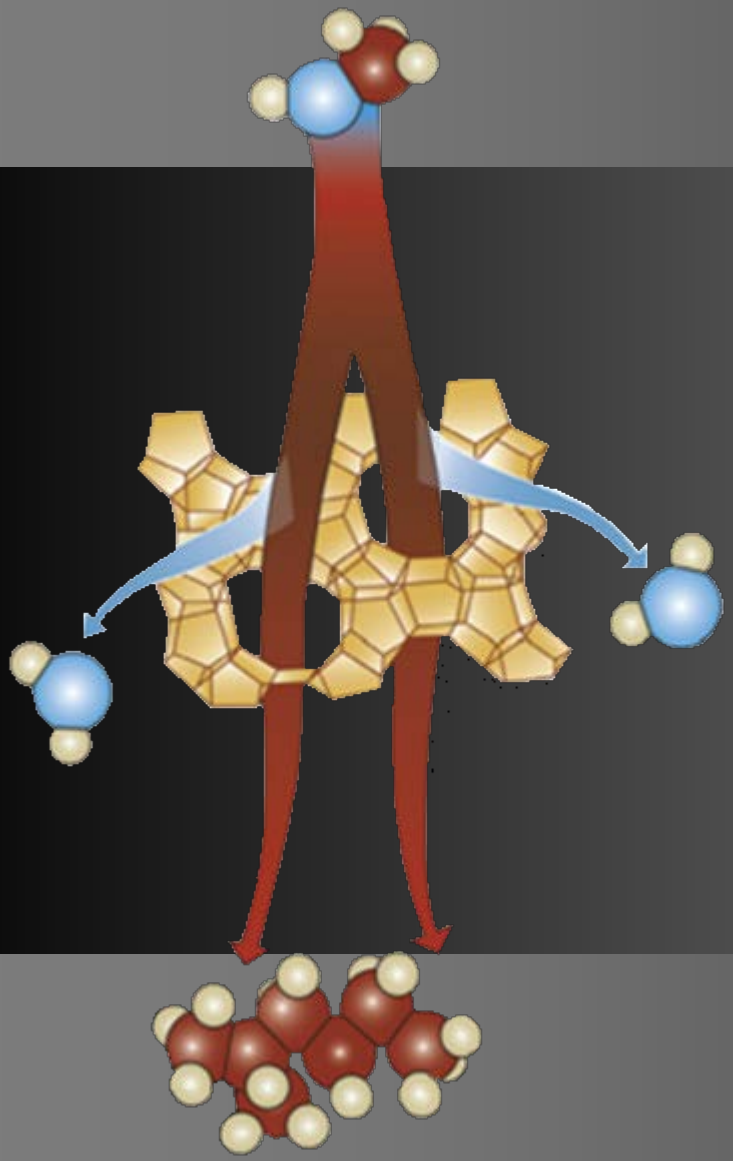
Methanol to Gasoline Technology
An Alternative for Liquid Fuel Production

Terry Helton and Mitch Hindman
ExxonMobil Research & Engineering Company (EMRE)

