



Low Cost Hydrogen Production from Biomass Using Novel Membrane Gasification Reactor

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Project ID PD13

2005 DOE Hydrogen Program Review

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- > Start: ?
- > End: ?
- > Percent complete: 1%

Budget

- > Total project funding: \$3,372,126
 - DOE share: \$2,697,701
 - Contractors share: \$674,425
- > Funding received in FY04: \$0
- > Funding for FY05: \$?

Overview (con't)

Barriers

- > Hydrogen Production from Biomass Barrier
 - G. Efficiency of Gasification, Pyrolysis, and Reforming Technology
- > DOE Technical Target
 - \$2.5/kg H₂ for hydrogen from biomass by 2010

Partners

- > Arizona State University
- > National Energy Technology Laboratory
- > Schott Glass North America
- > Wah Chang, an Allegheny Technology Company

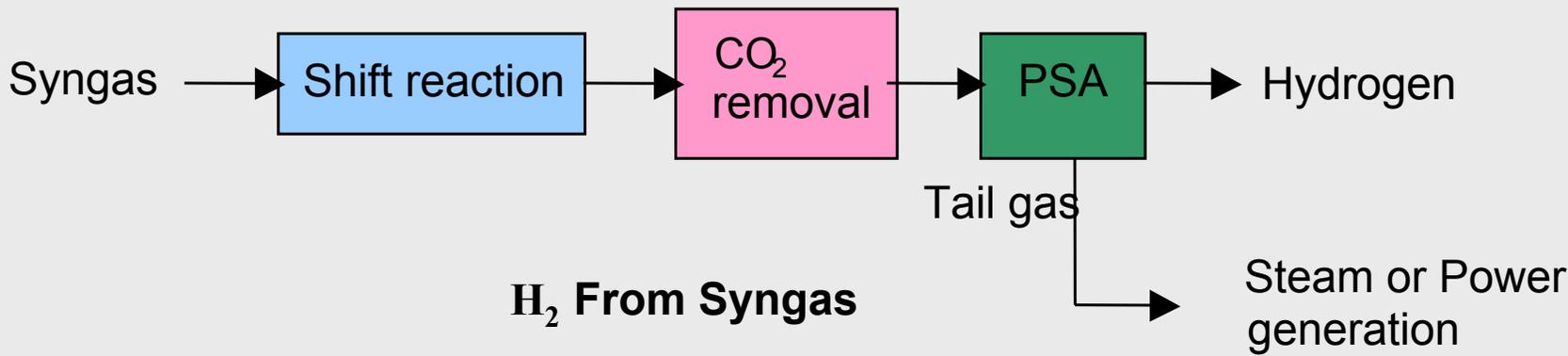
Project Objectives

- > Reduce the cost of hydrogen from biomass to \$2.5/kg H₂ by developing an efficient novel membrane reactor combining biomass gasification, reforming and shift reaction in one step
- > Develop hydrogen-selective membrane materials compatible with the biomass gasification conditions
- > Demonstrate the feasibility of the concept in a bench scale biomass gasifier

