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Hydrogen

Wabash Valley Resources FEED Study

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Hydrogen Shot Summit

Wabash Valley Resources FEED Project Introduction

Wabash Valley Resources owns the Wabash Gasification Facility.

- Originally constructed in 1994. Commercially operated until 2016. Proven reliability and low-cost production of hydrogen-rich syngas.
- The plant is ideally situated, providing access to multiple energy markets including mobility markets for the important Midwest transportation corridor.
- The project is funded under DOE Cooperative Agreement FE0031994 for FEED Study completion, specifically focused on the integration of the existing Wabash assets with commercially proven technologies to achieve net-zero hydrogen production.

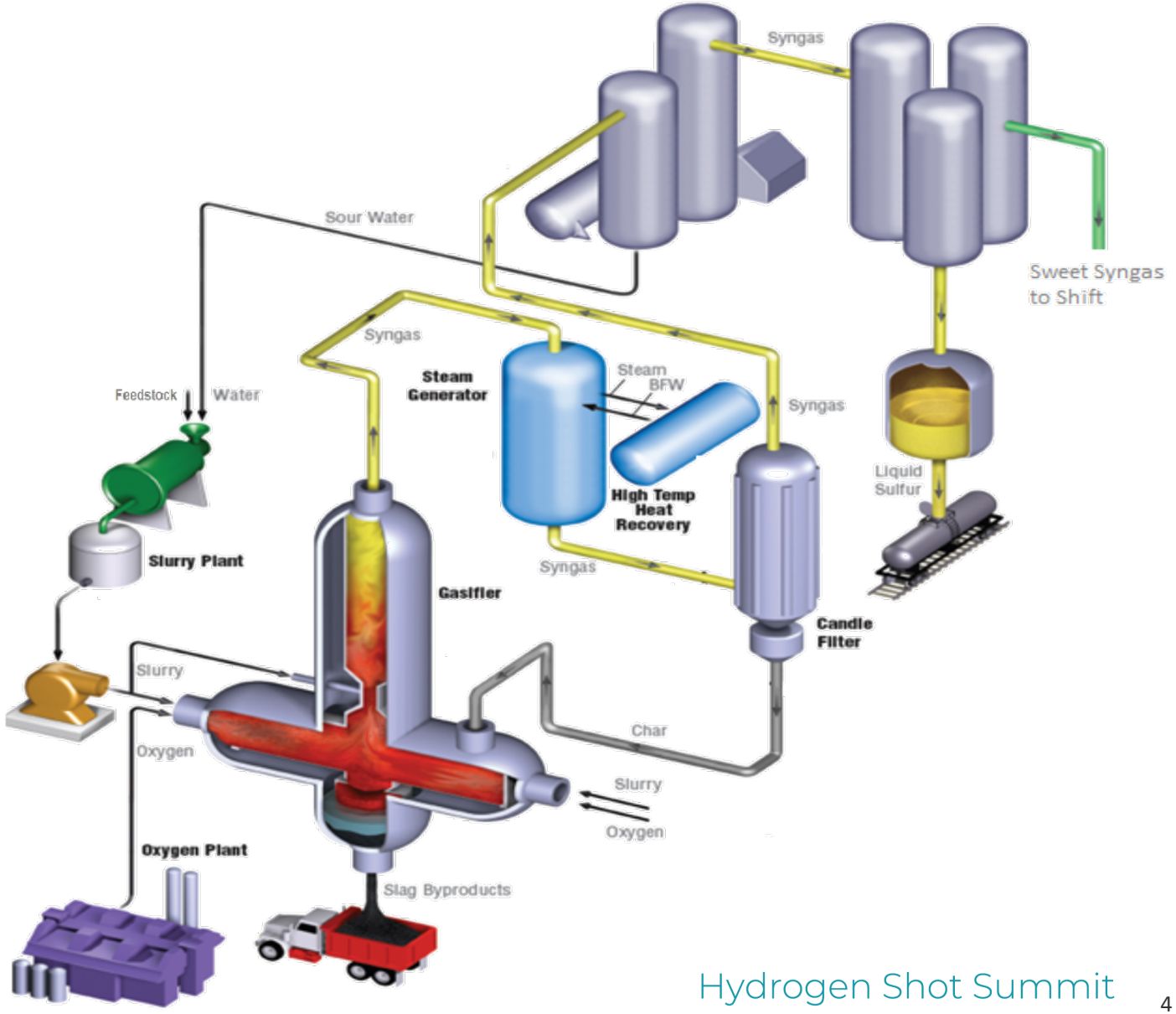
Wabash Valley Resources FEED Project Introduction

