



Hydrogen Production from Coal

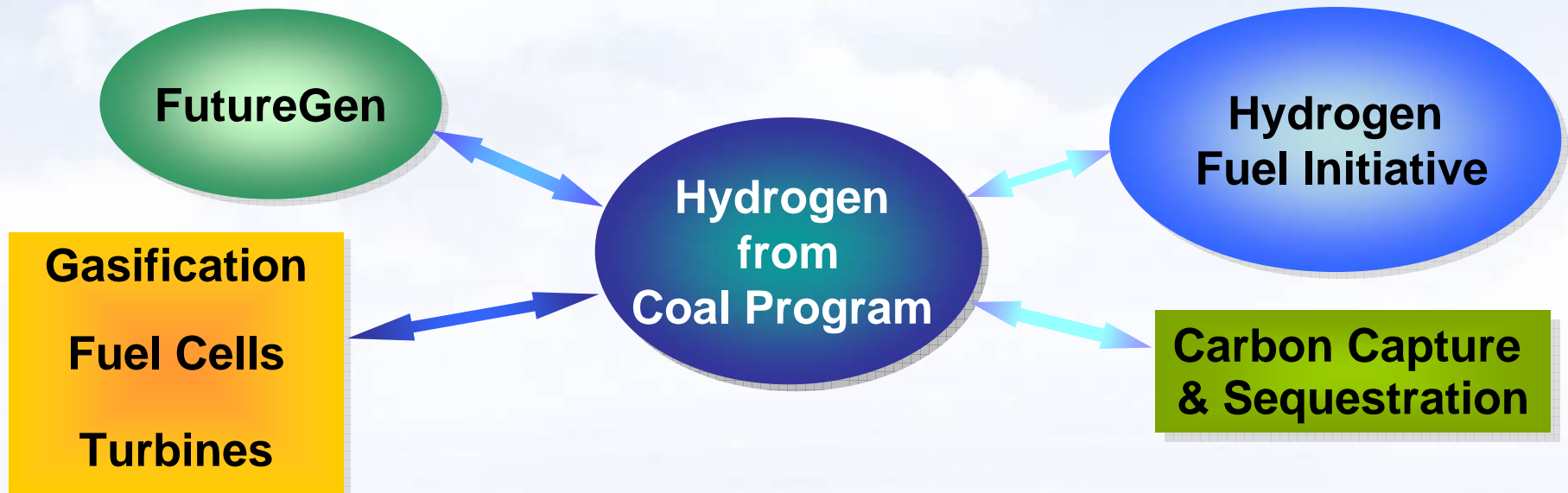
2005 Annual DOE Hydrogen Program Review

Edward Schmetz and Lowell Miller
Office of Sequestration, Hydrogen, and Clean Coal Fuels
May 23, 2005





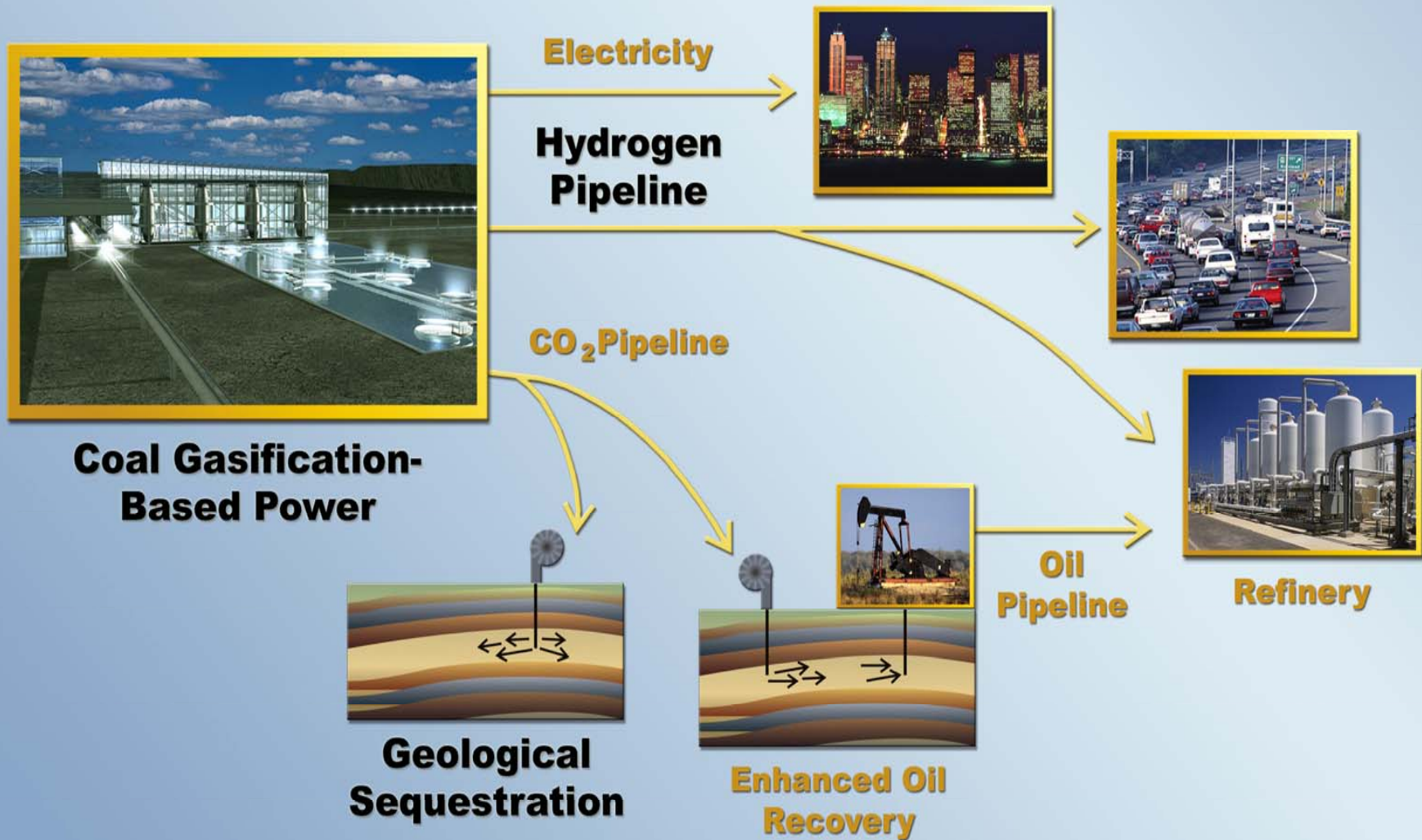
The Hydrogen from Coal Program is part of the Hydrogen Fuel Initiative and Supports the FutureGen Project