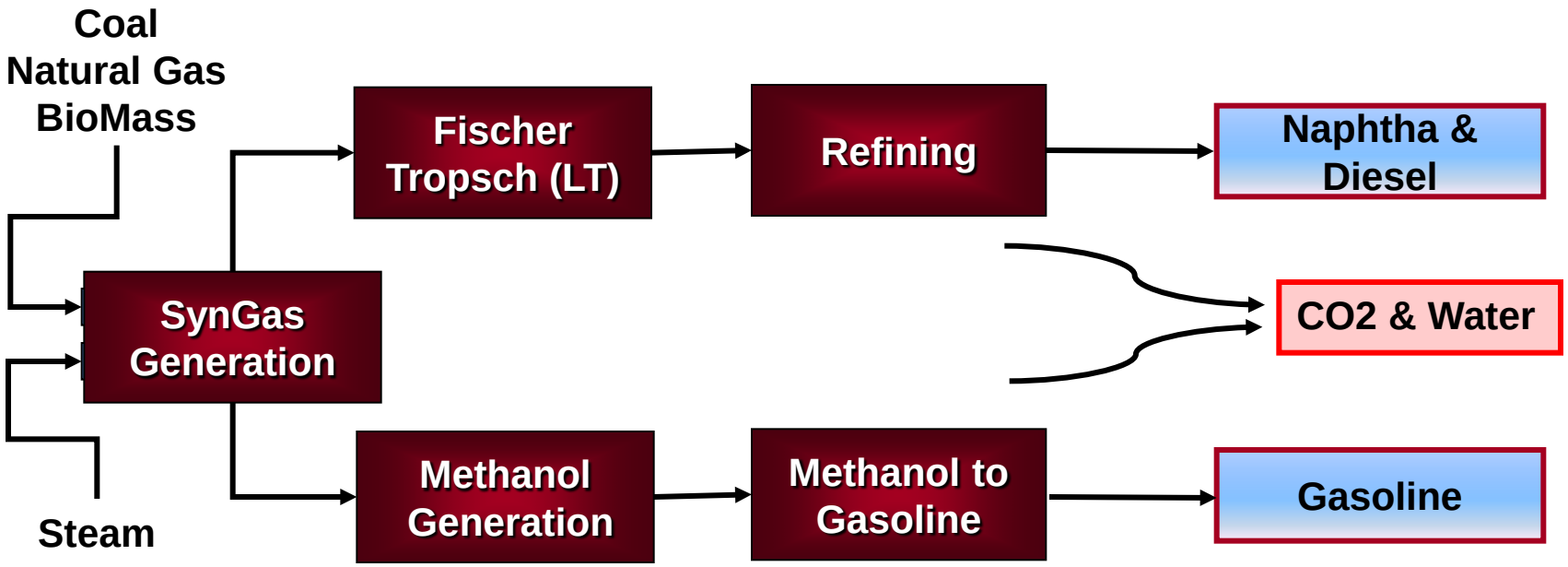
ExxonMobil



MTG as GTL Alternative

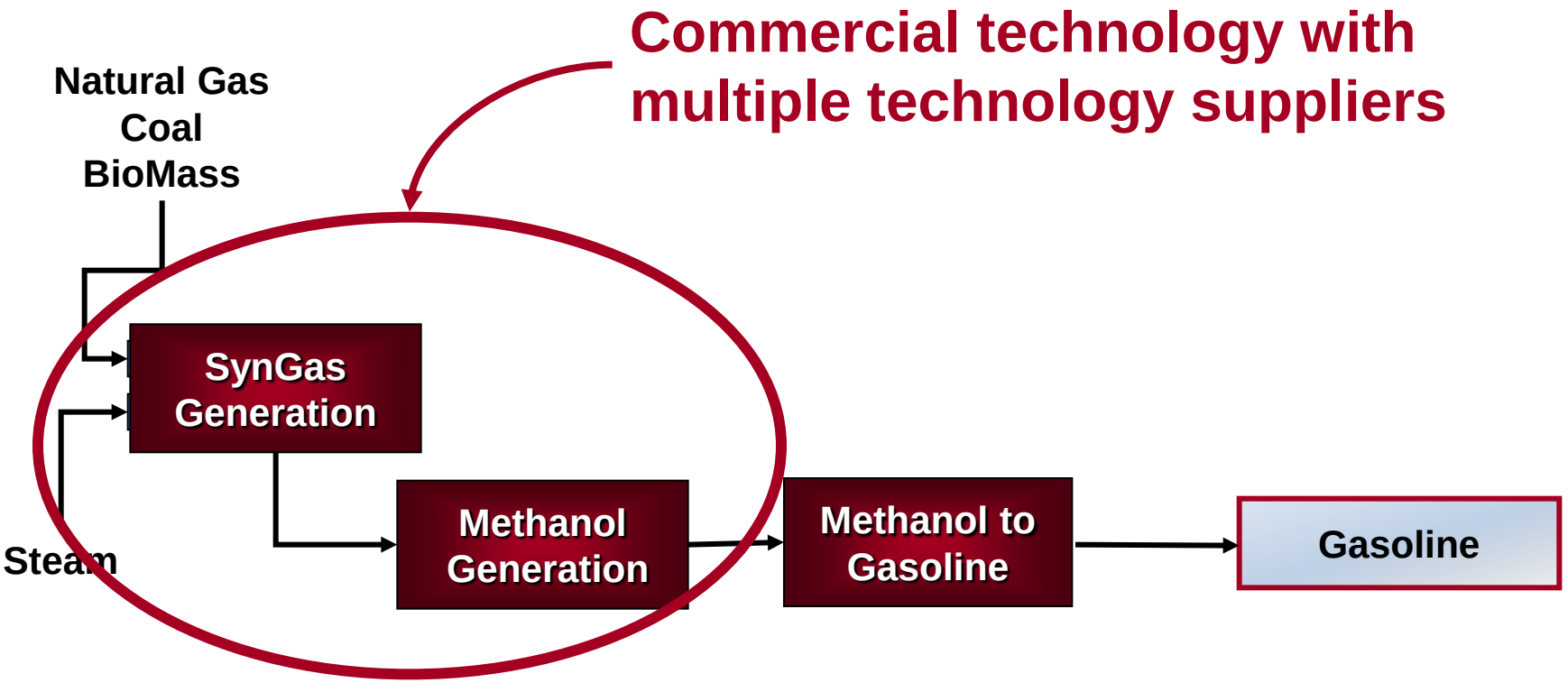
ExxonMobil
Research and Engineering

Routes for Synthetic Transportation Fuel

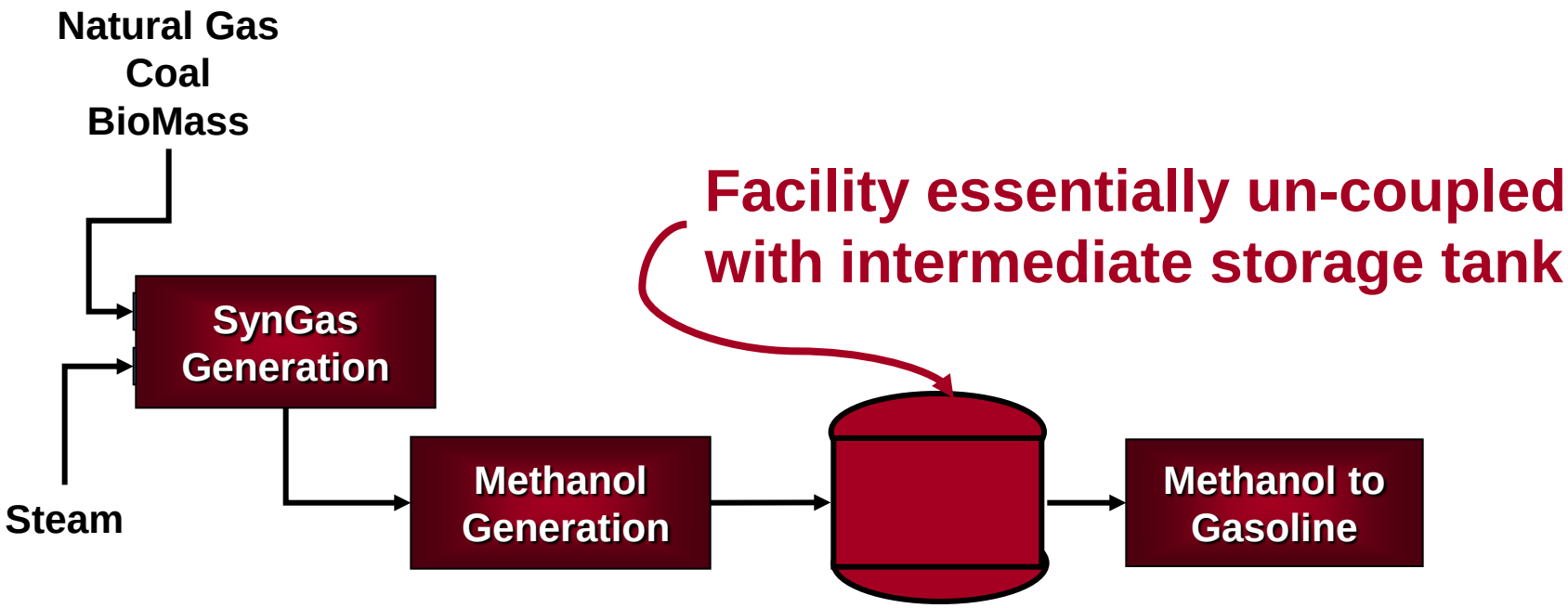


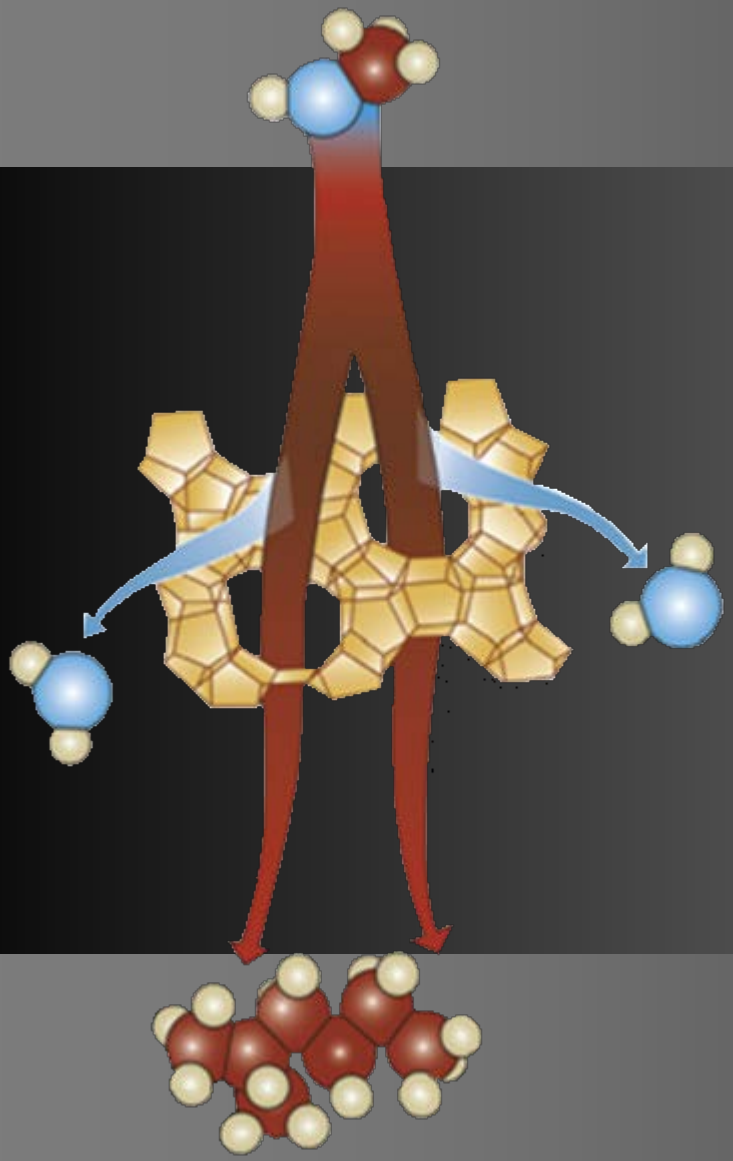
- Both are 3 Step Process
- Thermal Efficiencies are Essentially Governed by initial C/H Ratios...Fuels are ~C/H_2
  - Coal is CH to Fuels plus CO_2
  - Natural gas is CH_4 to Fuels plus H_2O

