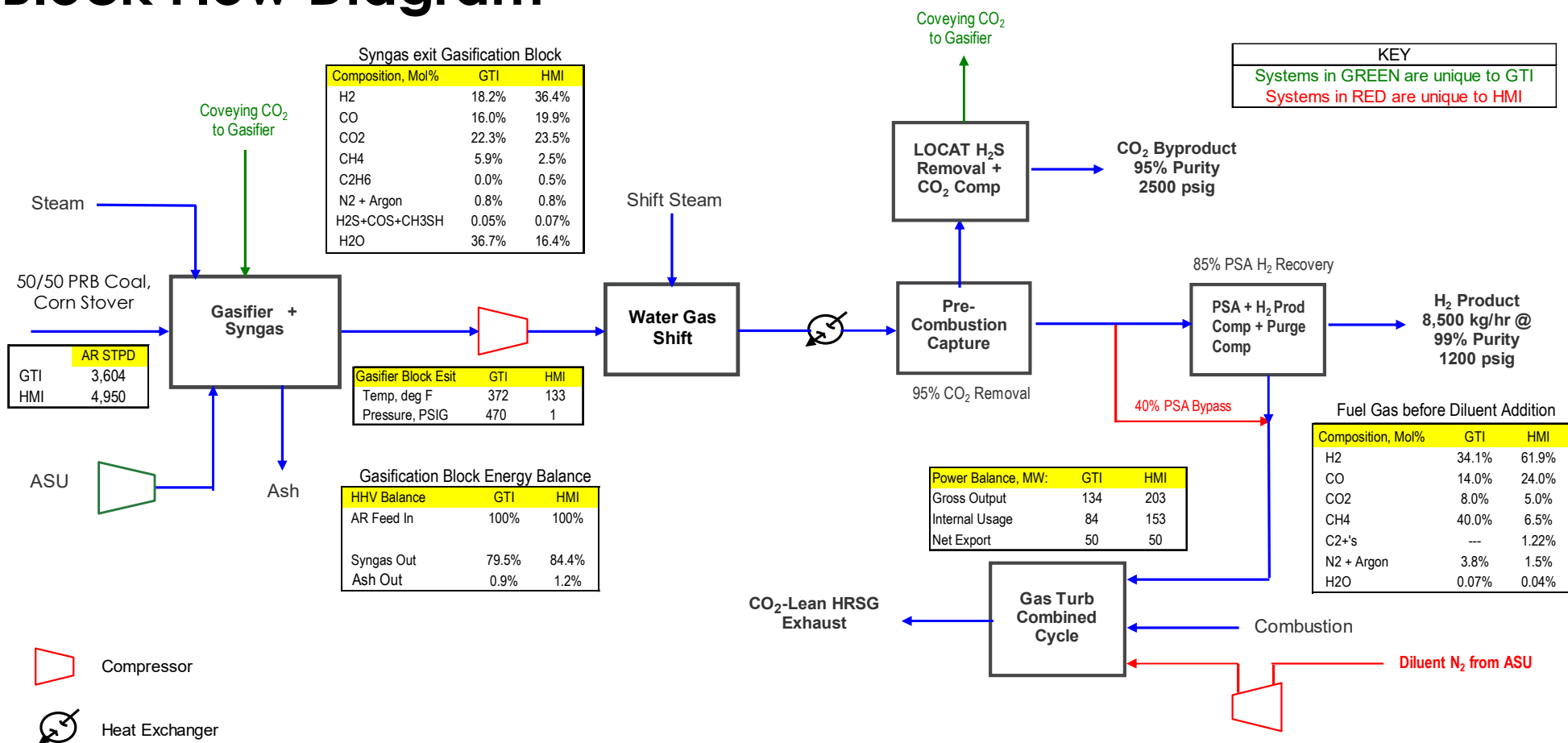
Workforce Readiness Plan

- Identified skillsets and training needed to support project
- Training plans exist
 - NPPD in-house training
 - Collaboration with Southeast Community College
- Identified Economically Distressed Communities
 - Evaluated 50-mile radius from proposed project location
 - City of Lincoln, Lancaster County, Nebraska (<20 miles)
 - 8 designated Opportunity Zones
 - Up to 55% of households living below the poverty line.
 - Nebraska City, Otoe County, Nebraska (<50 miles)
 - 9 Enterprise Zones - areas of “economic distress”

