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EFI Virtual Forum

Fluidized bed Methanol to Gasoline (MTG):
A reliable and cost-effective solution for production of renewable gasoline

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Agenda

MTG chemistry

ExxonMobil MTG development history

Fixed bed / fluid bed MTG process overview

Overall advantages of fluid bed vs. fixed bed MTG

- Complexity and CAPEX
- Operation reliability and OPEX
- Product yields and quality stability
- CO_2 footprint / CI

Fluid bed MTG technology readiness and commercialization

Summary

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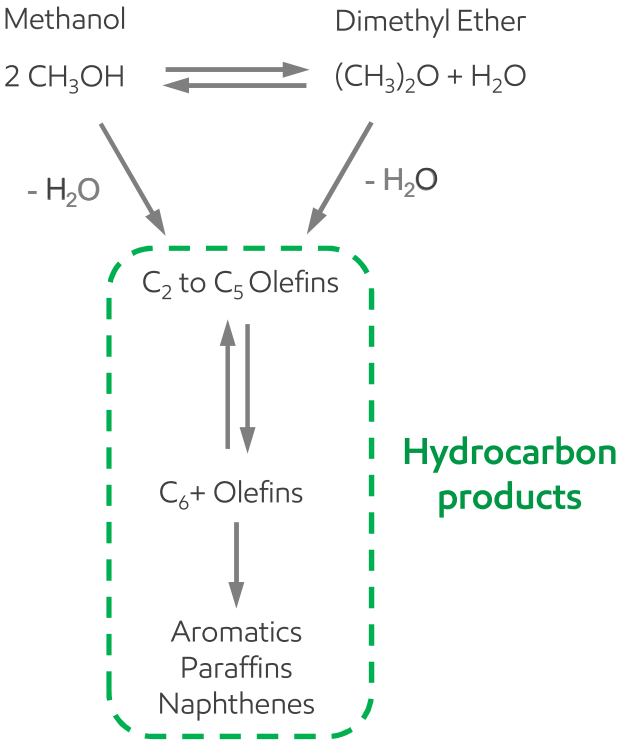
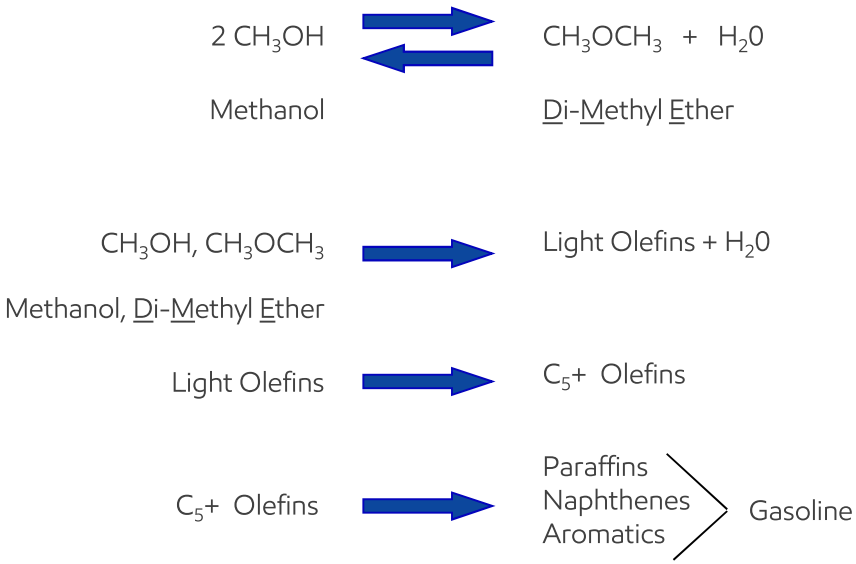
MTG chemistry





Theoretical Chemistry

	CH3OH →	H2O +	CH2 + Heat
Mass	32	18	14
wt %	**100%**	**56%**	**44%**

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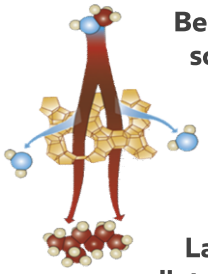
ExxonMobil MTG development history

Fixed bed:

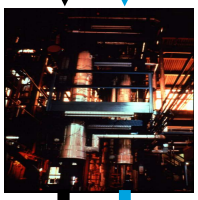
- ✓ MTG catalyst discovered in the early 1970's
- ✓ MTG catalyst limits the synthesis reactions to gasoline range hydrocarbons only