Methanol to Gasoline



MTG Technology Is Easily Integrated Into Existing Methanol Plant Infrastructure





MTG Process

ExxonMobil
Research and Engineering

Methanol to Gasoline Chemistry

$2\ CH_3OH \rightleftharpoons CH_3OCH_3 + H_20$

Methanol — Di-Methyl Ether

$CH_3OH, CH_3OCH_3 \rightarrow$ Light Olefins + H_20

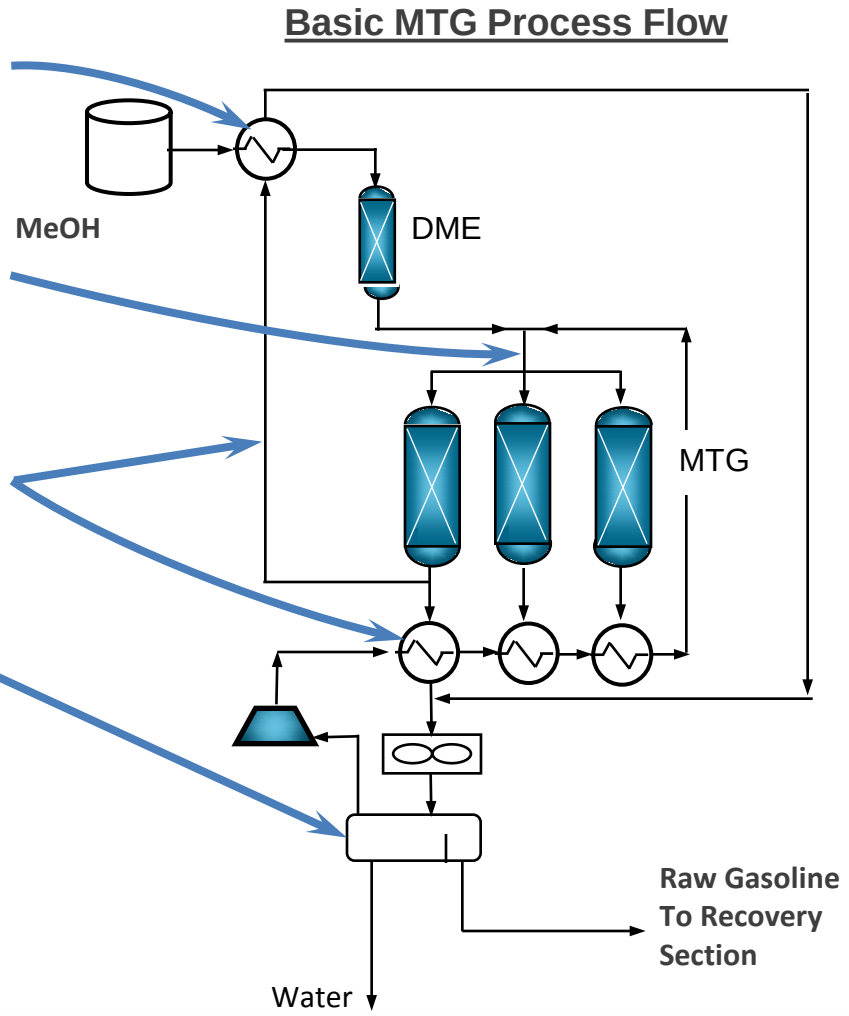
Methanol, Di-Methyl Ether

Light Olefins $\rightarrow$ C_5+ Olefins

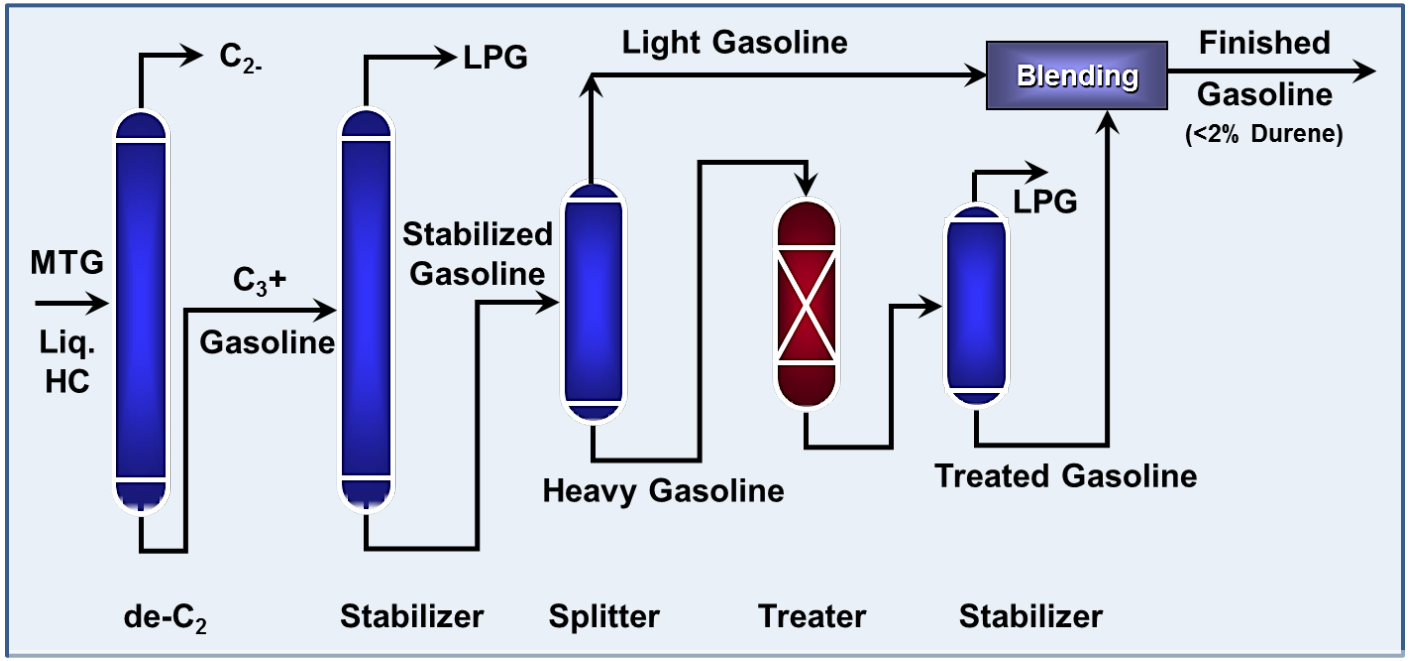
C_5+ Olefins $\rightarrow$ Paraffins, Naphthenes, Aromatics $\rightarrow$ Gasoline

