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**EFI Virtual Forum**

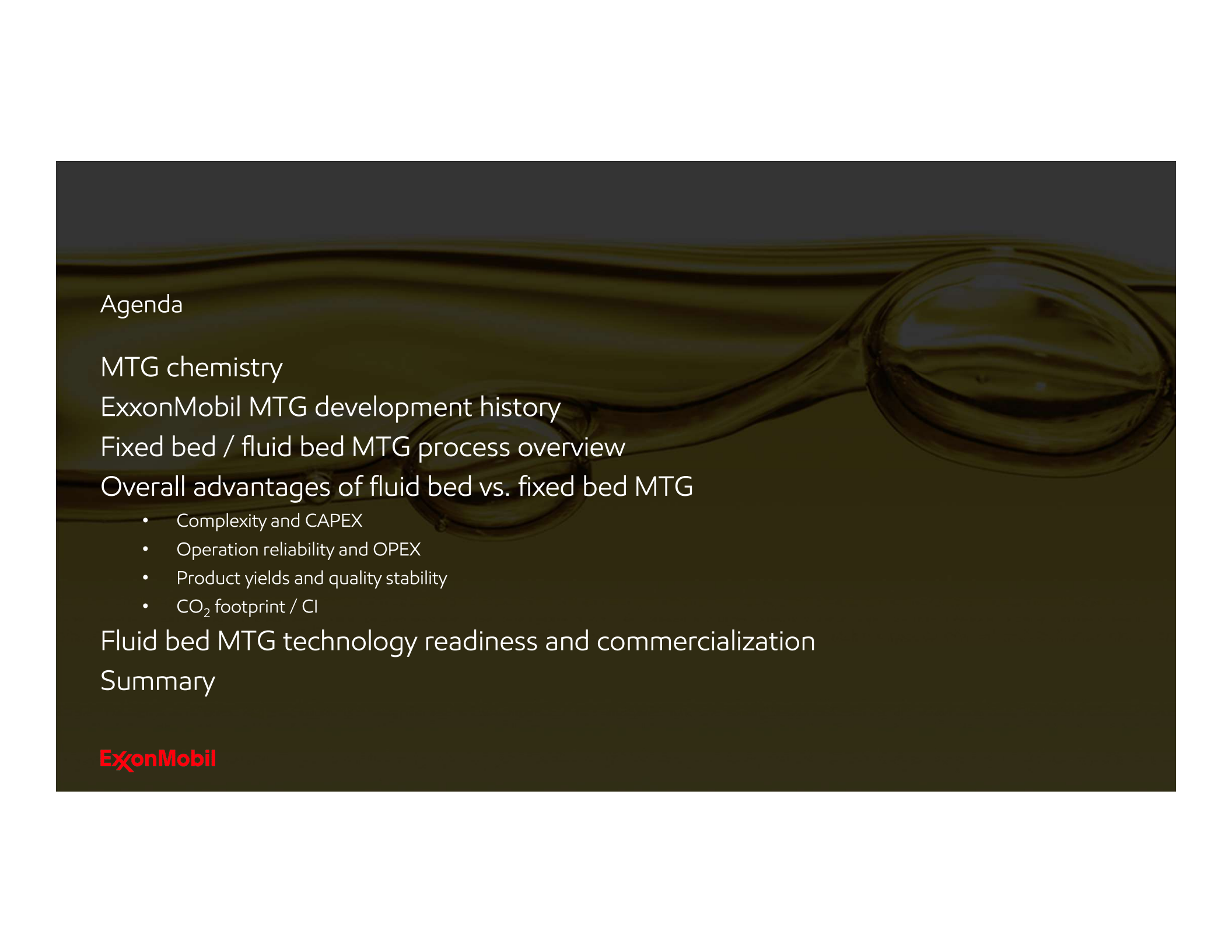
## Fluidized bed Methanol to Gasoline (MTG): A reliable and cost-effective solution for production of renewable gasoline



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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

