



# **Direct Hydrogen Production from Biomass Gasifier Using Hydrogen- Selective Membrane**

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Hydrogen Initiative Forum

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# Project Objectives

- > Develop novel membrane reactor process for hydrogen production from biomass that is low cost and efficient
- > Develop hydrogen-selective membrane materials compatible with the biomass gasification conditions
- > Demonstrate feasibility of the concept in a downdraft biomass gasifier

# Project Overview

- Project Sponsor: Xcel Energy
- Project duration: 2 years
- Project cost: \$860,000
- Project team:

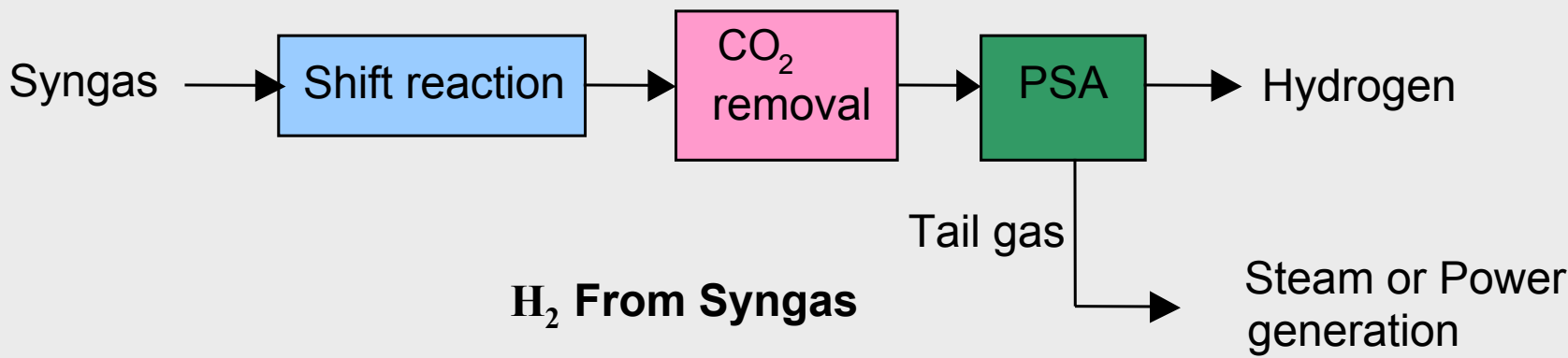
Gas Technology Institute

Natural Resources Research Institute (NRRI)  
University of Minnesota at Duluth

# Conventional Hydrogen Production from Biomass Gasification



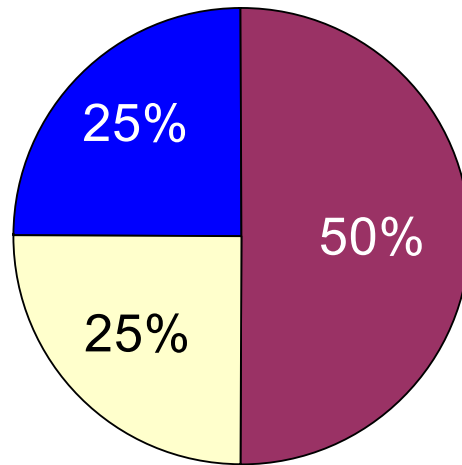
**Biomass Syngas Platform**



**H<sub>2</sub> From Syngas**

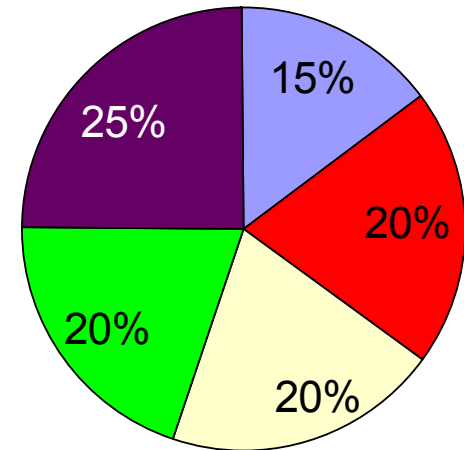
# Hydrogen Production Cost from Biomass Gasification

