04 METHANOL ROAD TRANSPORT FUELS
Alternative Fuel Drivers

- **Scale**: The feedstock base needs to be large enough to support global transportation market.

- **Sustainability**: There needs to be a viable pathway to low- or no-carbon transport, while reducing smog.

- **Subsidy**: Can’t rely on government support forever, so someone needs to make money.

- **Consumer**: Demands seamless transition and ease of use.
Beyond Oil & Gas: The Methanol Economy

- 2006 seminal book by USC’s Nobel Prize Laureate George Olah and Prof. Surya Prakash

- “The concept of the “Methanol Economy” has broad advantages and possibilities. It is suggested that methanol be used as: (i) a convenient energy storage medium; (ii) a readily transported and dispensed fuel, including uses in methanol fuel cells; and (iii) as a feedstock for synthetic hydrocarbons and their products.”

- In 2013, Israeli Prime Minister awarded $1 million Prize for Innovation in Alternative Fuels for Transportation to Profs. Olah and Prakash.
Feedstock: Abundant/Sustainable

Market: Large/Diverse

- plastic
- paint
- glue
- and much more

- M3
- M15
- M85
- M100
- GEM
- MTBE
- biodiesel
- DME
- marine
- fuel cell
- MTG
Methanol Production Bridge to Sustainability

- Methanol is a “future proof” molecule that can be made from conventional fossil sources and emerging renewable feedstocks.

- Expansion of energy markets for methanol builds demand for sustainably-sourced and locally-produced methanol.
Methanol - Practical Liquid Fuel Alternative

The diagram illustrates a comparison of various transportation fuels based on their net gravimetric energy density and net volumetric energy density. Key points include:

- **Dominant global transportation fuels**, high energy density
  - Diesel
  - Gasoline

- **A Practical alternative**
  - Methanol

- **Low energy density**
  - Batteries
  - 700 bar H2
  - 200 bar Methane

- **High on board storage costs**
  - L H2

- **E85**
  - M85

The graph highlights the energy density and volumetric density of different fuels, with Methanol positioned as a practical alternative with high energy density.
Methanol: A Global Energy Resource

Out of the ~70 million metric tons (23.3 billion gallons/88 billion liters) of methanol sold globally in 2015, energy and fuel uses represent one-third of total demand.

- Direct Methanol Fuel Blending
- Diesel Substitution
- MTBE
- Biodiesel
- DME
- MTG/MTO
- Fuel cells

From 2009-2014, direct methanol fuel blending has increased at an annual rate of nearly 23%.
Transportation Fuel Applications

**Direct Fueling**
- Blended with gasoline (M3 – M85)
- 7 million metric ton annual demand
- BioMethanol is 2\textsuperscript{nd} Generation biofuel

**Dimethyl Ether**
- Either DME or BioDME
- 4.7 million ton methanol demand
- Can be used neat or blended with propane
- Low-carbon, no-sulfur, diesel replacement
- Transport market is emerging with partners like Volvo and Nissan. Pilots in EU, Japan and C

**Biodiesel**
- Key ingredient in esterfication
- 1.3 million ton methanol demand
- Renewable methanol can make ultra-clean biodiesel
- Roughly 15-20% of oil source by mass
Transportation Fuel Applications

MTBE/BioMTBE
- Extensive world markets remain for MTBE
- 8.5 million ton methanol demand
- Up to 15% MTBE content allowed in EU, compliance with Renewable Energy Directive with BioMTBE attractive

Methanol-to-Olefins
- A 600,000 tonnes/year MTO project requires 1.8m tonnes/year of methanol
- 9 million ton methanol demand
- MTO eases burden of petroleum supply by diversifying feedstocks for light olefins

Methanol-to-Gasoline
- ExxonMobil and Haldor Topsoe both offer MTG technology producing sulfur-free drop in gasoline from methanol feedstock
- Better yields than Fischer-Tropsch fuels at lower costs
Methanol: Essential Chemical Building Block

