

# Scale-Up of Hydrogen Transport Membranes for IGCC and FutureGen Plants

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PD009

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# Overview

## Timeline

- Phase I Start Oct. 1, 2005
- Phase II Start Oct. 1, 2009
- Phase II End June 2012
- ~75% Complete

## Budget

- Total project funding: \$8,824,788
  - DOE Share: \$7,059,830
  - Contractor Share: \$1,764,958
- FY10 funding: \$2,500,000
- FY11 funding: \$1,869,229

## Barriers Addressed

- Reducing hydrogen cost
- Membrane durability
- Membrane testing & analysis

## Partners

- Project Lead: Eltron R&D
- Partners: Eastman Chemical Co.

# Relevance

## Overall Program Objectives

- Cost-effective H<sub>2</sub> / CO<sub>2</sub> separation system
- Retains CO<sub>2</sub> at gasifier pressures
- Operates near water-gas shift conditions
- Tolerates reasonably achievable levels of coal impurities

## Objectives June 2010 – May 2011

- Membrane manufacturing – Scale-up
- Construct, Install, & Operate 12 lbs/day membrane reactor
- Continued bench-scale testing

# Technical Approach

- **Materials Development**
  - Membrane substrate manufacturer comparison
  - Catalyst deposition scale-up
- **Performance Screening**
  - Membrane testing under expected operating conditions for scale-up
  - Establish range of operating conditions
- **Mechanical Design**
  - Assess strength of materials, embrittlement, welding techniques, flow dynamics
  - Address manufacturing costs and maintenance issues
- **Process Design and Economics**
  - Integrate into IGCC flow sheets – with and without co-production of H<sub>2</sub> & power
  - Compare process economics versus other technologies
- **Scale-up steps**
  - 12 lbs/day H<sub>2</sub> production – coal-based syngas slipstream
  - 250 lbs/day H<sub>2</sub> production – coal-based syngas slipstream + WGCU

