METHANOL INSTITUTE

Overview of Global Methanol Fuel Blending

Gregory Dolan, CEO – Methanol Institute

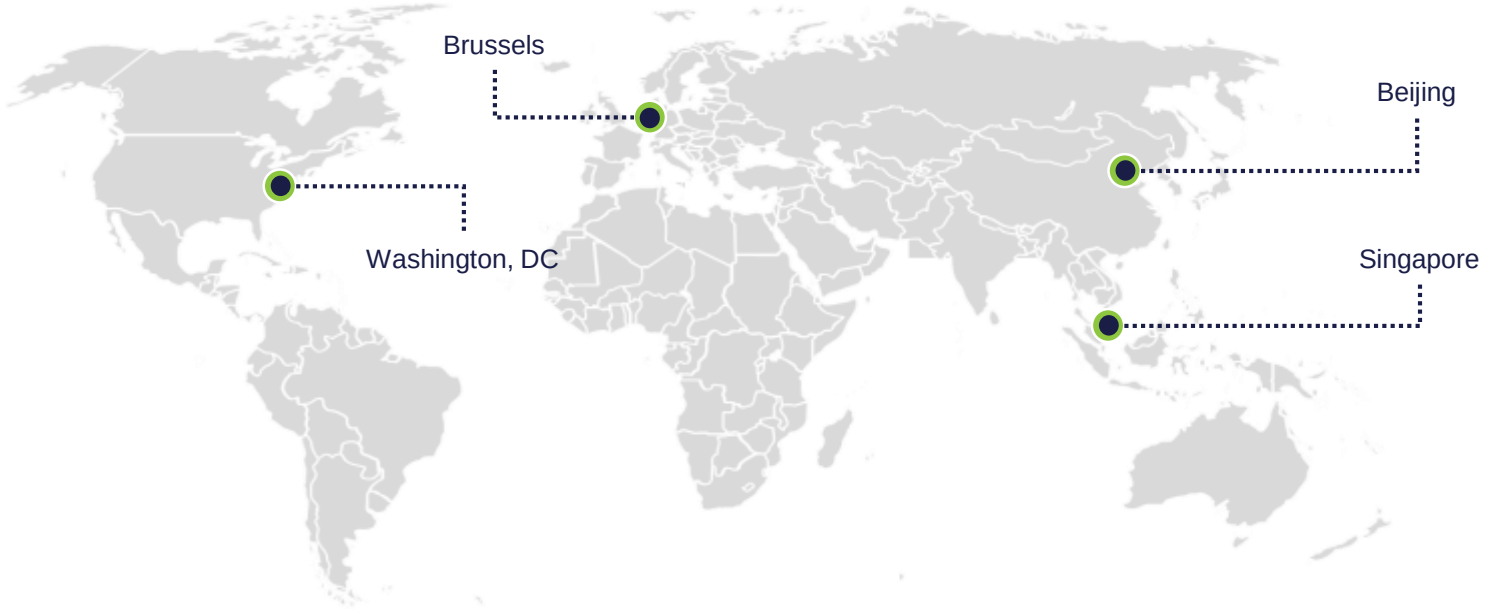
Trinidad and Tobago Methanol Fuel Blending Forum

24 January 2019

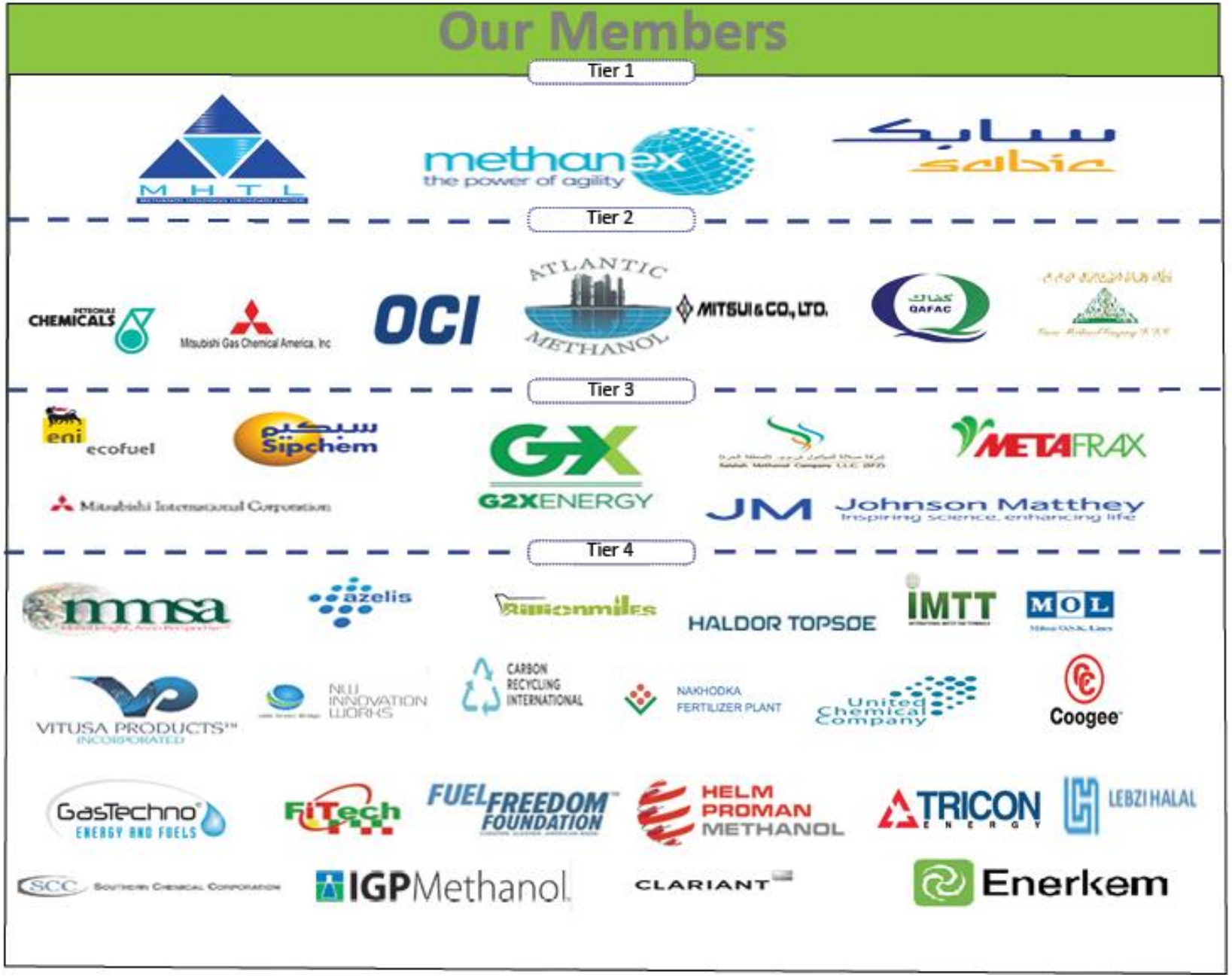
01 WHO WE ARE

MI History

- The Methanol Institute (MI) was established in 1989
- 30 years later, MI recognized as the trade association for the global methanol industry
- Facilitating methanol's expansion from our Singapore headquarters and regional offices in Washington DC, Brussels, and Beijing

