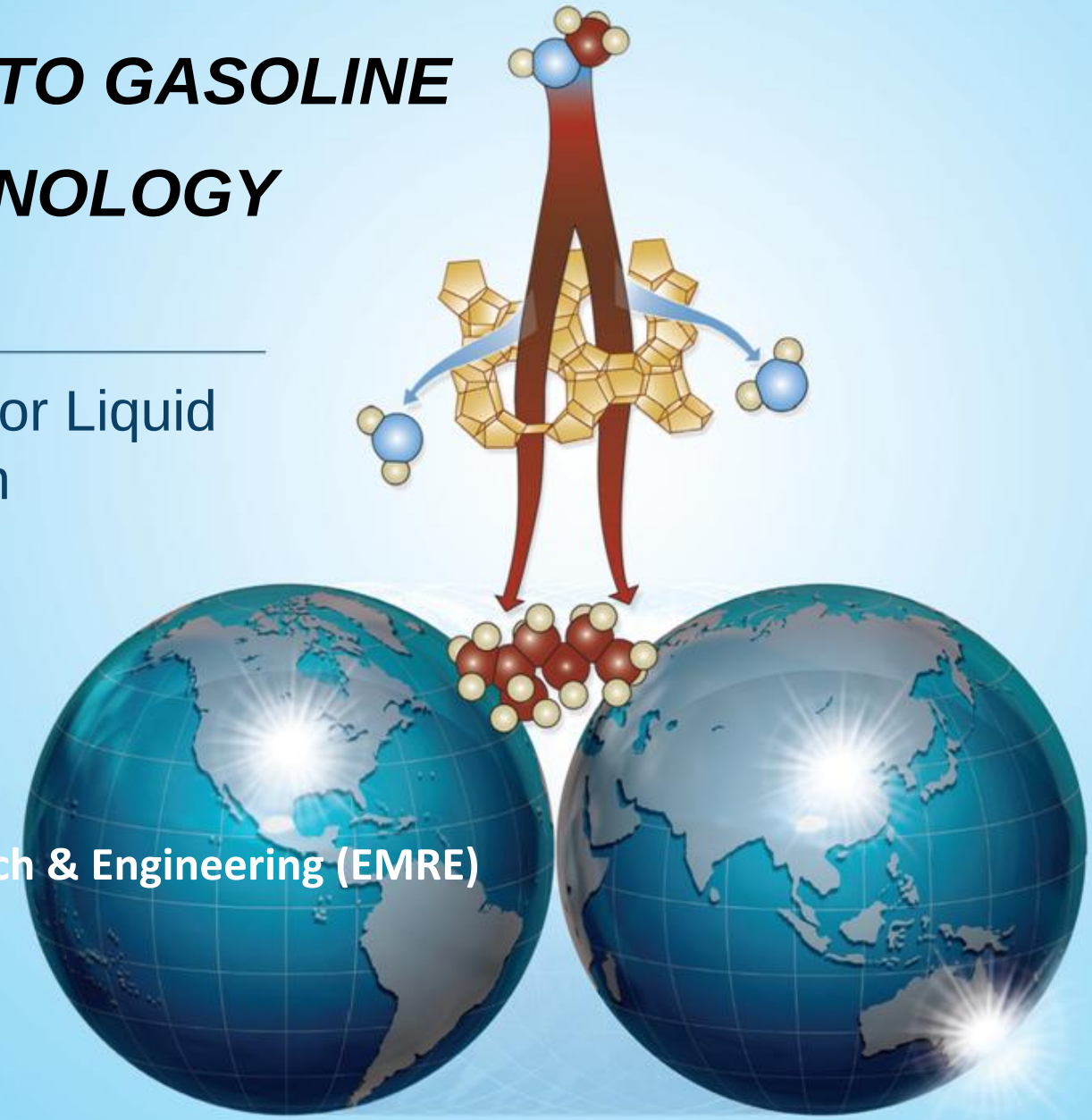
METHANOL TO GASOLINE (MTG) TECHNOLOGY

An Alternative for Liquid Fuel Production



Mitch Hindman
ExxonMobil Research & Engineering (EMRE)

ExxonMobil Research and Engineering

World CTL Conference

World CTL 2010

AGENDA

- Coal/Biomass to Liquid Fuels Background
- EMRE Methanol to Gasoline Technology
- MTG and Fischer-Tropsch Comparative Analysis
- EMRE MTG Licensing – The MTG Advantage