- The Hydrogen Fuel Initiative is a \$1.2 billion RD&D program to develop hydrogen production, storage, delivery, and utilization technologies
- FutureGen is an integrated sequestration and hydrogen research initiative to test advanced technologies in a world-scale co-production plant
- Hydrogen from Coal Program will coordinate with associated DOE programs in Gasification, Fuel Cells, Turbines, and Carbon Capture & Sequestration

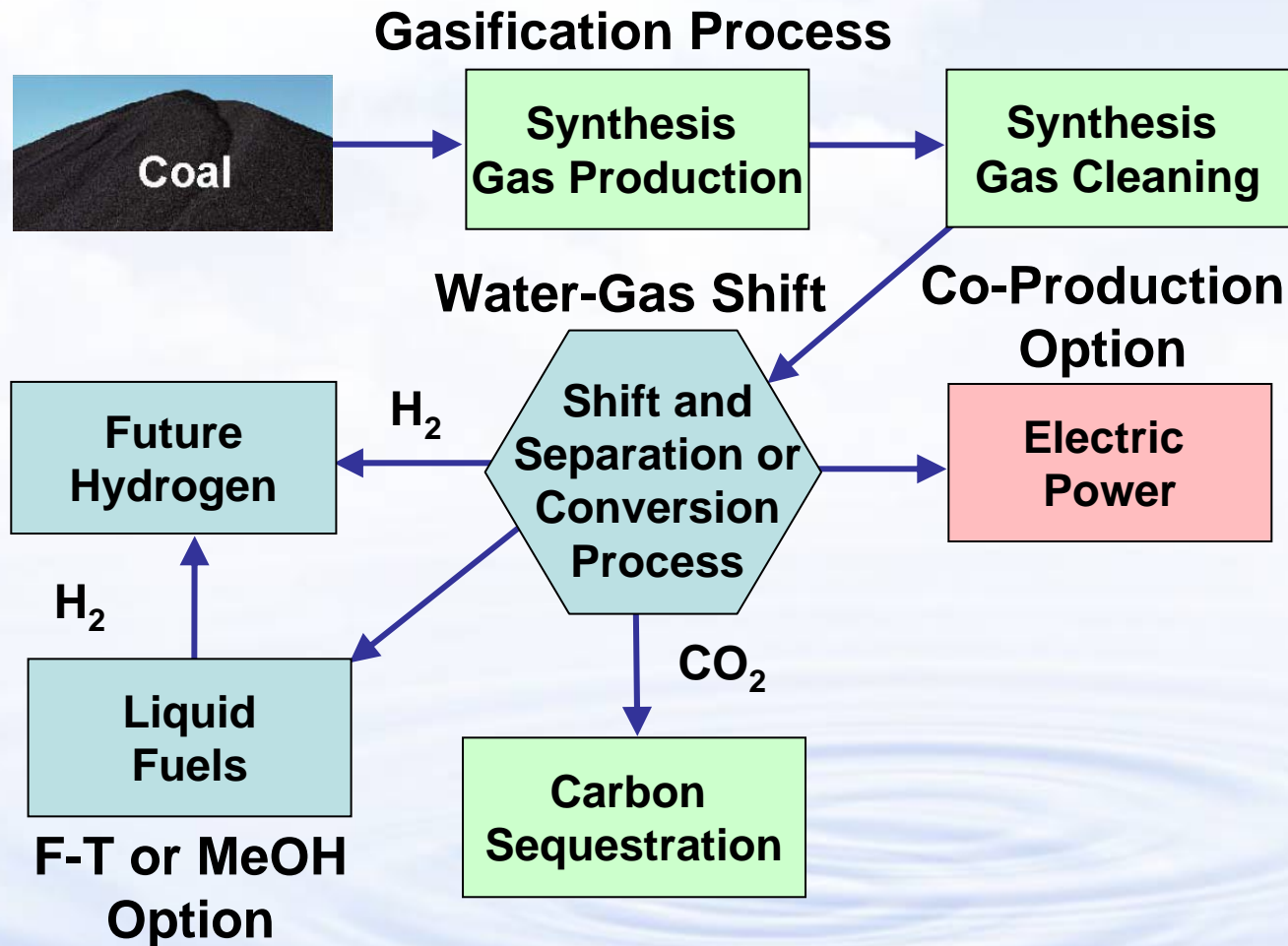


FutureGen Project Concept





Hydrogen is Cleanly Produced from Coal through Gasification



IGCC Plants provide the option for efficient hydrogen production with the ability to co-produce electricity and clean liquid fuels.



Summary of Hydrogen from Coal Cases



	Case 1	Case 2	Case 3
Gasifier*	Conventional	Advanced	Advanced
Separation System	PSA	Membrane	Membrane
Carbon Sequestration	Yes (87%)	Yes (100%)	Yes (100%)
Hydrogen Production (MMSCFD)	119	158	153
Coal (TPD) as received	3000	3000	6000
Efficiency (%) (HHV basis)	59	75.5	59
Excess Power (MW)	26.9	25	417
Capital (\$MM)	417	425	950
RSP of Hydrogen (\$/MMBtu) / (\$/kg)	8.18 / 1.10	5.89 / 0.79	3.98 / 0.54

* Conventional gasification technology assumes Texaco quench gasification; advanced gasification technology assumes advanced E-gas gasification. Plant boundary costs based on Mitretek Systems economic assumptions