Methanol In Our Lives

<table>
<thead>
<tr>
<th>Primary Derivatives</th>
<th>Derivatives</th>
<th>Diverse Demand Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORMALDEHYDE</td>
<td>Urea formaldehyde</td>
<td>Renovation, new building activity, automobile production, panel board substitution for solid wood, changing wood panel mix, growth in high technology chemicals.</td>
</tr>
<tr>
<td></td>
<td>Phenol formaldehyde</td>
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<tr>
<td></td>
<td>1,4-butanediol</td>
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<tr>
<td></td>
<td>Acetal Resins</td>
<td></td>
</tr>
<tr>
<td>ACETIC ACID</td>
<td>Vinyl acetate monomer</td>
<td>Building activity, durables output, automobile production, clean air legislation, packaging trends, growth in plastic recycling, paints and coatings.</td>
</tr>
<tr>
<td></td>
<td>Acetic anhydride</td>
<td></td>
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<tr>
<td></td>
<td>Terephthalic acid</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solvent acetate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solvent esters</td>
<td></td>
</tr>
<tr>
<td>CLEAN FUELS</td>
<td>Methanol/water blends</td>
<td>Demand for better health/cleaner environment, clean air legislative goals, displacement of gasoline components (e.g. lead, aromatics), safety and engine performance.</td>
</tr>
<tr>
<td></td>
<td>- fuel cell &quot;hydrogen carrier&quot;</td>
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<tr>
<td></td>
<td>Refomulated gasoline</td>
<td></td>
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<tr>
<td></td>
<td>- MTBE</td>
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<tr>
<td>OTHER</td>
<td>Methyl methacrylate</td>
<td>Total chemical production, general economic activity, alternative fuel developments, environmental pressures.</td>
</tr>
<tr>
<td></td>
<td>Methylamines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chloromethanes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direct use</td>
<td></td>
</tr>
</tbody>
</table>

Source: Methanex
Oil Displacement Drives Demand Growth

2004 – 2014 CAGR:
Energy: 12.2%
Total: 6.3%*

2015 – 2018 CAGR:
Energy: 12.1%
Total: 7.8%*

Source: IHS Chemical, March 2015
Excludes integrated methanol demand for methanol to olefins
Examples of Energy Use

- Passenger Cars
- Shipping
- Heavy Duty
Various Gasoline Blend Options

**M3 – M15**
- EU allows M3 (EN228) *Blended a.o. in UK and NL*
- China uses M15 *Estimated 7 million metric tons ~75% of cars built by international automakers*
- Trials in Australia, Israel, a.o.

**A20 – A30**
- Automakers call for higher octane to facilitate greater engine efficiency *(higher compression, turbocharging, downsizing)*
- Methanol and ethanol alcohol fuels together at mid-level blends provide needed octane

**M51-100**
- ASTM D5797 standard revision
- M100 dedicated vehicles *(e.g. Geely)*
- Use of SI technologies in Light and Heavy Duty vehicles
- Few changes needed to existing vehicle technologies at low cost
Low-Level Gasoline Additive

- Last year, China used 7 million metric tons of methanol as M15 for use in the existing fleet of vehicles representing well over 6% of the country’s fuel pool.

- Domestic automakers supply less than 25% of the cars sold in China, which means that cars built by international automakers are running every day on M15.

- We are seeing anecdotal use of M3 and lower blends in the European market.
Methanol and ethanol have high blending octane (anti-knocking)

Increasing octane allows automakers to use:

- Higher compression ratio engines
- Greater turbocharging
- More direct fuel injection
- Engine downsizing

Mid-Level Mixed Alcohol High Octane Fuels
GEM Cars

Tri-flex-fuel vehicles or GEM cars are capable of operating on any combination of gasoline/ethanol/methanol.

Relatively few changes required to existing engines at cost estimated not to exceed US$100/vehicle for running high methanol/ethanol blends.
Range of Technologies for HDV Benefit

BENEFITS
- High break thermal efficiency
- Low emissions
- Low soot
- Easy handling
- Compatible with existing engine technologies
- Opportunities for optimization
- Affordable

- DIESEL BLENDS
- DME
- DUAL FUEL
- MD95
- PPC ENGINE
- SPARK IGNITION
Methanol Fuel Examples Around the World

- **USA** – methanol motorsport fuel
- **UK** – EN228 low blend
- **Israel** – M15 trials
- **Africa** – cooking stoves
- **Sweden** – methanol marine fuel
- **Denmark** – methanol fuel cells
- **China** – M15 to M100
- **Australia** – GEM fuel
## China Provinces in the Driver Seat

<table>
<thead>
<tr>
<th>Province</th>
<th>Local Methanol Gasoline Standards</th>
<th>Implemented Since</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gansu</td>
<td>M15 &amp; M30</td>
<td>2009</td>
</tr>
<tr>
<td>Guizhou</td>
<td>M15</td>
<td>2010</td>
</tr>
<tr>
<td>Hebei</td>
<td>M15 &amp; M30</td>
<td>2010</td>
</tr>
<tr>
<td>Heilongjiang</td>
<td>M15</td>
<td>2005</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>M45</td>
<td>2009</td>
</tr>
<tr>
<td>Liaoning</td>
<td>M15</td>
<td>2006</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>M15 &amp; M25</td>
<td>2004</td>
</tr>
<tr>
<td>Shandong</td>
<td>M15</td>
<td>2012</td>
</tr>
<tr>
<td>Shanghai</td>
<td>M100</td>
<td>2013</td>
</tr>
<tr>
<td>Shanxi</td>
<td>M5, M15, M85 &amp; M100</td>
<td>2008</td>
</tr>
<tr>
<td>Sichuan</td>
<td>M10</td>
<td>2004</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>M15 &amp; M30</td>
<td>2007</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>M15, M30 &amp; M50</td>
<td>2009</td>
</tr>
<tr>
<td>Ningxia</td>
<td>M15 &amp; M30</td>
<td>2014</td>
</tr>
</tbody>
</table>
Oil displacement drives demand growth