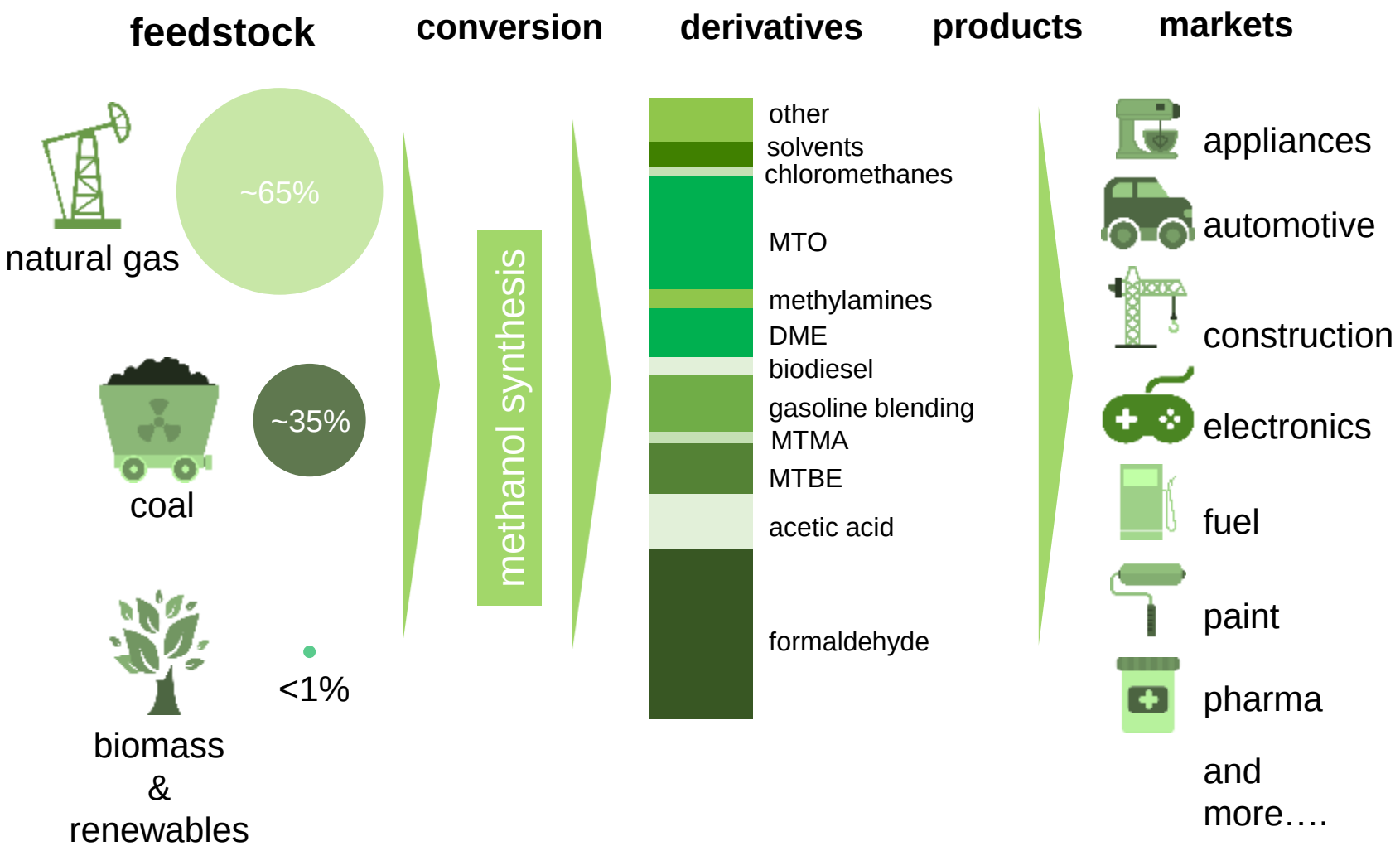


Our Members


Tier 1
MHTL
methanex
the power of agility
سابك
sabic
Tier 2
CHEMICALS
Mitsubishi Gas Chemical America, Inc
OCI
ATLANTIC METHANOL
MITSUI & CO., LTD.
QAFAC
Tier 3
eni ecofuel
سبكيم
Sipchem
GX
G2XENERGY
METAFRAX
Mitsubishi International Corporation
JM
Johnson Matthey
Inspiring science, enhancing life
Tier 4
mmsa
azelis
HALDOR TOPSOE
IMTT
MOL
VITUSA PRODUCTS
INCORPORATED
NILU
INNOVATION
WORKS
CARBON
RECYCLING
INTERNATIONAL
NAKHODKA
FERTILIZER PLANT
United Chemical Company
Coogee
GasTechno
ENERGY AND FUELS
FiTech
FUEL FREEDOM FOUNDATION
HELM
PROMAN
METHANOL
TRICON
ENERGY
LEBZI HALAL
SCC
Southern Chemical Corporation
IGPMethanol
CLARIANT
Enerkem

02 METHANOL PRODUCTION AND DEMAND

Methanol: Broad Feedstocks and Markets



Methanol is a versatile fuel source

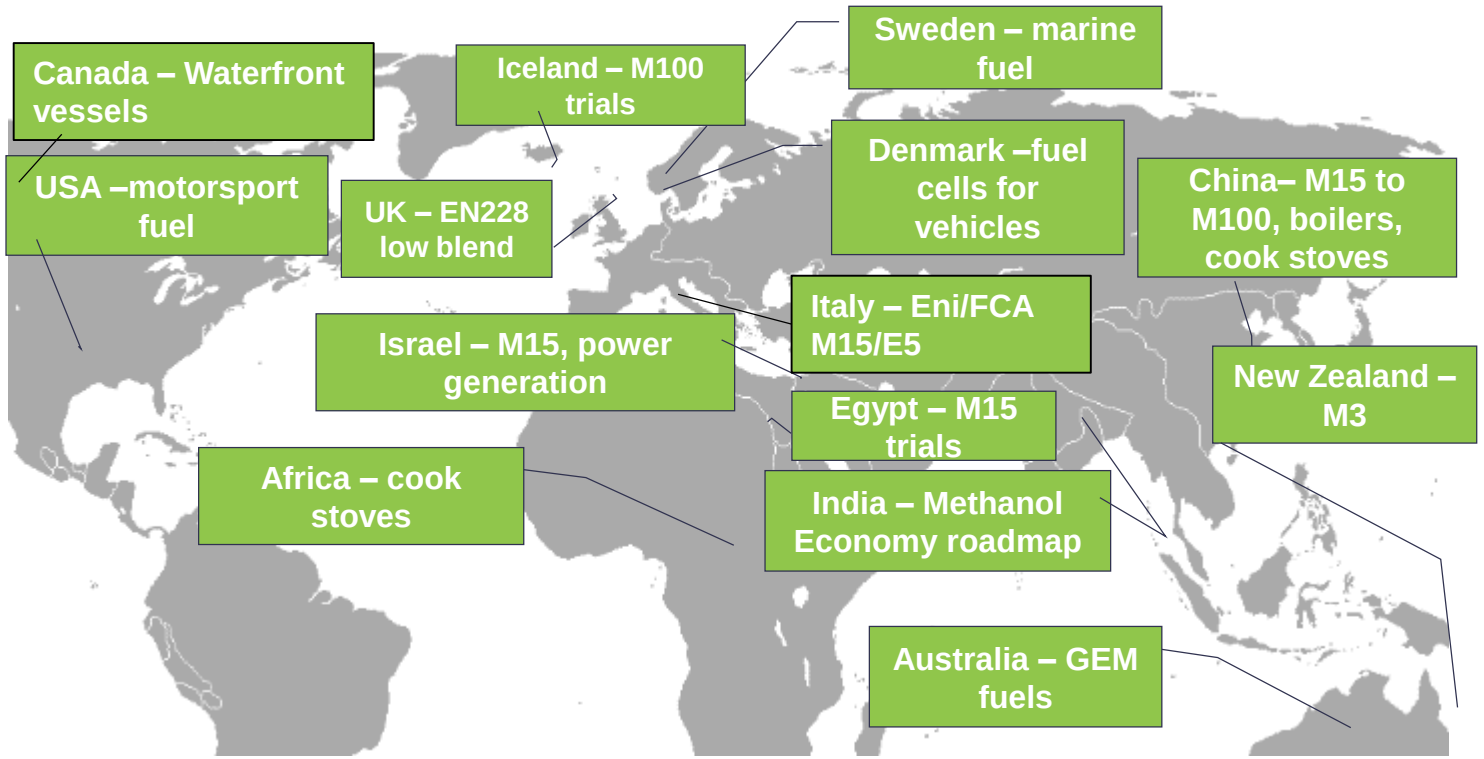
Out of the ~80 million metric tons of methanol sold globally in 2018, energy and fuel uses represent 40% of total demand

FUELS
- Neat fuel
- Low blends
- High blends
- GEM
- MTBE
- Biodiesel
- DME & OME
- MTG