Coal/Biomass TO LIQUID FUELS BACKGROUND

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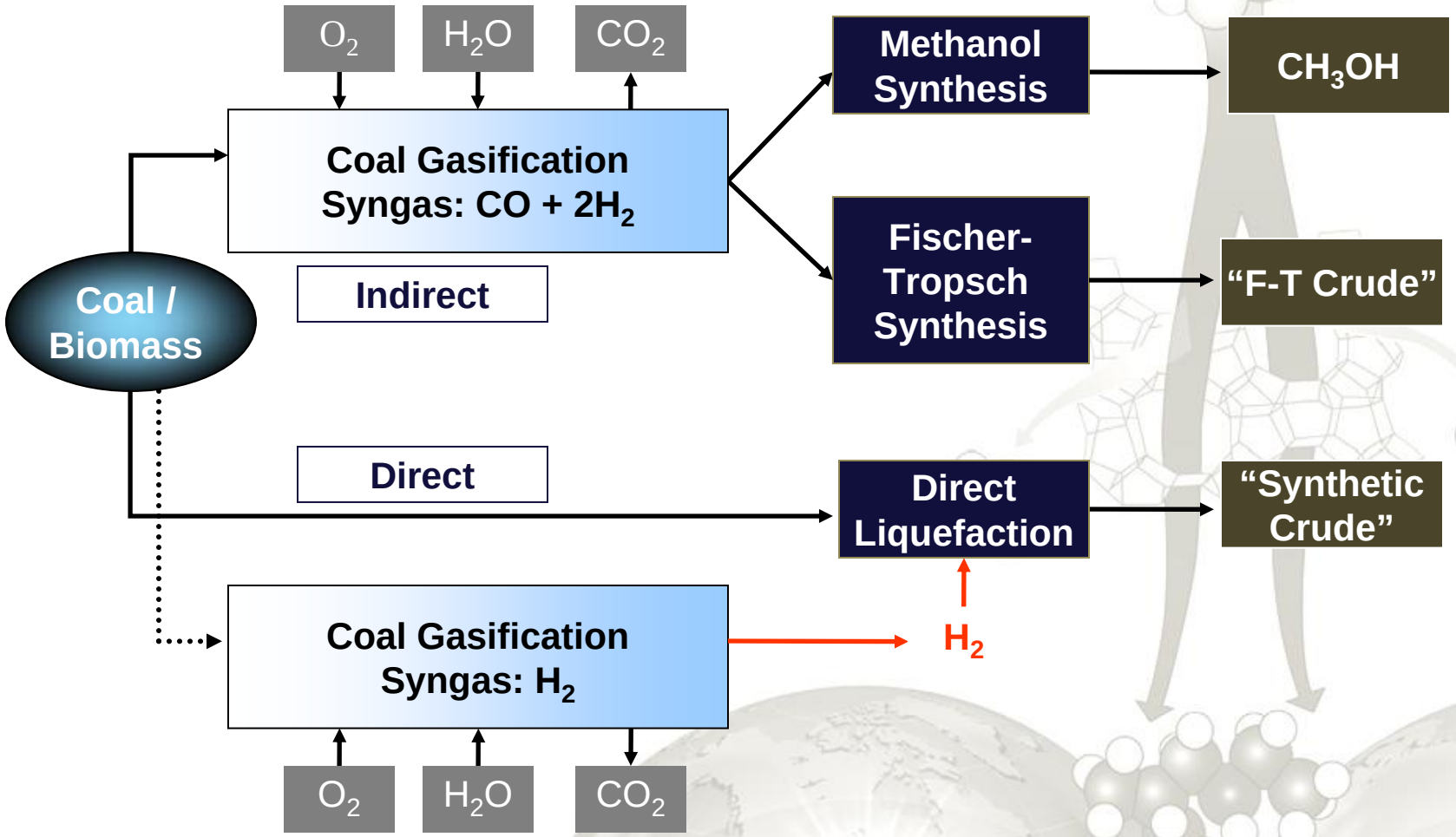
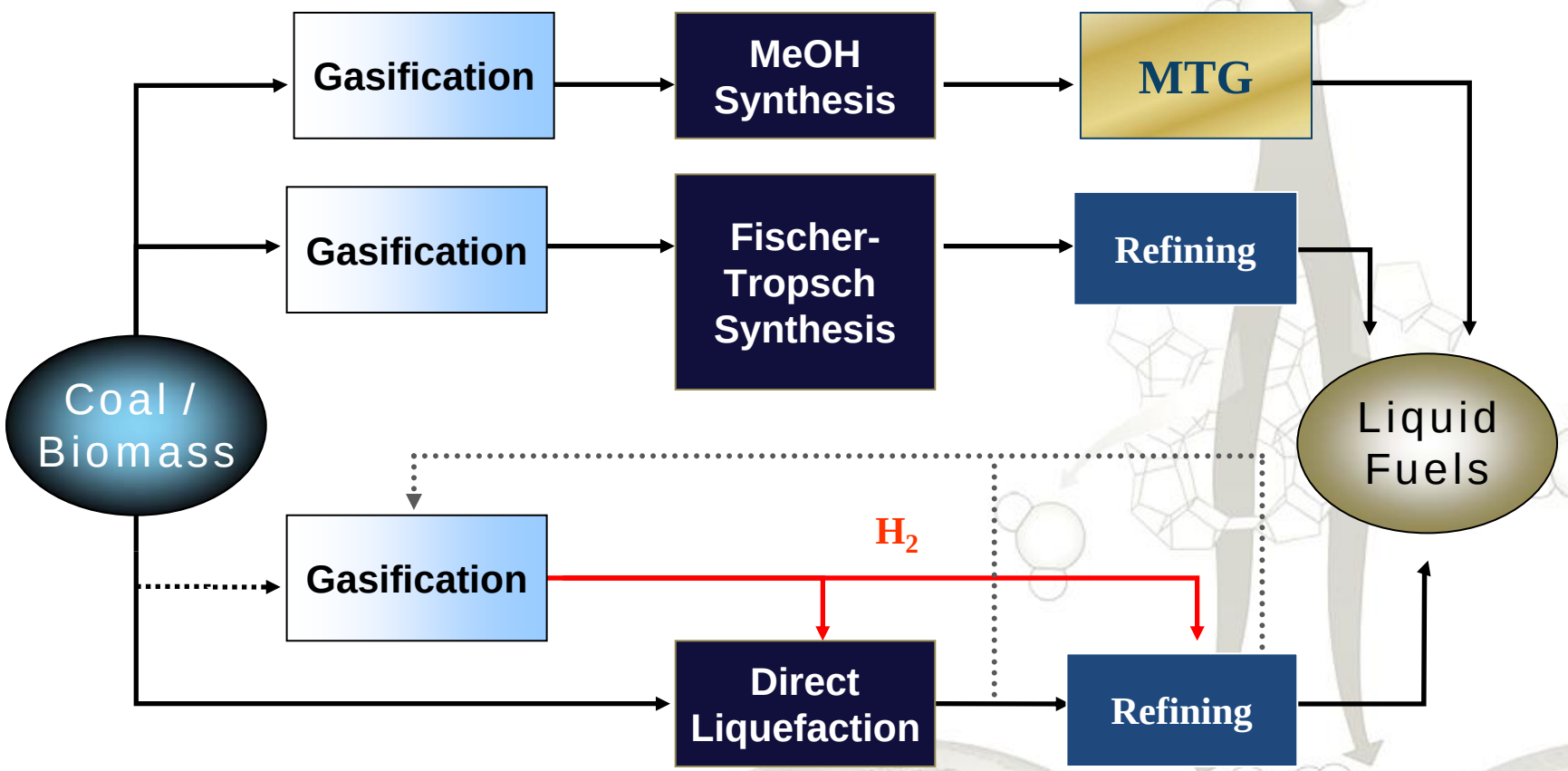
OPTIONS FOR COAL LIQUEFACTION