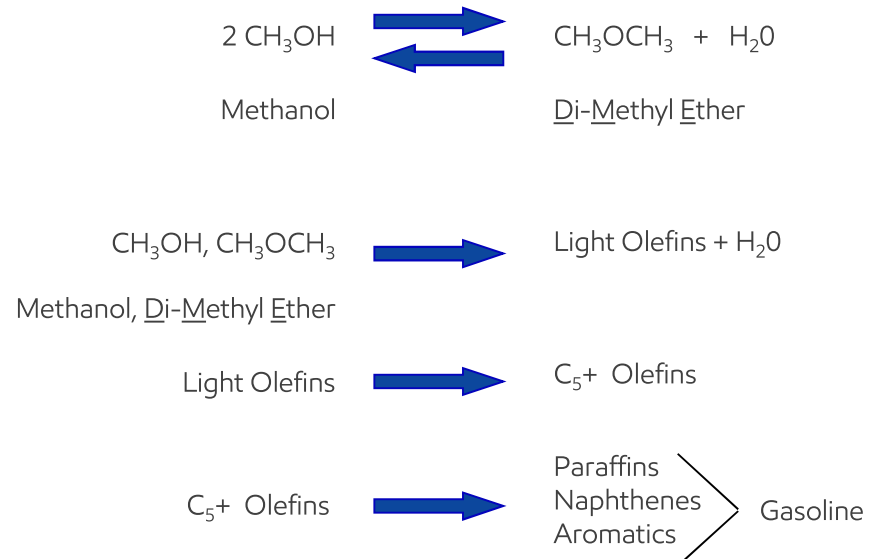
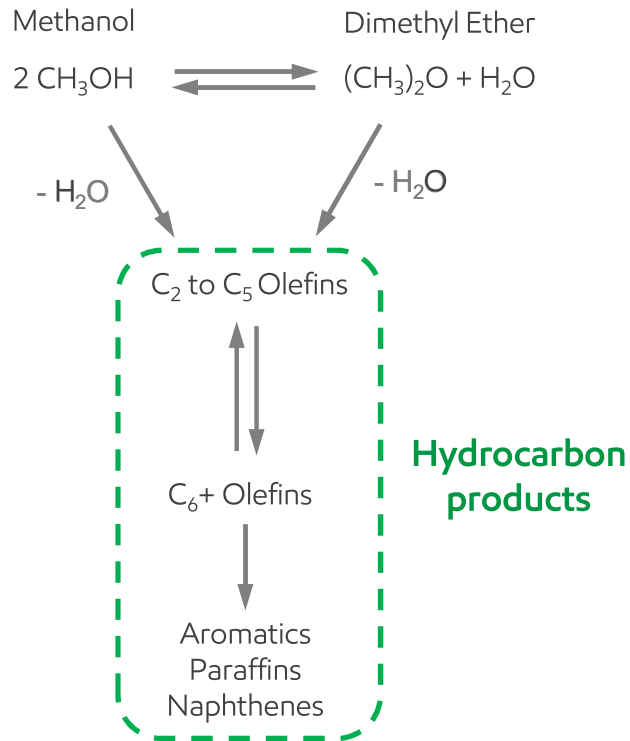
- Complexity and CAPEX
- Operation reliability and OPEX
- Product yields and quality stability
- CO<sub>2</sub> footprint / CI

Fluid bed MTG technology readiness and commercialization

Summary

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# MTG chemistry



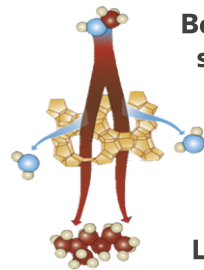
## Theoretical Chemistry

	CH <sub>3</sub> OH	$\rightarrow$	H <sub>2</sub> O	+	CH <sub>2</sub>	+	Heat
Mass	32		18		14		
wt %	100%		56%		44%		