Conventional Hydrogen Production from Biomass Gasification



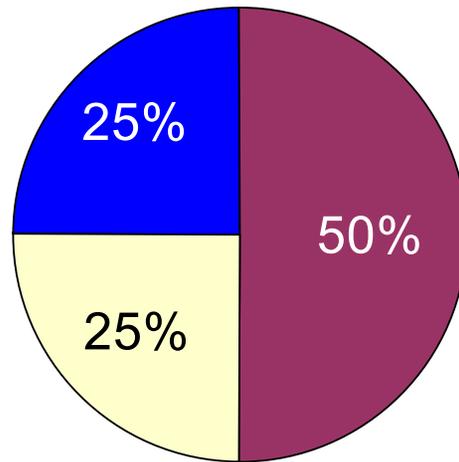
Biomass Syngas Platform



H₂ From Syngas

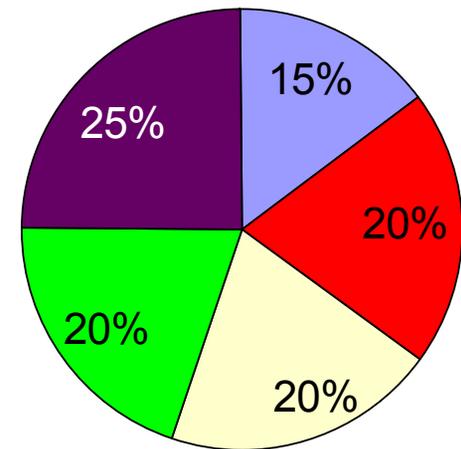
Hydrogen Production Cost from Biomass Gasification

Total cost breakdown



- feedstock
- capital
- operation & maintenance

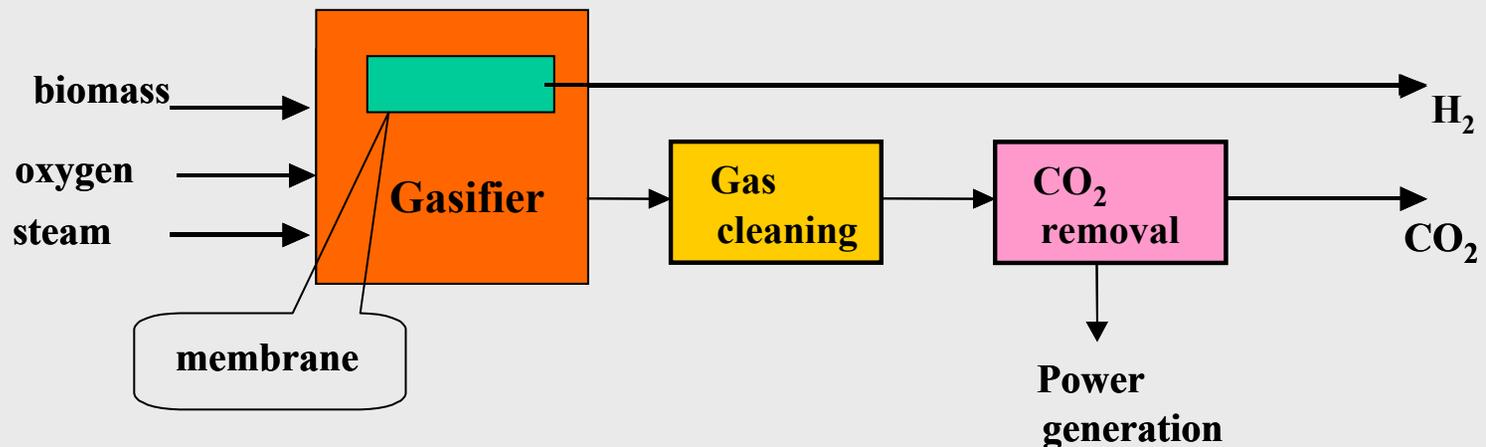
Capital cost breakdown



- biomass feed handling
- gasifier
- air separation
- reforming & separation
- balance of plant

Approach

- > Extract hydrogen directly from gasifier using high temperature H₂-selective membrane
- > Achieve one-step biomass gas reforming, shift and hydrogen separation



Potential Benefits of Membrane Reactor for Hydrogen Production from Biomass

> High H₂ production efficiency:

- Thermodynamic analysis indicates potentially over 40% improvement in H₂ production efficiency over the current gasification technologies

Eliminate loss in PSA tail gas

More CO shift $H_2O + CO = CO_2 + H_2$

Reform CH₄ $CH_4 + H_2O = CO + 3H_2$

> Low cost:

- reduce/eliminate downstream processing steps

> Clean product:

- no further conditioning needed, pure hydrogen

> CO₂ sequestration ready:

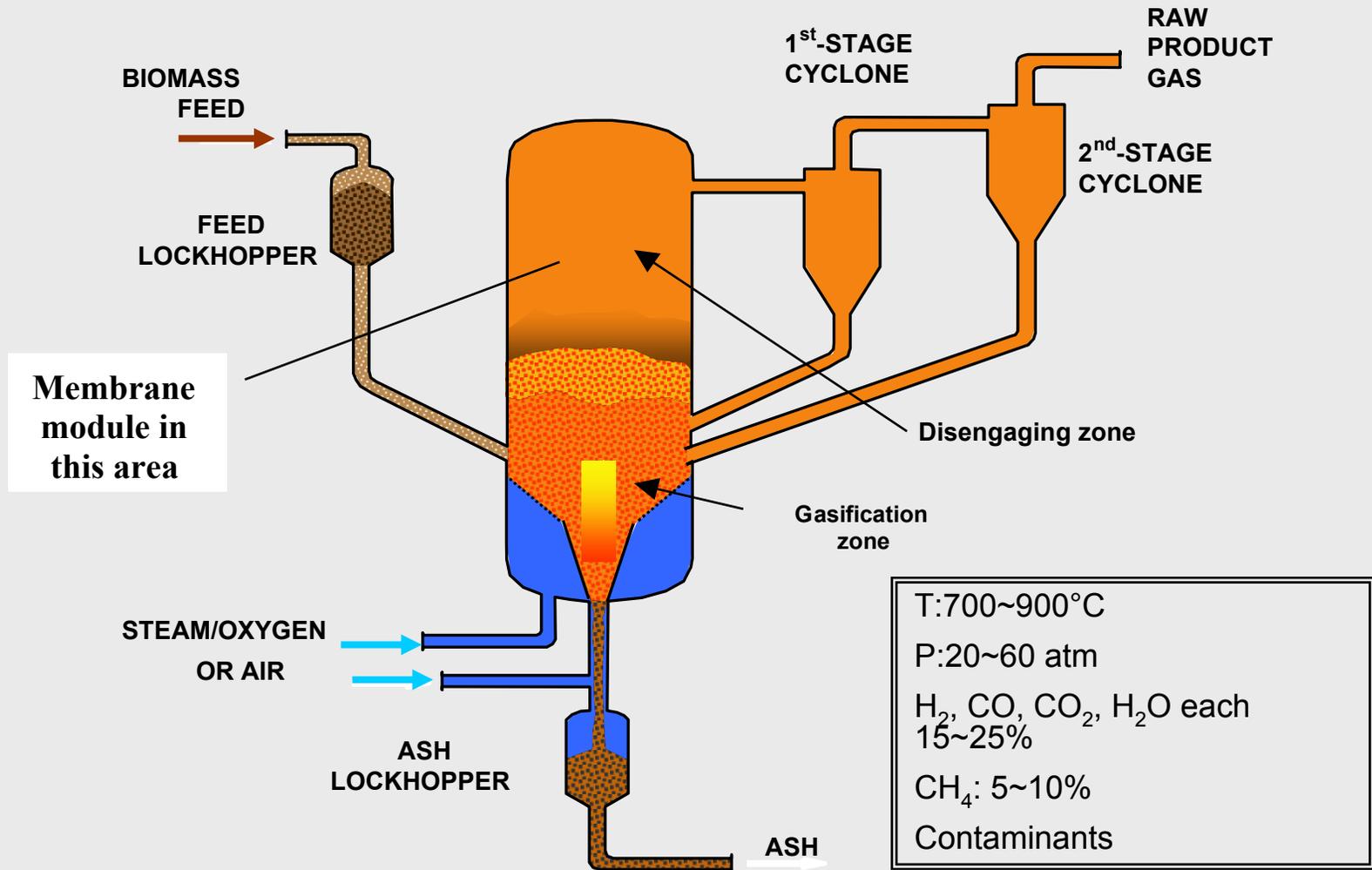
- simplify CO₂ capture process

> Power co-generation:

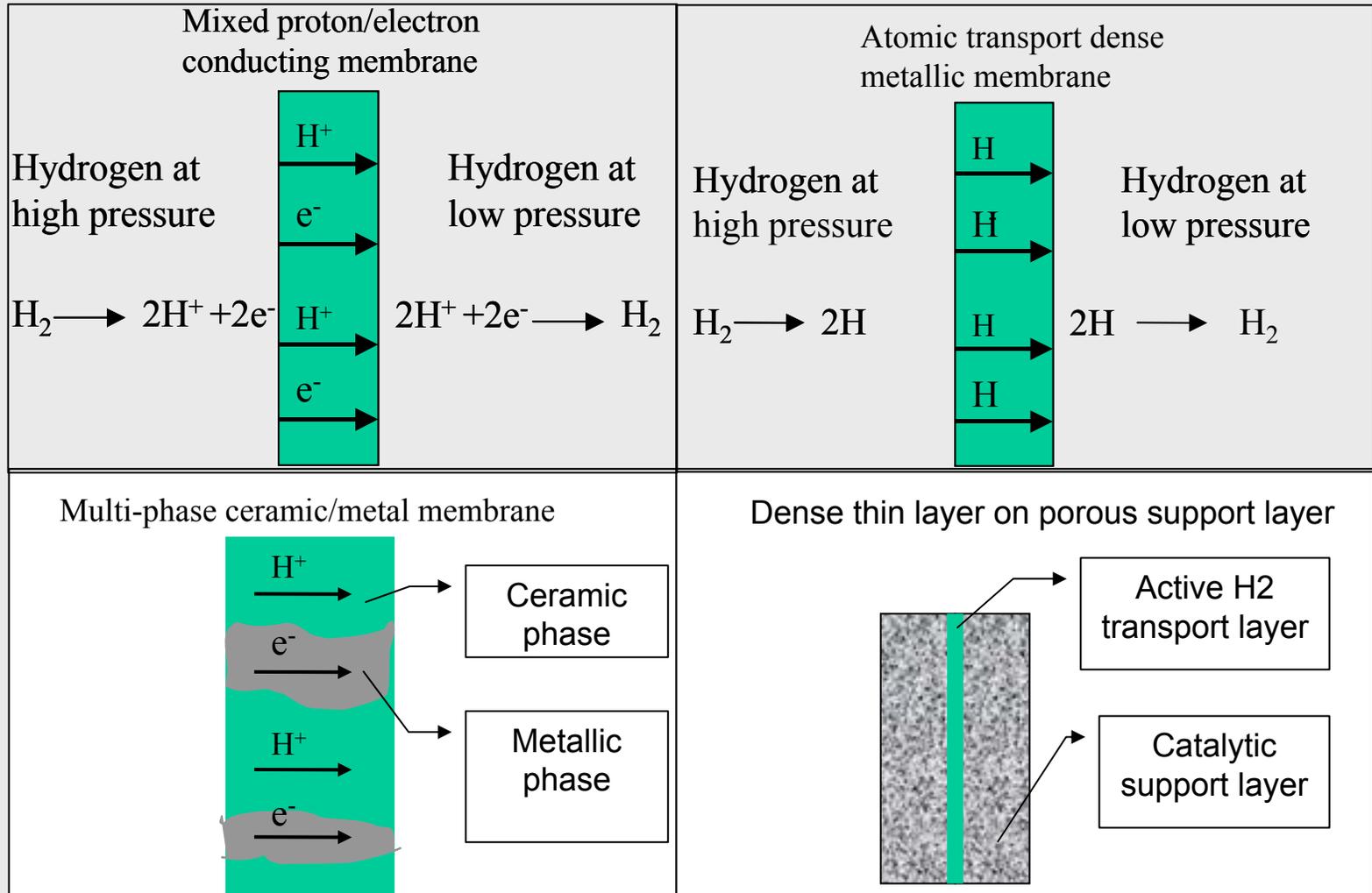
- utilization of non-permeable syngas

GTI's Fluidized Bed Gasifier RENUGAS®

Ideal for Membrane Gasification Reactor



Advanced Inorganic Membranes for Biomass Gasification Application



Scope of Work

- > Task 1 Membrane material development
 - Subtask 1.1 Ceramic material synthesis and testing
 - Subtask 1.2 Metallic membrane synthesis and testing
 - Subtask 1.3 Multi-phase membrane synthesis and testing
 - Subtask 1.4 Optimization of selected candidate membranes
- > Task 2. Gasification membrane reactor process development and economic analysis

Scope of Work (con't)

- > Task 3. Design of membrane module configuration
- > Task 4. Membrane module fabrication
- > Task 5. Bench scale biomass gasifier design and construction
- > Task 6. Testing of a bench scale biomass gasification membrane reactor

Task 1.1 Ceramic Membrane Material Synthesis and Testing

led by Arizona State University

- > Proton-conducting material synthesis
 - Powder preparation by citrate method
 - Membrane fabrication by pressing-sintering
- > Material characterization
 - Conductivity/flux measurement
- > Chemical stability evaluation
 - Compatible to biomass-derived syngas
- > Improve hydrogen separation and flux
 - Membrane seal