- WVR's team and partners will retrofit the facility to separate CO_2 for sequestration and maximize production of clean hydrogen for power generation or offtake opportunities.
  - Initial capacity of 14,000 kg/hour hydrogen production (over 100k tons per year)
  - Potential for approximately 290 gross megawatts clean electricity generation
- Biomass will be introduced and blended with traditional feedstocks to offset upstream and uncaptured carbon intensity impacts
  - Targeting 10-15% biomass feed (by energy).
- Previous research funded through the DOE CarbonSAFE program has identified local geology that is conducive to CO_2 sequestration by the project. WVR's UIC Class VI permitting is in progress.

Wabash Valley Resources FEED Project Configuration

Existing Facilities

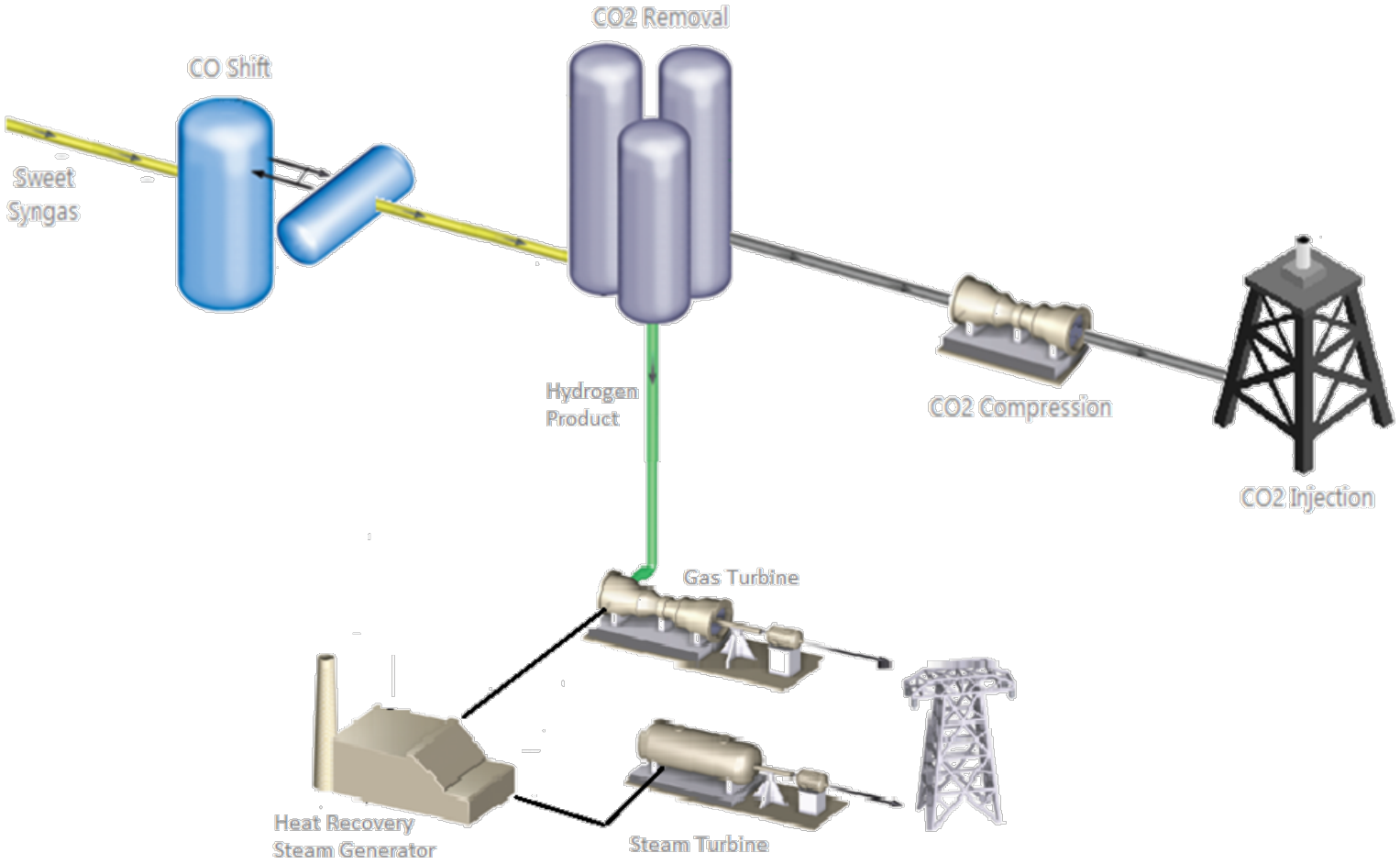
- 2,000 tpd Oxygen plant
- Proven E-Gas gasification process
- Efficient heat recovery and particulate removal
- Typical amine-based sulfur removal
- Typical 3-stage sulfur recovery plant with tail gas recycle.



