Low Cost Hydrogen Production from Biomass Using Novel Membrane Gasification Reactor

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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 H_2 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 H_2 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

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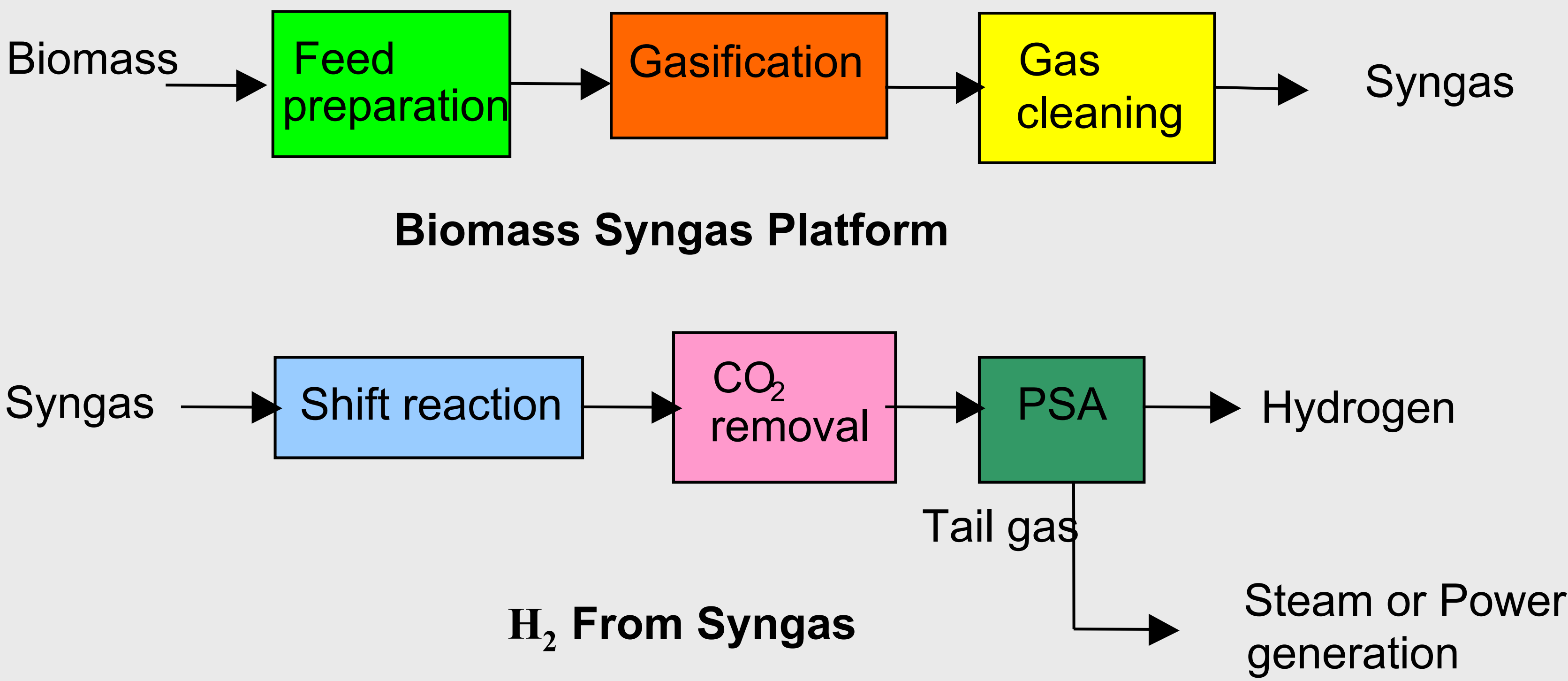
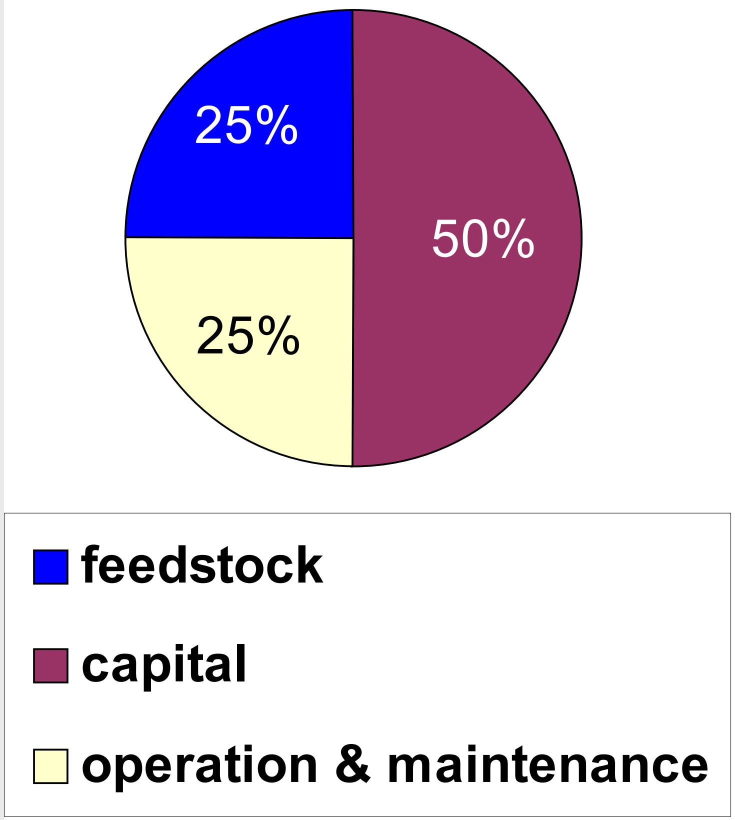
Conventional Hydrogen Production from Biomass Gasification