Source: Hydrogen from Coal, Mitretek Technical Paper MTR 2002-31. July 2002.

- RD&D is estimated to reduce the cost of hydrogen from coal by 25%.
- Co-production of hydrogen and electricity can further reduce the cost of hydrogen production by 32%.



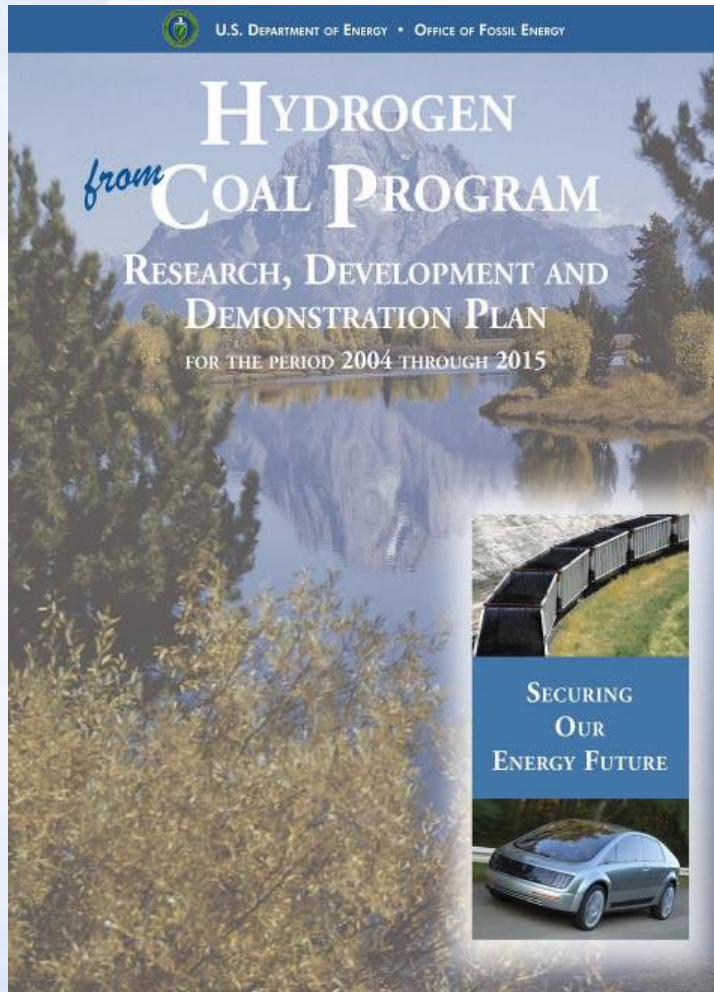
Hydrogen from Coal Barriers



- **Central production of hydrogen requires significant reduction in pathway cost**
- **Alternative route requires reduction in hydrogen carrier cost and cost of reforming liquid fuel to hydrogen**
- **Without improvements in hydrogen from coal technologies**
 - **Cost goals may not be met**
 - **Environmental benefits may not be realized**
- **Sequestration of carbon technology must be proven and cost effective to reduce environmental concerns over global warming**
- **Technology demonstrations are needed to validate integrated system with sequestration**



Hydrogen from Coal RD&D Plan



- **Addresses H₂ from Coal Program:**
 - Goals
 - Milestones
- **Defines:**
 - H₂ from coal pathways
 - Research areas
 - Technical targets
 - RD&D activities



Goal: Hydrogen From Coal

Facilitate the transition to a sustainable hydrogen economy through the use of coal, our largest domestic fossil resource