TECHNOLOGIES
- SI & CI engines
- Turbines
- Fuel cells

SEGMENTS
- Road & non-road transportation
- Power & heat generation
- Marine

Global Methanol Fuel Examples



03 Methanol Blending

Solutions for gasoline and diesel engines

gasoline

- Low blends
- Mid level blends
- High blends

diesel

- FAME
- SI/CI HDVs
- DME/OME

Various Gasoline/Diesel Blend Options

M3 – M15

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

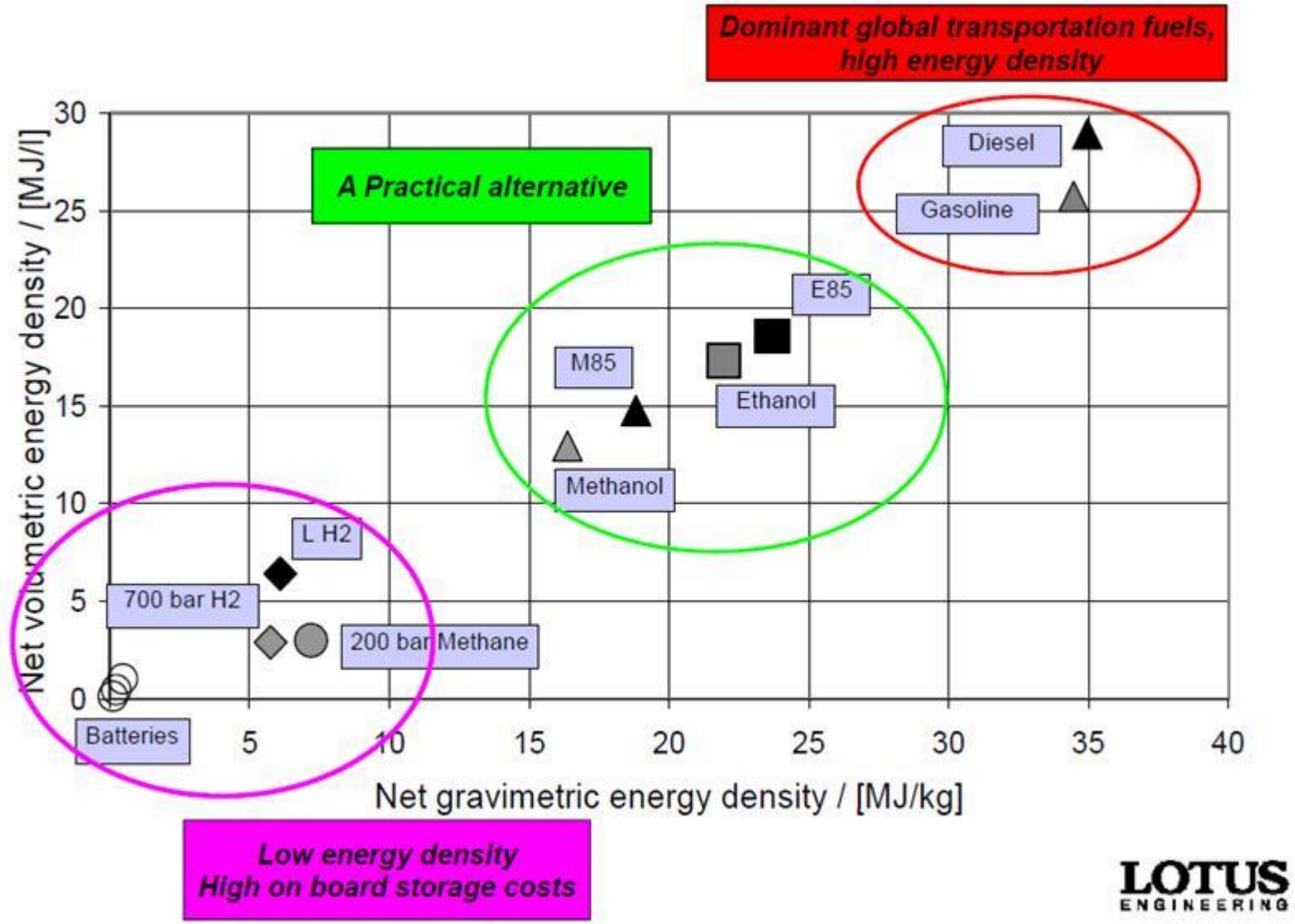
A20 – A30

- Automakers call for higher octane to facilitate greater engine efficiency
- Methanol and ethanol alcohol fuels together at mid-level blends provide needed octane

M51-100

- ASTM D5797 standard M51-M85
- M100 dedicated vehicles *(e.g. Geely)*
- Use of SI technologies in light duty vehicles
- Both SI and CI for heavy duty vehicles

Methanol - Practical Liquid Fuel Alternative



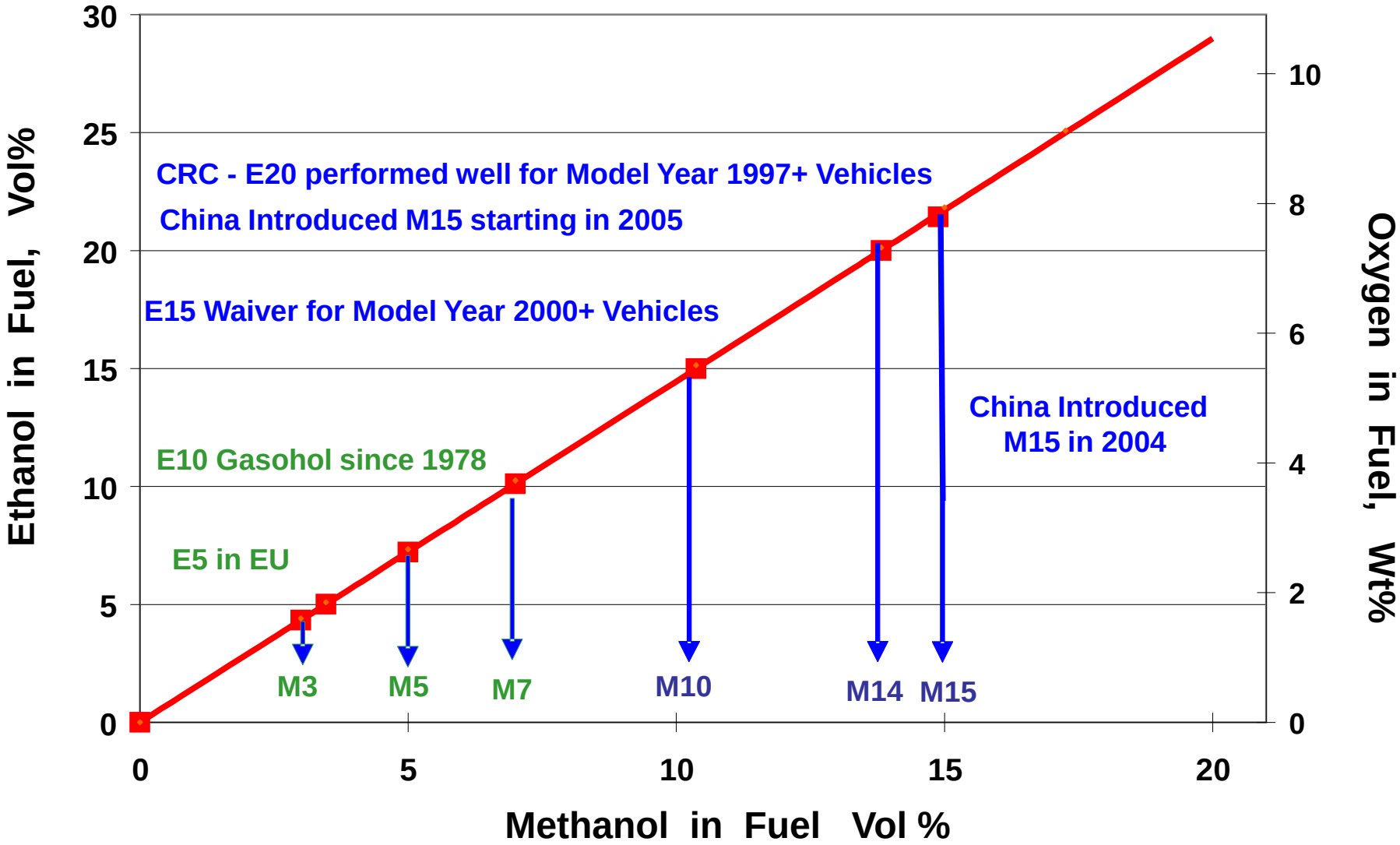
LOTUS ENGINEERING

Fuel Properties

Property	Gasoline	Diesel	Ethanol (E85)	Methanol (M85)
Chemical Structure	C_4 to C_{12}	C_8 to C_{25}	CH_3CH_2OH	CH_3OH
Feedstocks	Crude Oil	Crude Oil	Corn	Natural Gas, Coal, Biomass, CO_2
Gasoline Gallon Equivalent	100%	113%	75%	65%
Energy Content (LHV)	116,090 Btu/gal	128,450 Btu/gal	76,330 Btu/gal	57,250 Btu/gal
Energy Content (HHV)	124,340 Btu/gal	137,380 Btu/gal	84,530 Btu/gal	65,200 Btu/gal
Pump Octane	84-93	n/a	110	**112**

Newer Model Year Vehicles Can Manage Higher Alcohol Blends

Ethanol vs Methanol Gasoline Blend Vehicle Performance



Global Fuel Standards Allowable Methanol Content

- **Earlier commercial Fuel Standards started with nominal 3 vol % methanol in gasoline**

- **Higher methanol content in gasoline allowed as global automotive fuel system technology and materials continue to improve in global vehicle fleets**

Approved Methanol Gasoline Blends with Requirements for Co-solvent Alcohols and Additives						
Market Region		**Introduction Year**	**Maximum Volume % Methanol**	**Minimum Volume % Co-solvent**	**Maximum Wt % Oxygen**	**Corrosion Additives**
Europe	EC Directive	1985	3.0	≥ Methanol	3.7 %	
U.S.A	Sub Sim *	1979	2.75	≥ Methanol	2.0 %	
U.S.A	Fuel Waiver	1981	4.75	≥ Methanol	3.5 %	Required
U.S.A	Fuel Waiver	1986	5.0	2.5	3.7 %	Required
China, Shanxi	M15 Standard	2007	15.0	For Water Tolerance	~7.9 %	Required