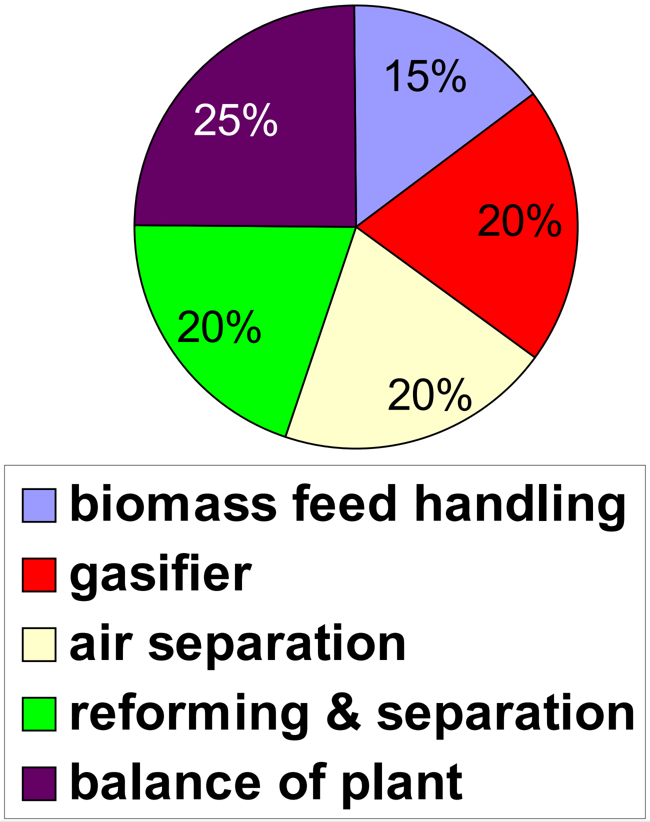


Hydrogen Production Cost from Biomass Gasification

Total cost breakdown



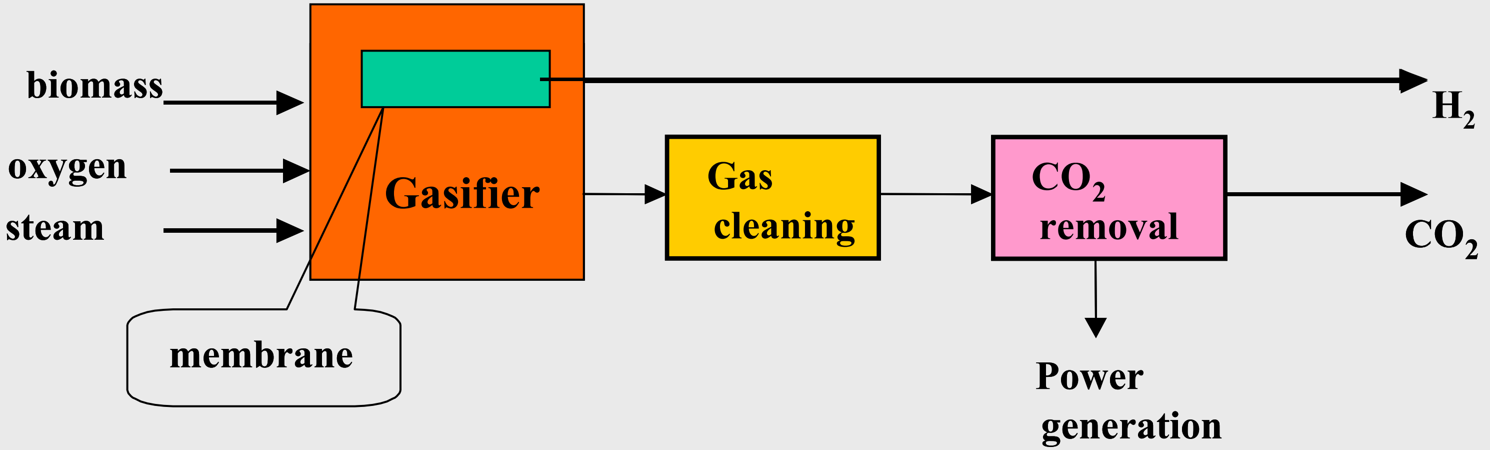
Capital cost breakdown



Approach

> Extract hydrogen directly from gasifier using high temperature H_2-selective membrane