Bench scale

- ✓ Mobil studied fixed bed MTG options in 70's at 4BPD MeOH pilot plant scale

Large pilot unit (4 BPD)



Commercial scale

- ✓ New Zealand,14.5KBD MTG – 1985-1997
- ✓ JAMG-1, China, 2.5KBD MTG S/U in 2009
- ✓ JAMG-2, China, 2016, 12.5 KBD X 2

Demo unit 100 BPD

Fluid bed:

- ✓ Mobil studied fluid bed MTG options in 70's at 4BPD MeOH pilot plant scale
- ✓ 100 B/D Fluid Bed MTG Unit was built in the early 1980's in Germany
  - ✓ Was considered "Technically Ready"
  - ✓ No recycle
- ✓ EM and SEG Fluid Bed CDA (2014 -2017)
  - ✓ Was considered "Technically Ready"
  - ✓ With recycle

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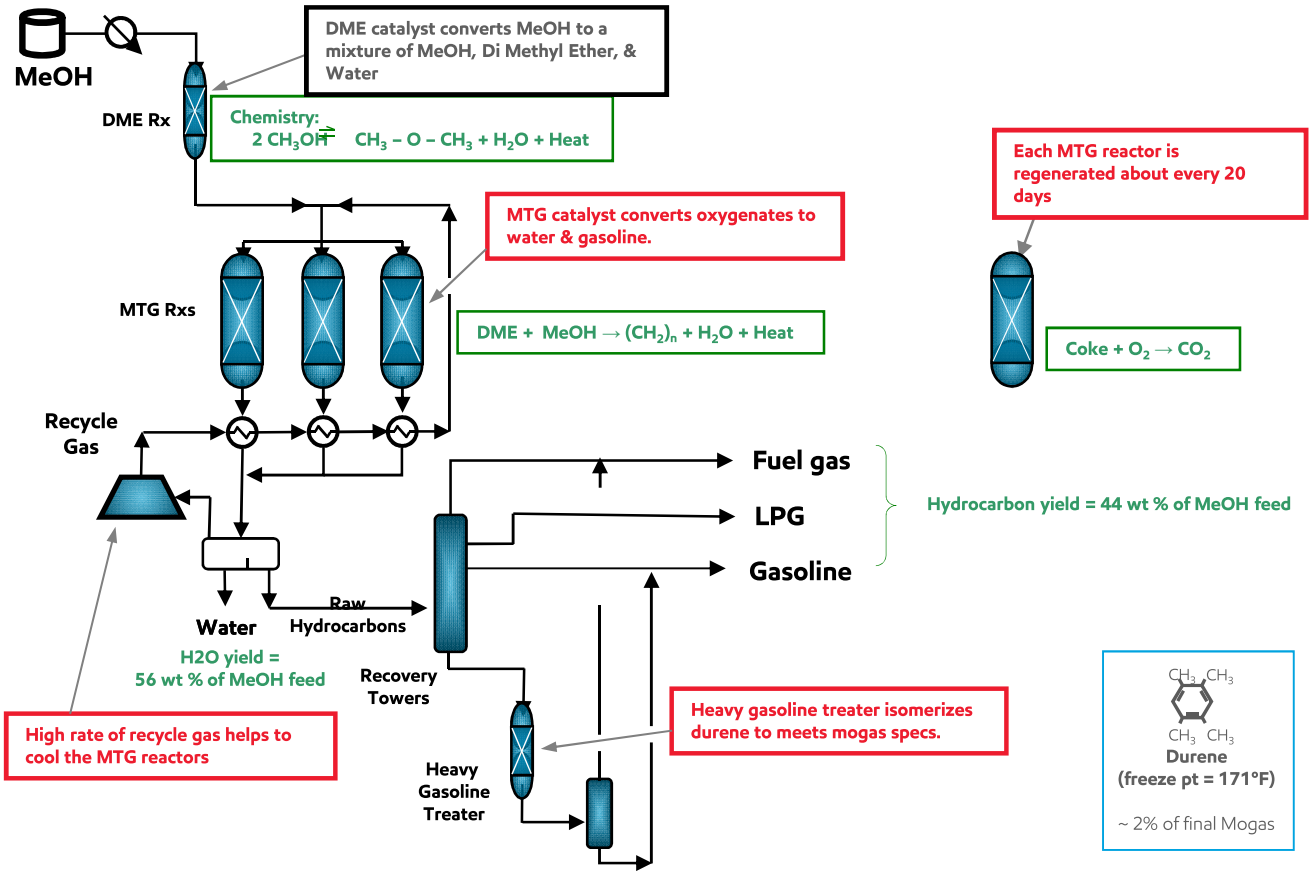
Process overview