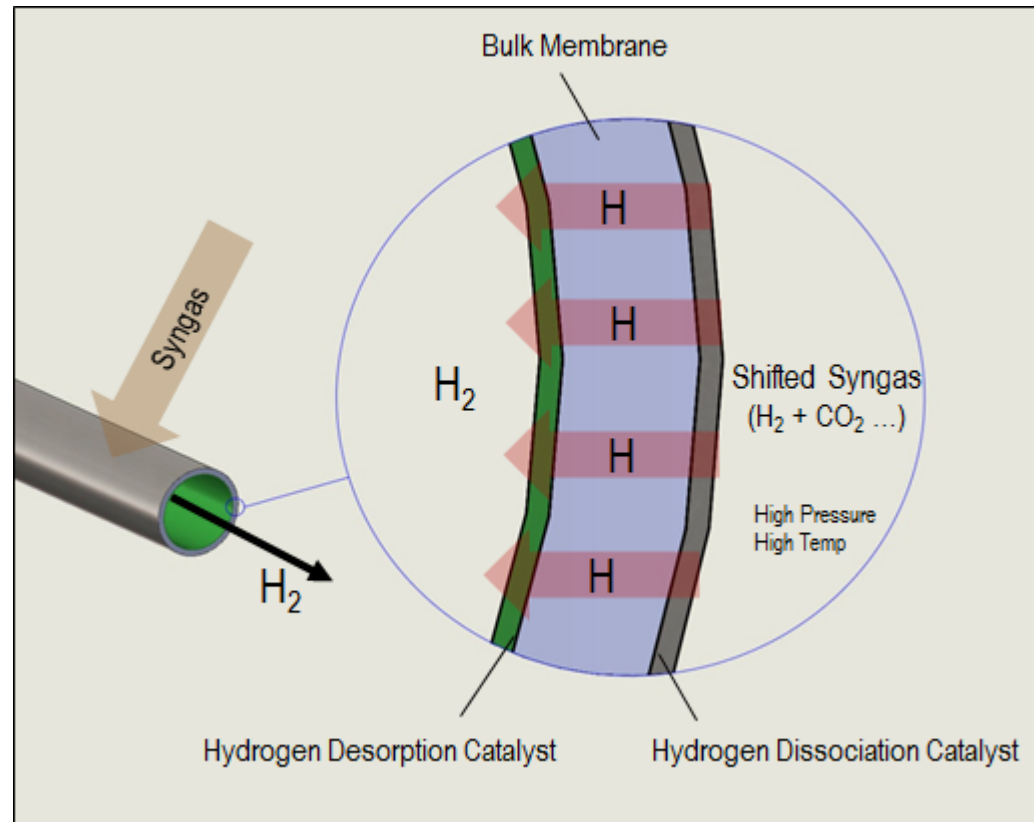
# Approach - Milestones

	Milestone
FY10 Q3	Complete membrane module design and skid layout. Status: Completed
FY10 Q4	Complete construction of 12 lbs/day unit. Status: Completed
FY11 Q1	Complete installation of the 12 lbs/day reactor. Status: Completed
FY11 Q2	Complete mechanical shake-down of the 12 lbs/day reactor. Status: Completed
FY11 Q3	Collect hydrogen separation material and process performance data on the 12 lbs/day reactor. Status: In Progress
FY11 Q4	Update process economics based on 12 lbs/day performance. Status: In Progress

# Eltron's Membrane System

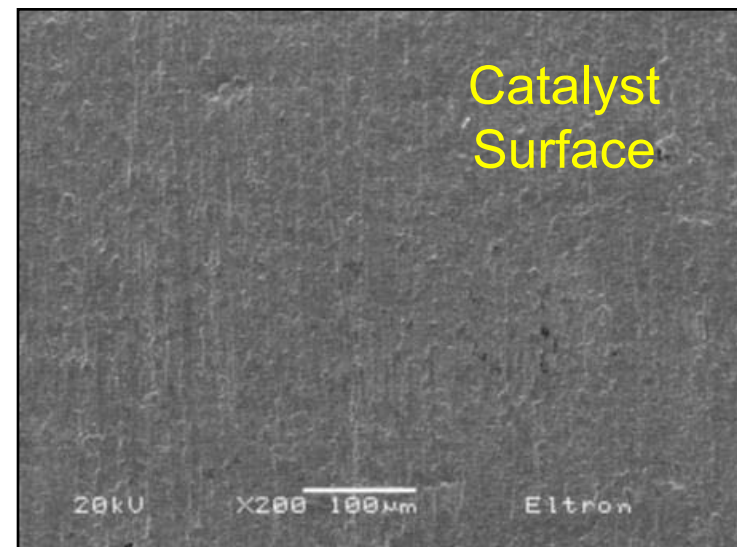
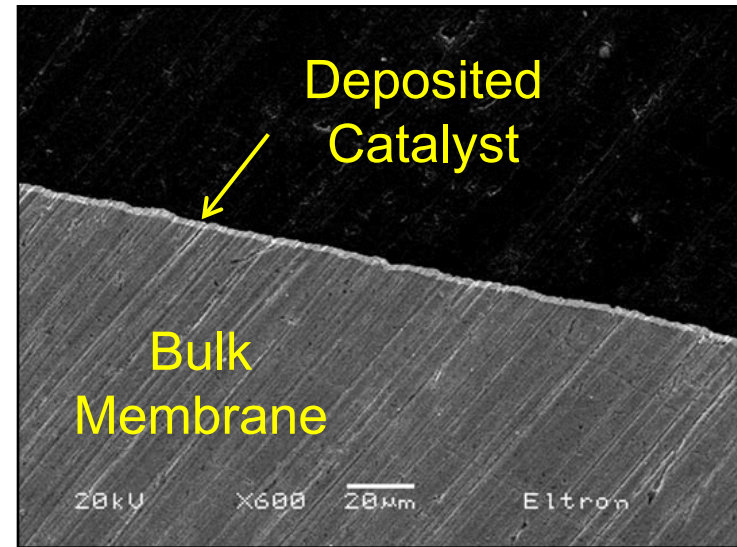
## Key Features

- 3-layer, dense metal alloy
  - Self-supporting
  - 100% selective
- CO<sub>2</sub> retained at high pressure
- Operates near water-gas shift temperatures.