Wabash Valley Resources FEED Project Configuration

New Facilities

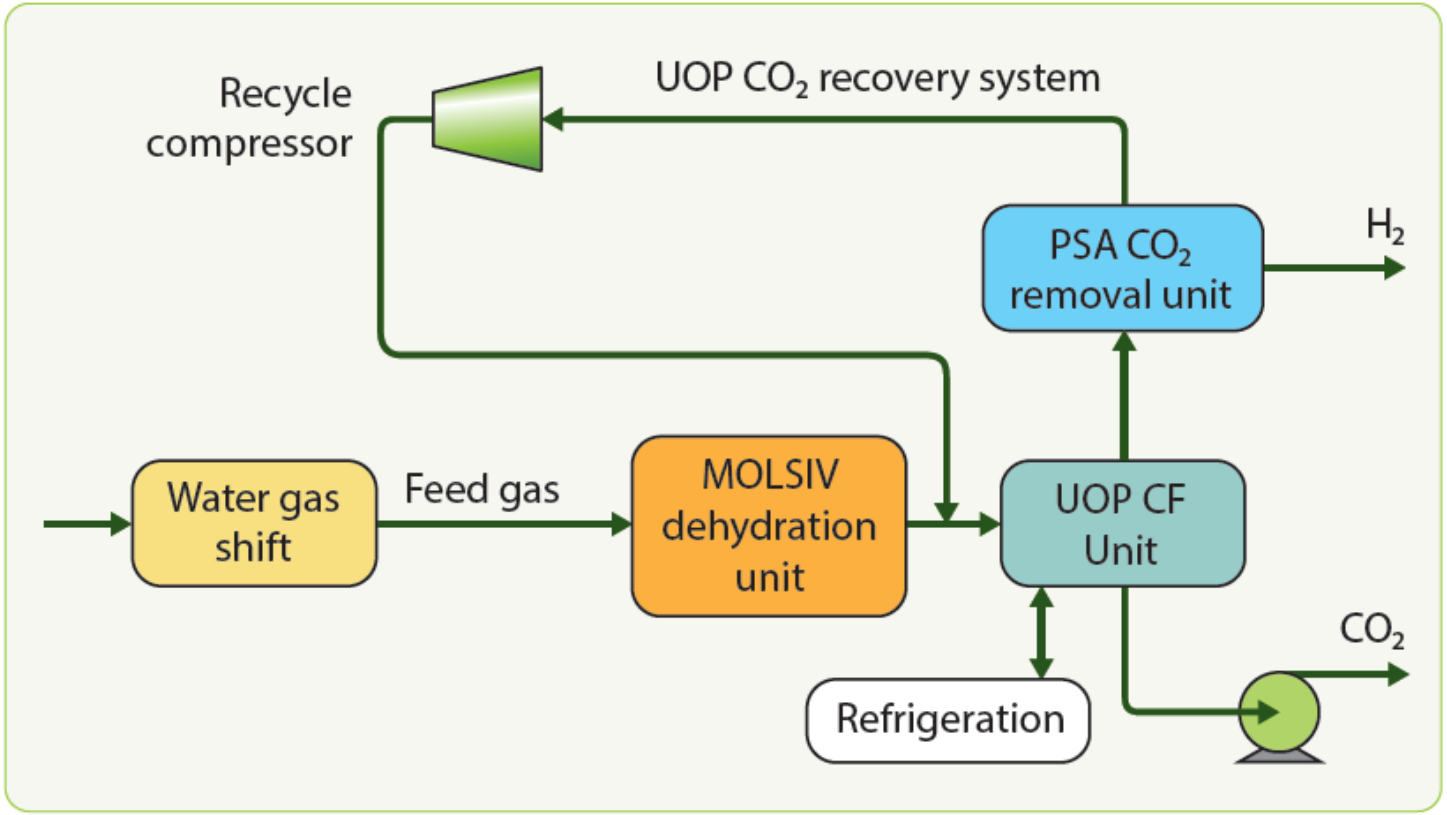
- Water-Gas shift reactors with heat recovery
- Efficient syngas dehydration and fractionation of CO_2
- CO_2 sequestration infrastructure
- PSA purification
- Hydrogen gas turbine combined cycle
- Hydrogen offtake processes as opportunity is identified