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



Bench 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

## 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



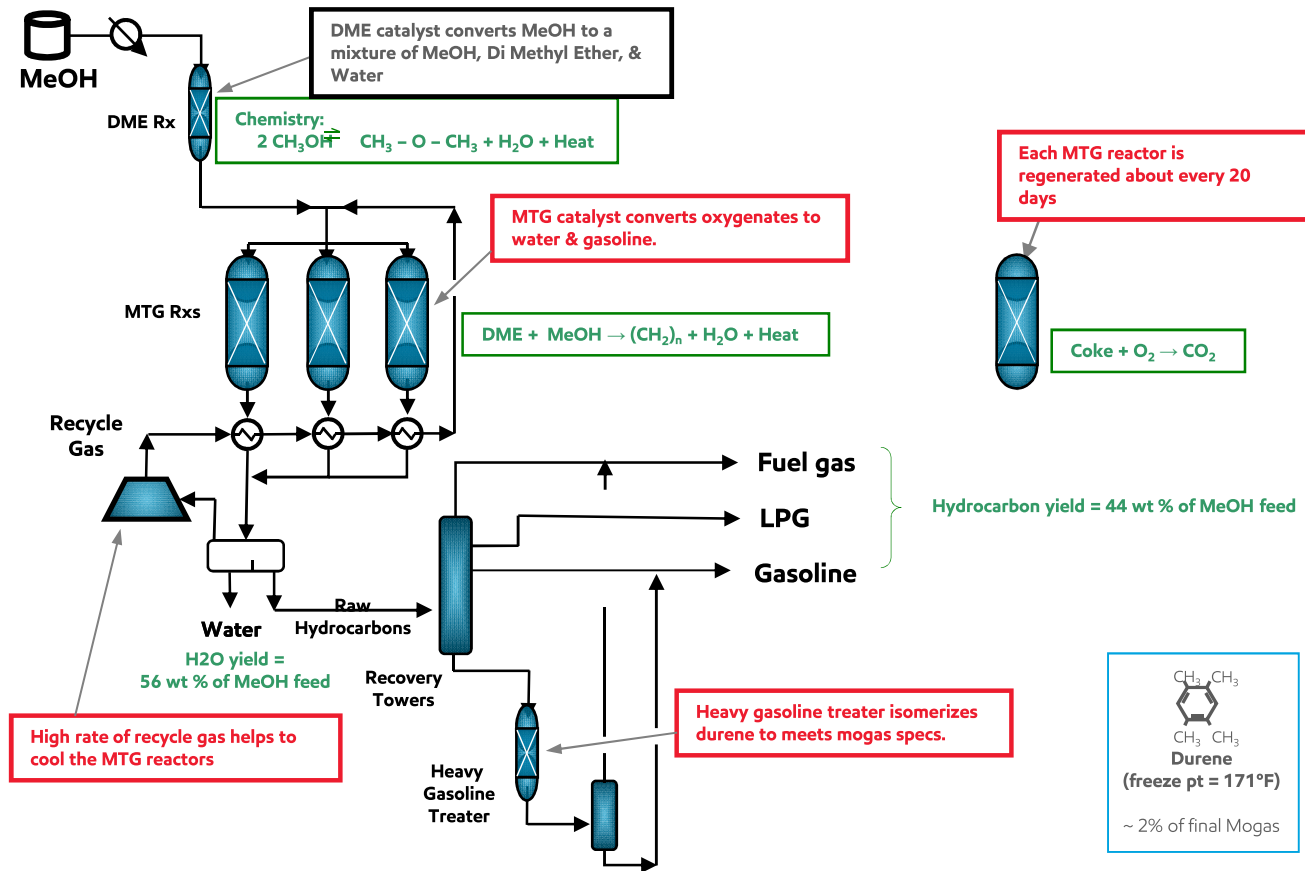
Demo unit 100 BPD



- ✓ EM and SEG Fluid Bed CDA (2014 -2017)
  - ✓ Was considered "Technically Ready"
  - ✓ With recycle