- **Production: Central Pathway**
 - **By 2015, demonstrate a 60% efficient, zero emissions, coal-fueled hydrogen and power co-production facility that reduces the cost of hydrogen by 25% compared to current coal-based technology**
- **Production: Hydrocarbon Pathway**
 - **By 2011, complete tests and evaluations of most promising hydrogen-rich, coal-derived liquids for hydrogen production through reforming applications**



Hydrogen from Coal Program Research Areas



Production

Separations

- Absorption/solvent separation systems
- Advanced Membrane Separation
- Membrane Reactors
- Polishing Filters
- Advanced Concepts
- Process Intensification
- Chemical Looping

Synthesis

- Gas-Derived Hydrogen-Rich Liquid Fuels
- Fuels Production
- Fuels Reforming
- Catalysts/Reactors

Delivery

Hydrogen & Natural Gas Mixtures

- Define feasible, low-cost delivery routes

Storage

High Hydrogen Affinity Material

- Metal Organic Frameworks
- Others

Utilization

Advanced Engines

- Hydrogen/Natural Gas Mix
- ### Polishing Filters (for ultra-clean hydrogen production)

Computational Science and Modeling – Supporting Sciences



Hydrogen Separation – Technical Targets



Performance Criteria	Current Status (Microporous)	2007 Target	2010 Target	2015 Target
Flux (a)	100	100	200	300
Temp, °C	300-600	400-700	300-600	250-500
S tolerance	Yes	Yes	Yes	Yes
Cost, \$/ft ²	150-200	150	100	<100
WGS Activity	Yes	Yes	Yes	Yes
ΔP Operating Capability (b)	100 (partial pressure)	100	Up to 400	Up to 800 to 1000
Carbon monoxide tolerance	Yes	Yes	Yes	Yes
Hydrogen Purity (c)	up to 98%	95%	99.5%	99.99%
Stability/Durability (years)	nd	3	7	>10



Steps Taken to Implement Hydrogen Fuel Initiative



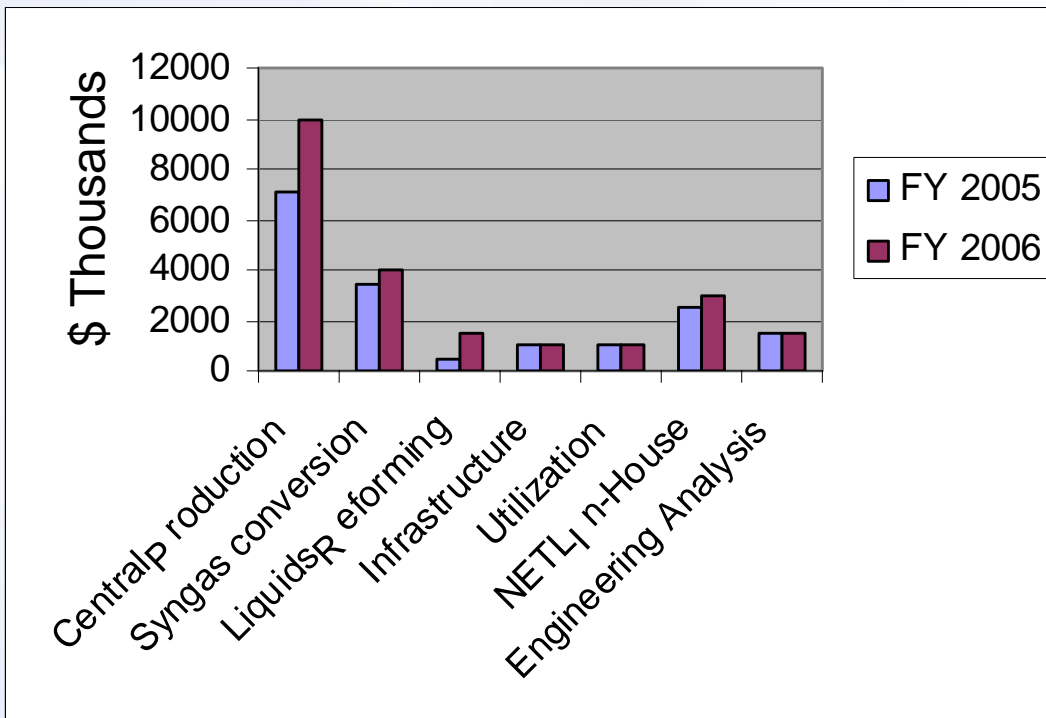
- **Organizationally combined Program Offices for Hydrogen from Coal and Carbon Capture and Storage**
- **Restructured and focused existing R&D Program to be responsive to new and existing coal R&D priorities**
- **Completed series of workshops and discussions leading to the drafting, publication and distribution of the Hydrogen from Coal RD&D Program Plan**
- **Distributed revised Sequestration Program Roadmap**
- **Hydrogen Program Implementation by Competitive Solicitations in FY 2004 & FY 2005**
- **Hydrogen from Coal RD&D Plan to be updated by 4th Quarter (FY 2005)**