Wabash Valley Resources FEED Project Configuration

- WVR will combine three proven commercial processes to achieve CO_2 capture and compression: Dehydration, Fractionation, Pressure Swing Adsorption

- Selection of process influenced by
  - Modularized/Smaller Plot
  - Lower CAPEX
  - Low Steam Consumption
  - Requirement for dry CO_2 and Hydrogen products



Unique Characteristics of the WVR Hydrogen Project

- Large and commercially proven gasification plant, with reduced CAPEX due to retrofit of existing facility.
- Self-supply of clean electricity
  - Avoids need to procure clean electricity
  - Ensures goal of net-zero hydrogen production
- Flexibility to shift or divert hydrogen during peak/non-peak electricity demand – clean electricity dispatchability

Barriers and Challenges for the WVR Hydrogen Project

- Large-scale biomass pretreatment process and logistics
  - Typical biomass torrefaction and pyrolysis plants are too small to supply needs for WVR facility. High biomass supply costs are being realized as a result of limited industrial scale production.
  - Supply chain for potential low-cost sources of biomass (corn stover) are not well established.
- Limited market in the Midwest currently for clean hydrogen
  - Anticipate that a ramp-up of hydrogen offtake will result over time.

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

Horst Hack, EPRI

Hydrogen Shot Summit

Project Award Summary

- **DOE Award Number:** DE-FE0031993
- **Project Title:** Gasification of Coal and Biomass: The Route to Net-Negative-Carbon Power and Hydrogen
- **Funding:** $11,742,350 ($9,393,880 gov't, $2,348,470 cost share)
- **Period of Performance:** 36-months (18-months for each phase)
- **DOE Program Manager:** Debalina Dasgupta
- **Team:** EPRI, NexantECA, Bechtel, GTI, HMI, Wartsila, NPPD
- **Principal Investigator:** Horst Hack (EPRI)