Task 2 – Design Development

- Developed design and costs basis for design development
- Prepared several design options for evaluation, and selected the preferred gasifier design to be used for the Phase II FEED study
- Completed process simulation, equipment sizing, and integration model development for each gasifier design option
- Optimized plant designs using process models
- Prepared the final design package to be used as the basis for the Phase II FEED study

Block Flow Diagram



Technical Comparison of Performance (PRB/ Stover)

	GTI Energy	HMI
<u>PRIMARY EXPORT PRODUCTS:</u>		
Net 99% (V%) Purity H ₂ Export, kg/hr.	8,500	8,500
Net Power Export, MWe	50	50
<u>Overall Thermal Efficiency, %HHV:</u>	48.7%	35.3%
<u>Excess Carbon Recovered, %</u>	25.5 %	10.4%
(above the CO ₂ in coal feed)		

Cost Comparison for Gasification Systems

Cost Item	GTI Energy Total x 1000	HMI Total X 1000	Delta (HMI-GTI Energy) x1000
Total Erected Project Cost *	\$878,605	\$1,406,131	\$526,135
Annual Operating Costs **	\$154,460	\$206,415	\$51,955

*For comparison purposes, contingency was not included in the CAPEX build-up

** Annual Operating Costs include fuel cost for 330-day operation

Gasifier Down Select Analysis Methodology

Selection Criteria	Weighting Factor
Capital Cost	40%
Operating Cost	20%
Commercial Gasification Experience	5%
Company Technical Strength	5%
Company Financial Strength	3%
Project Execution Capability	2%
Feedstock Flexibility	4%
Operational Flexibility	12%
Plant Operational Reliability	3%
Environmental	4%
Lifecycle Considerations	2%

Gasifier Down Selection Results

- Qualitative and quantitative ranking applied using methodology
- Rankings shared with all team members, including the gasification system suppliers (GTI Energy and HMI)
- GTI Energy U Gas[®] based plant configuration scored higher
 - Lower capital and operating costs (by far the most important criteria)
 - Greater commercial experience
 - Less complex gasifier
- GTI Energy U Gas[®] gasifier is selected for detailed FEED study in Phase II

Task 3 – Investment Case Preparation

- Completed the Investment Case Analysis for the preferred site-specific design option selected in Task 2
- Estimated the discounted cash flow for electricity, hydrogen and CO₂ capture
- Conducted the dispatch modeling and revenue analysis using the EPRI REGEN model
- Projected economics at other U.S. locations
 - Wyoming and Alabama

Task 4 – Host Site Selection

- Evaluated two potential host sites for engineering-scale prototype
- Performed site reconnaissance to assess suitability
- Reviewed need for host site permits
- Completed site evaluation using weighted decision matrix
- Obtained host site management approval for location at selected site and provided to DOE for review

Site Selection Methodology

- The 21st Century Power Plant would be located at an existing NPPD power plant
- Based on site selection criteria, Sheldon Station has been selected for the project site

Major Selection Category	Category Weight	Sheldon Station Scoring	Gerald Gentlemen Station Scoring
Site Development	25%	12.50	12.50
Site Economics	40%	15.20	11.20
Permitting	10%	4.20	4.20
Environmental	10%	4.40	4.60
Business and Finance	10%	3.80	3.80
Operation	5%	1.75	1.60
Total	100%	41.85	37.90