Hydrogen from Coal Research Areas



FY 2006 Budget Request \$ 22.0 M
FY 2005 Appropriation \$ 17.0 M



ACTIVE PROJECTS *

Membrane research	5
Module Scale-up	1
Membrane reactors	2
CO ₂ removal	1
Liquid H ₂ carriers	1
Storage	1
Utilization	<u>5</u>

TOTAL ACTIVE 16

NEGOTIATION

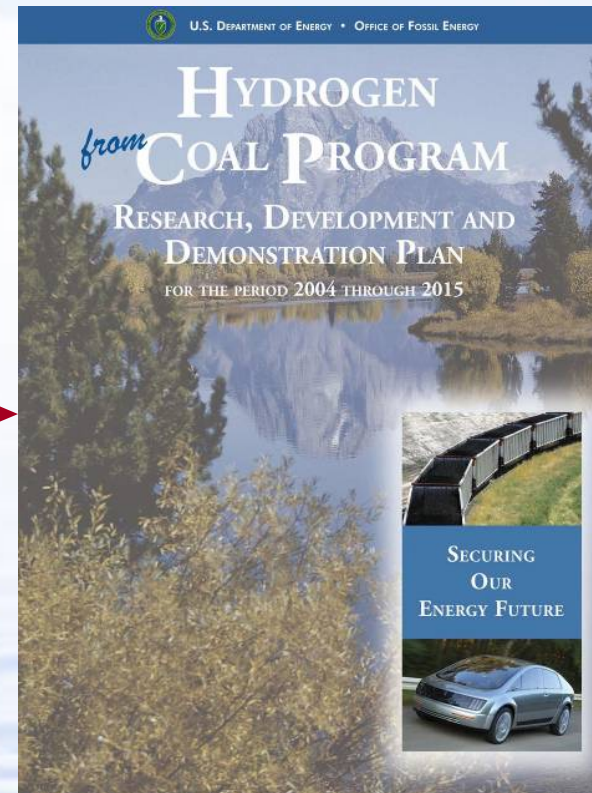
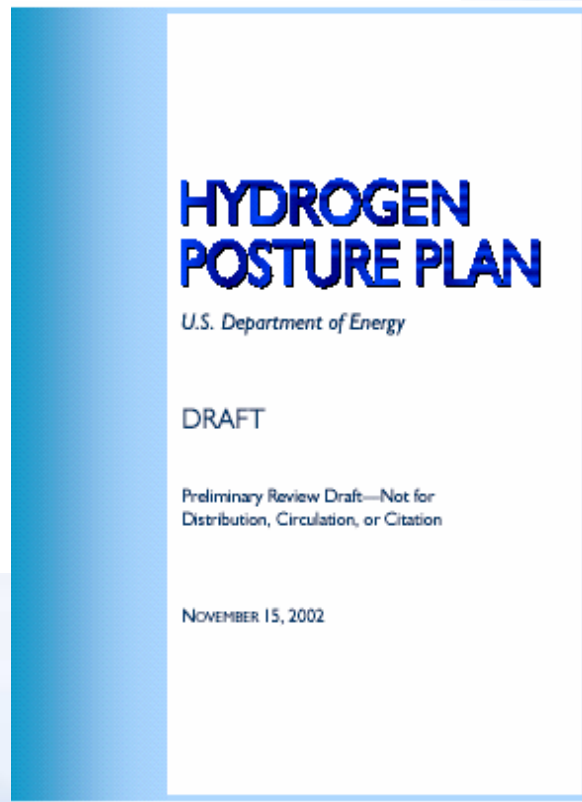
Membrane research	1
Membrane reactor & process intensification	5
Novel sorbent	1
Liquid H ₂ Carriers	3
Storage	<u>2</u>

TOTAL NEGOTIATION 12

* Complementary projects are supported by the Gasification & Sequestration Programs.