Global Methanol demand by application (Million Metric Ton)

China methanol demand by application (Million Metric Ton)

Source: IHS Chemical, November 2015
### China Methanol Fuel Status

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>China adopted national standards for M85 and M100.</td>
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<tr>
<td>2012</td>
<td>MIIT “high proportion” methanol demonstration to serve as the basis for M85 vehicle standards in Shanxi, Shaanxi, and Shanghai, and has expanded to other provinces and cities.</td>
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<tr>
<td>2014</td>
<td>7 million tons (2.3 billion gallons/8.7 billion liters) of methanol blended with gasoline, against total gasoline consumption of 2.25 million barrels per day or 34.5 billion gallons/130 billion liters.</td>
</tr>
</tbody>
</table>

160,000 Vehicles converted to methanol fuel, mostly taxis.
On July 14, Li Shufu, who is chairman of the Geely Group and Volvo stated that methanol fuel is safety, economy and environmentally friendly. 


Geely has been conducting research on methanol fuels since 2005, with 27 patents.

Geely’s plant in Jinzhong, Shanxi Province capable of producing 250,000 methanol-fueled cars per year.
OK Denmark Recently Opened 1st Methanol Fuel Pump in the EU

- In Denmark the Green Methanol Infrastructure consortium (Serenergy, OK and Hamag) recently opened the 1st methanol fuel pump in Europe
- Cars use Serenergy RMFC technology as range extender and CRI methanol as fuel
- The consortium reports a battery powered vehicles to drive 800 kilometers on one tank
Israel Methanol Fuels Demonstrations

- Israel fundamentals:
  - Large gas finds in Israel
  - Strategic need to reduce oil dependence
- Prime Minister Netanyahu established Fuel Choices Initiative.
- Driven 900,000 kms on M15 fuels with improved power and torque.
- Emissions of HC, CO, NOx, CO2, methanol, and formaldehyde all lower or similar to gasoline and all under EU standards
Australia Methanol Fuel Blending

- Methanol Fuels being commercialized in Australia
  - Project led by Coogee. Methanex is a partner
  - Path to energy security
  - Methanol excise tax free status for 10 years (~A$38c/litre, ~$US 480/t)
  - Successful road trials and testing programs completed
  - Commercial roll out of GEM 8 planned in 2016; GEM15 & GEM56 in the future
EU Rally Racing with GEM Fuels

- Methanol Institute, Methanex and OCI NV (Natgasoline) sponsored GEM fuels in 2013, 2014, and 2015 World Rally Championship.
- GEM Fuels: 37% Gasoline; 21% Ethanol; 42% Bio-Methanol
- 2013 Junior WRC and 2014 Fiesta Trophy Results:
  - 24 young drivers in 10 Rally Race events across Europe drove 16,000 km
  - Consumed 38,000 liters of GEM fuels
  - Saved 66,000 kilograms of CO2
Safe Handling for Blending Terminal

Guidance from China Ministry of Industry and Information Technology, 2015

- In addition to the standard safety practices for bulk methanol storage and transfer, additional precautions are suggested for terminal blending of methanol with gasoline or diesel fuels.
- Terminal operators should be methanol-trained, and operators must wear anti-static overalls.
- Combustible gas detection alarm devices must be installed in the fuel allocation center and storage depot.
- In case of a fire, alcohol-resistant extinguishing foams should be used.
- Once tanker enters loading area, all safety equipment must be checked, and the grounding wire must be connected before loading.
- Strictly control the flow rate when loading the tanker.
Safe Handling for Retail Fuel Station

Guidance from China Ministry of Industry and Information Technology, 2015

• All parts of the methanol fueling equipment must be maintained to have good performance.

• Before using the fuel dispenser, the operator should check that the filling equipment is functioning properly without leakage.

• Fuel flows should not exceed 50 liters/minute.

• Do not directly fill methanol into a non-medal container like a plastic barrel.

• Methanol fuel should not be ingested, and eye and skin contact must be avoided.