OPTIONS FOR COAL TO LIQUID FUELS



EMRE METHANOL TO GASOLINE TECHNOLOGY

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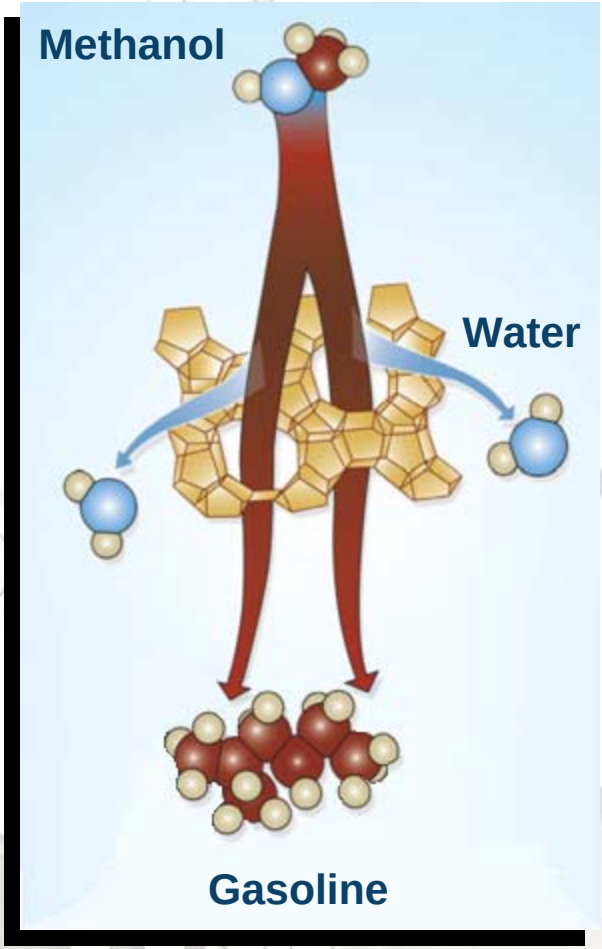
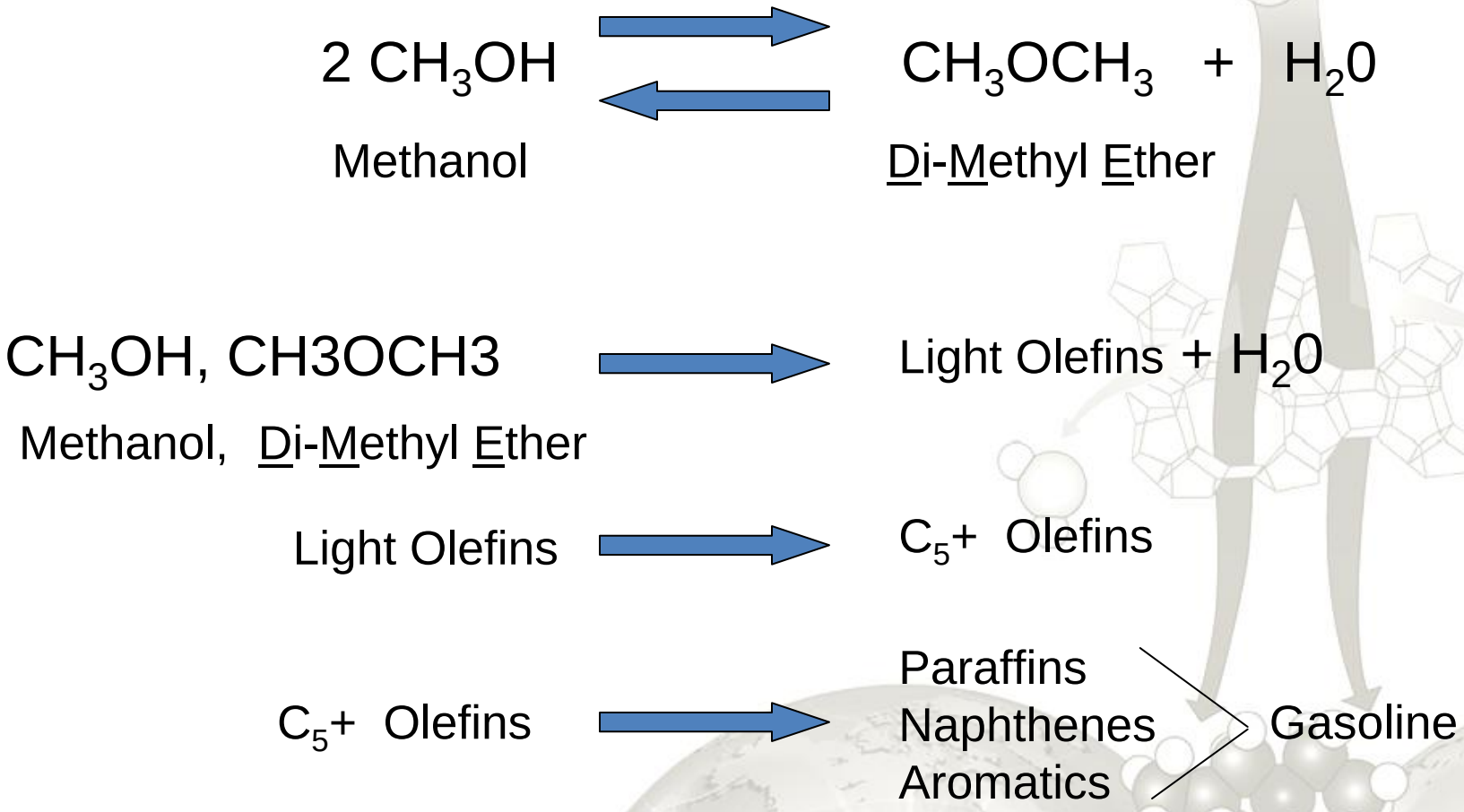
EXXONMOBIL MTG TECHNOLOGY

