One Step Biomass Gas Reforming-Shift Separation Membrane Reactor

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Project ID PD5

Overview

Timeline

- Start: 02/01/2007
- End: 01/31/2011
- Percent complete: 2%

Budget

- Total project funding: $3,396,186
  - DOE share: $2,716,949
  - Contractors share: $679,237
- Funding received in FY06: $0
- Funding for FY07: $676,403 ($450k rec'd ytd)

Overview (con't)

Barriers

- >Hydrogen Production from Biomass Barriers

  G. Efficiency of Gasification, Pyrolysis, and Reforming Technology I. Impurities N. Hydrogen Selectivity
  O. Operating Temperature P. Flux

- >DOE Technical Targets
  - $2-3/kg H_2 from biomass delivered target
  - $1.60/kg H_2 from biomass without delivery

Partners

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

Project Objectives

> Reduce the cost of hydrogen from biomass to \$1.60/kg H_2 (without delivery)
> Develop an efficient membrane reactor that combines biomass gasification, reforming, shift reaction and H_2 separation 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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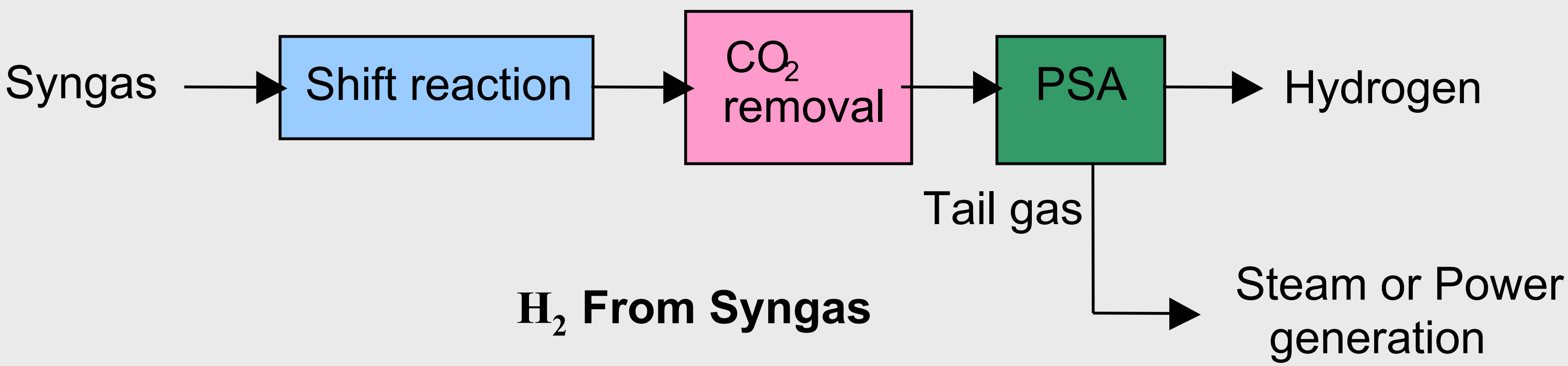
Hydrogen Production from Biomass Gasification Based On Conventional Technologies