ExxonMobil MTG Process: MTG Reactor Section

- Methanol is vaporized by heat from the MTG reaction and fed into a DME reactor
- DME reactor effluent is mixed with recycle gas & fed to the MTG reactors
- Recycle gas controls reactor temperatures
- MTG reactor effluent is cooled by the methanol feed, recycle gas & air or water
- Condensed effluent is separated into gasoline, water and gas
- Raw gasoline is pumped to a recovery section



Raw Gasoline Recovery Section

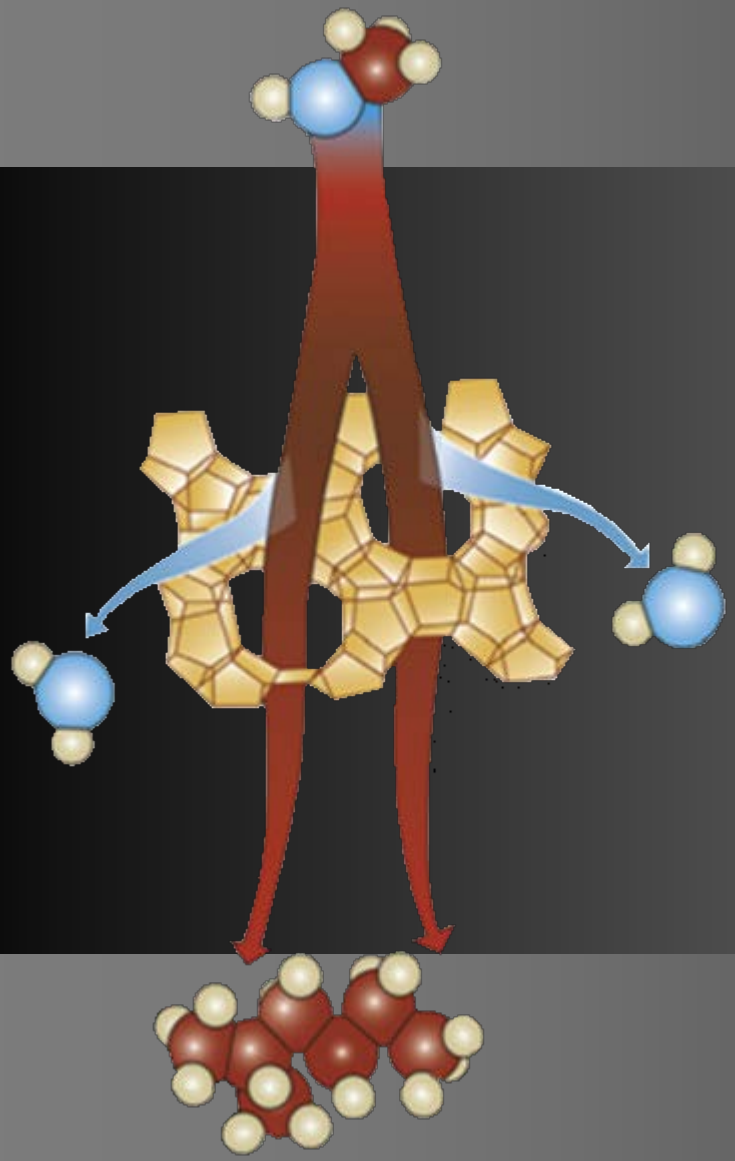


- Raw MTG gasoline is fed to de-ethanizer and stabilizer columns to remove fuel gas and LPG fractions from the gasoline
- Stabilized gasoline is split into light and heavy gasoline fractions
- Heavy gasoline is mildly hydro-treated to reduce Durene (1,2,4,5 tetra-methyl benzene) content
- Treated heavy gasoline and light gasoline or blended into finished product

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%	-

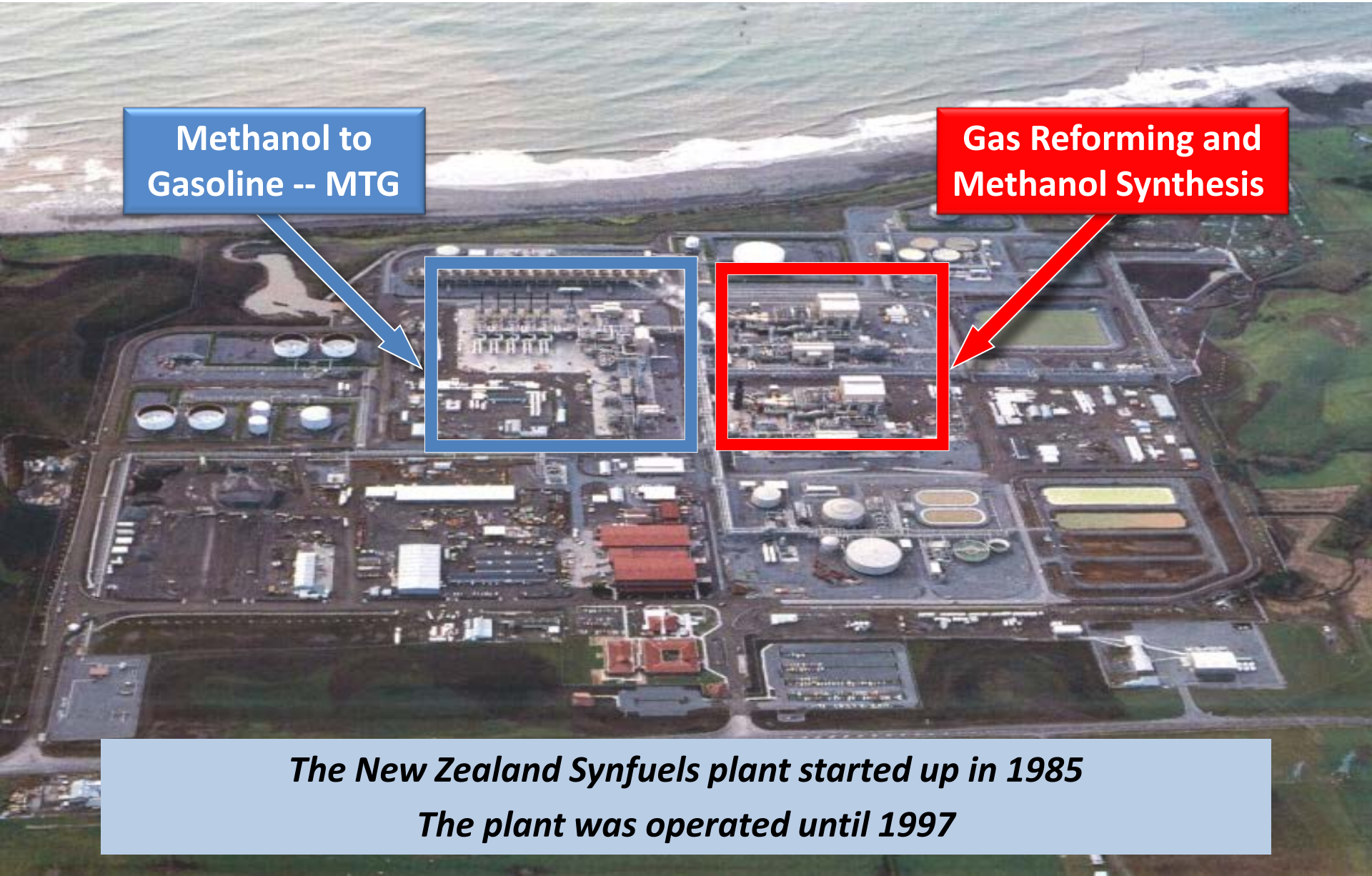
MTG GASOLINE PROPERTIES/COMPOSITION	
Octane, RON	**92**
Octane, MON	**82**
(R+M)/2	**87**
Paraffins, vol%	**53**
Olefins, vol%	**12**
Naphthenes, vol%	**9**
Aromatics, vol%	**26**
Benzene, vol%	**0.3**
Sulfur	**nil**