- MTG reactions de-hydrate methanol and convert the available carbon and hydrogen into various hydrocarbons
- The “Shape Selective” MTG catalyst limits the synthesis reactions to 10 carbons
- The result is sulfur free gasoline with a typical 92 Research Octane
- The first MTG plant was operated in New Zealand from 1985 to 1997 converting natural gas to gasoline



MTG REACTION PATH



MTG YIELDS AND PROPERTIES/COMPOSITION

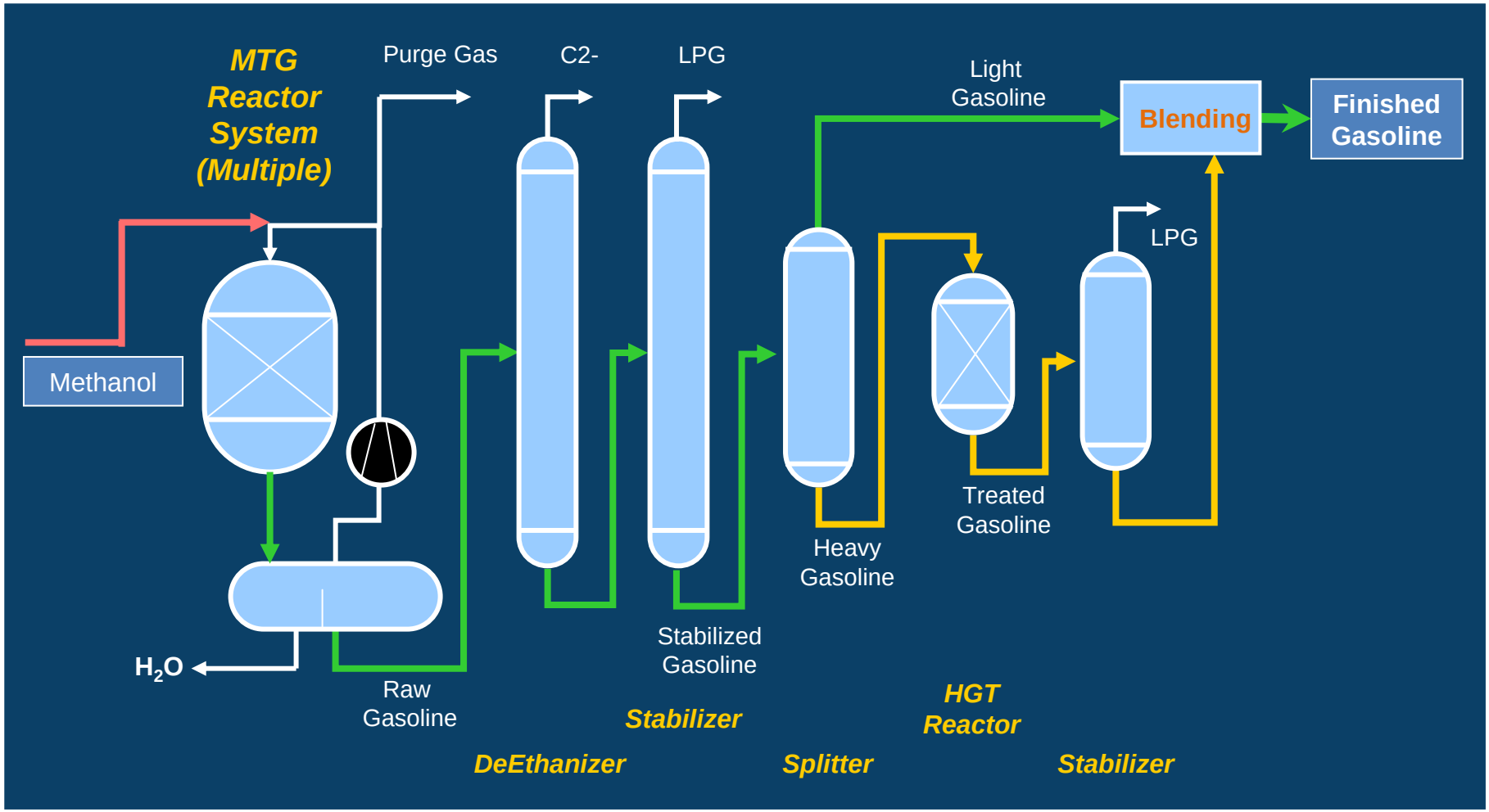
MTG GASOLINE YIELDS		
	Percent of Feed	Percent of Hydrocarbon Product
Gas	1%	**2%**
LPG	5%	**11%**
Gasoline	38%	**87%**
H_2O	56%	-