Hydrogen from Coal – Clean, Secure, Affordable Energy for the Future



<http://fossil.energy.gov/programs/fuels/>



Back-up Slides



Financial Assumptions for Case Studies



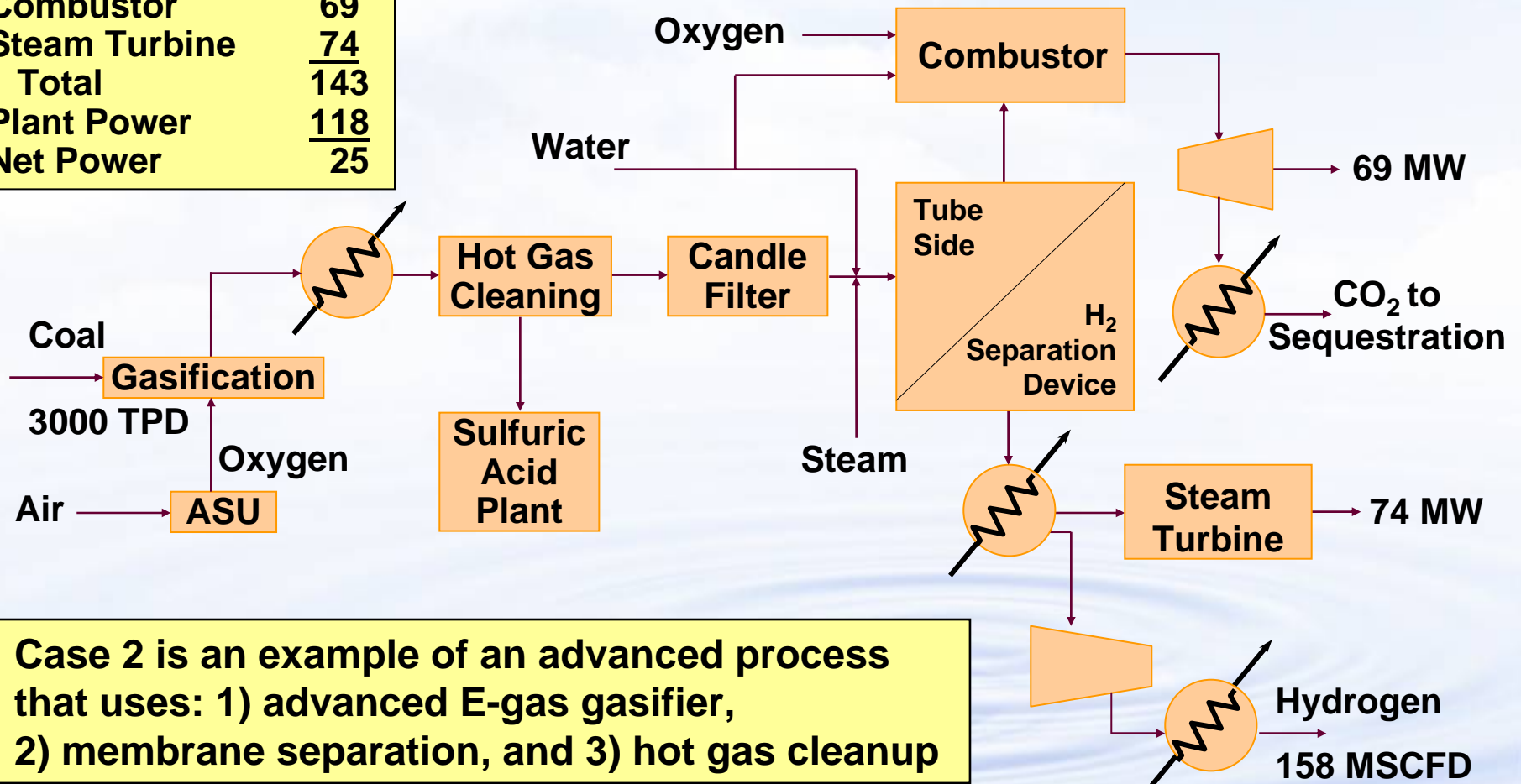
- **25 year plant life**
- **67/33 % debt/equity financing**
- **15 % return on equity**
- **8 % interest, 16 year term**
- **3 % inflation (coal de-escalation of 1.5 % per annum below general inflation)**
- **16 year DDB depreciation**
- **40 % combined Federal and State tax rate**
- **3 year construction, 50 % output in start-up year**
- **Sequestration of high pressure CO₂ stream costs \$10/ton carbon**



Case 2: Hydrogen from Coal Using Membrane Separation (Sequestration)



Power Summary	MW
Combustor	69
Steam Turbine	74
Total	143
Plant Power	118
Net Power	25