MTG Commercial Experience

ExxonMobil
Research and Engineering

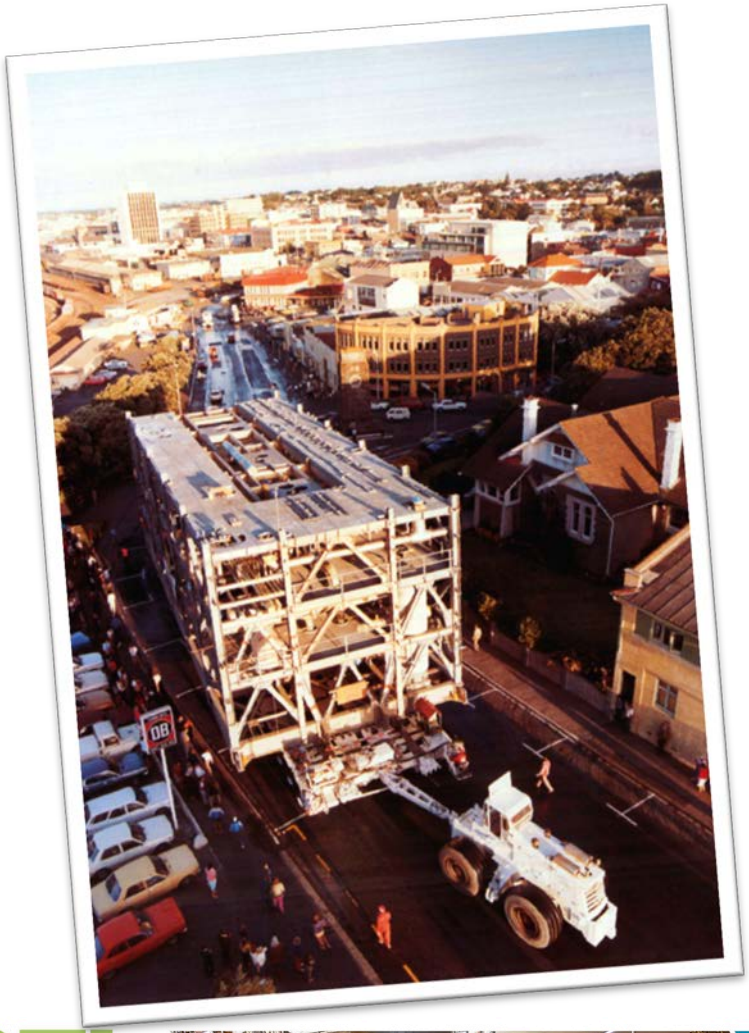
New Zealand SynFuel MTG Plant



The New Zealand Synfuels plant started up in 1985

The plant was operated until 1997

New Zealand Synfuel Plant Built with Modular Construction



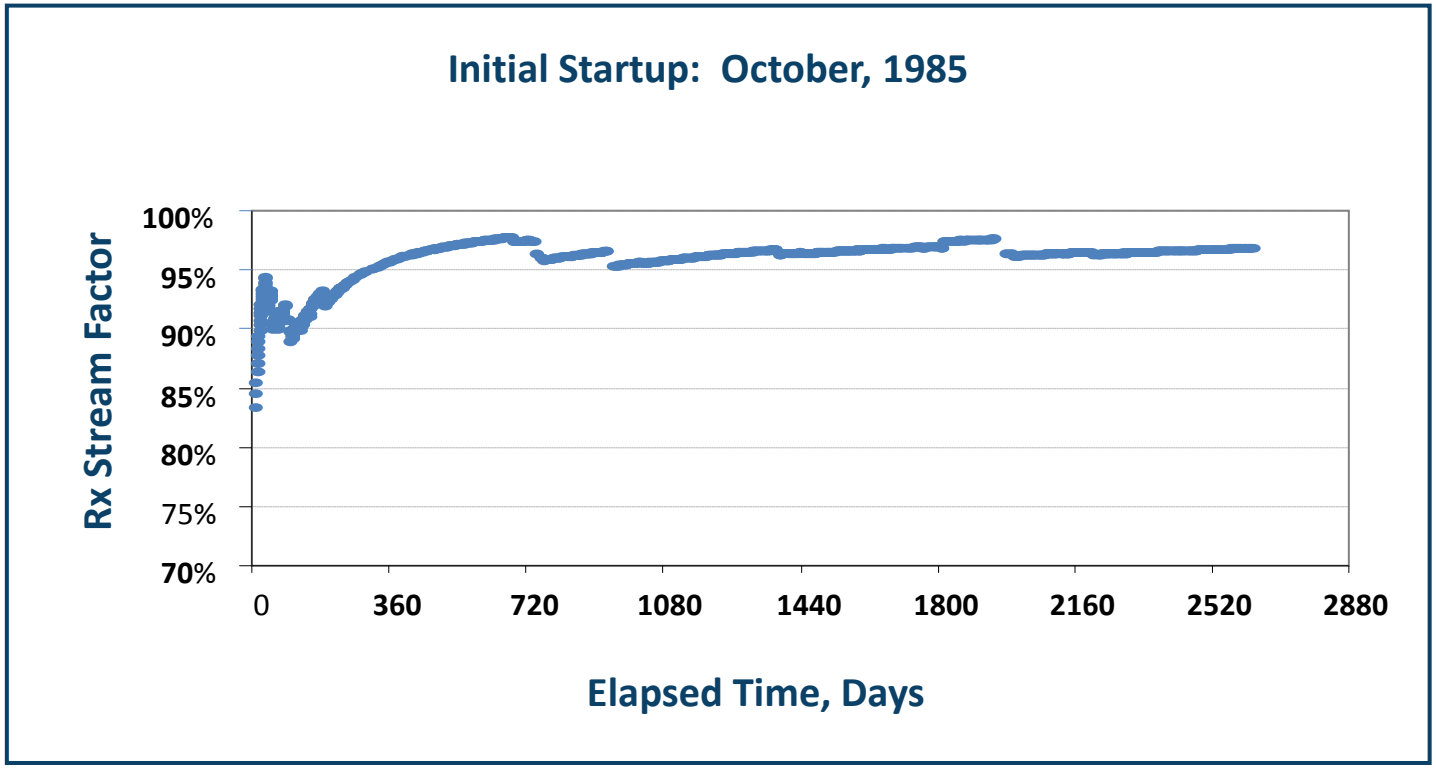
- A Methanol Plant Compressor in Route

- Modular Construction History
  - Maximum Module
    - 33 by 15 Meters
    - 600 tonnes
  - Total Lift
    - 66 Modules
    - 15,000 tonnes