MTG GASOLINE PROPERTIES/COMPOSITION	
Octane, RON	**92**
Octane, MON	**82**
(R+M)/2	**87**
Paraffins, vol%	**53**
Olefins, vol%	**12**
Naphthenes, vol%	**9**
Aromatics, vol%	**26**
Benzene, vol%	**0.3**
Sulfur	**nil**

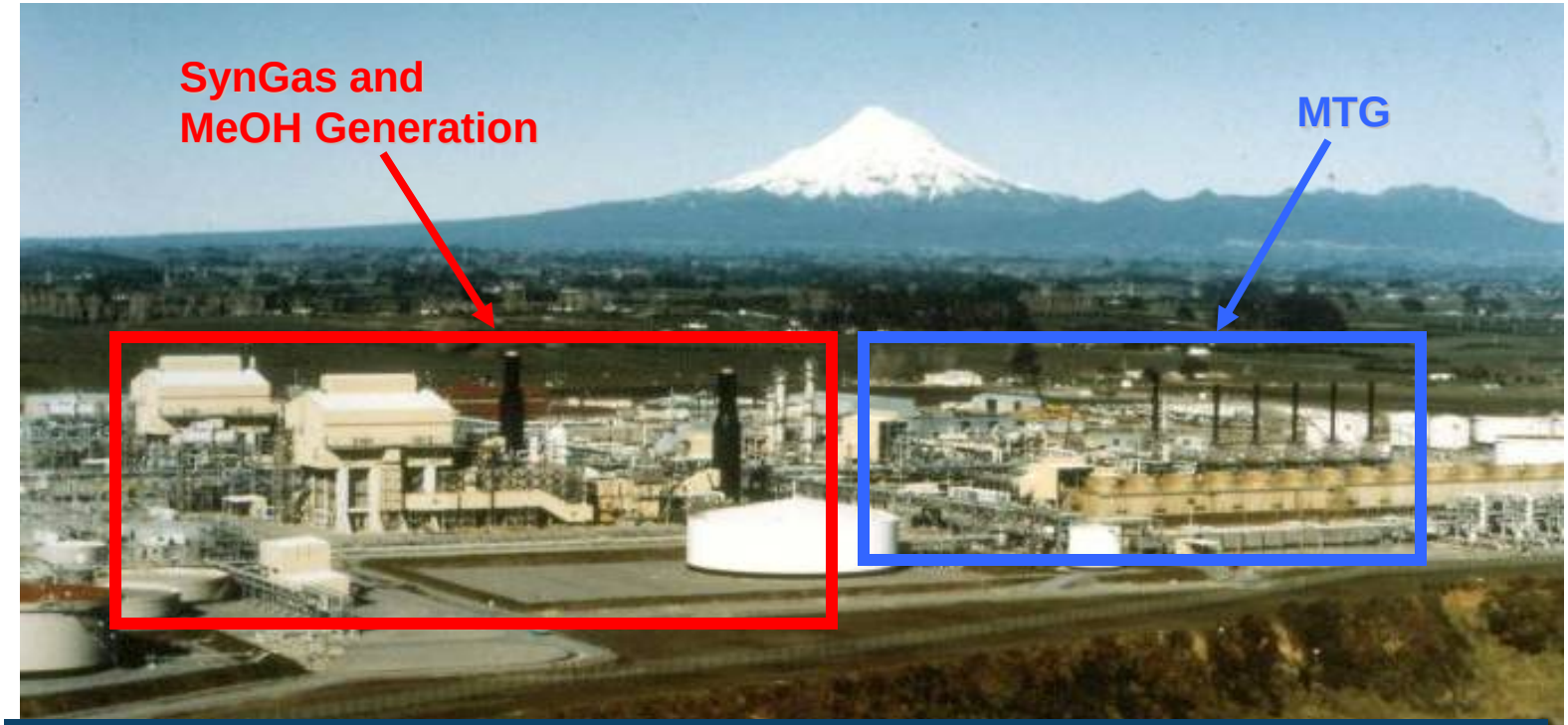
EMRE MTG PROCESS

- Methanol is fed to a fixed bed reactor system where all of the methanol is converted to hydrocarbon and water
- MTG reactor effluent is separated into gas, raw gasoline and water
- Raw gasoline is separated into LPG, light gasoline & heavy gasoline
- Heavy gasoline is hydro-treated to reduce durene content
- Heavy and light gasoline are re-combined into finished MTG gasoline