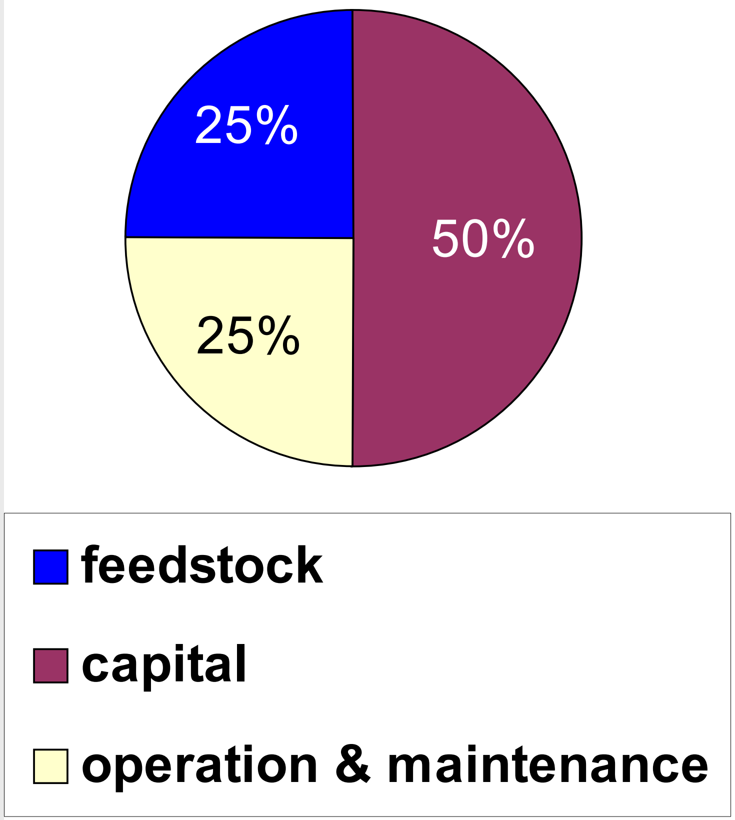
Biomass Syngas Platform



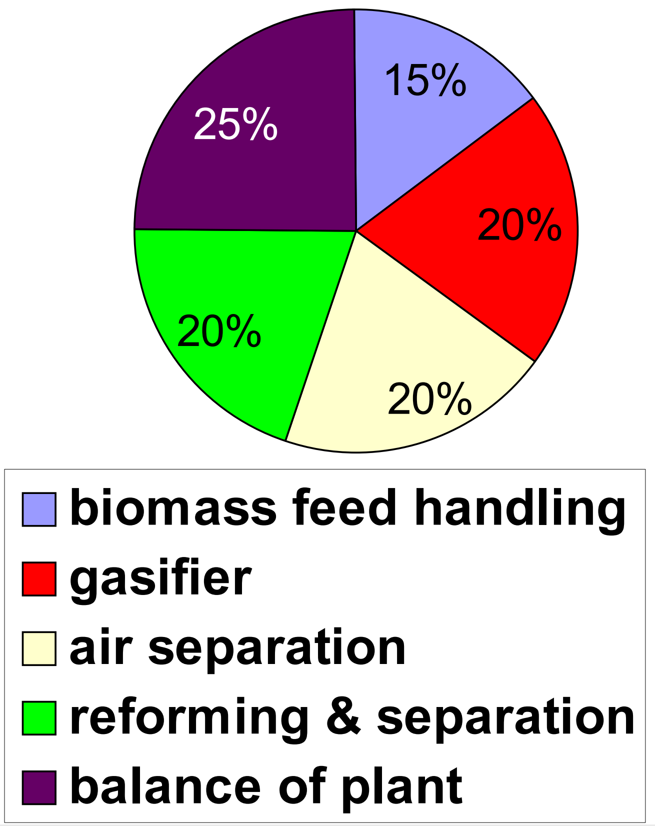
H_2 From Syngas

Hydrogen Production Cost from Biomass Gasification

Total cost breakdown



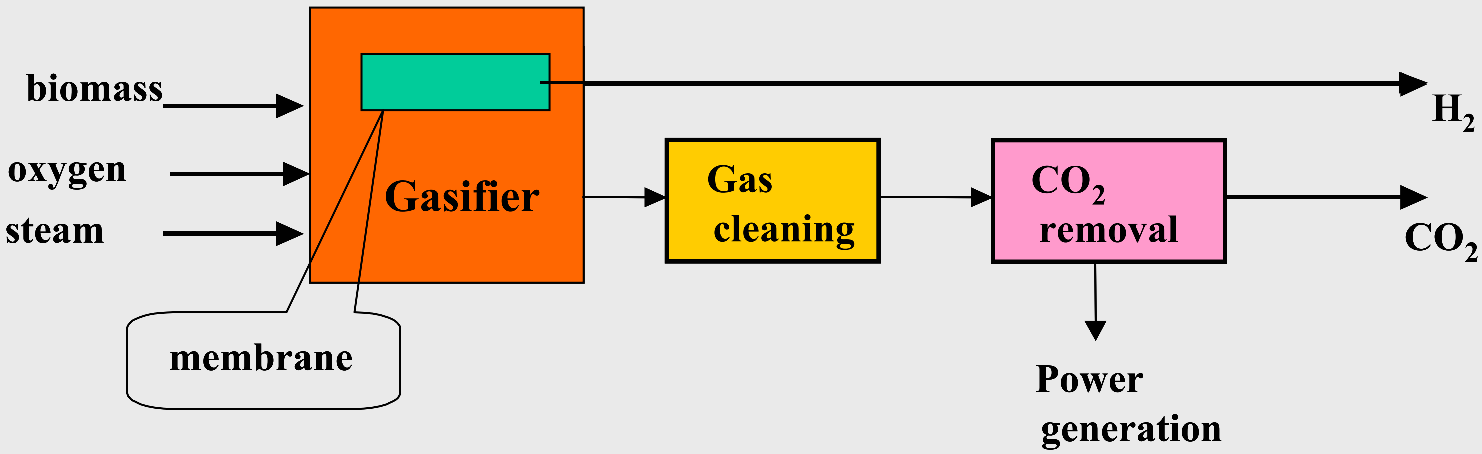