 - Thin membrane (to 5 micron)

Task 1.2 Metallic Membrane Material Synthesis and Testing

led by NETL

- > Verification of sulfur resistance of Pd-Cu alloy membrane
 - No inhibition of H₂ flux for Pd₇₀Cu₃₀ under 1000 ppm H₂S
- > Optimization of Pd-Cu alloy compositions
 - With respect to permeability and sulfur resistance
- > Effect of non-sulfur contamination on Pd-Cu membrane
 - N, Cl, Na
- > Durability test

Task 1.3 Multi-Phase Membrane Material Synthesis and Testing

- > Fabricate single-phase ceramic membranes
- > Fabricate multi-phase membranes
 - Metal phase to increase electronic conductivity
 - Thin membrane on a support layer
- > Conduct permeation and chemical stability testing under simulated biomass syngas conditions
- > Incorporate catalyst to the membrane support layer
 - Tar cracking, reforming and shift reactions



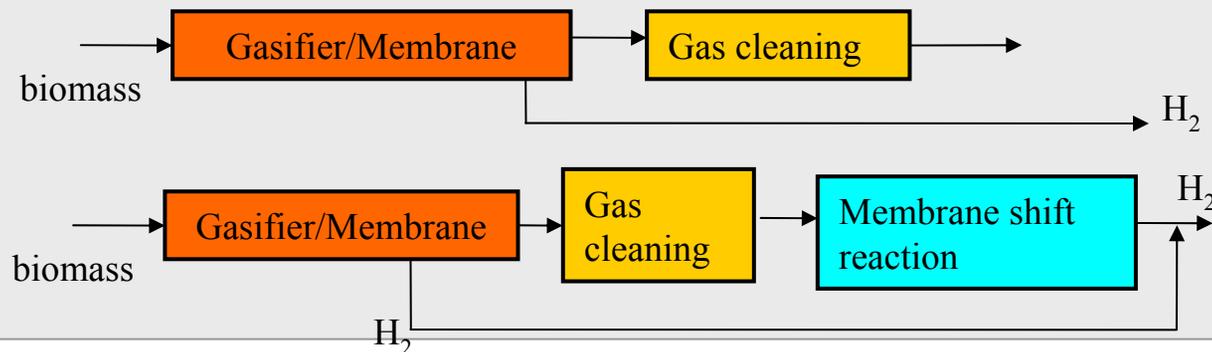
Task 1.3 Multi-Phase Membrane Material Synthesis and Testing (Glass-Based)

led by Schott Glass

- > Survey of known glass-ceramic compositional families with respect to H₂ permeability
- > Material development to evaluate and optimize the prospective materials in the Schott Glass Test Melt facility
- > Evaluate using glass as a substrate to incorporate other hydrogen transport materials