EMRE MTG PROCESS FLOW DIAGRAM



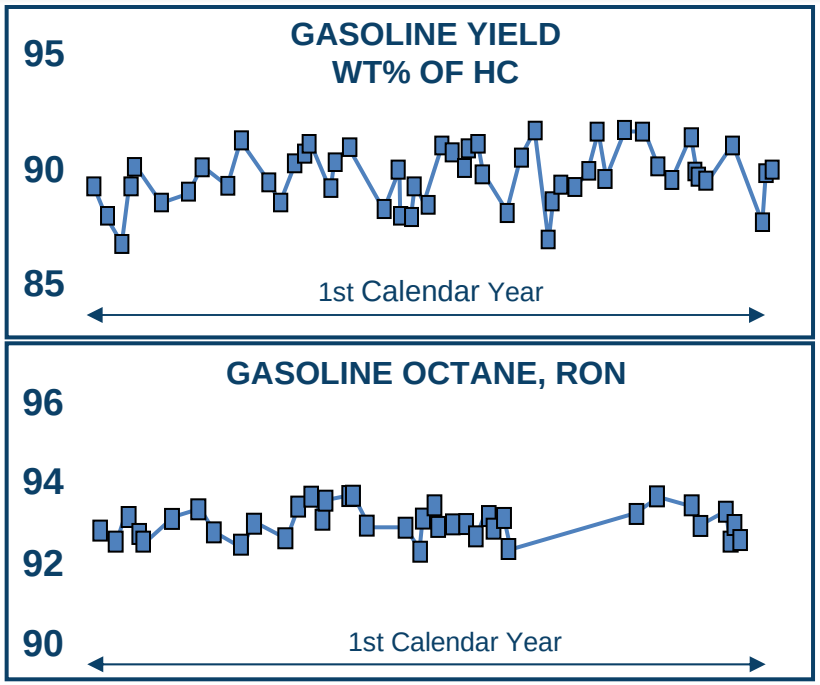
NEW ZEALAND MTG FACILITY: NEW PLYMOUTH NZ

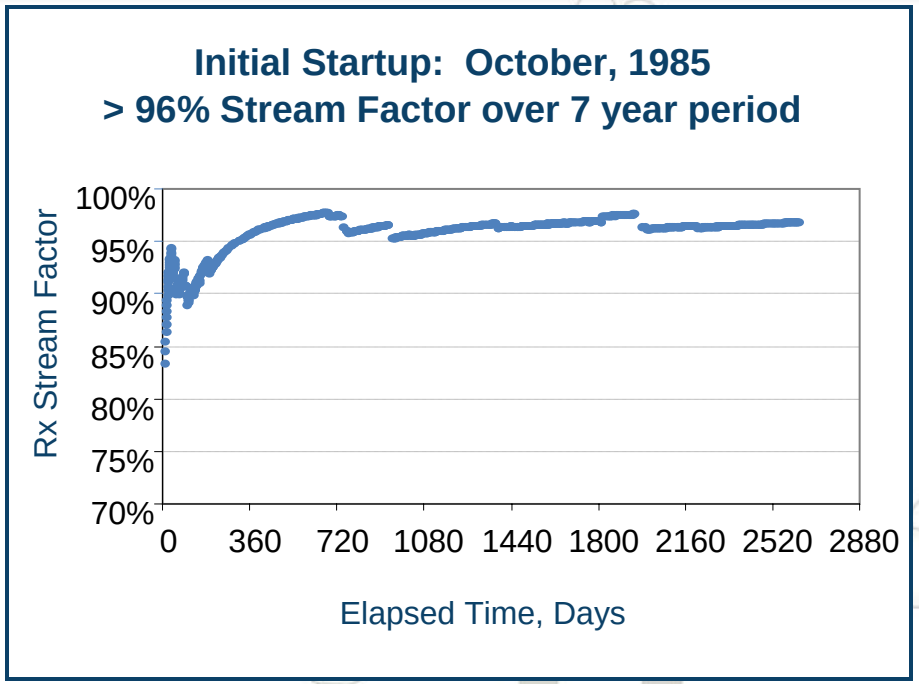


14,500 BPD plant in New Plymouth New Zealand.

Plant ownership 75% NZ Government and 25% ExxonMobil.

NEW ZEALAND PLANT OPERATING EXPERIENCE





- The New Zealand MTG experience demonstrated MTG to be a robust technology
- Daily gasoline yield and octane indicated a very consistent process performance
- After start up the unit ran reliably with an on-stream factor greater than 96%

KEY MTG FEATURES

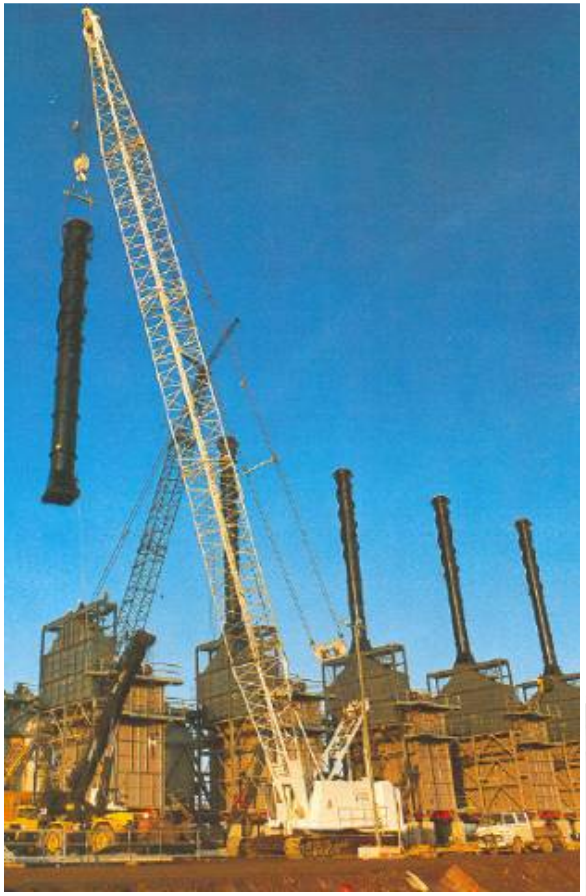
- **Operability**
  - Gas phase conventional fixed bed reactors
  - On-stream MTG catalyst regeneration and replacement
  - Gasoline production is de-coupled from syngas generation and methanol synthesis -- Improves on-stream factor vs. direct coupled operation