Total cost breakdown



- feedstock
- capital
- operation & maintenance

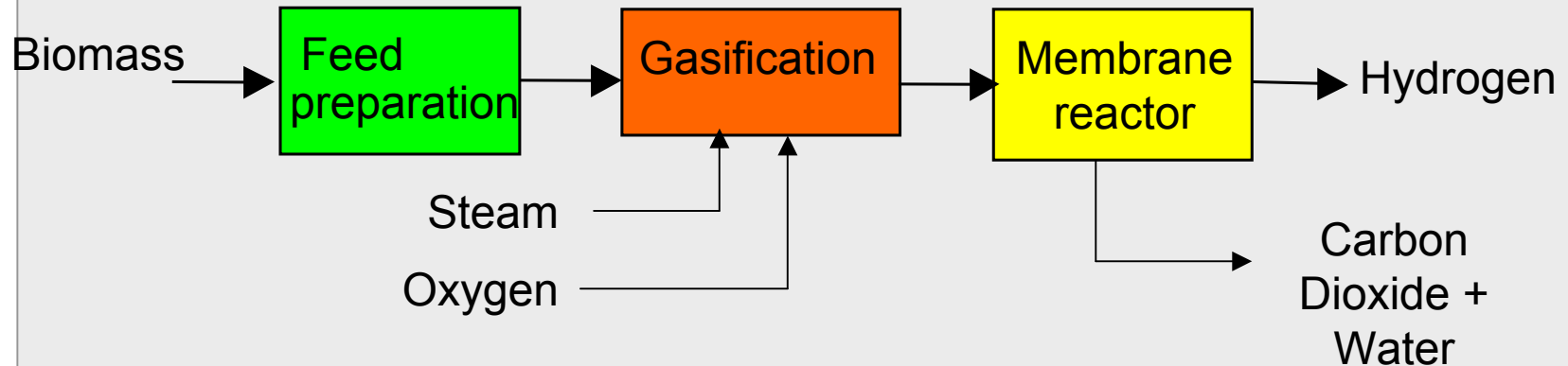
Capital cost breakdown



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

# Approach

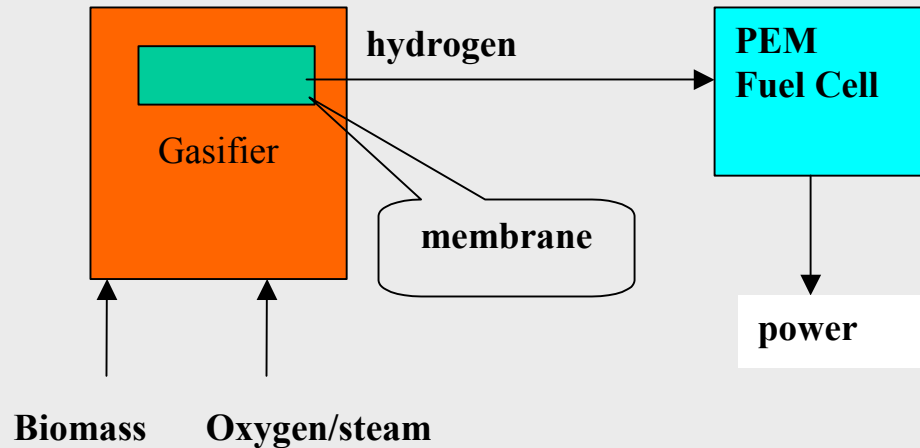
> Use high temperature H<sub>2</sub>-selective membrane to achieve one-step biomass gas reforming, shift and hydrogen separation