New Zealand MTG Fixed Bed Reactor

Loading the Fixed Bed MTG Reactor

New Zealand MTG Plant Reliability



- On-stream factor greater than 96% over 7 year period

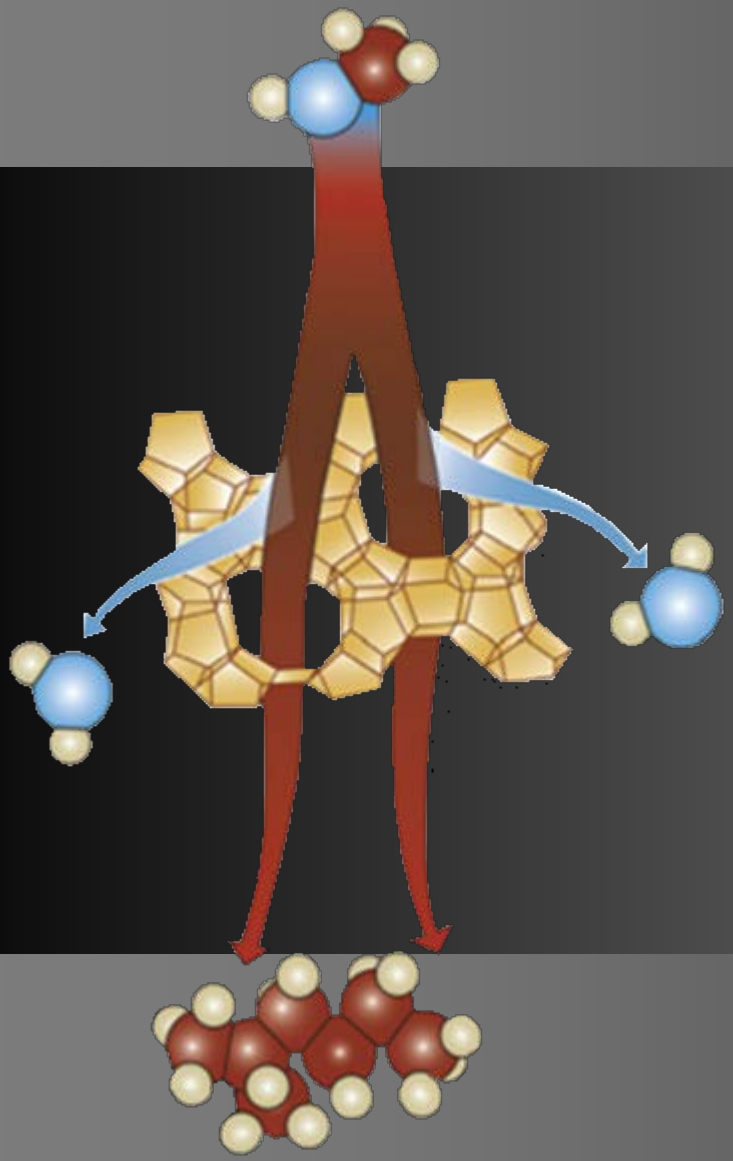
World's First Coal to Liquids Plant using MTG

In 2009, Jincheng Anthracite Mining Group (JAMG) plant in Shanxi Province China became the first 2nd generation MTG Plant; 2,500 Barrels per day of Gasoline

In 2011 JAMG Licensed a 25,000 Barrels per day MTG Complex (JAMG II)

JAMG 2,500 B/D MTG Unit, Shanxi Province

Second JAMG Grassroots MTG Plant (2 x 12.5 kbd) Construction, 1Q2014



MTG Licenses

ExxonMobil
Research and Engineering

Current MTG Licenses

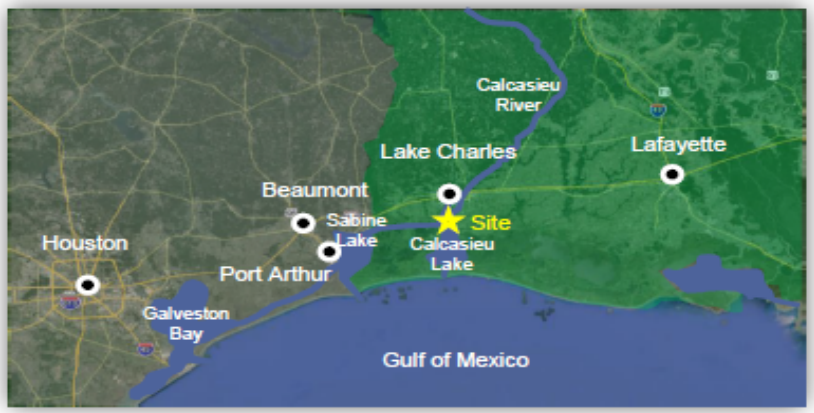
- JAMG, Shanxi Province China, 2,500 B/D, CTL, S/U in 2009
- JAMG, Shanxi Province China, 25 KBD (2 x 12.5 KBD), S/U 2016
- G2X Energy: Multi-License Gas to Gasoline Agreement
  - Lake Charles, LA, USA, 12.5 KBD
- Sundrop Fuel, Louisiana, USA, 3.5 KBD GTL/BTL
- DKRW, Wyoming, USA, 15 KBD, Coal to Liquids
- Synthesis Energy Systems, West Virginia, USA, Coal to Liquids
- ZeoGas LLC, Gulf Coast, USA, Gas to Gasoline, 16 KBD

G2X is in advanced stages of development for its first Gasoline Plant

Key Highlights

- 200 acre site owned by the Port of Lake Charles
- Located five miles south of Lake Charles, LA, on the deep water Industrial Canal
  - Access to Gulf Intracoastal Waterway
  - Access to Gulf of Mexico
- Close proximity to multiple interstate natural gas pipelines
- Water (for process and cooling) and power connection easily accessible

Site Location & Plant Rendering



Big Lake Fuels project in Lake Charles

Plant Rendering

G2X has assembled the critical components for success

G2X Energy has assembled proven processes, proven expertise, and proven partners, to develop mid-stream infrastructure projects in order to create high-value fuels from abundant supplies of low-cost natural gas located in North America

PROVEN

TEAM

- With a 30-year record of success in starting, capitalizing and building businesses, G2X Energy's leadership team is equipped to develop, finance, build, and operate large-scale natural gas to gasoline projects in North America

PROCESS

- Proman Group, the world leader in building and operating methanol plants, is an investor in G2X Energy as well as a strategic partner that will contribute important development, construction and operational capabilities

TECHNOLOGY

- ExxonMobil Research and Engineering, who has developed a clean and proven methanol to gasoline technology, has granted G2X certain license rights to its technology