NPPD Candidate Host Sites

Gerald Gentleman Station
Sutherland, Nebraska

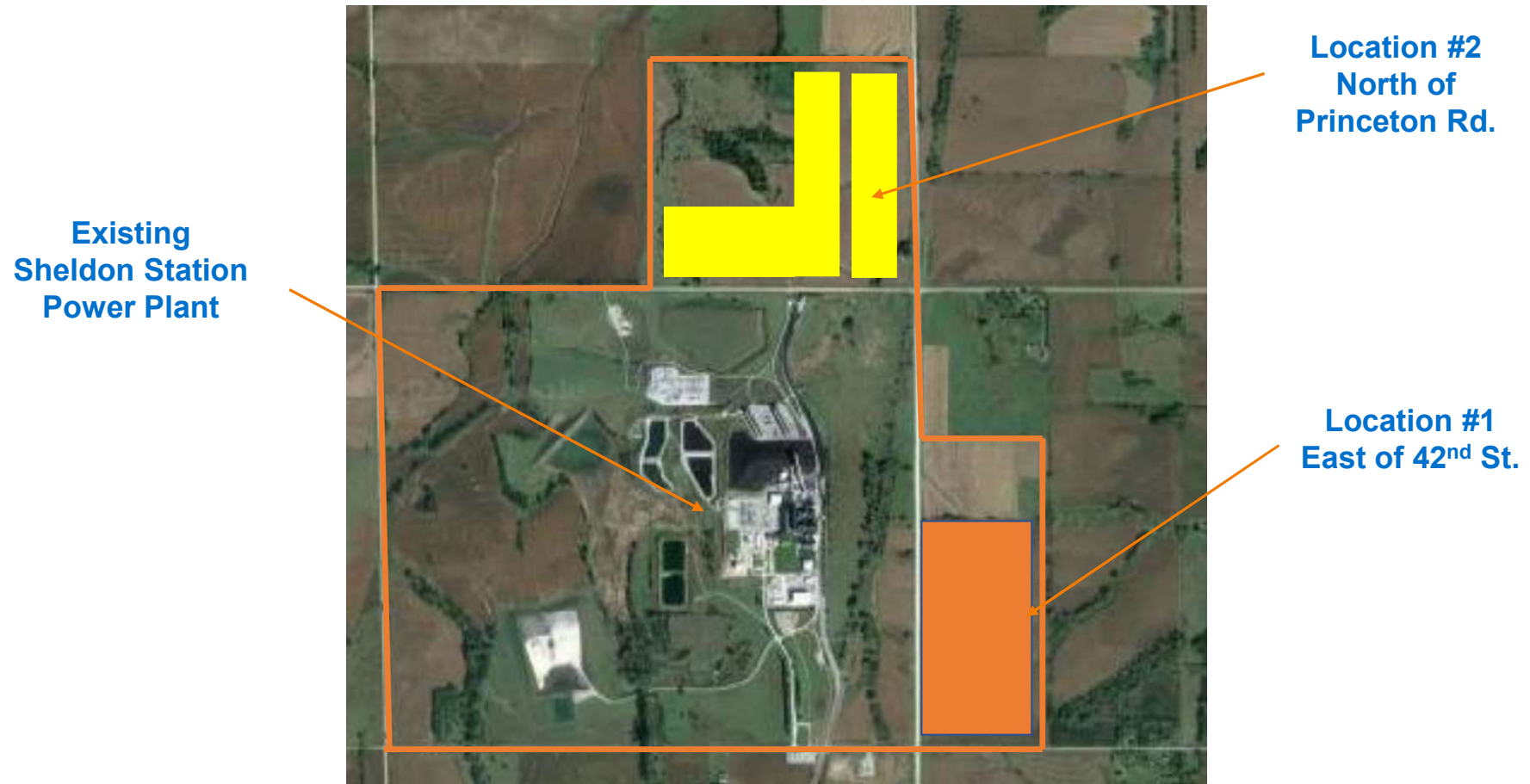


Sheldon Station
Hallam, Nebraska

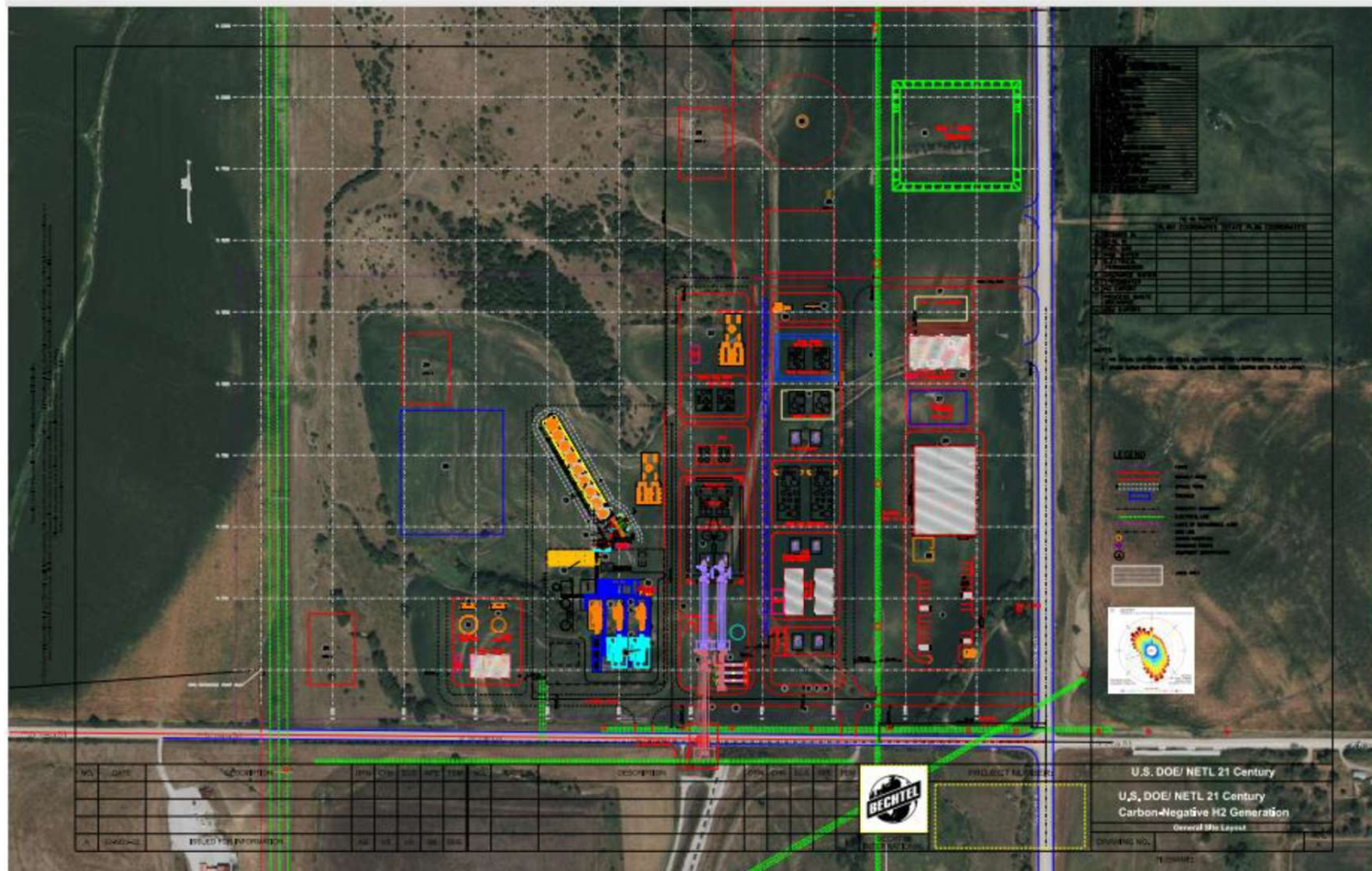


Selected site
Report submitted

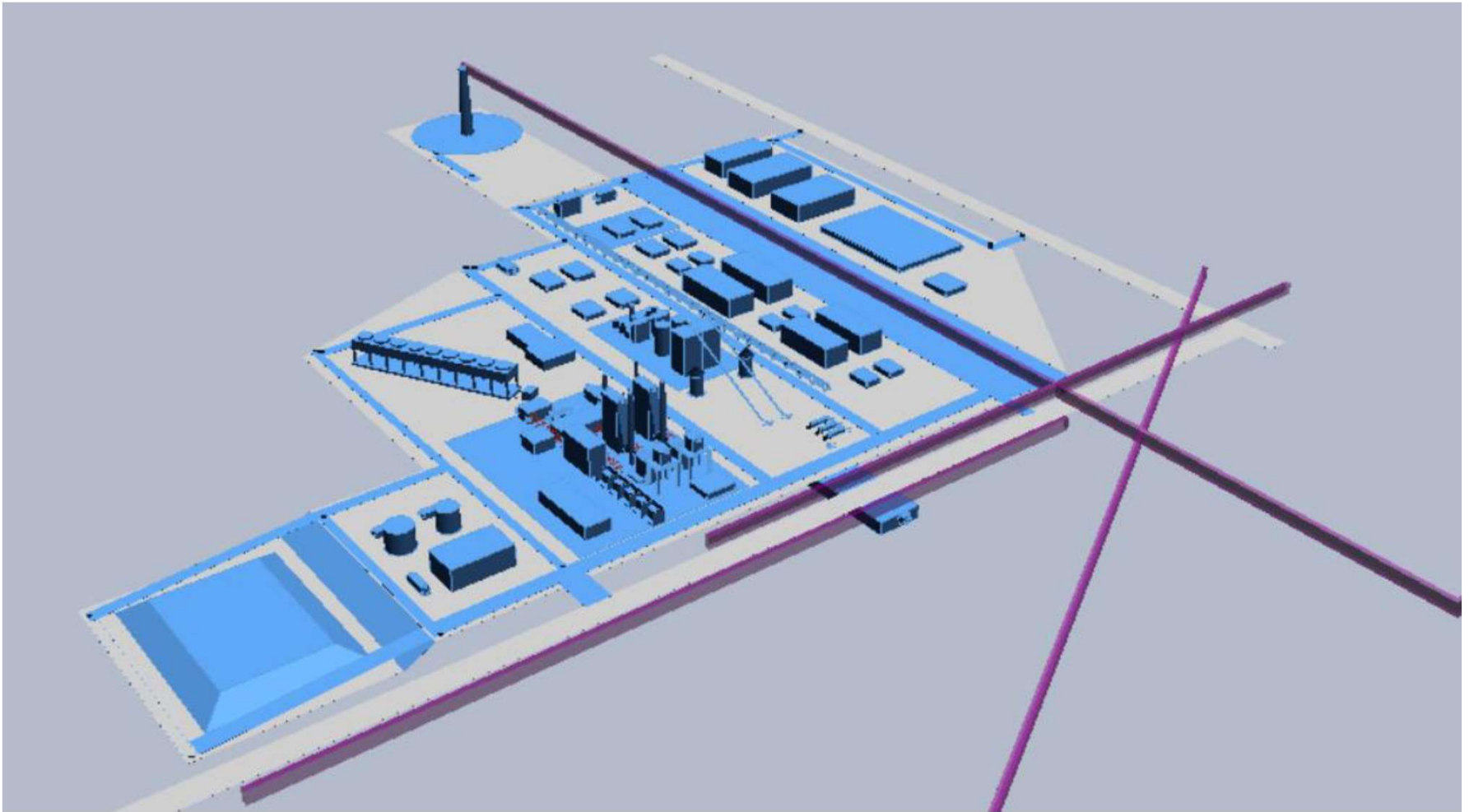
Locations Evaluated at Sheldon Station Project Site



Preliminary Plot Plan – Location #2



3D Model of Gasification Plant – Location #2



Task 5 – Environmental Information Volume (EIV)

- Prepared initial EIV and submitted it to DOE/NETL for review
- Updated EIV to address comments
- Final EIV was prepared and submitted with the Phase II Continuation Application

EIV Key Findings

- Low probability of adverse environmental, safety, health, and cultural resource impacts
- Low probability of adverse air quality impacts
- Low probability of adverse impacts to groundwater resources and hydrologically connected surface waters