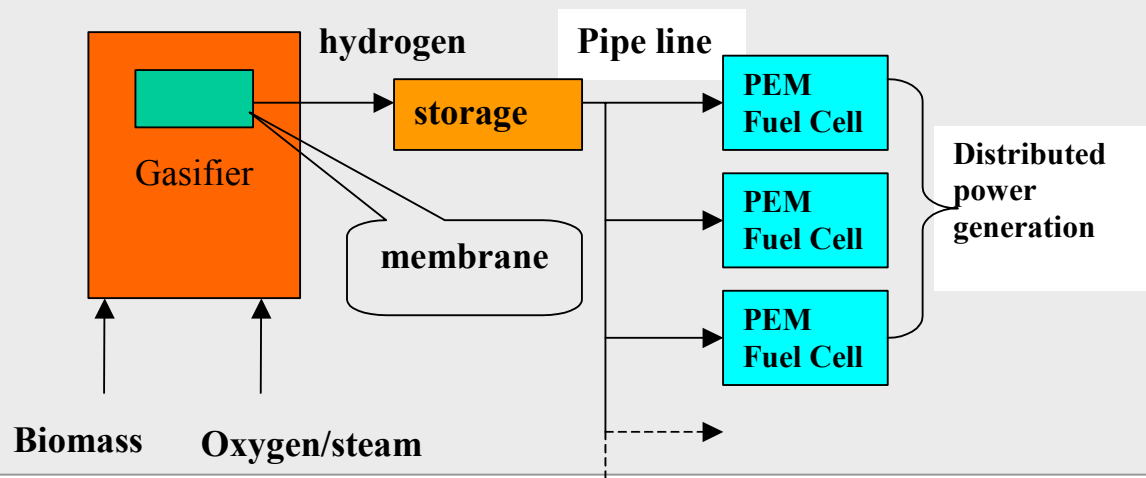
# Hydrogen From Biomass Combined with Fuel Cells

- long term vision

Direct integration



Central production



# Potential Benefits of Membrane Reactor for H<sub>2</sub> Production from Biomass

- > **High H<sub>2</sub> production efficiency:**
  - Thermodynamic analysis indicates potentially over 40% improvement in H<sub>2</sub> production efficiency over current gasification technologies

Eliminate loss in PSA tail gas

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

Reform CH<sub>4</sub>       $CH_4 + H_2O = CO + 3H_2$

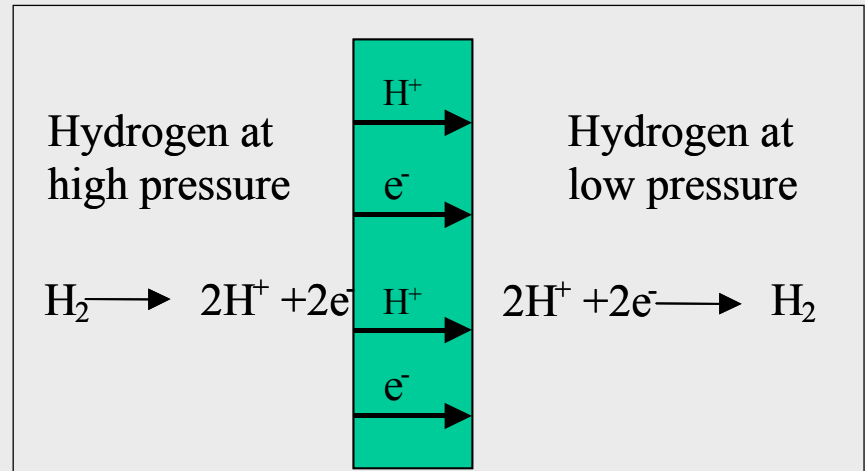
# Potential Benefits of Membrane Reactor for H<sub>2</sub> Production from Biomass (cont'd)

- > **Low cost:**
  - reduce/eliminate downstream processing steps
- > **Clean product:**
  - no further conditioning needed, pure hydrogen
- > **CO<sub>2</sub> sequestration ready:**
  - simplify CO<sub>2</sub> capture process
- > **Power co-generation:**
  - utilization of non-permeable syngas