2ND GENERATION MTG TECHNOLOGY

- Second Generation Design based on 10 years learning's from New Zealand operation
- Improved heat integration
- Improved process efficiency

Ongoing 2nd Generation MTG Catalyst Research

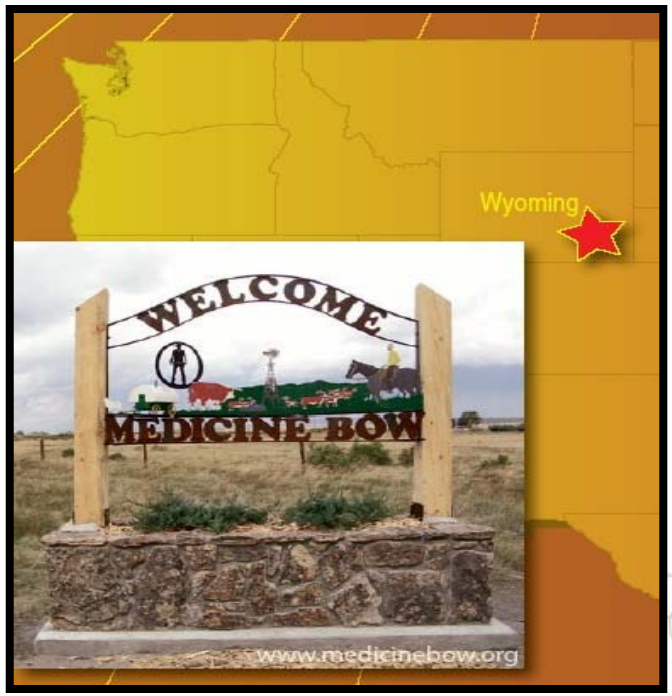
ExxonMobil is the world leader In catalyst development and manufacture



World's First Coal to Liquids Plant using MTG

- First 2nd generation MTG: JAMG plant in Shanxi Province China
- Start Up; June 2009, 2,500 B/D gasoline

OTHER MTG LICENSES



- DKRW announced in Dec. 2007 the first U.S. CTL plant to utilize MTG in their 15 KBD Medicine Bow, WY Project
- Synthesis Energy Systems in September, 2008 announced their license for MTG Technology for a series of global CTL projects

MTG AND FISCHER-TROPSCH COMPARATIVE ANALYSIS

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F-T & MTG COMPARATIVE STOICHIOMETRY

FISCHER-TROPSCH

SYN GAS

$(CO + 2H_2) \rightarrow \underline{(-C_1H_2-)} + H_2O$

Gas & **F-T Liquids**

MTG

SYN GAS **METHANOL**

$(CO + 2H_2) \rightarrow CH_3OH \rightarrow \underline{(-C_1H_2-)} + H_2O$

Gas & **MTG Gasoline**

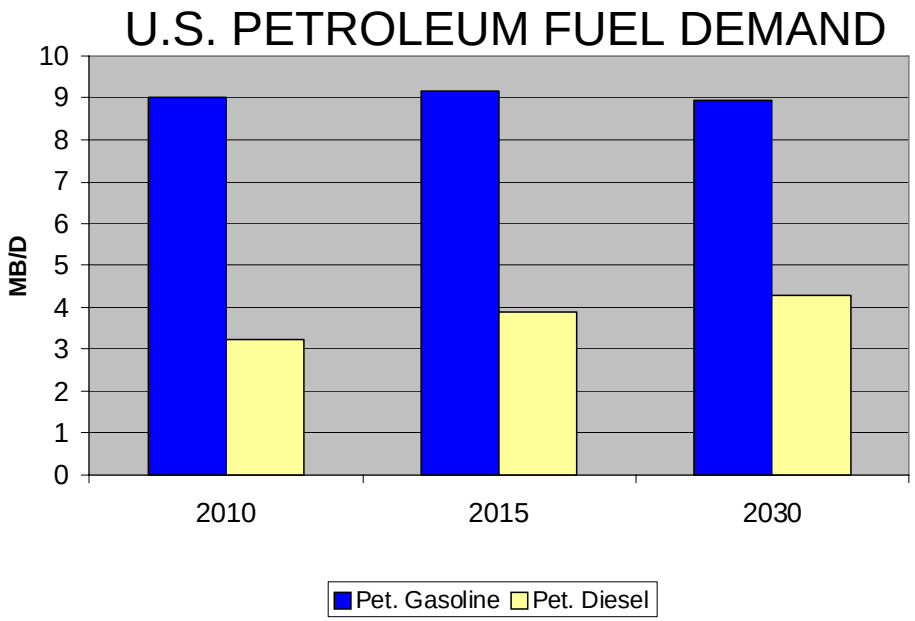
F-T & MTG COMPONENT YIELDS

Components	Fischer-Tropsch Co Catalyst @ 220 C	Fischer-Tropsch Fe Catalyst @ 340 C	MTG
Fuel Gas	6	15	1.1
LPG	6	23	10.0
Naphtha	19	36	
GASOLINE			**88.8**
Distillate/Diesel	22	16	
Fuel Oil/Wax	46	5	
Oxygenates	1	5	

- F-T yields depend on catalyst, temperature and specific technology
- F-T processes produce a range of hydrocarbons that require refining processes to convert F-T liquids to conventional fuels
- MTG produces a conventional gasoline and an LPG stream

Data Sources: Sasol 2004 publication.