Fixed bed MTG



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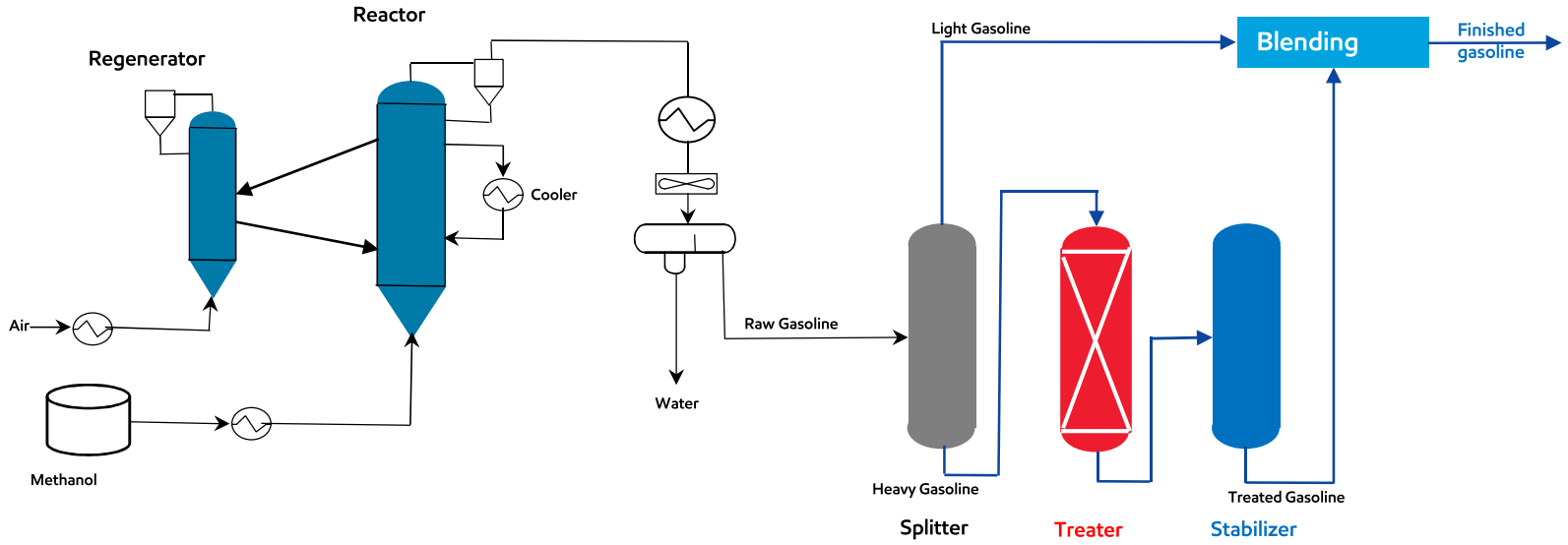
Process overview

Fluid bed MTG



Feedstock (typical)

~4wt% water + ~96wt% Methanol

Property of MTG gasoline	Typical values
Octane number, RON	92 – 95
Octane number, MON	82 – 85
Aromatics, vol%	25 – 35
Olefins, vol%	10 – 14
Benzene, vol%	≤ 0.3
Durene, wt%	≤ 2
Sulfur, mg/Kg	≤ 10
Final boiling point (FBP), deg C	200 – 210

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Fluid bed vs. fixed bed MTG

Overall advantages

Compared to fixed bed MTG, fluid bed MTG demonstrates following advantages:

More efficient CAPEX/OPEX

- Single reactor/regenerator
- Significant reduction in equipment/piping
- Less recycle gas
- Better heat integration

