U.S. Department of Energy
Office of Fossil Energy

Hydrogen Production from Natural Gas

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Hydrogen Coordination Meeting

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Introduction

- Natural gas is currently the lowest cost alternative to produce hydrogen
- Natural gas provides 95% of the hydrogen used to supplement refinery and chemical industry needs
- Steam methane reforming (SMR), the most widely used method to produce hydrogen, is near its theoretical limits

Program Goal and Benefits

- Goal: Reduce the cost of producing hydrogen from natural gas by 25 percent

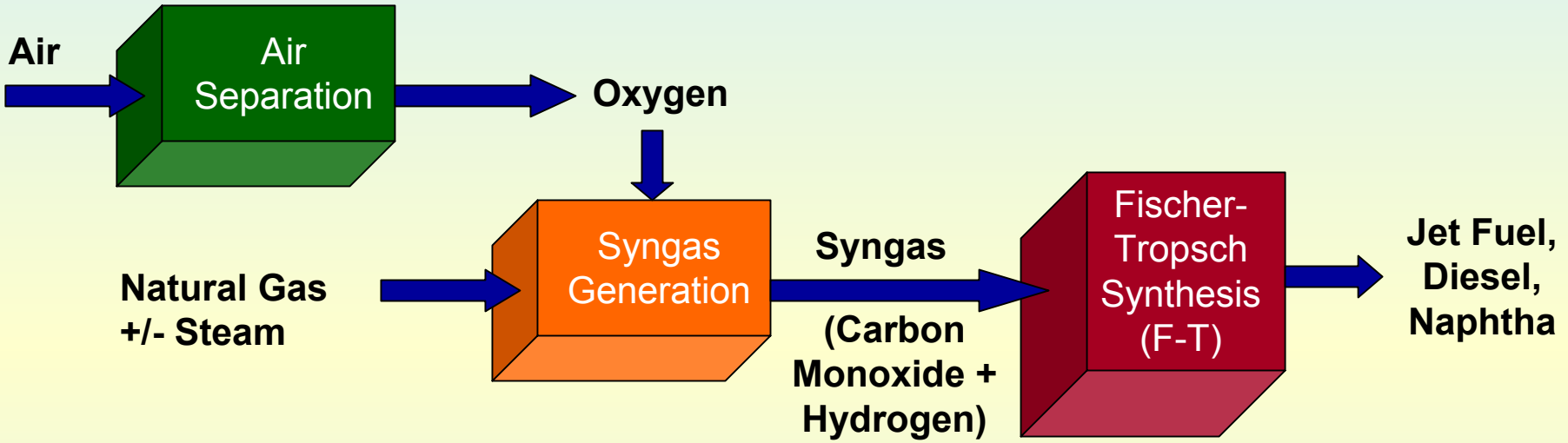
- Benefits:
  - Provide the earliest transitional source of hydrogen for the FreedomCAR program and the hydrogen economy
  - Provide near- and mid-term energy security and environmental benefits

History of the FE Hydrogen from Natural Gas Program

Past	Present	Future
GTL →	Syngas Production →	Emphasis on H_2 Production

- Platform Technology
- Membranes to separate O_2 from air and to partially combust CH_4
- Produces CO and H_2

Gas-to-Liquids (GTL) Process Overview



About 40% of Capital Cost is Associated With the Separation of Oxygen from Air

Membrane Technology to Eliminate Oxygen Plant

- **Ion Transport Membrane (ITM) Reactor – Air Products and Chemicals, Inc.**
- **Autothermal Reforming (ATR) – Praxair Inc.**