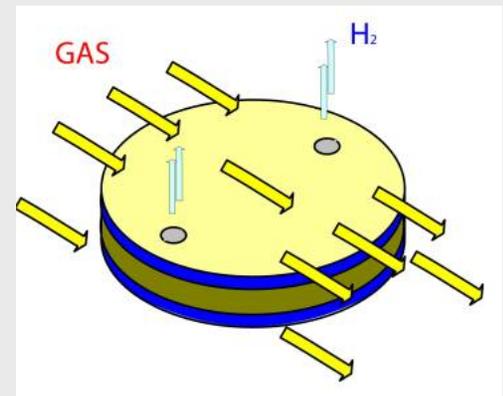
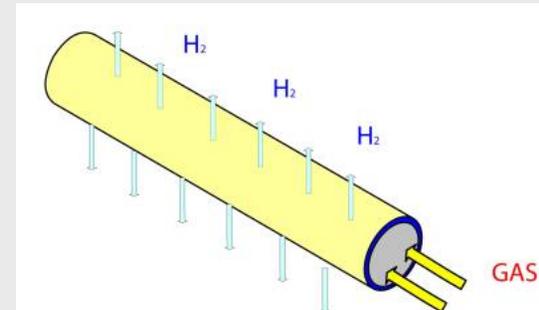
Task 2. Membrane Reactor Process Development and Economic Analysis

- > Develop membrane permeation model or correlation based on the measured data
- > Evaluate overall process performances for hydrogen production from biomass based on different membrane reactor process options
- > Perform analysis on process economics
- > Provide feed back and targets for the performance and cost of the membrane materials



Task 3. & 4. Design and Fabrication of Membrane Module Configuration

- > Conceptual design, tubular, planar, or monolithic
- > Modeling approach for sizing
- > Sealing development
- > Mechanical design
- > Assisted by Wah Chang and Schott Glass



Task 5. Bench Scale Biomass Gasifier Design and Construction

- > GTI's RENUGAS[®] fluidization bed technology
- > Make use of components from an existing low pressure unit
- > Two to four inches in gasifier diameter
- > Oxygen/air blown
- > 60 bar and 1000°C



Task 6. Integrated Testing of Membrane Reactor with Bench Scale Biomass Gasifier

- > Commission the new bench scale gasifier
- > Install the membrane module to the gasifier
- > Prepare test plan and conduct testing
- > Demonstrate technical feasibility of one step hydrogen production from biomass gasifier using membrane reactor
- > Biomass feed:
wood pellet, ~1 kg/hr



Road Map to Successful Membrane Gasification Reactor Technology

Membrane Material Development

- Material synthesis
- Screening and testing
- Contaminant issues
- Stability and durability

Membrane Module Development

- Design of membrane gasifier configuration
- Large-scale membrane manufacturing

Membrane Process Development

- Flow sheet development and simulation
- Optimize operation conditions
- Economic analysis

Membrane Gasifier Scale-up

- Engineering design
- Bench scale
- Pilot unit (GTI's FlexFuel unit)
- Prototype demonstration

Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

- > Hydrogen leakage
- > Equipment or instrument failure of high temperature and high pressure apparatus (permeation unit, gasifier)

Hydrogen Safety

Our approach to deal with this hazard is:

- > Hazard assessment
 - what-if/checklists, hazard and operability studies (HAZOP), failure mode and effects analyses (FMEA), fault tree analyses, and others.
- > Risk management plan
 - identify approaches and actions required to mitigate and minimize exposure to identified risks
- > Communication plan
 - failure reporting and corrective actions, periodic revision of all safety plans, training, emergency response plan development, and safety-related reporting to the sponsor