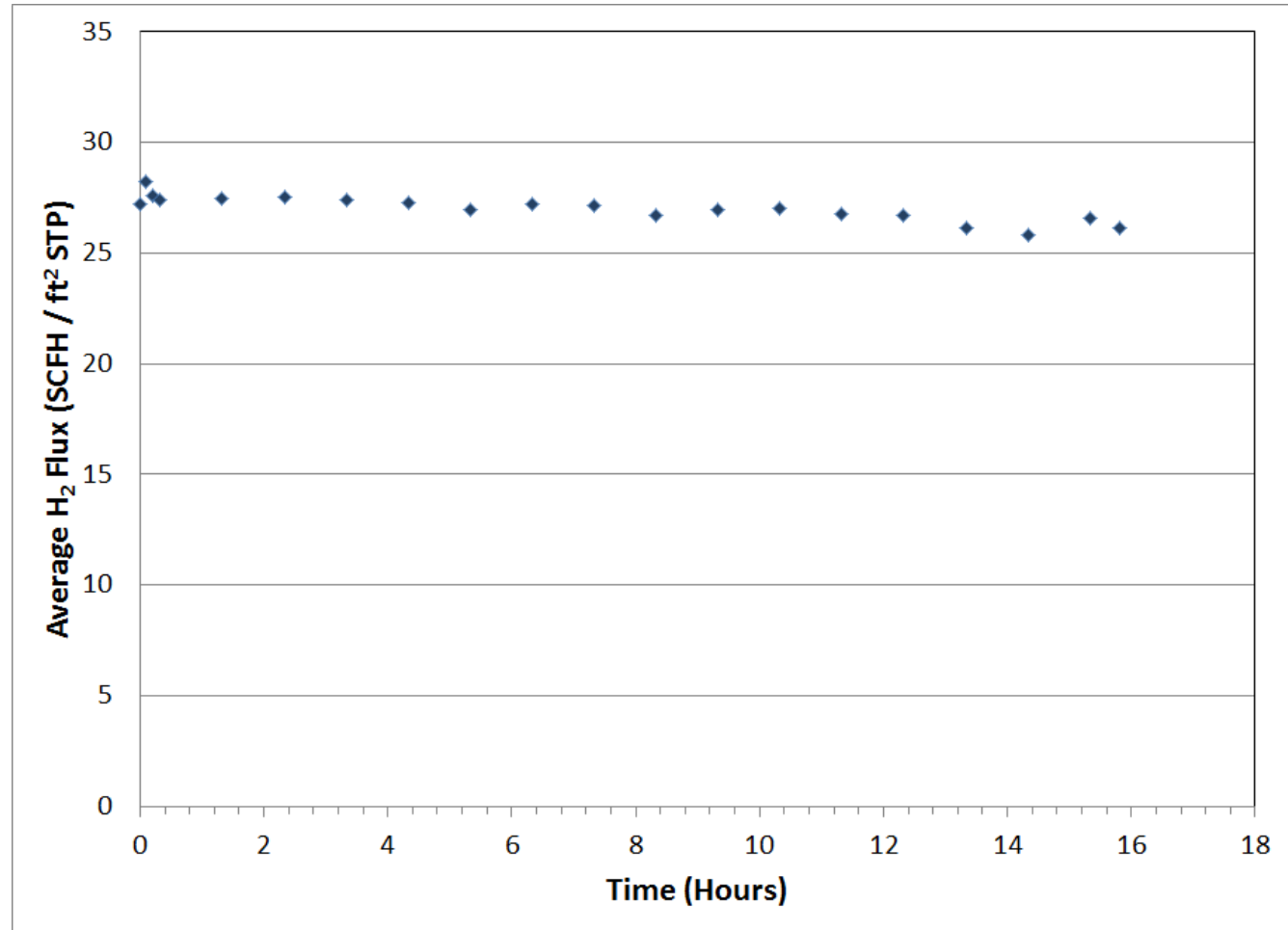
# Technical Accomplishments

- Membrane Manufacturing
  - 5' long membrane tubes
    - 1/2" OD
    - 500  $\mu\text{m}$  wall
  - Alloy catalyst deposited on the inside & outside surfaces
    - Uniform
    - Complete coverage



# Technical Accomplishments

- 2' Tubular Membrane
  - 500  $\mu\text{m}$
  - 340°C
  - Feed
    - WGS
    - 450 psig
  - Sweep
    - $\text{N}_2$
    - 50 psig
- 70%  $\text{H}_2$  Recovery