# Advanced Inorganic Membranes for Biomass Gasification Application

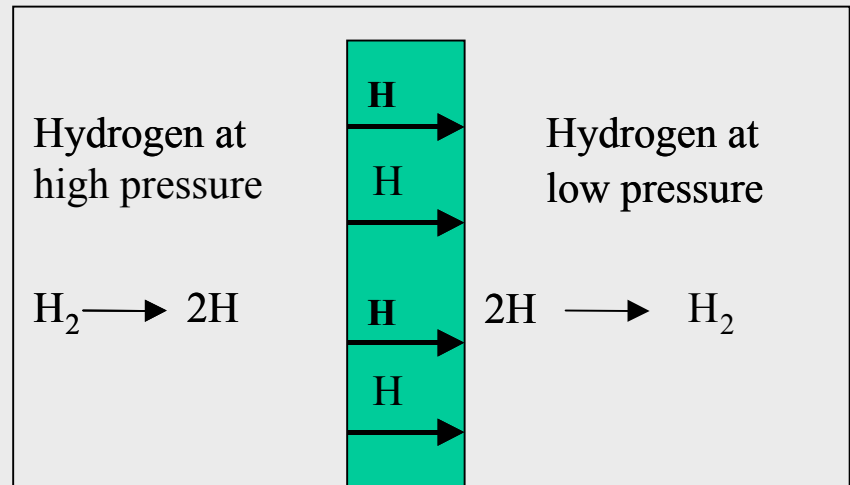
**Mixed proton/electron conducting membrane**