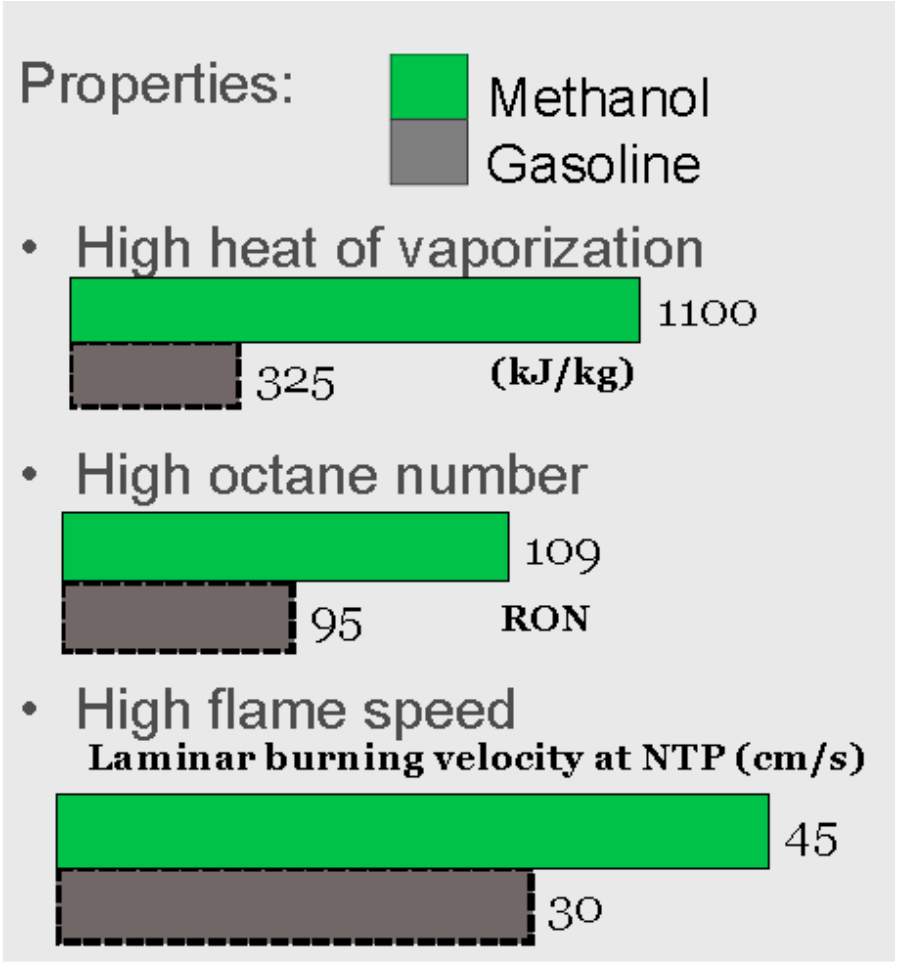
*** U.S. EPA's Substantially Similar Regulation for commercial gasoline**

Other countries evaluating introduction of methanol blending standards in gasoline: Egypt, India, Israel, Italy, New Zealand, Trinidad, Others

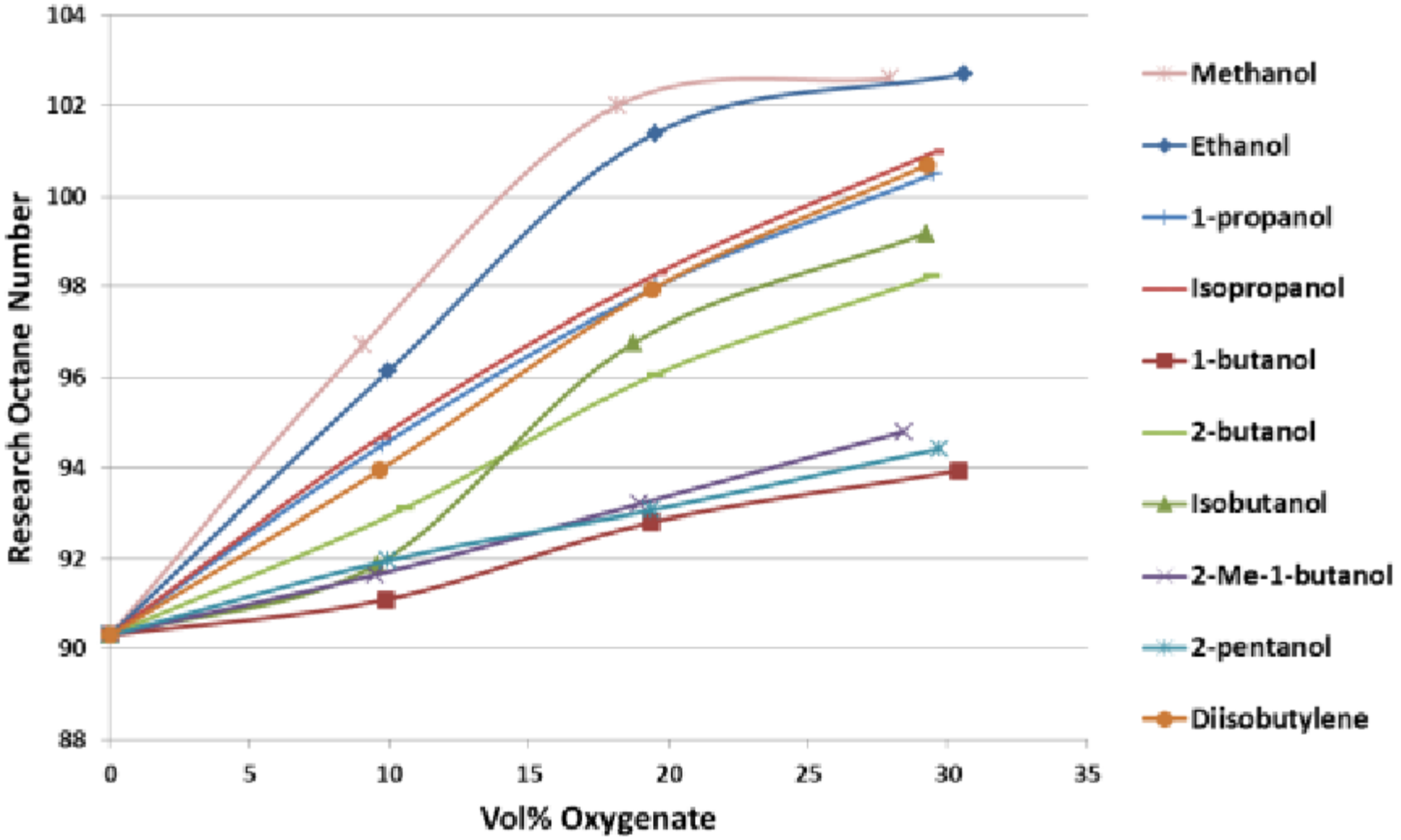
Methanol Blending Benefits

Ultra-high Efficiency Characteristics:

- Methanol use in spark ignition engines allows higher efficiencies by increasing the engine knock limit
- Methanol has much higher flame speed, which allows for tighter combustion control and more precise torque management
- Improving knock performance is important to help avoid undesired detonation while also allowing for highly effective recovery of energy from exhaust heat