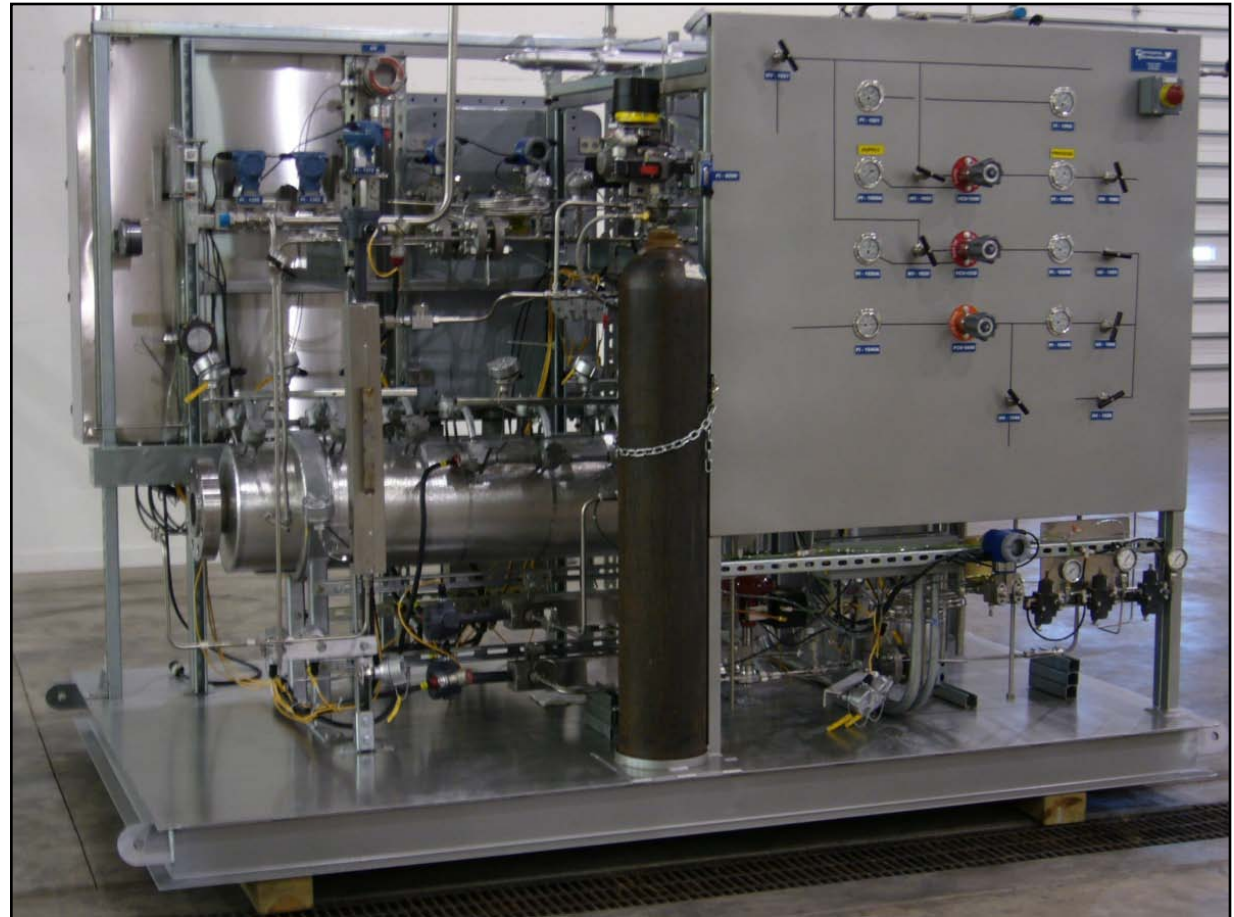




# Technical Accomplishments

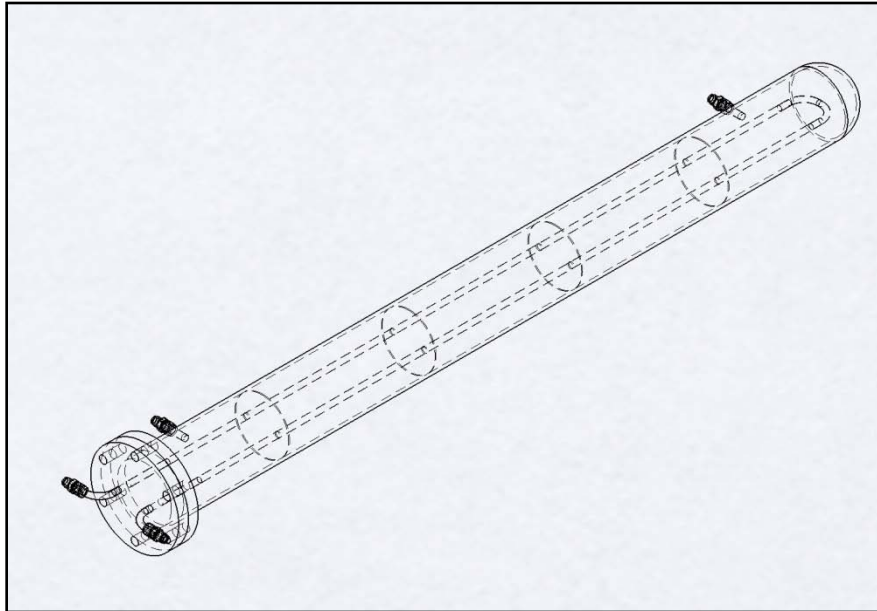
## 12 lbs/day H<sub>2</sub> Membrane Reactor Construction