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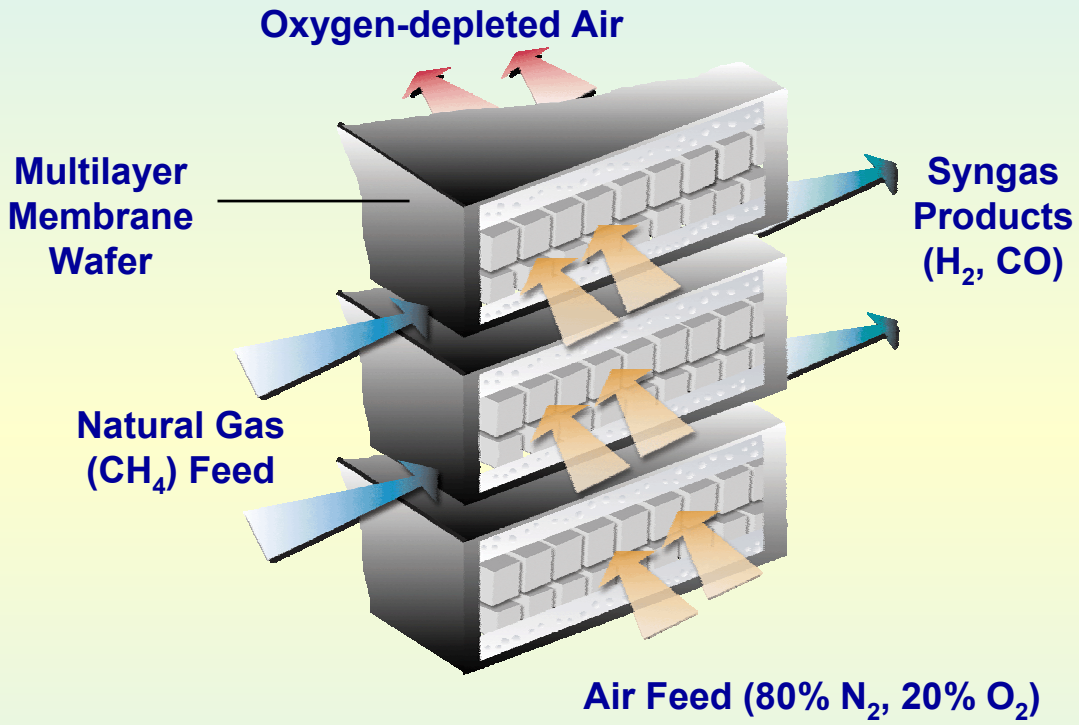
Revolutionary Platform Technology for Syngas Generation

- Ion Transport Membranes (ITM)
  - Non-porous, multi-component ceramic membranes
  - High oxygen flux
  - High selectivity for oxygen
- Platform technology leading to numerous applications
  - Hydrogen
  - Transportation fuels
  - Chemicals



$$CH_4 + \tfrac{1}{2} O_2 \xrightarrow{\text{catalyst}} CO + 2H_2$$

Operating Temperature 750°C to 1000°C
Operating Pressure 450 PSIA

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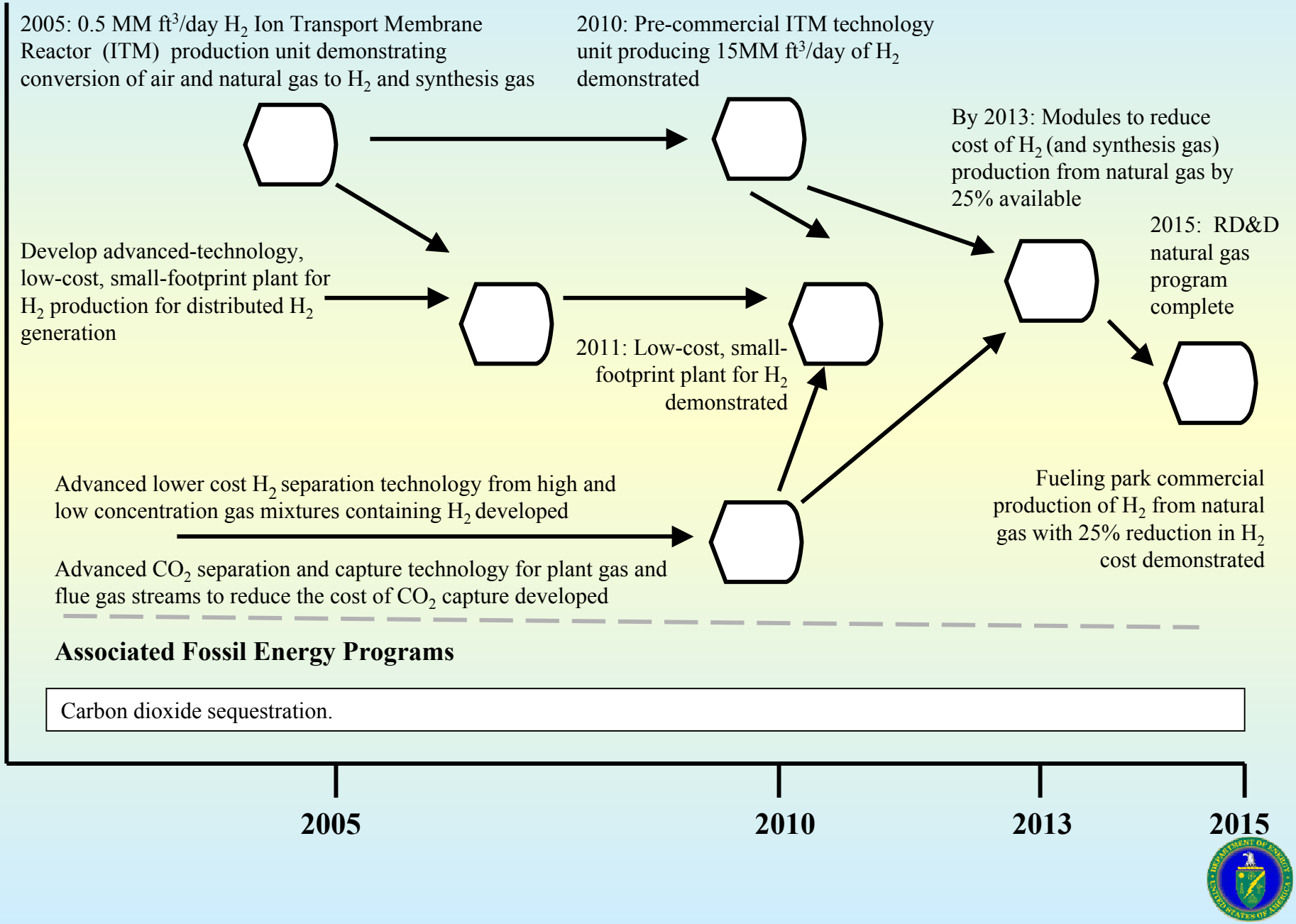
Hydrogen from Natural Gas Program Major Technical Milestones