Methanol Has Superior RON Blending Property



Key Performance Property Contribution To Gasoline Blending

Per Unit Volume and Per Unit of Energy Delivered to Gasoline Supplies

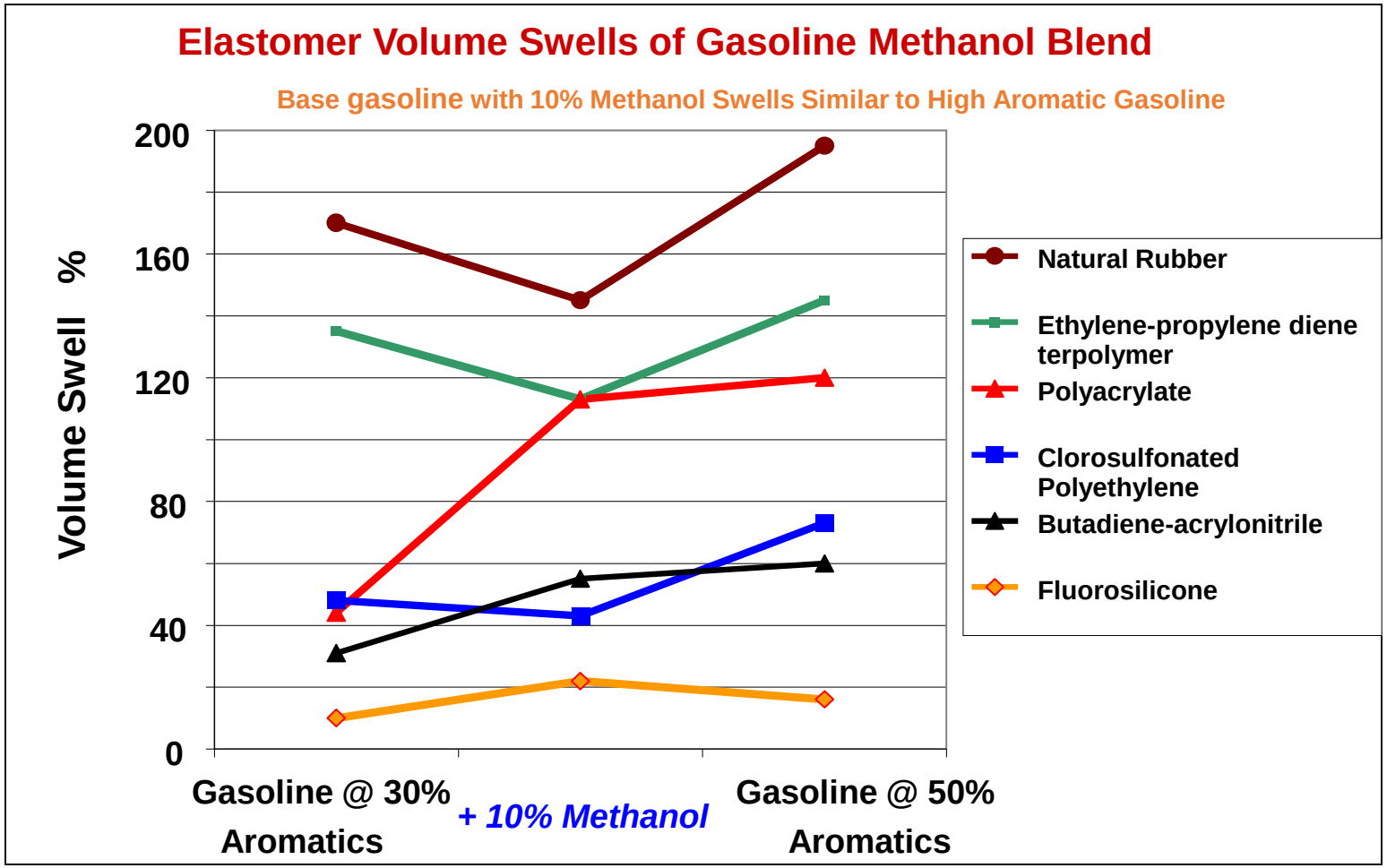
	Ethanol	Methanol	% over Ethanol
RON			
Oct-BBLs	10.5	11.5	+ 10
Oct-BBLs / GJ	3.12	4.60	+ 48
HoV (cooling)			
GJ / m3	0.66	0.91	+ 38
GJ / GJ	0.03	0.06	+ 86

Methanol delivers much more octane and evaporative cooling to gasoline blending than Ethanol

Material Compatibility With Methanol Blends Well Understood

- **Elastomer Compatibility with Methanol Blends well studied in the 1980's**

- ***Society of Automotive Engineers (SAE) Compatibility Guidelines established M15 as fuel standard for selecting materials used in vehicle fuel systems starting 1993***



Neat Methanol Material Compatibility [1, 2, 3]

Material	Compatibility	Material	Compatibility
304 stainless steel	A-Excellent	Hypalonr	A-Excellent
316 stainless steel	A-Excellent	Hytrelr	B-Good
Acetal (Delrinr)	A-Excellent	Kalrez	A-Excellent
Aluminum	A[1]-Excellent	Kel-Fr	A[1]-Excellent
Brass	A-Excellent	LDPE	A[1]-Excellent
Bronze	A-Excellent	Natural rubber	A-Excellent
Buna N (Nitrile)	A-Excellent	Neoprene	A-Excellent
Carbon graphite	A-Excellent	NORYLr	A-Excellent
Carbon Steel	A-Excellent	Nylon	B[1]-Good
Carpenter 20	A-Excellent	Polycarbonate	B[1]-Good
Cast iron	A-Excellent	Polyetherether Ketone (PEEK)	A-Excellent
Ceramic Al203	A-Excellent	Polypropylene	A[2]-Excellent
Ceramic magnet	A-Excellent	PPS (Ryton®)	A-Excellent
ChemRaz (FFKM)	A-Excellent	PTFE	A-Excellent
Copper	B[1]-Good	PVC	A[1]-Excellent
CPVC	A-Excellent	PVDF (Kynar®)	A-Excellent
EPDM	A-Excellent	Silicone	A-Excellent
Epoxy	B[1]-Good	Titanium	B-Good
Fluorocarbon (FKM)	C-Fair	Tygonr	A[1]-Excellent
Hastelloy-Cr	A-Excellent	Vitonr	C-Fair

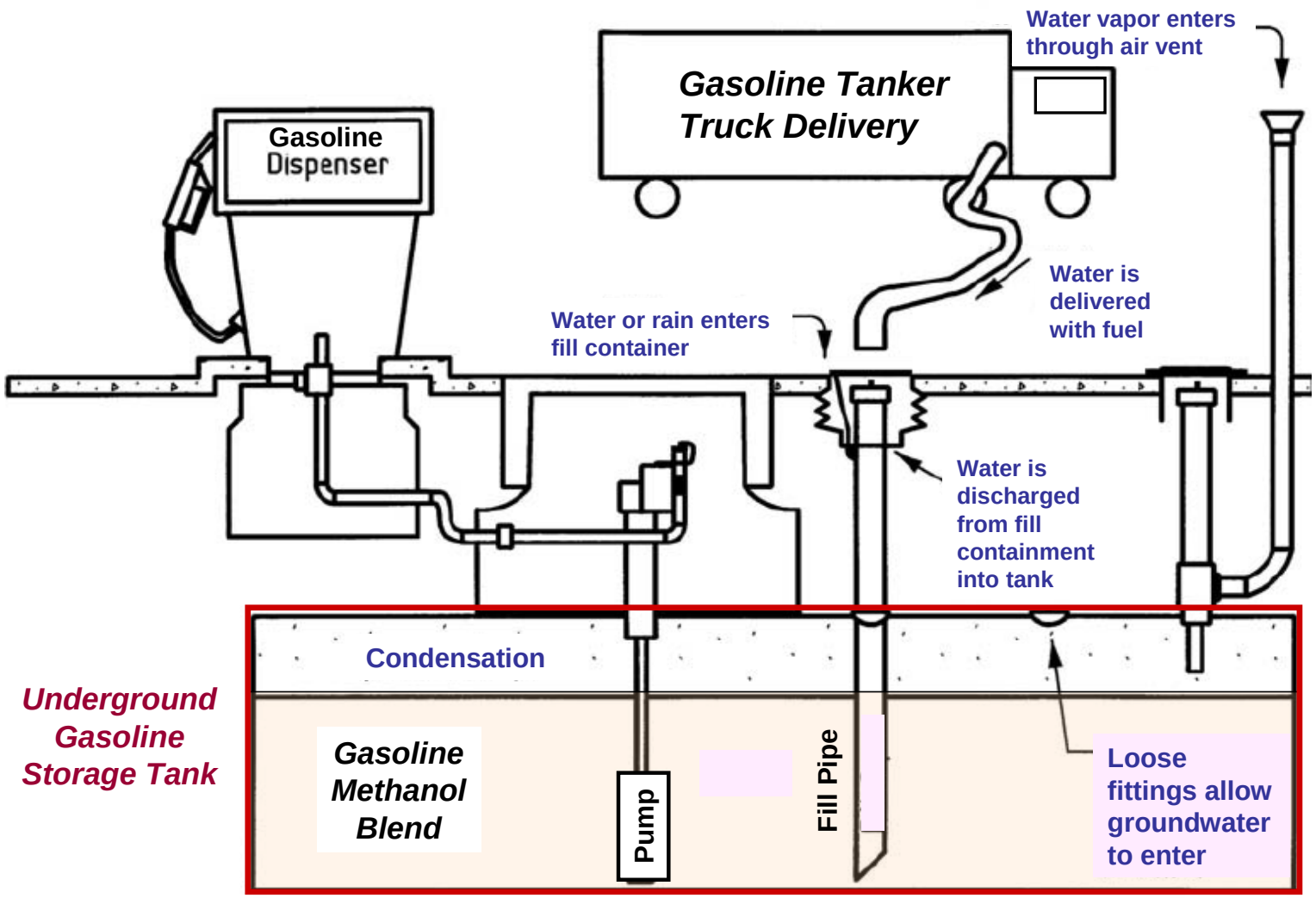
Footnotes for Previous Table:

1. Source: http://www.coleparmer.com/techinfo/chencompresults.asp
2. *Explanation of Footnotes*
   1. Satisfactory to 72°F (22° C)
   2. Satisfactory to 120°F (48° C)

   Ratings -- Chemical Effect
   A = Excellent.
   B = Good -- Minor Effect, slight corrosion or discoloration.
   C = Fair -- Moderate Effect, not recommended for continuous use. Softening, loss of strength, swelling may occur.
   D = Severe Effect, not recommended for **ANY** use.
   N/A = Information Not Available.
3. The only severe defect (level D) noted were for ABS plastic and polyurethane. However, neither of these materials is likely used in fuel wetted parts in vehicles, since aromatic compounds such as benzene, toluene and xylene each have an equivalent rating of severe defect level D for both ABS plastic and polyurethane. Thus, these specific material incompatibilities have no practical significance in the context of low level methanol blended transportation fuels.