> Achieve one-step biomass gas reforming, shift and hydrogen separation



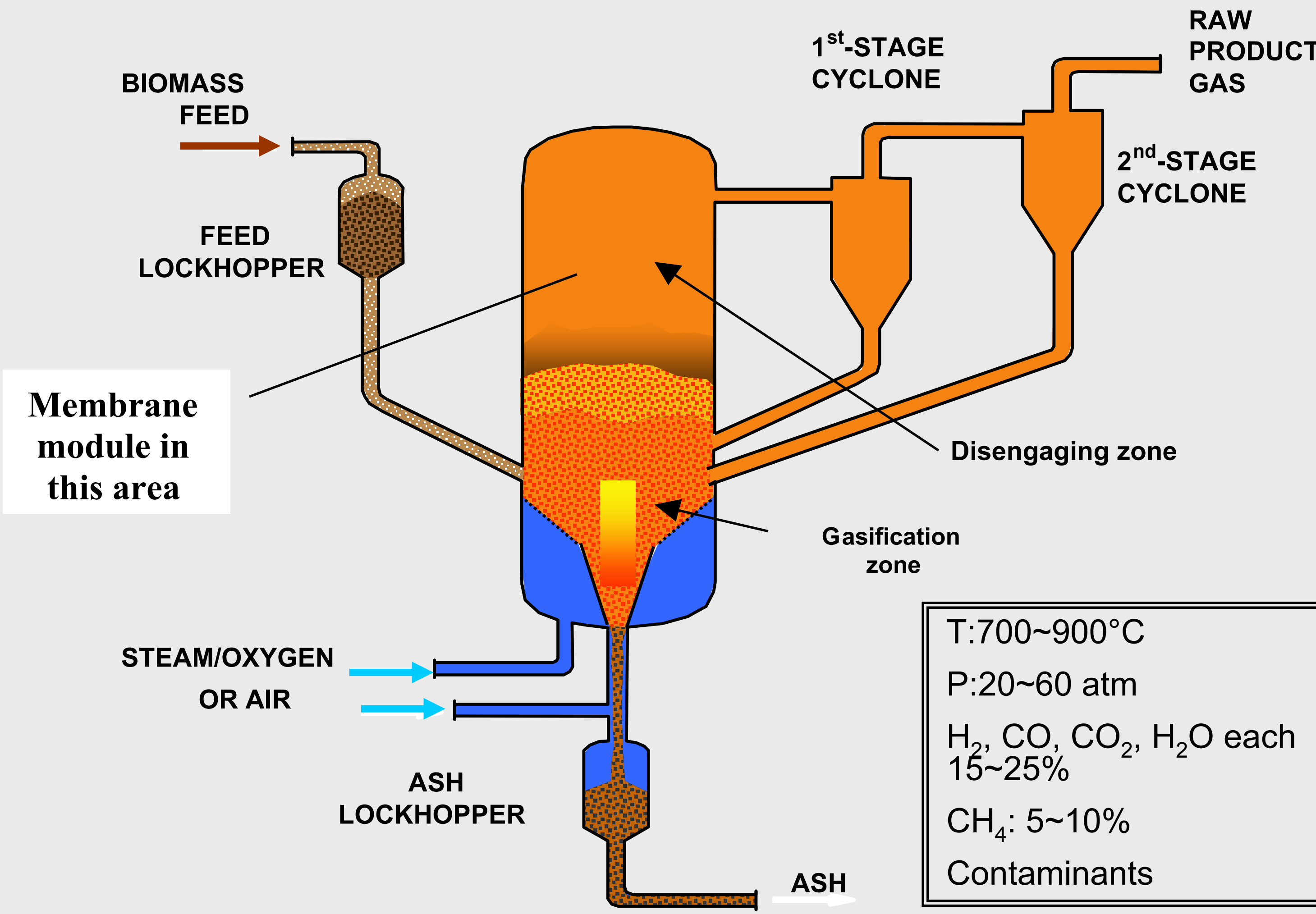
Potential Benefits of Membrane Reactor for Hydrogen Production from Biomass

- **High H_2 production efficiency:**
  - Thermodynamic analysis indicates potentially over 40% improvement in H_2 production efficiency over the current gasification technologies

Eliminate loss in PSA tail gas	
More CO shift	*$H_2O+CO = CO_2+H_2$*
Reform CH_4	*$CH_4+H_2O = CO+3H_2$*

- **Low cost:**
  - reduce/eliminate downstream processing steps
- **Clean product:**
  - no further conditioning needed, pure hydrogen
- **CO_2 sequestration ready**:
  - simplify CO_2 capture process
- **Power co-generation**:
  - utilization of non-permeable syngas