Overall Project Objectives

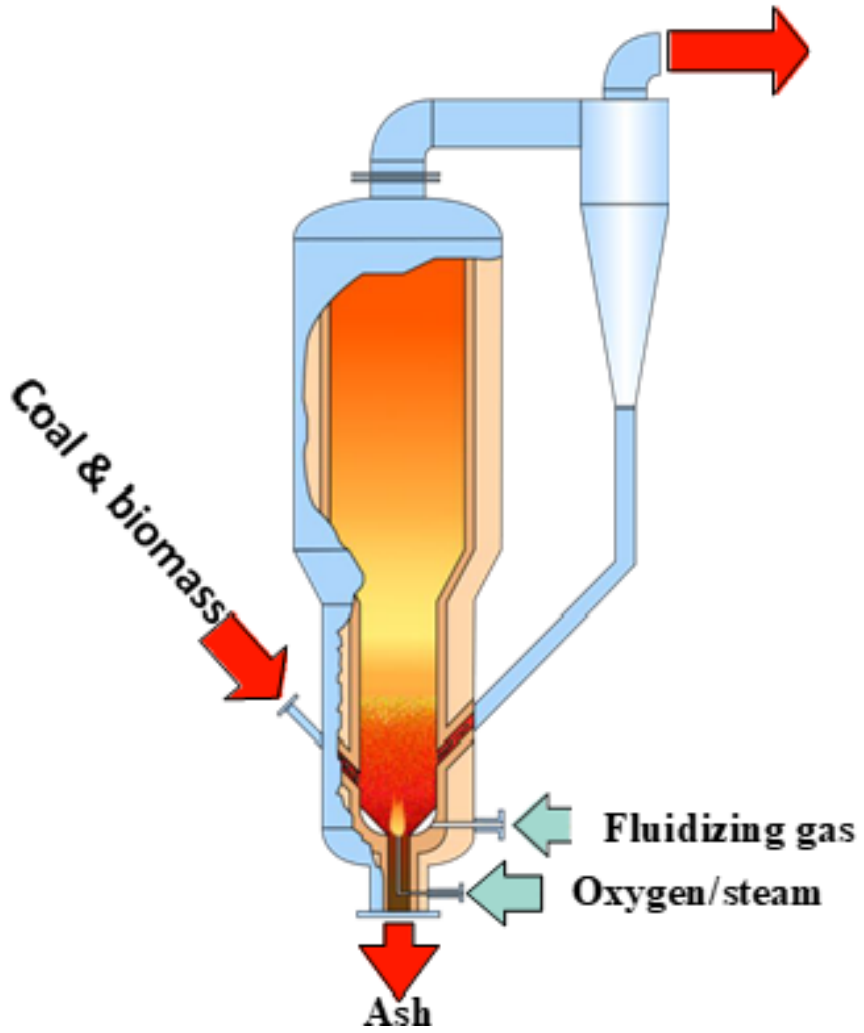
- Meet the goals of DOE's 21st Century Power Plant Initiative by gasifying a mixture of PRB coal and biomass to yield a syngas, which can have CO_2 removed and then be used to produce hydrogen as well as an off-gas that can be used to flexibly produce power
- Concept would be carbon net-negative and 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

Technical Objectives

- Perform a front-end engineering design (FEED) study on an oxygen-blown gasification system coupled with water-gas shift, pre-combustion CO_2 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 over 8500 kg/hr of hydrogen, achieve net-negative CO_2 emissions, and an overall efficiency of 50% net HHV.
- Finalize host site selection, and gasifier type (GTI fluid bed, HMI moving bed)
- Update gasifier and engine 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.