Capital cost breakdown



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	$CH_4 + H_2O = CO + 3H_2$

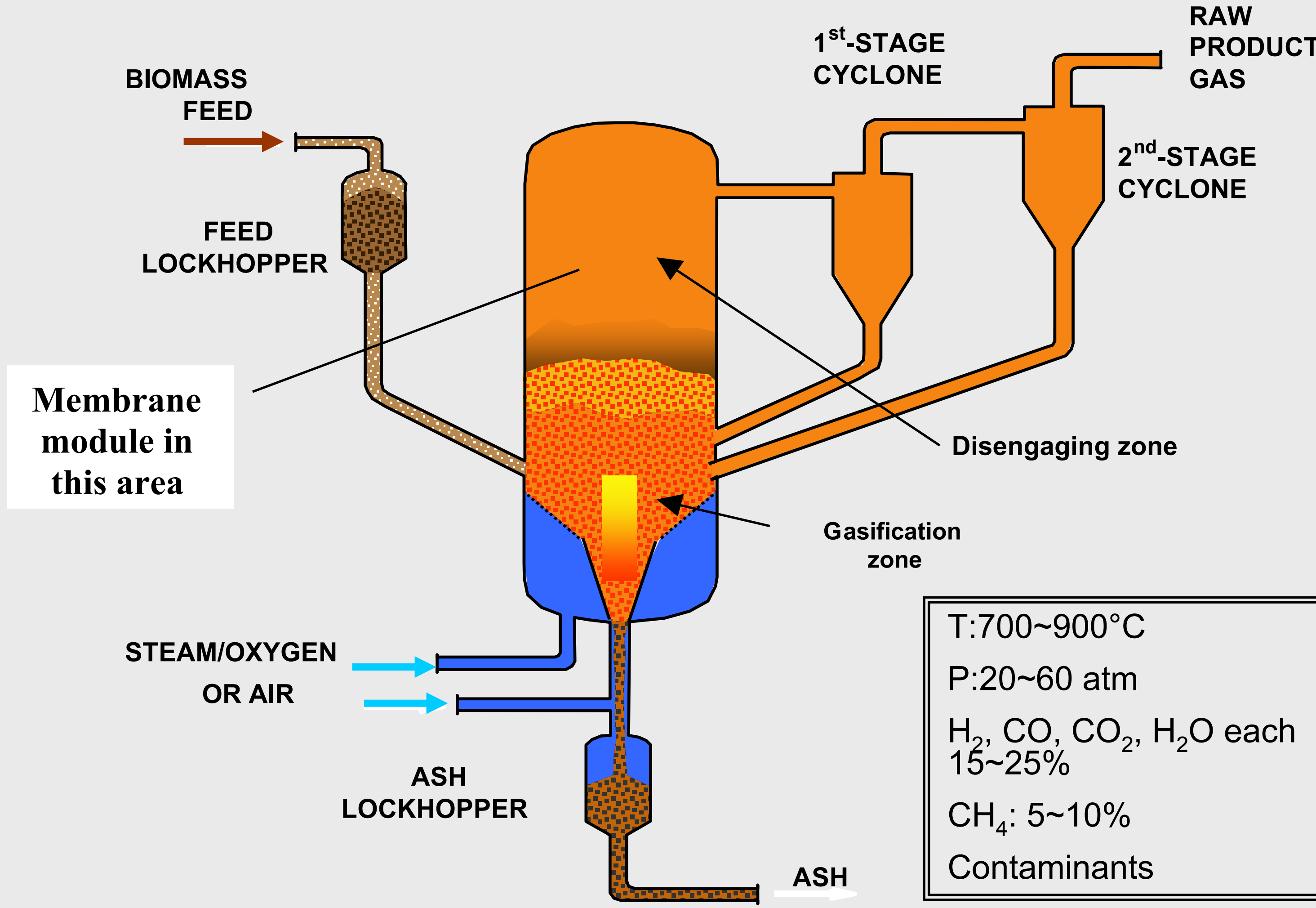
> **Low cost:**
  - reduce/eliminate downstream processing steps