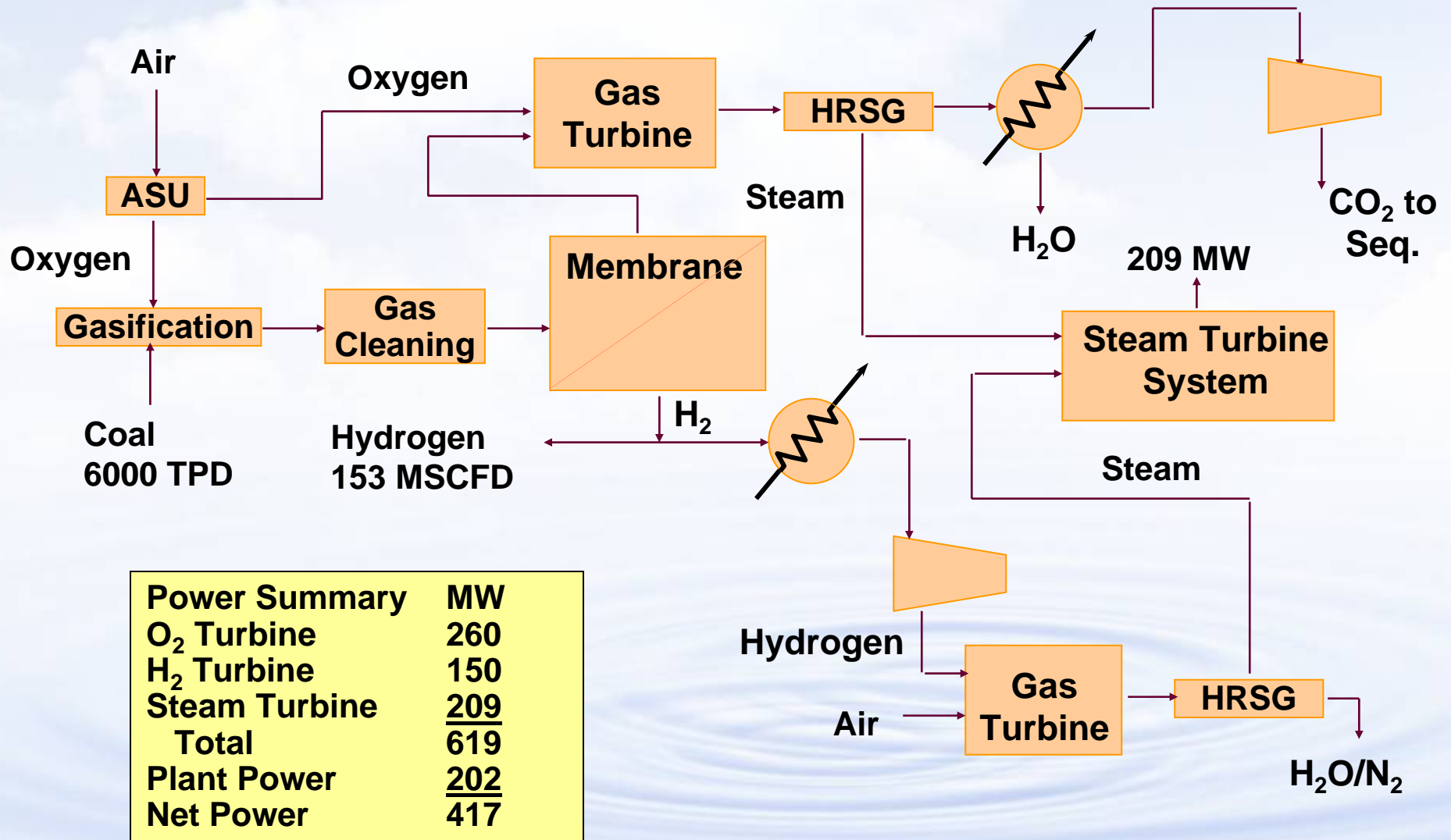


- Case 2 is an example of an advanced process that uses: 1) advanced E-gas gasifier, 2) membrane separation, and 3) hot gas cleanup

Source: Hydrogen from Coal, Mitretek Technical Paper MTR 2002-31. July 2002.



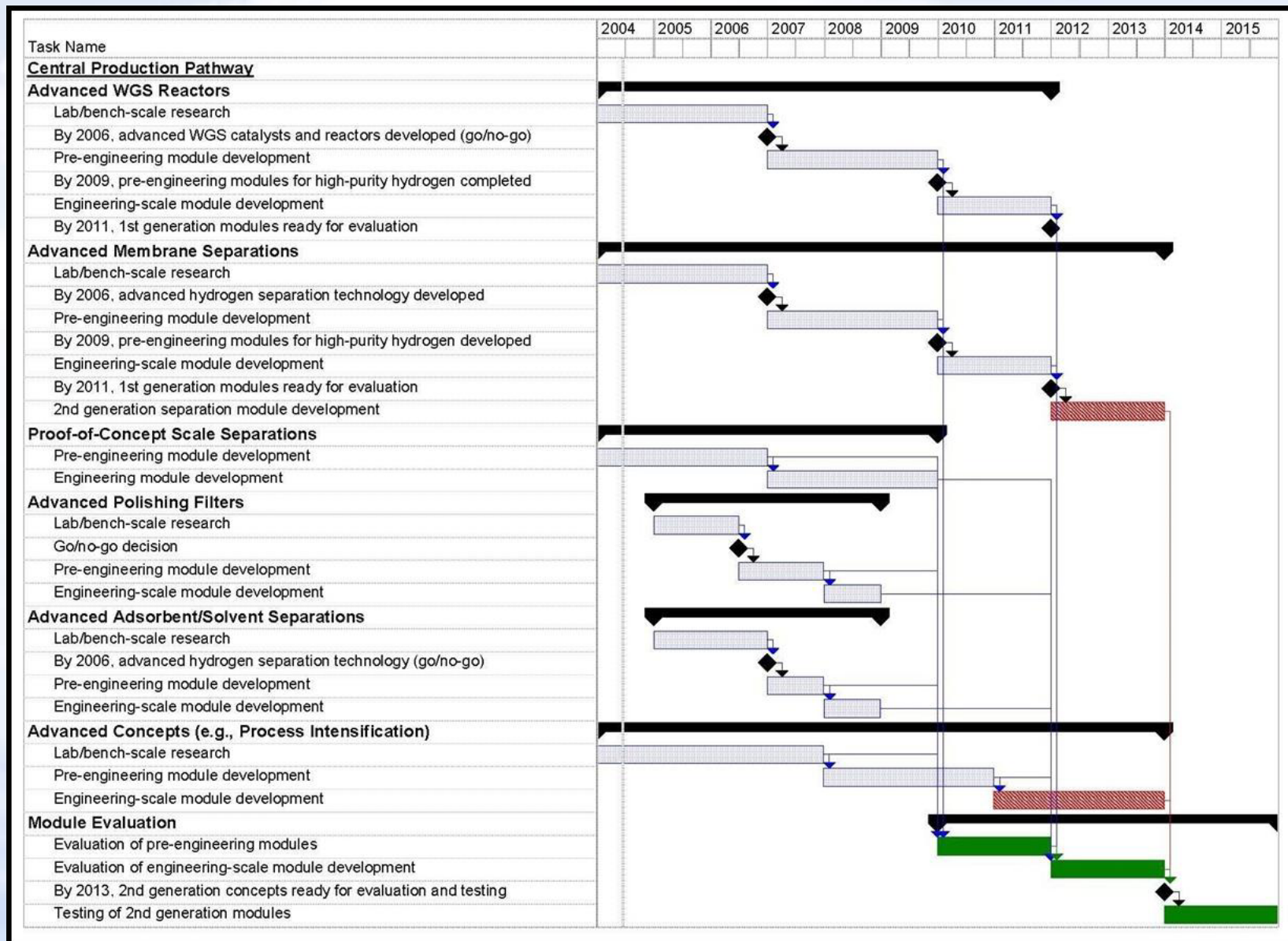
Case 3: Advanced Hydrogen from Coal with Co-Production/ Sequestration