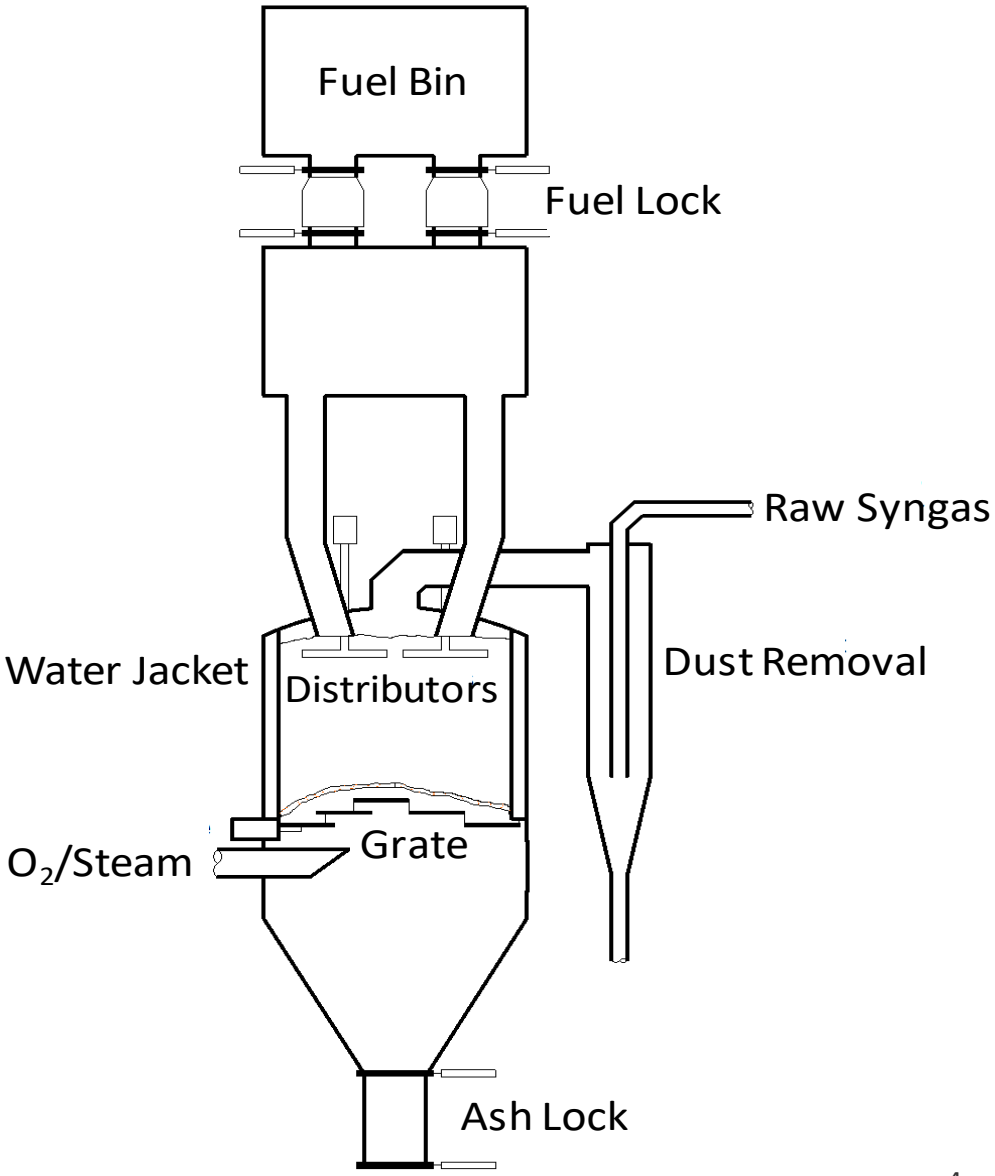
GTI U-GAS® Fluidized-Bed Gasifier

- 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

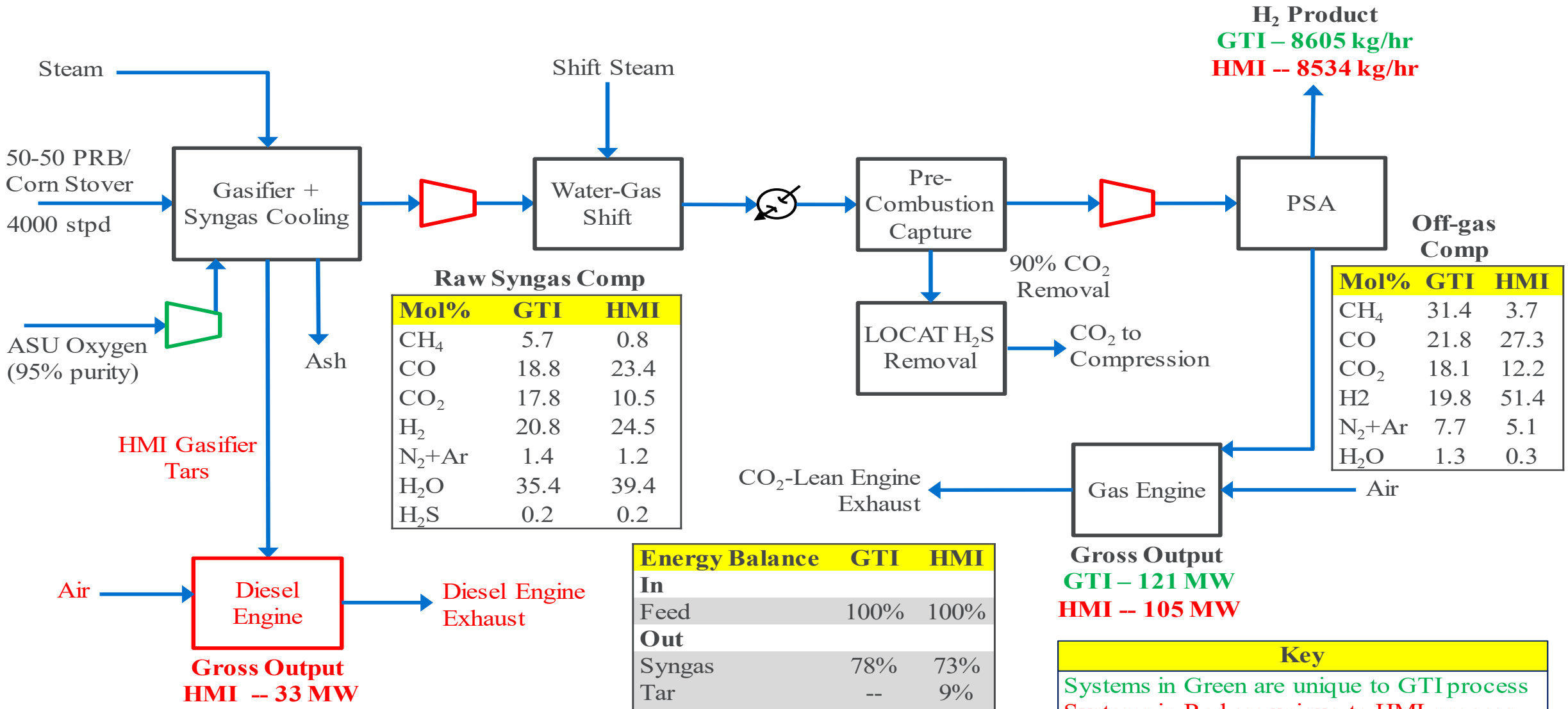


HMI Moving-Bed Gasifier

- This moving-bed gasification technology has demonstrated the ability to gasify nearly all coal ranks as well as biomass (peat, wood)
- Testing suggests that this gasifier will be well suited for corn stover
- 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 for removal
- The CO_2 produced by combustion and the steam from the blast react with the char in the gasification zone to produce CO and H2
- Streams leaving the gasifier are ash out the bottom and dry gas/tar/water vapor/dust out the top



Overall Flowsheet for Both Gasification Processes



Energy Balance	GTI	HMI
In		
Feed	100%	100%
Out		
Syngas	78%	73%
Tar	--	9%
Ash/Dust	4%	7%
Total	**82%**	**89%**

Key
Systems in Green are unique to GTI process
Systems in Red are unique to HMI process

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NPPD Candidate Host Sites

Gerald Gentleman Station
Sutherland, Nebraska

Sheldon Station
Hallam, Nebraska

Project Tasks – Phase I

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.

Project Tasks – Phase II

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.

Acknowledgment and Disclaimer

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