> **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

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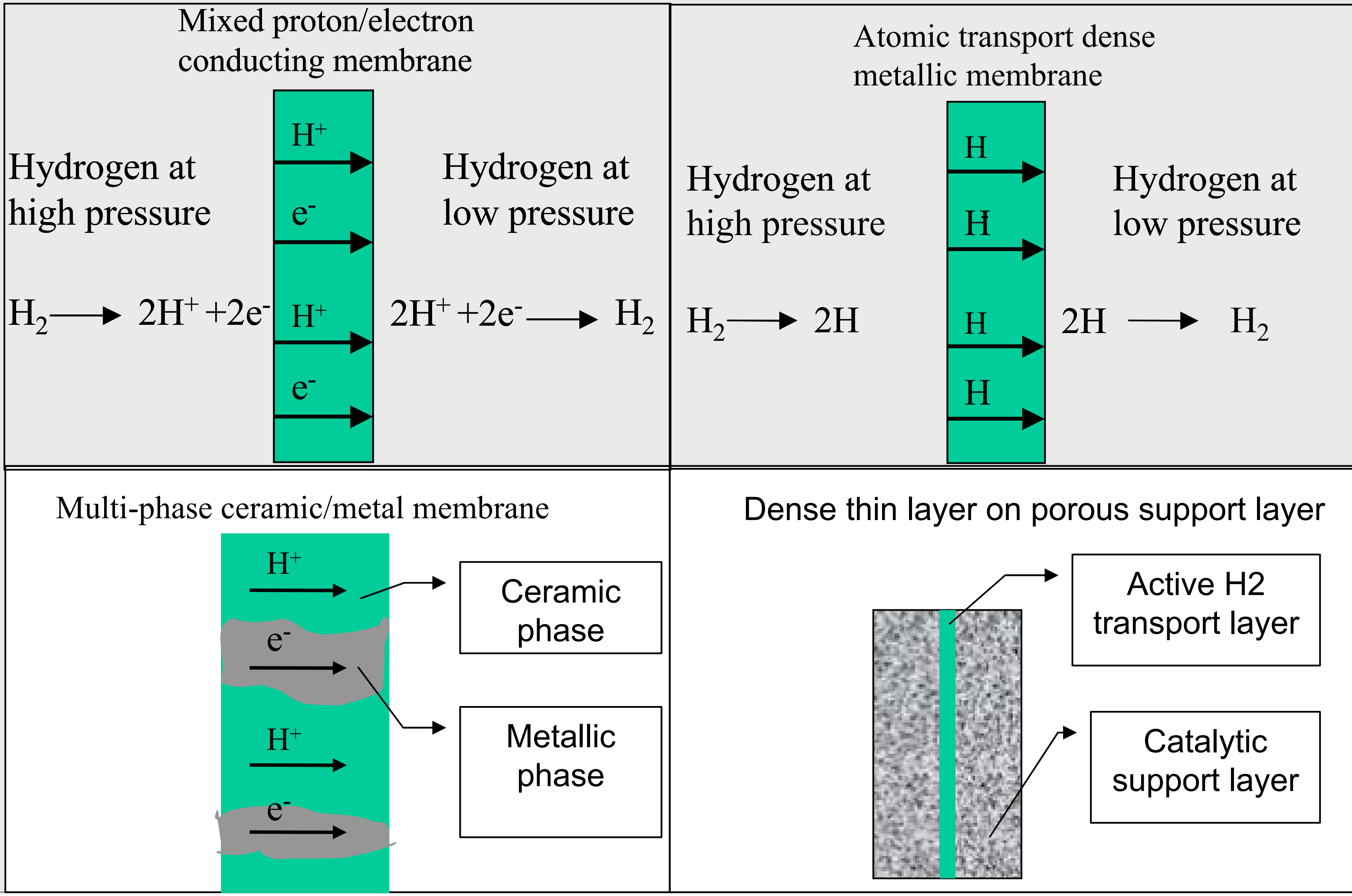
Advanced Inorganic Membranes for Biomass Gasification Application