- Skid Mounted System
- PLC Safety System
- 10' of ½" OD tubular membrane



# Technical Accomplishments

## 12 lbs/day H<sub>2</sub> Membrane Module



# Technical Accomplishments

## 12 lbs/day H<sub>2</sub> Membrane Reactor Installation

- Eastman Chemical Co. Kingsport, TN
- All utilities connected
- Mechanical shake-down
- Operator training

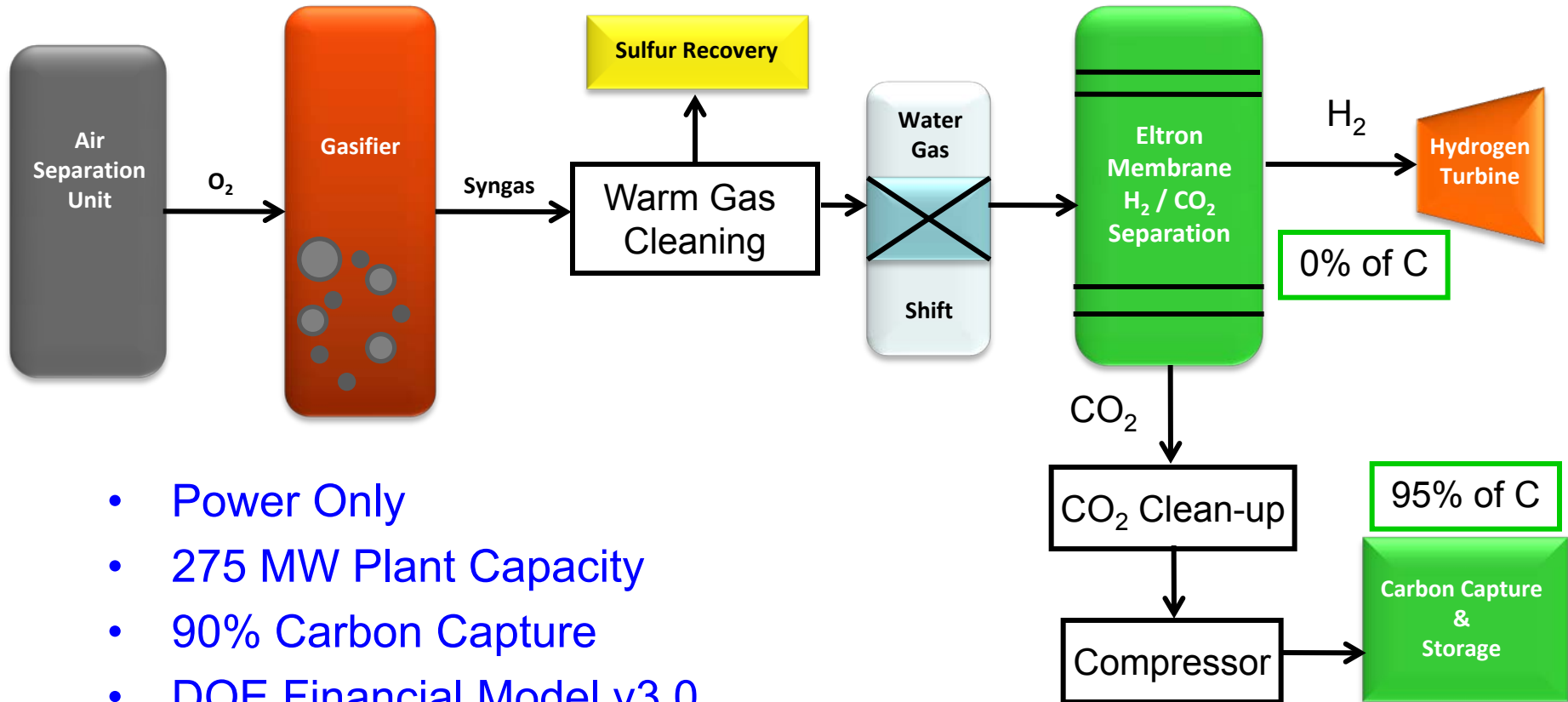
## Operation

- 30 days
- Effect of operating conditions under coal-derived syngas and operating procedures on membrane performance
- Cycling
- Lifetime