Monitoring For Water Maintains Quality / Stability of Methanol Blends

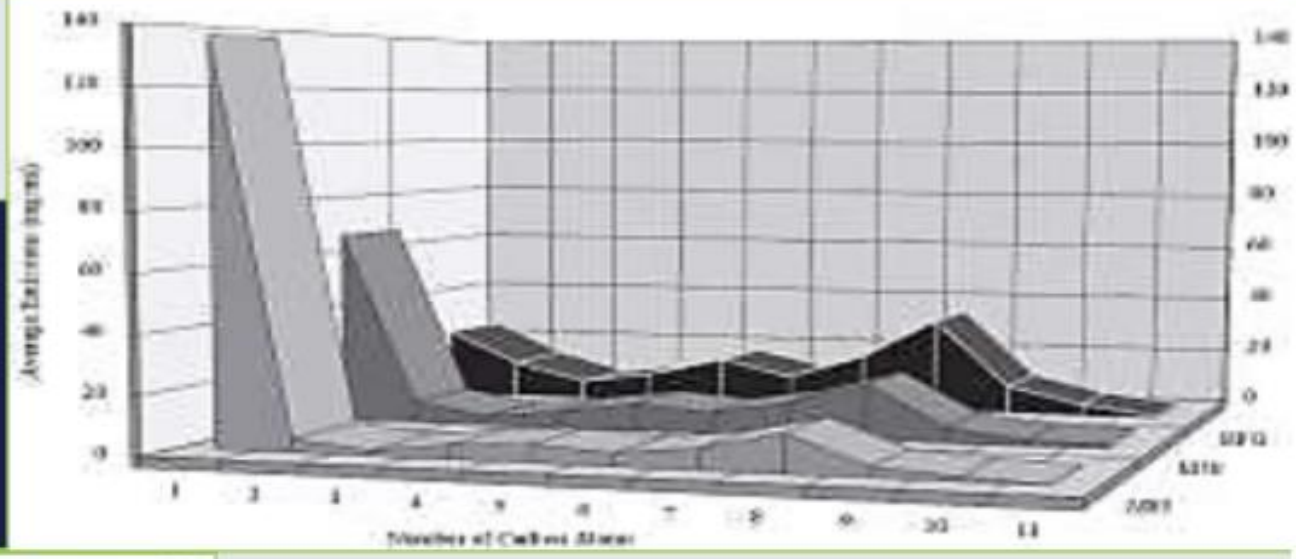
- **Good operating practices in gasoline distribution system maintain quality gasoline**



Methanol Air Quality & GHG Benefits

Inherently lower NOx and PM due to low temperature combustion properties;

C1 compounds in M85 compared to the much higher carbon content of reformulated gasoline



A lack of carbon-carbon bonds results in ultra-low particulate emissions;

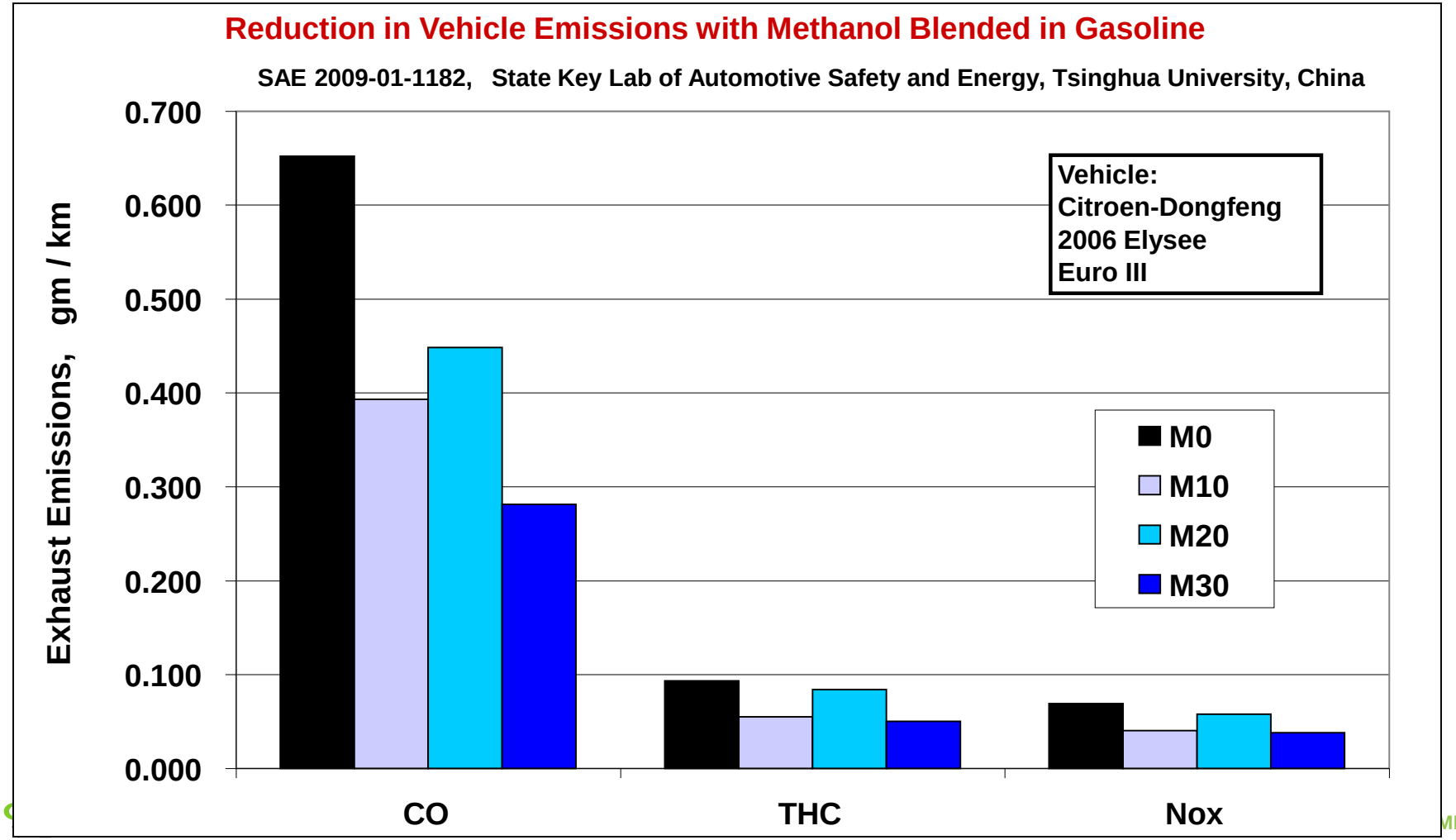
The atmospheric reactivity of methanol is recognized to have lower ozone forming potential compared to the olefins and aromatics present in gasoline

Methanol Provides Environmental Benefits

- Blending clean burning methanol also adds oxygen and volatility to gasoline which

- reduces vehicle exhaust emissions that reduces air pollution from Mobile Sources