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Scope of Work

- Task 1. Membrane material development
  - 1.1 Ceramic material synthesis & testing
  - 1.2 Metallic material synthesis & testing
  - 1.3 Composite membrane synthesis & testing
  - 1.4 Optimization of selected candidate membranes
- Task 2. Gasification membrane reactor process development and economic analysis
- Task 3. Bench-scale biomass gasifier design and construction

Scope of Work (con't)

- Task 4. Integrated testing of initial membrane with gasifier
  - 4.1 Design of membrane module configuration
  - 4.2 Membrane module fabrication
  - 4.3 Testing of bench-scale membrane reactor
- Task 5. Integrated testing of best candidate membrane with gasifier
- Task 6. Project Management and reporting

Task 1.1 Ceramic Membrane Material Synthesis and Testing

led by Arizona State University

- Improve proton and electronic conductivity and chemical stability of ceramic membrane
  - Cerate-based ceramic membrane
  - Doping one or two elements
- Study H_2 permeation and chemical stability of proton conducting ceramic membranes
  - Compatible to biomass-derived syngas
- Develop synthesis methods to prepare thin membranes of the modified ceramics
  - Increase hydrogen flux

Task 1.2 Metallic Membrane Material Synthesis and Testing

led by NETL

- Oxidation and Sulfidation Corrosion Analysis
  - TGA of PdCu and other alloys under gasifier conditions
- Permeability Characterization in H_2S
  - Steady-state testing of membrane materials in presence of S
- Influence of Gasifier Constituents on Permeability
  - Effect of biomass impurities (e.g. NH_3, Cl, Na)
- Robust Membrane Materials
  - Development of novel membrane concepts to withstand gasifier conditions

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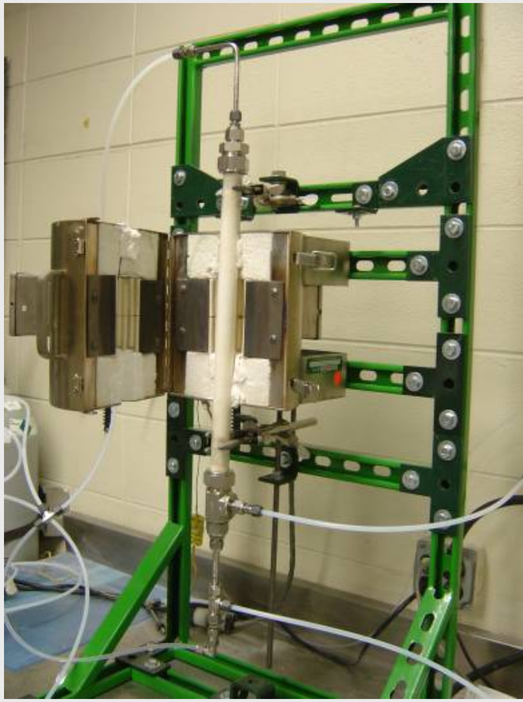
Task 1.3 Composite Membrane Synthesis and Testing