- Low probability of adverse impacts to surface water
- Low probability of adverse impacts from solid/hazardous waste management
- Not expected to have an adverse impact on any Federal or state listed threatened or endangered species or their critical habitat
- Low probability of adverse impacts to terrestrial resources
- No significant cultural or historical resources have been identified that would be adversely impacted by the Project
- Low probability of significant cultural or historical resources occurring within the Project Area
- Low probability of adverse impacts to wetlands and nearby surface water features
- No conditions within the Project Area or at the Sheldon Station that would expose DOE to previous liability

Summary and Next Steps

- Budget Period 1 (Tasks 1-5) have been completed
- Budget Period 2 activities (Tasks 1, 6-7)
- Proceed with the FEED Study based upon:
 - Sheldon Station site, Location #2 (North of Princeton Rd.)
 - GTI Energy U-Gas gasifier system
- Perform a Greenhouse Gas Life Cycle Analysis (LCA)
- Update the Investment Case Analysis based upon FEED findings
- Prepare and submit the Final Report
- Conduct closeout meeting with DOE

Acknowledgment and Disclaimer

- **Acknowledgment**: This material is based upon work supported by the Department of Energy under Award Number DE-FE0031933.
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Questions?

A blue-tinted photograph of four people, two men and two women, standing in a row. They are all wearing white lab coats or work shirts. The woman on the far right is wearing a hard hat. They are all smiling and looking towards the camera. The background is a plain, light-colored wall.

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