**Perovskite ceramic**



**Atomic transport dense metallic membrane**

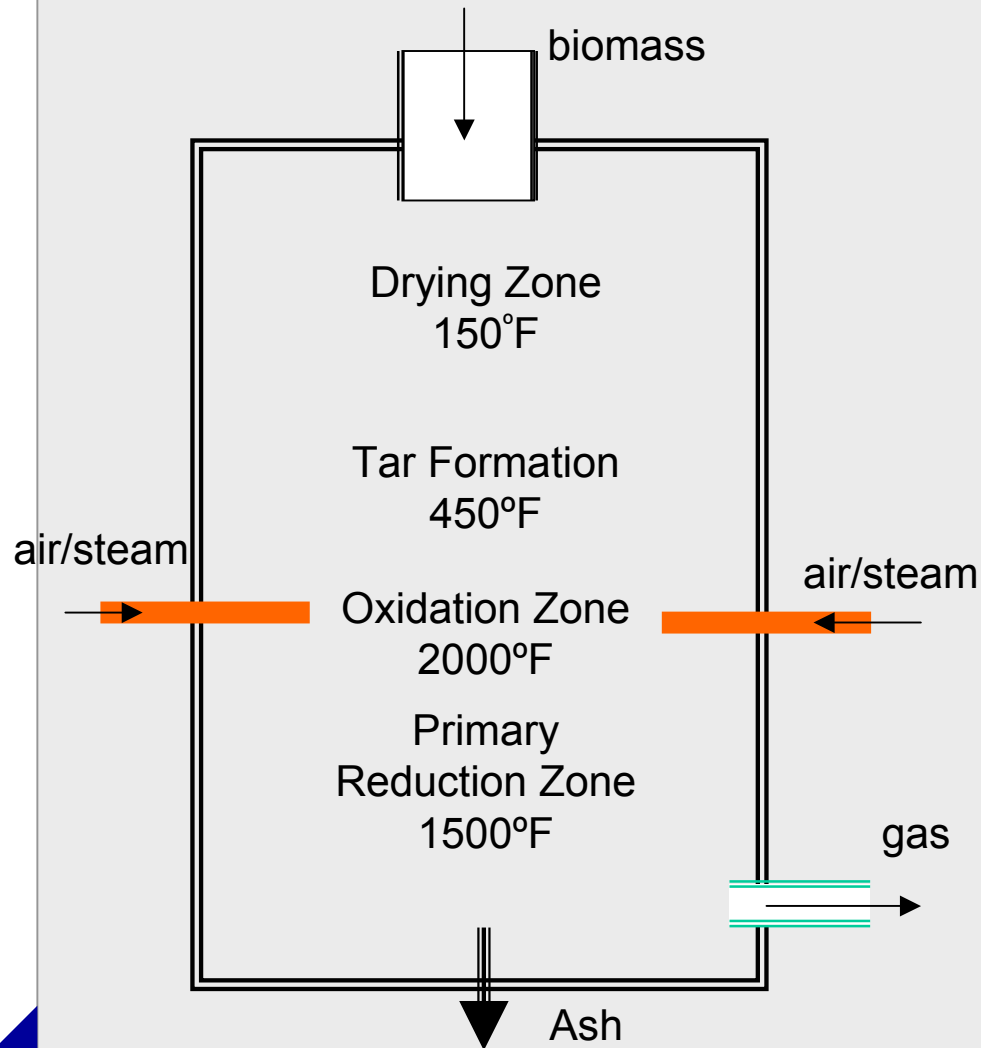
**Palladium-alloy**



# NRRI Biomass Gasification Facility



# Downdraft Biomass Gasification



# Characteristics of Downdraft Gasification of Biomass

## > Advantages

- Simple construction
- Nearly no tar in product gas
- High rate of carbon conversion

## > Disadvantages

- Lump or block size of feed, uneven gas distribution
- Low moisture content of fuel
- Difficult to scale up

## NRRI Biomass Downdraft Gasifier

- Manufactured by Biomass Corporation
- 270 lb/hr feed or 1.5 MMBtu/hr
- Equipped with a Caterpillar 6-cylinder engine, 100 KW
- Rotating grate for solid ash discharge



# Scope of Work

## > Task 1. Identify and Select Candidate Membrane Materials

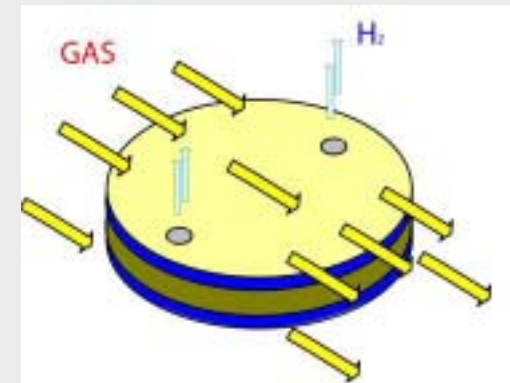
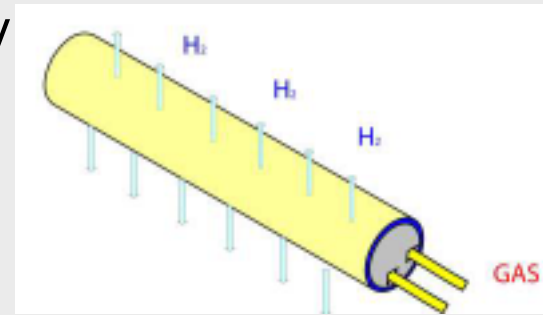
- Identify candidate membranes
- Procure and prepare membranes
- Test membranes for thermo and chemical stability
- Test membranes for hydrogen permeability



# Scope of Work (con't)

## > Task 2. Construct a Hydrogen Permeation Cell Unit

- Design and build a hydrogen permeation cell unit that can be transported to the NRRI facility for testing with their downdraft biomass gasifier unit
- Membrane geometry
  - Planar or tubular
- Membrane fabrication
- Cell module design
- Module construction



# Scope of Work (con't)

## > Task 3. Install, Instrument and Shake Down a Down Draft Biomass Gasification Unit

- Task 3.1 Feed Stock Preparation

  - Woody and agricultural (pelletized) biomass

- Task 3.2 Gasifier Installation

  - Unit in functional condition before being relocated to NRRI facility

  - Needs refurbishing

- Task 3.3 Commissioning

  - Conducted by NRRI with assistance from GTI

# Scope of Work (con't)

- > **Task 4. Test Hydrogen Permeation Unit Under Simulated Gas Conditions**
  - Test the new permeation unit under the controlled laboratory environments before shipped to the field.

# Scope of Work (con't)

## > Task 5. Integrated Testing of Hydrogen Permeation Unit and Down Draft Biomass Gasifier

- A slip stream from the downdraft biomass gasifier for the feed of the permeation unit
- Engine to consume excess syngas
- Continuous operation up to 5 days
- Full product gas characterization and gasifier performance assessment
- Demonstrate direct hydrogen production from biomass syngas
- Identify future development needs for membrane

# 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