Barriers to Hydrogen Production from Natural Gas

- Steam reforming and pressure swing adsorption are mature technologies – there is **limited potential** for cost improvements
- Small-scale hydrogen production from natural gas for on-site applications will reduce distribution infrastructure; however, current technology has high cost because it lacks economy of scale
- Carbon dioxide capture and sequestration is expensive
- Demonstrations of technologies are needed

Technology Gaps for Hydrogen Production from Natural Gas

- Novel hydrogen production that combines air separation and partial oxidation in one step [ion transport membrane (ITM) syngas reactor]
- Advanced hydrogen membrane separations
- Concentration and capture of carbon dioxide
- Demonstration of advanced technology concepts will enable commercialization

Mission

- Produce and deliver affordable H_2 with reduced or near-zero emissions

- Provide earliest transitional source of H_2 for FreedomCar

Approach

Industry solicitation for new H_2 production technologies

Partnership with National Laboratories for fundamental research

Limited solicitation for on-going projects in other program areas

In-house R&D at the National Energy Technology Laboratory (NETL)

Four UCF Projects in Oil and Gas Funding Table

Participant	Project	Funding ($millions)	
		FY03	FY04*
Praxair Inc.	NG to Syngas to F-T	2.5	TBD
Conoco	NG to Syngas to F-T	0	TBD
ICRC/Syntroleum	NG to Syngas to F-T	7.0	TBD
Air Products and Chemicals, Inc.	NG to Syngas	4.5	TBD

* FY04 funding to be determined (TBD). Not part of Hydrogen Initiative.

FE Hydrogen from Natural Gas Program Budget ($thousands)

	FY04 DOE Request	FY05 DOE Request
Hydrogen from Natural Gas	$6.555 million	TBD

The FE Hydrogen from Natural Gas Program funding in FY03 was zero (program did not exist). The FY05 request is to be determined.

Projects/Activities

- Air Products and Chemicals, Inc.
  - Eight-year, three-phase, $90 million government/industry-funded project
  - Ion Transport Membrane (ITM) synthesis gas reactor technology
- Praxair, Inc.
  - Four-year, $53 million government/industry-funded project
  - Oxygen Transport Membrane (OTM) synthesis gas reactor technology

Combines air separation and partial oxidation in one step

Reduced capital and operating costs

Lower emissions

Applicable for both large and small-scale operations

Projects/Activities (continued)

- Conoco Inc.
  - Five-year, $16.9 million government/industry-funded project
  - Life-cycle analyses and market assessment of synthesis gas-derived liquid fuels

- ICRC/Syntroleum
  - Three and a half-year, $38.3 million government/industry-funded project
  - Design and construct a modular, small footprint plant to produce synthesis gas-derived liquid fuels

Reduced capital and operating costs	***Reduced capital and operating costs***
Lower emissions	***Lower emissions***
	Mobile and easily modifiable to take advantage of diverse feedstocks

Outcomes

- 2011: Low-cost, small-footprint plant for H_2 demonstrated
- 2013: Modules to reduce cost of H_2 (and syngas) production from natural gas by 25% available
- 2015: Fueling park – commercial production of H_2 from natural gas with 25% reduction in H_2 cost demonstrated
- 2015: Hydrogen from Natural Gas RD&D Program complete