GTI's Fluidized Bed Gasifier RENUGAS®
Ideal for Membrane Gasification Reactor



T:700~900°C

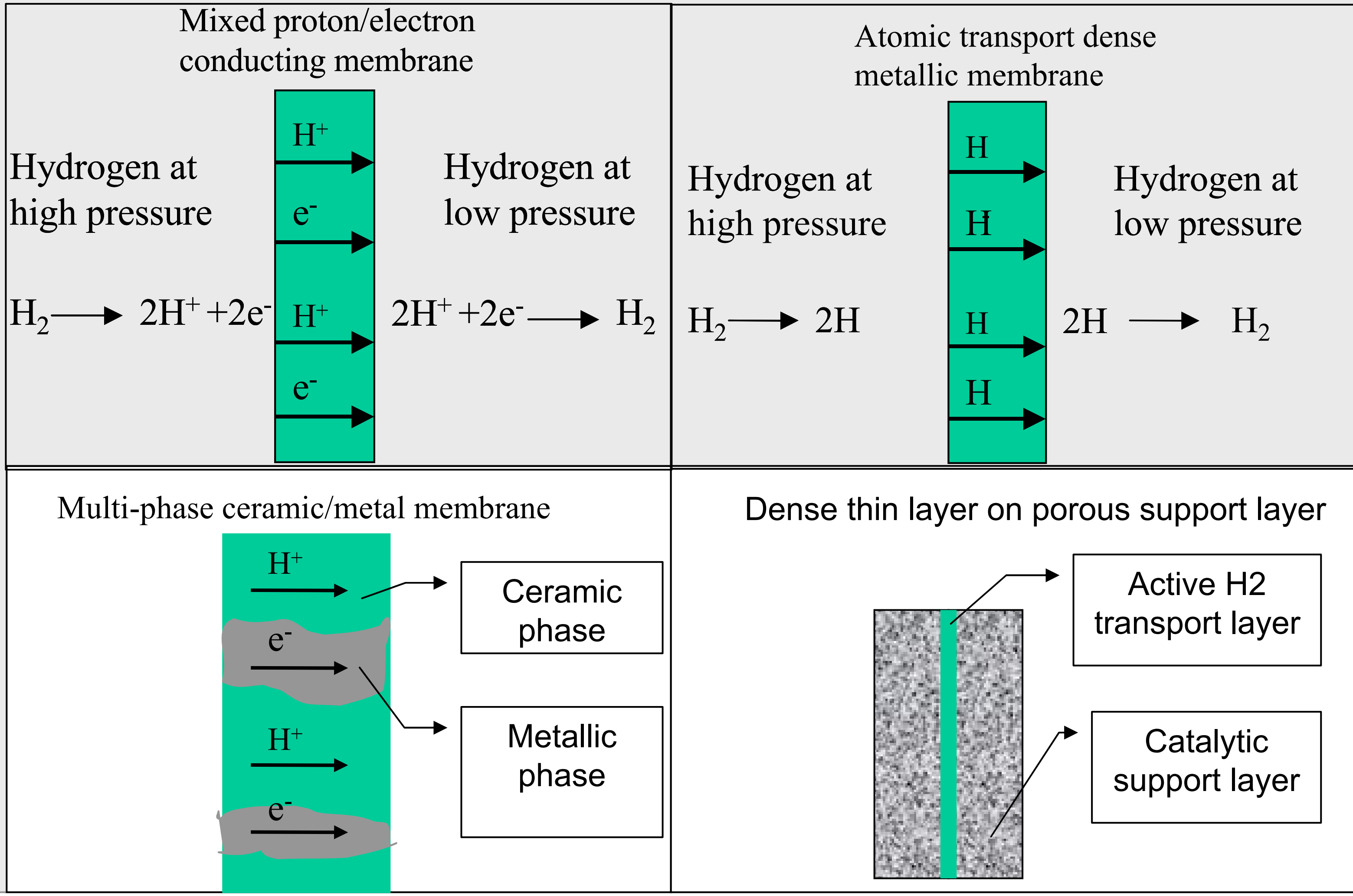
P:20~60 atm

H_2, CO, CO_2, H_2O each 15~25%

CH_4: 5~10%

Contaminants

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)