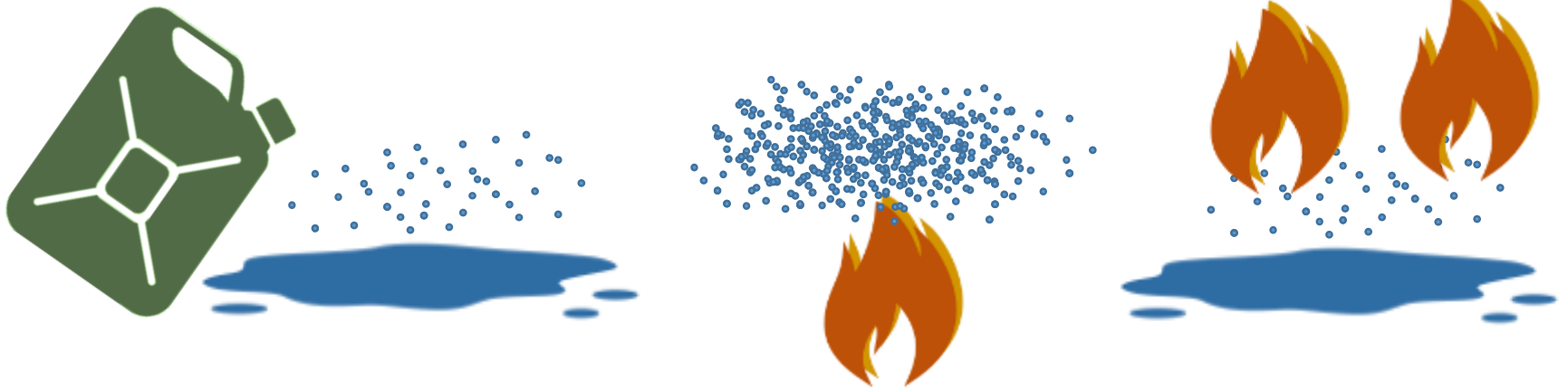
- improves combustion efficiency that raises methanol's net energy contribution from 50% of gasoline energy equivalent up to ~ 60% which further lowers vehicle's CO2/km



Fuel safety comparing apples to apples

	METHANOL	DIESEL	GASOLINE
Hazard pictograms (CPL)			
Signal word: (CPL)	Danger	Danger	Danger
Hazard statements (CPL)	H225 Highly flammable liquid and vapour. H301 Toxic if swallowed. H311 Toxic in contact with skin. H331 Toxic if inhaled. H370 Causes damage to organs.	H226: Flammable liquid and vapour. H304: May be fatal if swallowed and enters airways. H315: Causes skin irritation. H332: Harmful if inhaled. H351: Suspected of causing cancer. H373: May cause damage to organs through prolonged or repeated exposure. H411: Toxic to aquatic life with long lasting effects	H224: Extremely flammable liquid and vapour. H304: May be fatal if swallowed and enters airways H315: Causes skin irritation H340: May cause genetic defects H350: May cause cancer H361: Suspected of damaging fertility or the unborn child H336: May cause drowsiness or dizziness H411: Toxic to aquatic life with long lasting effects
Precautionary statements (CLP)	P210 - Keep away from heat. - No smoking P280 - Wear protective gloves, protective clothing, eye protection, face protection P304+P340 - IF INHALED: remove victim to fresh air and keep at rest in a position comfortable for breathing P305+P351+P311 - IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P301+P310 - IF SWALLOWED: Immediately call a POISON CENTRE or doctor P403+P235 - Store in a well-ventilated place. Keep cool	P201: Obtain special instructions before use P210: Keep away from heat/sparks/open flames/hot surfaces – No smoking P240: Ground/bond container and receiving equipment P241: Use explosion-proof electrical/ventilation/ lightning equipment P242: Use only non-sparing tools P243: Take precautionary measures against static discharge P260: Do not breathe dust/fume/gas/vapours/spray P264: Wash hands thoroughly after handling P270: Do not eat, drink or smoke when using this product P273: Avoid release to the environment P280: Wear protective gloves/clothing/eye protection P301+P310: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician P302+P352: IF ON SKIN: Wash with plenty of soap and water P305+P351+P353: IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P304+P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing P308+P313: IF exposed or concerned: Get medical advice/attention P312: Call a POISON CENTER or doctor/physician if you feel unwell P331: Do NOT induce vomiting P332+P313: If skin irritation occurs: Get medical advice/attention P370+P378: In case of fire: Use water spray or foam for extinction P391: Collect spillage P403+P235: Store in a well-ventilated place. Keep container tightly closed P405+P235: Store in a well-ventilated place. Keep cool P405: Store locked up P501: Dispose of contents/container in accordance with local/regional/national/international regulation	P201: Obtain special instructions before use P202: Do not handle until all safety precautions have been read and understood P210: Keep away from heat/sparks/open flames/hot surfaces – No smoking P233: Keep container tightly closed P240: Ground/bond container and receiving equipment P241: Use explosion proof electrical/ventilation/ lightning equipment P242: Use only non-sparing tools P243: Take precautionary measures against static discharge P261: Do not breath fume/gas/mist/vapours/spray P264: Wash hands thoroughly after handling P271: Use only outdoors or in a well-ventilated area P273: Avoid release to the environment P280: Wear protective gloves/clothing/eye protection P301+P310: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician P302+P352: IF ON SKIN: Wash with plenty of soap and water P305+P351+P353: IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower P304+P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing P308+P313: IF exposed or concerned: Get medical advice/attention P312: Call a POISON CENTER or doctor/physician if you feel unwell P331: Do NOT induce vomiting P332+P313: If skin irritation occurs: Get medical advice/attention P370+P378: In case of fire: Use water spray or foam for extinction P391: Collect spillage P403+P235: Store in a well-ventilated place. Keep cool P405: Store locked up P501: Dispose of contents/container in accordance with local/regional/national/international regulation

Methanol has lower fire risk than gasoline



Methanol

evaporates slowly

needs lots of vapour to burn

confined fire zone;
fires less likely

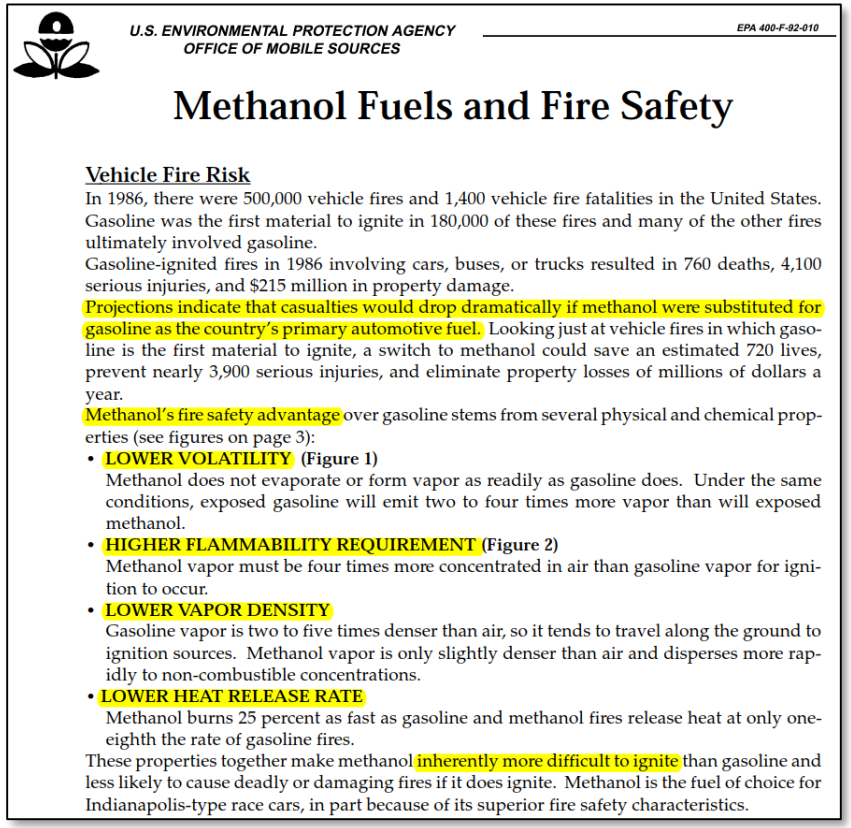
Gasoline

evaporates fast

needs little vapour to burn

broad fire zone;
fires more likely

Methanol is less dangerous than gasoline



U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF MOBILE SOURCES

EPA 400-F-92-010

Methanol Fuels and Fire Safety

Vehicle Fire Risk

In 1986, there were 500,000 vehicle fires and 1,400 vehicle fire fatalities in the United States. Gasoline was the first material to ignite in 180,000 of these fires and many of the other fires ultimately involved gasoline.

Gasoline-ignited fires in 1986 involving cars, buses, or trucks resulted in 760 deaths, 4,100 serious injuries, and $215 million in property damage.

Projections indicate that casualties would drop dramatically if methanol were substituted for gasoline as the country's primary automotive fuel. Looking just at vehicle fires in which gasoline is the first material to ignite, a switch to methanol could save an estimated 720 lives, prevent nearly 3,900 serious injuries, and eliminate property losses of millions of dollars a year.

Methanol's fire safety advantage over gasoline stems from several physical and chemical properties (see figures on page 3):

- **LOWER VOLATILITY (Figure 1)**
  Methanol does not evaporate or form vapor as readily as gasoline does. Under the same conditions, exposed gasoline will emit two to four times more vapor than will exposed methanol.
- **HIGHER FLAMMABILITY REQUIREMENT (Figure 2)**
  Methanol vapor must be four times more concentrated in air than gasoline vapor for ignition to occur.
- **LOWER VAPOR DENSITY**
  Gasoline vapor is two to five times denser than air, so it tends to travel along the ground to ignition sources. Methanol vapor is only slightly denser than air and disperses more rapidly to non-combustible concentrations.
- **LOWER HEAT RELEASE RATE**
  Methanol burns 25 percent as fast as gasoline and methanol fires release heat at only one-eighth the rate of gasoline fires.