Gasoline vs. Diesel as Synthesis Product

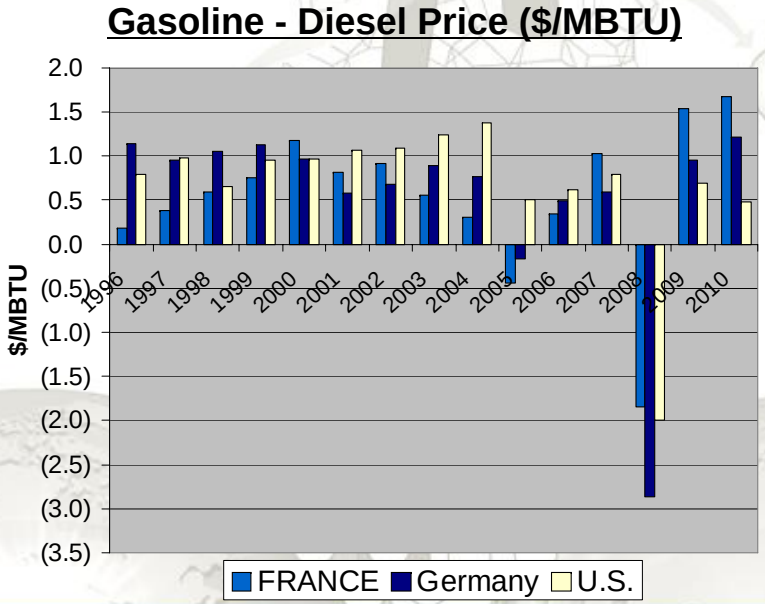


Despite demand shifts to diesel and ethanol substitution, U.S. projected to remain heavily dependent on petroleum gasoline.

(Source: U.S. EIA Annual Energy Outlook 2010))

Based on energy content, U.S. & Europe prices have consistently provided gasoline a premium over diesel

(Source: U.S. EIA, http://www.eia.doe.gov/state/state-energy-profiles-more-prices.cfm; http://www.eia.doe.gov/emeu/international/prices.html# Gasoline @ 5.25 MBTU/BBL, Diesel @ 5.83 MBTU/BBL: Transportation Energy Data Book)



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2009 STUDY:LIQUID TRANSPORTATION FUELS FROM COAL / BIOMASS*

- Joint Study by the U.S. National Academy of Sciences and National Academy of Engineering as part of the America Energy Future Project
- Study included a comparative analysis of MTG and Fischer-Tropsch as alternatives for coal/biomass to liquid fuels
  - 50,000 bpd of transportation fuel; i.e. gasoline (no naphtha) and/or diesel
  - Light fractions recycled for conversion or electric power
  - Study considered impact of Carbon Capture and Sequestration

*Liquid Transportation Fuels from Coal / Biomass: Technological Status, Costs and Environmental Impact, ISBN: 0-309-13713-6, http://www.nap.edu/catalog/12620.html

2009 NRC STUDY: LIQUID TRANSPORTATION FUELS FROM COAL / BIOMASS

F-T & MTG ECONOMIC COMPARISON		Fischer-Tropsch No CO_2 Capture	Fischer-Tropsch With CO_2 Capture	MTG No CO_2 Capture	MTG With CO_2 Capture
INPUT	Coal, tpd (as received)	26,700	26,700	22,900	23,200
OUTPUTS	Diesel, bpd	28,700	28,700		
	Gasoline, bpd	**21,290**	**21,290**	**50,000**	**50,000**
	Total Liquid Fuel, bpd	50,000	50,000	50,000	50,000
	Electricity, MW_e	427	317	145	111
THERMAL EFF. (LHV)		**49.1%**	**47.6%**	**54.2%**	**52.9%**
TOTAL PLANT COST ($M)		4,880	4,950	3,940	4,020
TOTAL PLANT COST ($K/bpd)		97.6	98.9	78.8	80.4
EST. BREAKEVEN CRUDE PRICE ($/BBL)		56	68	47	51

- The study indicated the MTG based plant had slightly higher overall efficiency and lower construction costs
- CO_2 Sequestration lowered efficiency by about 1.5% and raised costs 1.5-2%

Data Sources: Liquid Transportation Fuels from Coal and Biomass, © National Academy of Sciences, 2009; http//www.nap.edu/catalog/12620.html

MTG
Licensing

ExxonMobil
Research and Engineering

EMRE/Uhde Partnership Provides Full Range of Project Services

Coal/Biomass → **Gasification** → **Methanol** → **MTG** → Gasoline

Uhde ThyssenKrupp

- **Uhde provides feasibility studies for the entire process of clean gasoline production from coal.**
- **Uhde Licenses PRENFLO Gasification technology**
- **Uhde can support other CTL/BTL technologies to meet customer's specific needs**
- **Uhde can provide a range of engineering, procurement and construction services**

ExxonMobil Research & Engineering

- **EMRE Licenses Methanol to Gasoline Technology**
- **EMRE provides basic engineering design package for licensees to perform detailed engineering design and construction.**
- **EMRE provides catalysts for the MTG process.**
- **EMRE provides assistance for MTG start-up and troubleshooting.**

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