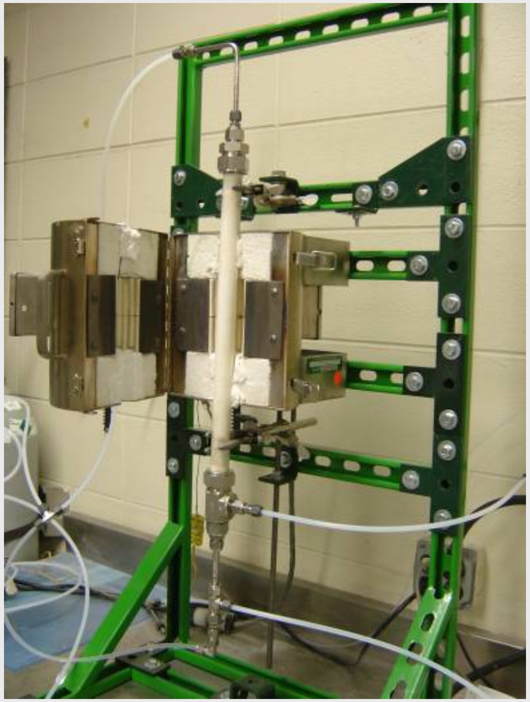
Task 1.2 Metallic Membrane Material Synthesis and Testing

led by NETL

- Verification of sulfur resistance of Pd-Cu alloy membrane
  - No inhibition of H_2 flux for $Pd_{70}Cu_{30}$ under 1000 ppm H_2S
- 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



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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 H_2 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

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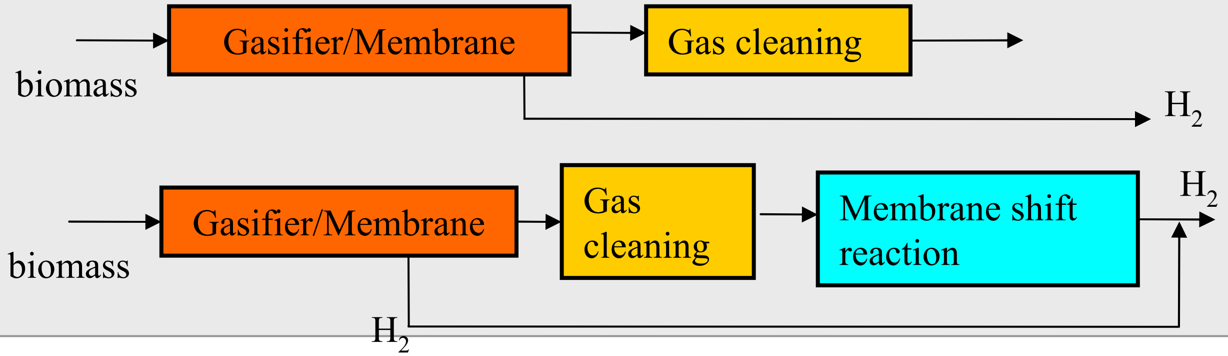
Task 2. Membrane Reactor Process Development and Economic Analysis

- 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

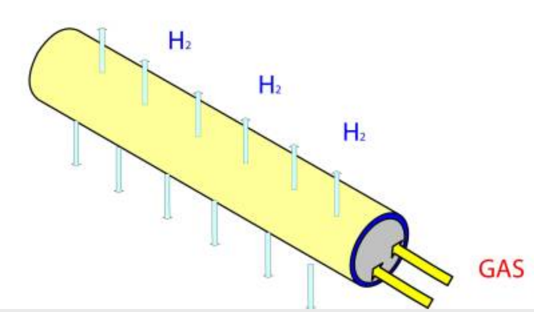
> Conceptual design, tubular, planar, or monolithic

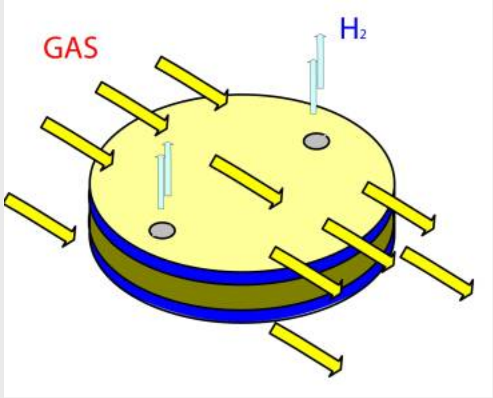
> Modeling approach for sizing

> Sealing development

> Mechanical design

> Assisted by Wah Chang and Schott Glass





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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

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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