Latest MTG Licensee: ZeoGas LLC

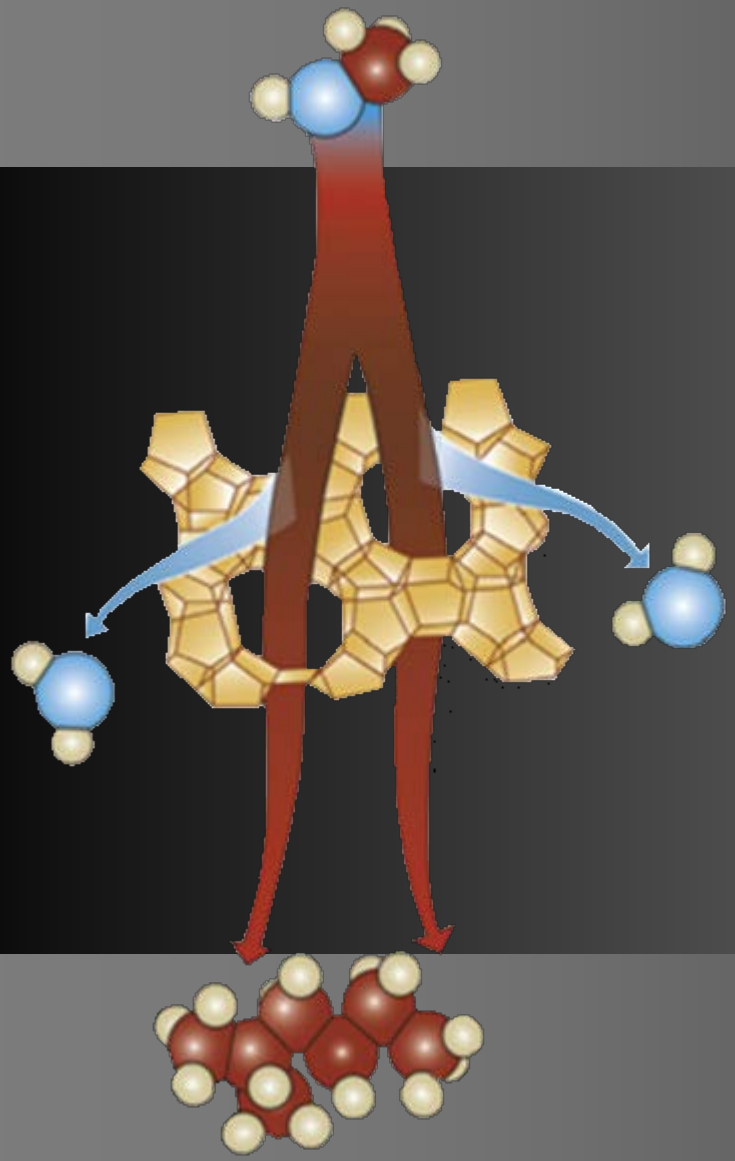
ZeoGas Awarded Methanol-to-Gasoline Technology License by ExxonMobil

Proven ExxonMobil technology to support new ZeoGas gas-to-liquids project on U.S. Gulf Coast

July 21, 2014 09:52 AM Eastern Daylight Time

HOUSTON--(BUSINESS WIRE)--ZeoGas LLC (ZeoGas), a developer of natural gas-to-gasoline projects, has entered into a license agreement to use ExxonMobil Research and Engineering Company's (ExxonMobil) methanol-to-gasoline technology in the development of a natural gas-to-gasoline plant on the U.S. Gulf Coast.

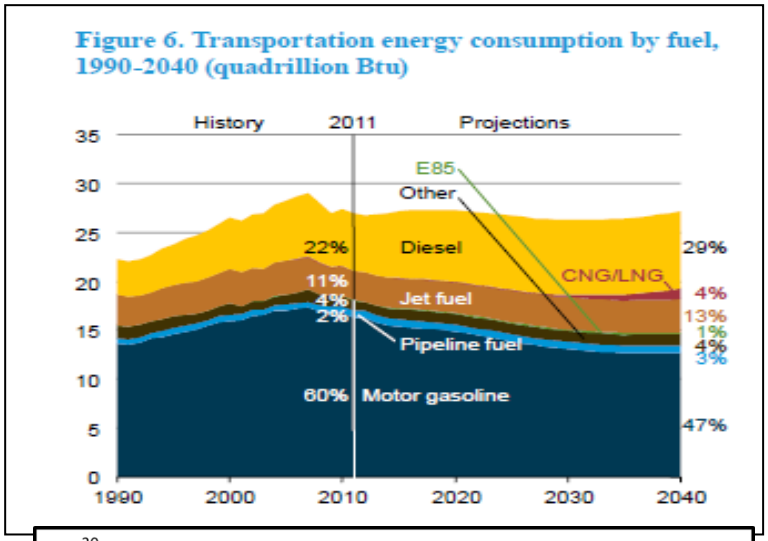
ZeoGas is developing a portfolio of projects to convert natural gas to gasoline to take advantage of the abundant and relatively low cost of natural gas in North America. Coupled with the 5,000 tons-per-day of planned methanol production, ZeoGas will produce more than **16,000 barrels per day of ASTM-spec, 87 Octane gasoline** with zero sulfur and about 50 percent less benzene than allowable standards.

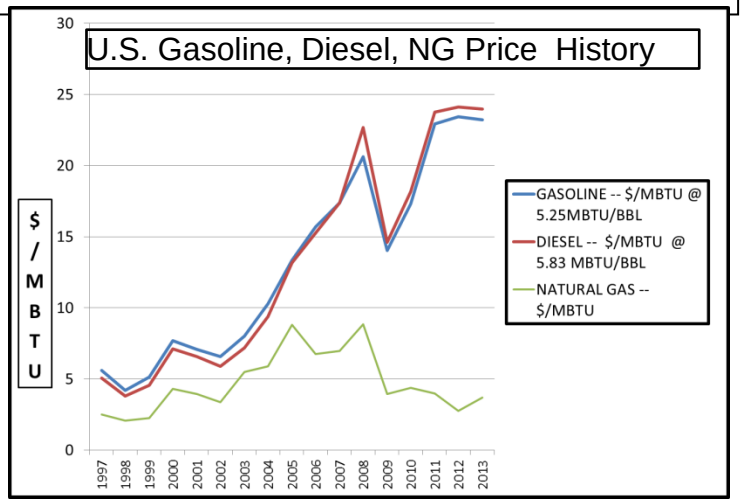


MTG Economic Considerations

ExxonMobil
Research and Engineering

U.S. Gasoline Market Considerations





- In 2011 gasoline was 60% of the U.S. transportation fuel market
- Improved fuel economy projected to reduce gasoline demand over time
- The U.S. EIA projects by 2040 gasoline to be under 50% of the U.S. transportation fuel market but double diesel demand

U.S. Energy Information Administration | Annual Energy Outlook 2013

- On a BTU basis, Diesel & Gasoline typically trade within about $1/MBTU
  - Shift to a slight premium for diesel since 2011
- The primary driver is the large gas to liquid spread since 2009

Source: U.S. EIA; Refiner Petroleum Product Prices by Sales Type, Sales for Resale; Motor Gasoline, No. 1 Distillate Fuel , HH Natural Gas

Gas to Methanol

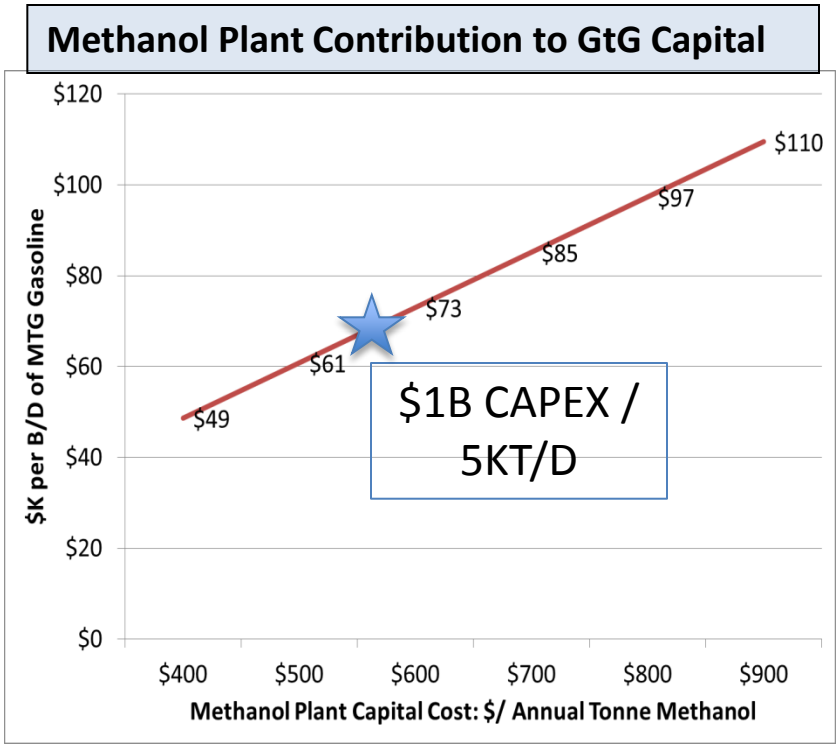
Based on the New Zealand case, Gas-to-Gasoline capital was split roughly 2/3 to methanol & 1/3 to MTG