Source: Hydrogen from Coal, Mitretek Technical Paper MTR 2002-31. July 2002.

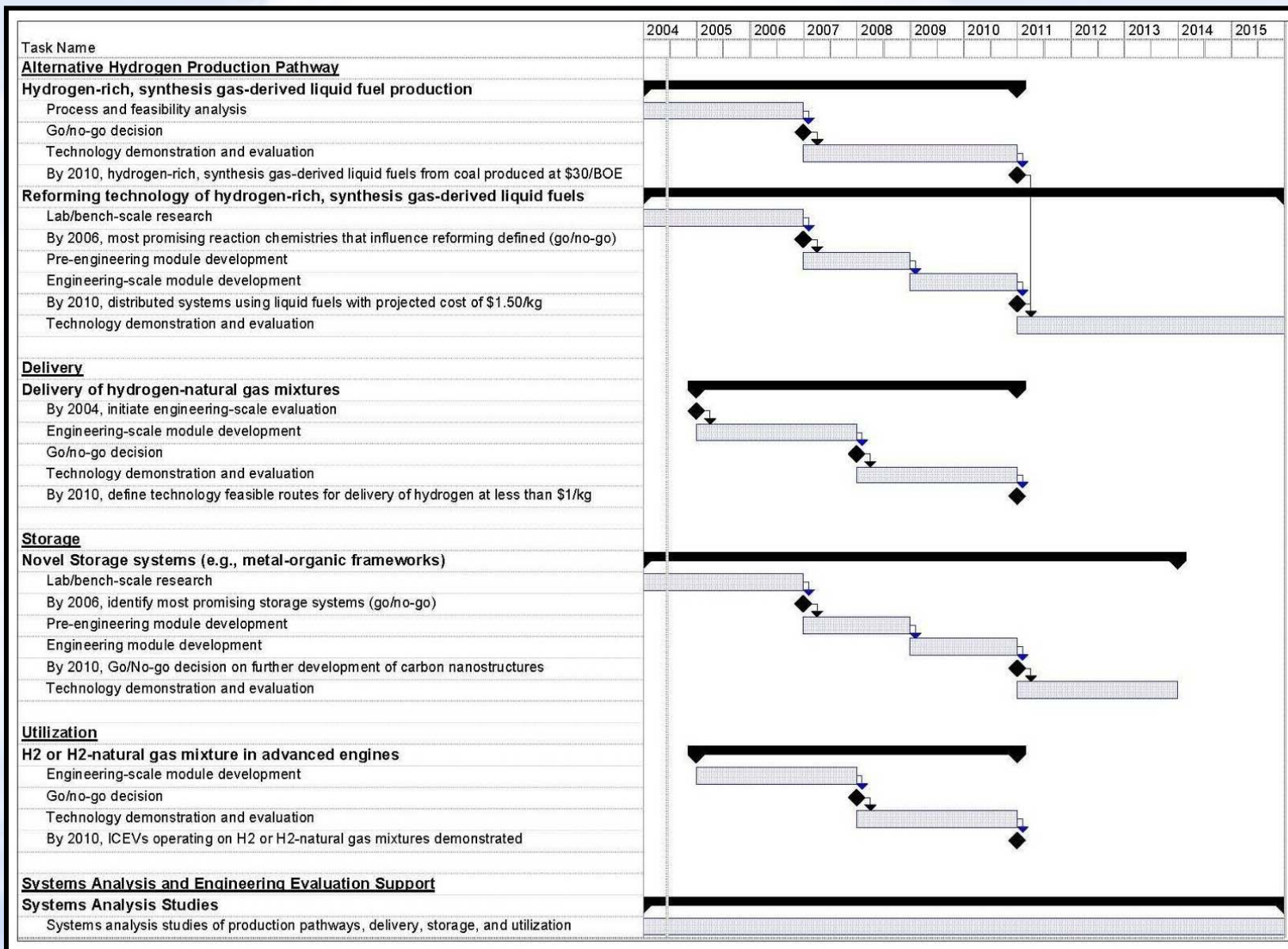


Hydrogen From Coal Program Gantt Chart (1)





Hydrogen From Coal Program Gantt Chart (2)





Hydrogen from Coal Technology