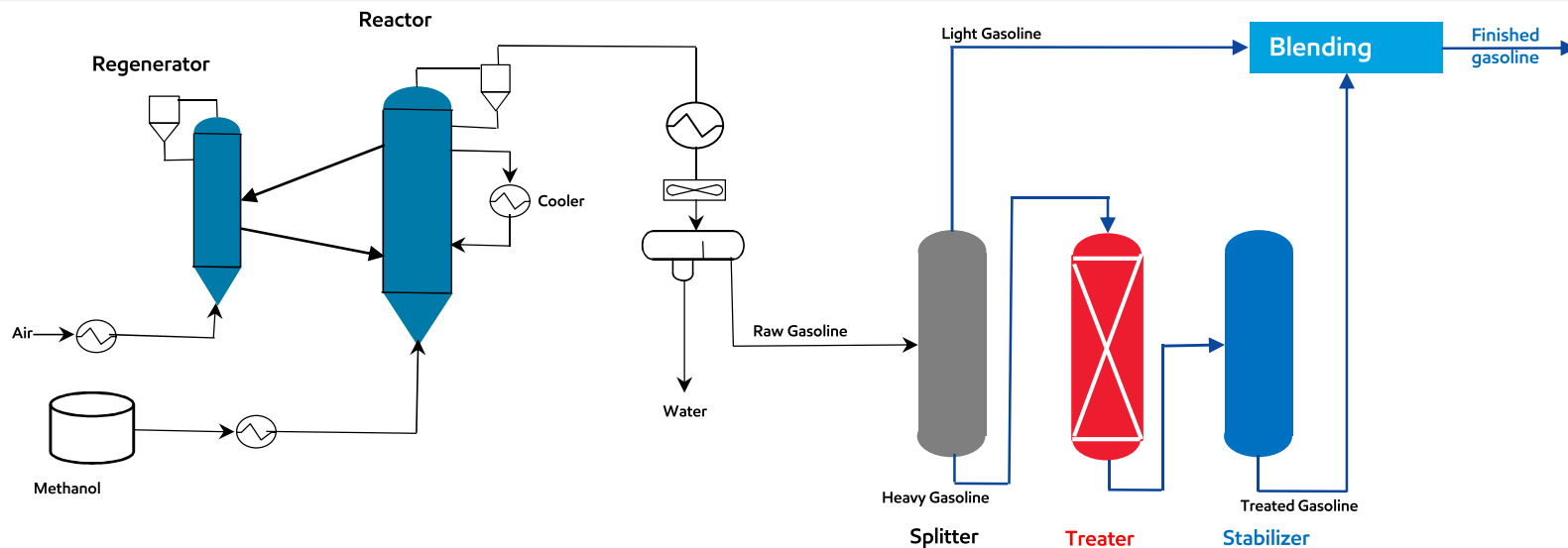
Process overview

# Fixed bed MTG



Process overview

# Fluid bed MTG



## Feedstock (typical)

~4wt% water + ~96wt% Methanol

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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

## 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

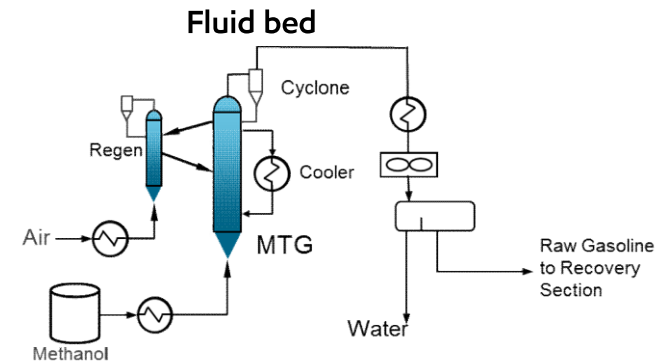
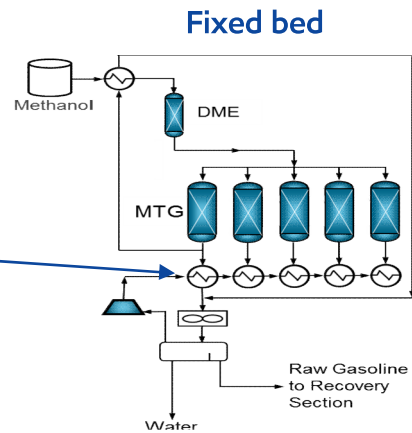
- Steady state operation mode
- Catalyst maintained in steady active state

### Lower CO<sub>2</sub> footprint and CI

- Lower CO<sub>2</sub> emissions due to lower energy consumption

Fixed bed vs. fluid bed

# Complexity and CAPEX



	Fixed Bed	Fluid Bed
<b>DME reactor</b>	Required to provide partial conversion of methanol with DME catalyst	No need
<b>Reactor</b>	Multiple fixed beds	Single fluid reactor & regenerator
<b>Complex control valve system</b>	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
<b>Recycle gas compressor</b>	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.





Fixed bed vs fluid bed

## OPEX / operation reliability

	<b>Fixed bed</b>	<b>Fluid bed</b>
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	<ul style="list-style-type: none"><li>✓ Very complicated at managing the variability of product yields &amp; quality by monitoring sequencing / regeneration of each reactor in multiple reactors</li><li>✓ Difficult to maintain the steady state yields &amp; quality</li></ul>	Stable product quality due to the steady state mode
<b>Heat integration</b>	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



## 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<sub>2</sub> and CO<sub>2</sub>-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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