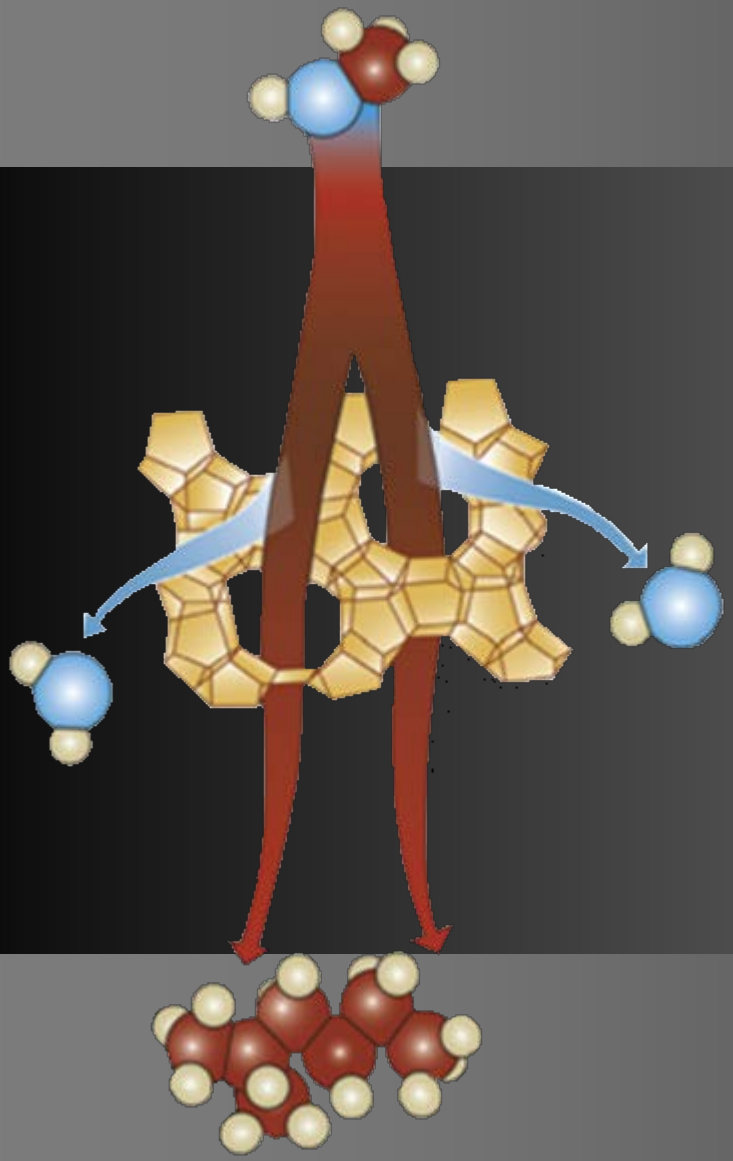
- Methanol produced from 2 x 2.2 KTD methanol units

- **World scale gas based methanol technology has advanced significantly since New Zealand**

- **Six 5 KT/D Gas to Methanol trains built since 2004**
  - **5 KT/D of MeOH yields16 KBD of MTG Gasoline**
  - **Nominally 160 MM scf/D of Gas**

- **Multiple technologies available at world scale for Reforming and Methanol Synthesis**



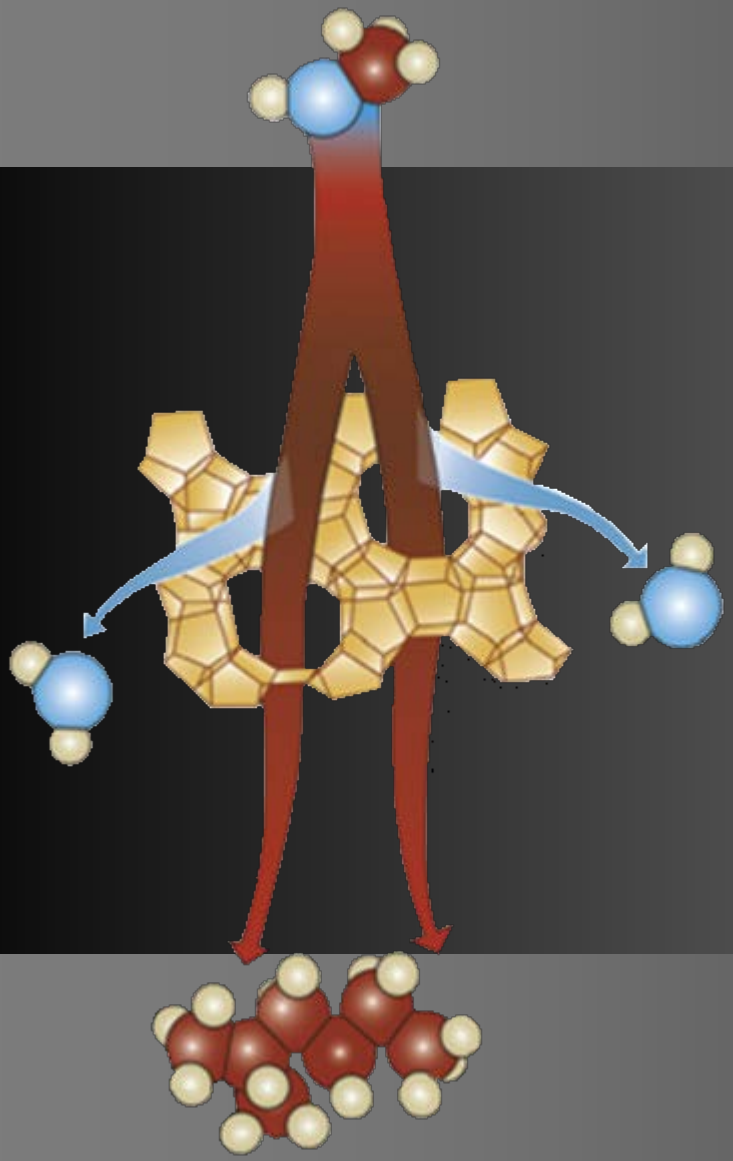


The MTG Advantage

ExxonMobil
Research and Engineering

Advantages of Carbon Conversion via EMRE MTG

- Low Technical Risk – All technology components are proven at a scale up to 15KBD
- Low Project Risk
  - Multiple proven technologies and experienced contractors for methanol front end
- Project Simplicity: Single liquid product suitable for transportation fuel
- Proven Scalability (2.5 kBD – 14.5 kBD) provides for range of applications



MTG Licensing

ExxonMobil
Research and Engineering

EMRE Licensing, Catalyst and Technical Services

- EMRE Licenses Methanol to Gasoline Technology
- EMRE provides a basic engineering design package for Licensees to perform engineering design and construction
- ExxonMobil Catalyst Technologies provides catalysts for the MTG Process
- EMRE Provides assistance as needed of EPC, Start-up and ongoing operations support

The World's First Commercial Scale Gas to Liquid Plant