# Technical Accomplishments

Process Modeling / Techno-Economics



- Power Only
- 275 MW Plant Capacity
- 90% Carbon Capture
- DOE Financial Model v3.0

# Technical Accomplishments

- Process Modeling / Techno-Economics

	Case 1	Case 2	Case 3	Case 4
Pre-Combustion Gas Cleaning & CO <sub>2</sub> Capture Method	2-Stage Selexol	Cold Gas (Amine) Cleaning & Eltron Membrane	Warm Gas Cleaning & Eltron Membrane	Warm Gas Cleaning & Eltron Membrane
Gasifier Cooling Method	Quench	Radiant-Convective	Radiant-Convective	Quench
Thermal Efficiency	27.4%	32.0%	33.6%	31.6%
% CO <sub>2</sub> Captured	90%	90%	95%	95%
Cost of Electricity (\$/MWh)	115.5	114.5	106.0	100.4

# Collaborations

- Eltron Research & Development Inc.
  - Prime Contractor
- Eastman Chemical Co.
  - Subcontractor
  - Gasified coal slip-stream
  - WGCU
- Two Key Membrane Manufacturers

# Future Work

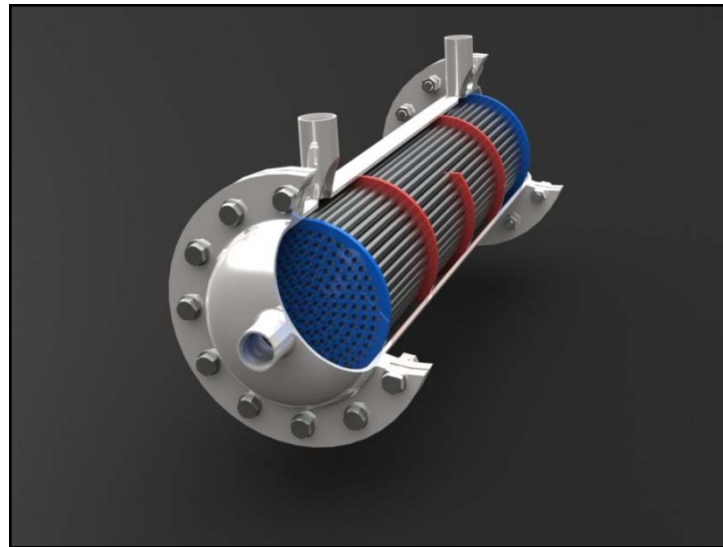
- FY2011 Q3
  - Operate 12 lbs/day H<sub>2</sub> Unit
- FY2011 Q4
  - Preliminary Design 250 lbs/day H<sub>2</sub> Unit
  - Go / No-Go Decision
- FY2012
  - Design, build, operate 250 lbs/day H<sub>2</sub> Unit integrated with WGCU

# Future Work – ARRA Project

- 10/1/10 - 9/30/15
- Total Project Cost: \$73.7 MM
- Scope
  - Accelerate 250 lbs/day pilot
  - Design, build, operate 4-10 T/day Pre-Commercial Module (PCM) demonstration reactor on coal-derived syngas
- Goal
  - Scale-up of HTM system for energy efficient carbon capture and hydrogen separation from industrial sources