- Fabricate multi-phase membranes
  - Metal phase to increase electronic conductivity
  - Thin membrane on a support layer metals, ceramics or glass ceramics
- **1.3.1 Glass-Ceramic Membrane Development**
- **1.3.2 Select Initial Candidate Membrane**
- **1.3.3 Select Best Candidate Membrane**



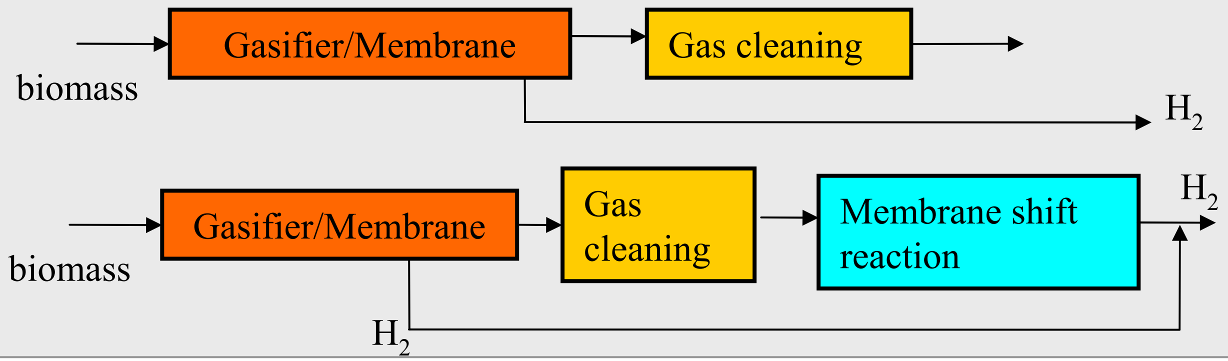
Task 1.3.1 Glass-Ceramic Membrane Development

led by Schott North America

- 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 such as Pd or other metals

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. Bench Scale Biomass Gasifier Design and Construction

- GTI's RENUGAS® fluidized-bed technology
- Make use of some components from an existing unit
- Two inch

  gasifier diameter
- Oxygen/air blown

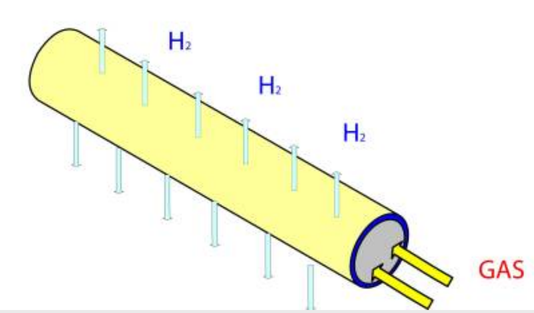
Task 4. Integrated Testing of Initial Membrane Reactor with Biomass Gasifier

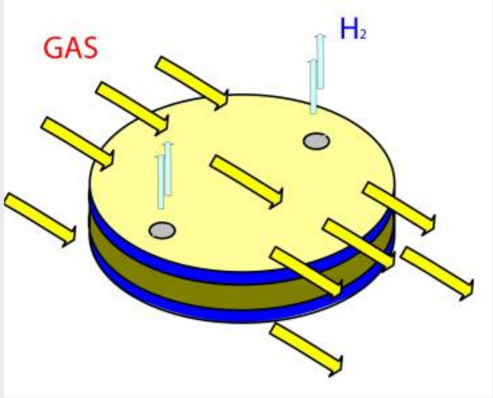
> Commission the new bench scale gasifier
> Install the membrane module to the gasifier
> Prepare test plan and conduct testing
> Demonstrate technical feasibility of one step hydrogen production from biomass gasifier using membrane reactor
> Biomass feed:

wood pellet, ~2 kg/hr

Task 4.1 - 4.2 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





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