Higher operation reliability

- More efficient quench
- Less switching of reactors
- Lower operating pressure

Steady product yields & quality

- Steady state operation mode
- Catalyst maintained in steady active state

Lower CO_2 footprint and CI

- Lower CO_2 emissions due to lower energy consumption

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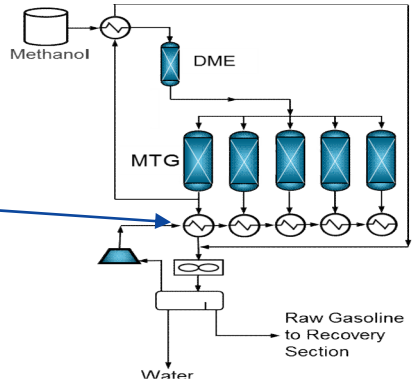
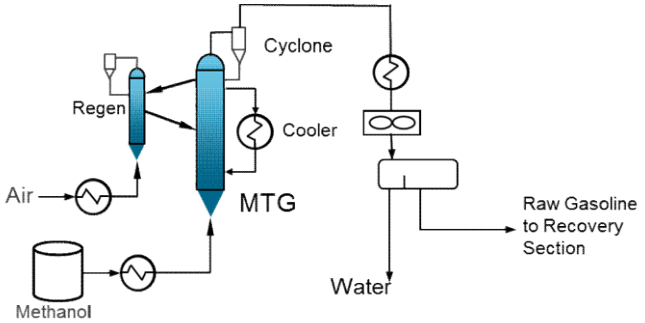
Fixed bed vs. fluid bed

Complexity and CAPEX

Fixed bed



Fluid bed



	Fixed Bed	Fluid Bed
DME reactor	Required to provide partial conversion of methanol with DME catalyst	No need
Reactor	Multiple fixed beds	Single fluid reactor & regenerator
Complex control valve system	Extremely complex valve system (*40+ Large Bore Motorized Valves for a 5 RXR system*) used to manage steady state yields of multi reactors	Significantly simplified
Recycle gas compressor	Require large recycle gas compressor to control heat	Significantly reduced due to much lower recycle

Higher CAPEX of fixed bed due to multi bed reactors, large control valves, larger heat exchangers, larger compressor etc.

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Fixed bed vs fluid bed

OPEX / operation reliability

	Fixed bed	**Fluid bed**
Operating pressure	~300psi	~70psi
Catalyst age monitoring	Require a rigorous programming and operation expertise to manage each reactor's catalyst age / cycle length to determine the catalyst change	Easy to keep catalyst activity the same by continuously adding make-ups
Gasoline yields & quality control	✓ Very complicated at managing the variability of product yields & quality by monitoring sequencing / regeneration of each reactor in multiple reactors ✓ Difficult to maintain the steady state yields & quality	Stable product quality due to the steady state mode
Heat integration	Require very large heat exchangers for recycle gas quench due to low gas/gas heat transfer	High pressure steam generation for much efficient quench
Stream factor	~91%	Expected to be similar to FCC unit

Higher OPEX of fixed bed due to higher operating pressure / larger recycle gas / lower gas-gas heat transfer etc.

Lower operation reliability of fixed bed due to complicated catalyst age monitoring, more switching, and higher operating pressure etc.

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Fluid bed MTG technology readiness and commercialization

Technology readiness:

- ✓ **Reactor section**
  Based on very mature, refinery FCC technology
- ✓ **Recovery and HGT section**
  Product recovery and HDT section commercially demonstrated
- ✓ **Catalyst**
  ZSM-5 based fluid catalysts available from ExxonMobil since 1990's
- ✓ **Pilot plant experience**
  Mobil studied fluid bed MTG options at 4BPD MeOH pilot plant scale (70's)

  100 B/D MeOH Fluid Bed MTG Unit was built in Germany (the early 1980's)

  EM and SEG Fluid Bed CDA at 4 BPD MeOH pilot plant scale (2014 -2017)

Technology commercialization:

No commercial scale unit yet

Recent on-going pilot plant experience paved the foundation for prospect commercial scale units

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Summary

ExxonMobil fluidized bed MTG technology could provide a more reliable and cost-effective solution in supporting the production of 1) new low-carbon emission renewable fuels, and 2) fossil-derived fuels:

eFuel

eH_2 and CO_2-based feedstock

Biofuel

MSW (municipal solid waste)-based feedstock

Biomass-based feedstock

Fossil-derived fuels

Natural gas-based feedstock

Coal-based feedstock

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