# Future Work – ARRA Project

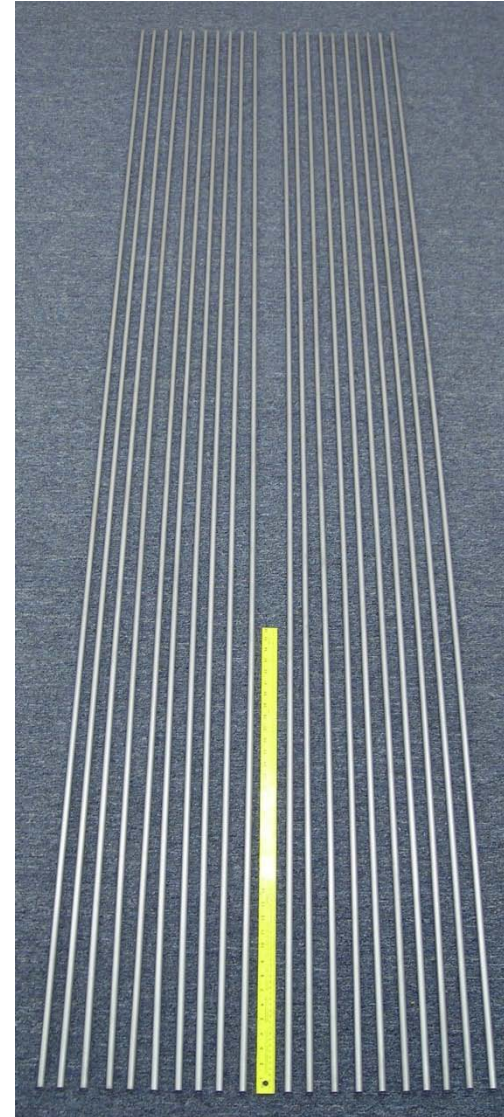


ID	Task Name	2010				2011				2012				2013				2014				2015			
		Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
1	<b>Scale-Up of Hydrogen Transport Membranes</b>	[Gantt bar: 2010 Q1 to 2015 Q4]																							
2	<b>Project Management</b>	[Gantt bar: 2010 Q1 to 2015 Q4]																							
3	<b>Task 1 Project Management, Planning, and Reporting</b>	[Gantt bar: 2010 Q1 to 2015 Q4]																							
8	<b>Membrane Scale-Up</b>	[Gantt bar: 2010 Q1 to 2013 Q4]																							
9	<b>Task 2 Membrane Technology Development Acceleration &amp; Scale-Up</b>	[Gantt bar: 2010 Q1 to 2013 Q4]																							
17	<b>Pre-Commercial Module</b>	[Gantt bar: 2010 Q1 to 2015 Q4]																							
18	<b>Task 3 PCM Pre-FEED</b>	[Gantt bar: 2010 Q1 to 2011 Q4]																							
21	<b>Task 4 PCM FEED</b>	[Gantt bar: 2011 Q1 to 2012 Q4]																							
24	<b>Task 5 PCM Detailed Design &amp; Construction</b>	[Gantt bar: 2012 Q1 to 2014 Q4]																							
29	<b>Task 6 PCM Operation &amp; Analysis</b>	[Gantt bar: 2014 Q1 to 2015 Q4]																							
32	<b>Task 7 Process Modeling, Techno-Economics, &amp; Commercial Applications E</b>	[Gantt bar: 2010 Q1 to 2015 Q4]																							

# Future Work

## ARRA Project - Status

- Cooperative agreement signed Feb. 18, 2011
- 10' tubular membrane procured
- RFP issued to EPC firms
- Evaluating 3 potential sites



# Summary

- **Relevance**
  - Cost-effective H<sub>2</sub> / CO<sub>2</sub> separation system
- **Approach**
  - Demonstrate performance and economics on gasified coal feed streams
- **Technical Accomplishments**
  - Catalyst deposition was successfully scaled up
  - 12 lbs/day reactor designed, constructed, installed at Eastman Chemical Co.
- **Collaborations**
  - Evaluating membrane substrate tubing from two manufacturers.
- **Future Work**
  - Scale-up testing on gasified coal feed stream
    - 250 lbs/day H<sub>2</sub> membrane unit

# Backup Slides

# DOE Performance Targets

Performance Criteria	2010 Target	2015 Target	Eltron Membrane
Flux (SCFH / ft <sup>2</sup> )	200	300	320
Operating Temperature (°C)	300-600	250-500	300-400
S Tolerance (ppmv)	2	20	2-20
System Cost (\$/ft <sup>2</sup> )	500	<250	<200
ΔP Operating Capability (psi)	400	800-1000	1000
Carbon Monoxide Tolerance	Yes	Yes	Yes
Hydrogen Purity (%)	99.5	99.99	99.999
Stability / Durability (Years)	3	>5	0.9
Permeate Pressure (psi)	N/A	N/A	>400