These properties together make methanol inherently more difficult to ignite than gasoline and less likely to cause deadly or damaging fires if it does ignite. Methanol is the fuel of choice for Indianapolis-type race cars, in part because of its superior fire safety characteristics.

TABLE 6-1
HAZARD SUMMARY[a]

	M100	Gasoline
Flammability		
Ease of Occurrence		
Open & Restricted Areas	4	9
Enclosed Spaces	8 (2-4) [b]	2
Relative Hazard if Fire		
Fire Severity	3	10
Ease of Extinguishing	7	10
Flame Visibility	8	1
Toxicity		
Inhalation-Low Conc.		
Toxicity	3	10
Ease of Occurrence	10	10
Inhalation - High Conc.		
Toxicity	10	10
Ease of Occurrence	3	4
Skin Contact.		
Toxicity	9	8
Ease of Occurrence	3	3
Ingestion		
Toxicity	10	10
Ease of Occurrence	8(2) [c]	3

Table adapted from Machiele, 1998; [a] 1-No concern. 2 to 3 = Low Level concern. 4 to 6 = moderate concern. 7 to 8 = high-level concern. 9 to 10 = extreme hazard. [b] Numbers in parenthesis reflect hazard reductions resulting from design changes. [C] Number in parenthesis incorporates the lowered likelihood of ingestion due to the presence of additives.

Source: Malcolm Pirnie, Inc. , Technical Memorandum

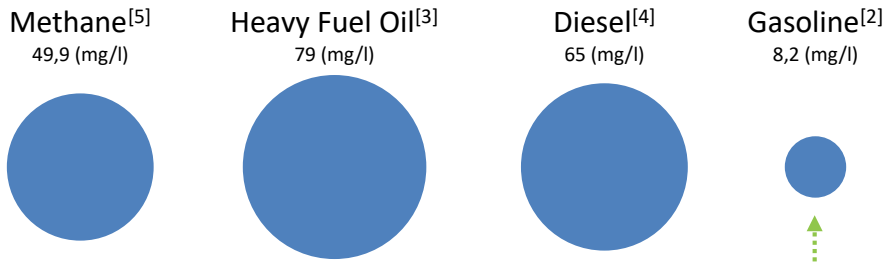
SAFER FOR THE ENVIRONMENT

LC50, LC = LETHAL CONCENTRATION

Concentration in water, at which half the population died within specified test duration

Methanol[1]
15,400 (mg/l)

Safer than Diesel by a factor of 240 times



Safer than Gasoline by a factor of 1900 times

[1] ECHA, European Chemicals Agency, registration dossier Methanol
[2] Petrobras/Statoil ASA, Safety Data Sheet, ECHA registration dossier Gasoline
[3] GKG/ A/S Dansk Shell, Safety Data Sheet
[4] ECHA, European Chemicals Agency, registration dossier Diesel
[5] ECHA, European Chemicals Agency, registration dossier Methane

Additional Source: Meyer-Werft

04 40 Years of Experience

40+ Years of Global Experiences with Methanol/Gasoline Blends

- **German Automakers and Oil Refiners conducted small vehicle fleet trials of methanol/gasoline fuels in mid-1970's**

- **Germans selected M15 as highest methanol content for use in vehicles with 1980's carburetor fuel systems and material compatibility**

- **Number of larger methanol/gasoline blend fleet trials conducted in late 1970's / early 1980's**

Germany	***~ 1,000 vehicles***
Sweden	***~ 1,000 vehicles***
New Zealand	***~ 950 vehicles***
China	***~ 500 vehicles***

Results: Methanol with corrosion inhibitors and co-solvent alcohols provided stable gasoline fuel, and protected fuel system metals in vehicles

- **The State of California managed extensive methanol/gasoline fuel programs in 1980's/1990's**

- **Some China Provinces initiated commercial M15 market trials in 2004**

The California Methanol Experience

Methanol Deployment in Light Duty Vehicles *Methanol Experience*

California Demonstrated Methanol as a Transportation Fuel in Light- and Heavy Duty Vehicles

mdj Research

THE CALIFORNIA & U.S. NATIONAL CONTEXT

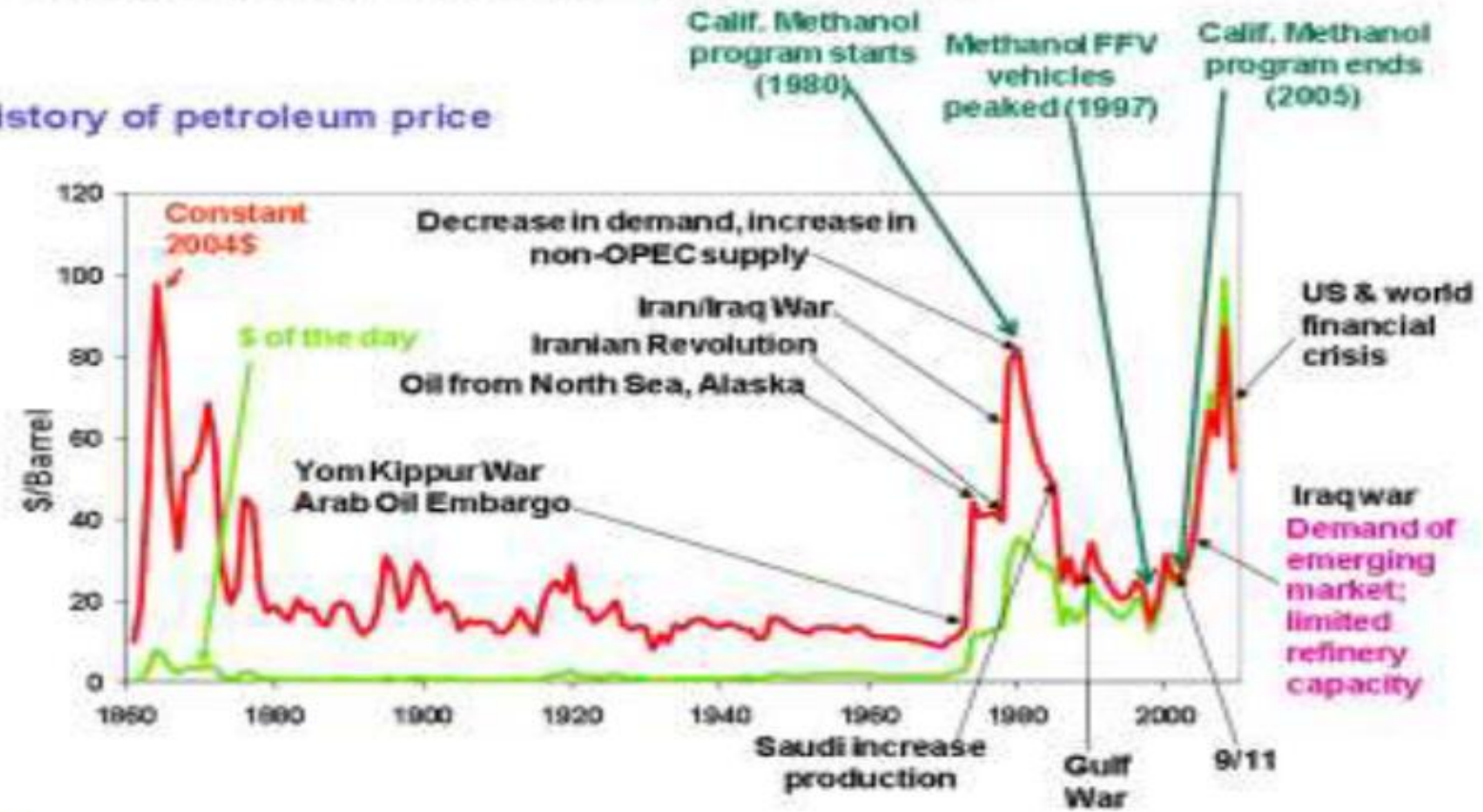
California Methanol Programs in the 1980s-90s, was fundamentally a technical success.

- ✓ Sixty retail fuelling stations
- ✓ 17,500 M85-compatible vehicles - first large scale production of Flexible Fuel Vehicles
- ✓ Over 200 million miles of successful vehicle operating experience along with a zero-incident health & safety record

However, despite the establishment of a California Fuel Methanol Reserve (CFMR), the low oil price during that period presented major competitive challenges…

US experience with Methanol

- Methanol succumbed to decreasing oil prices and lack of advocacy, replaced by MTBE (now banned) and ethanol



NOT ALL WAS LOST…

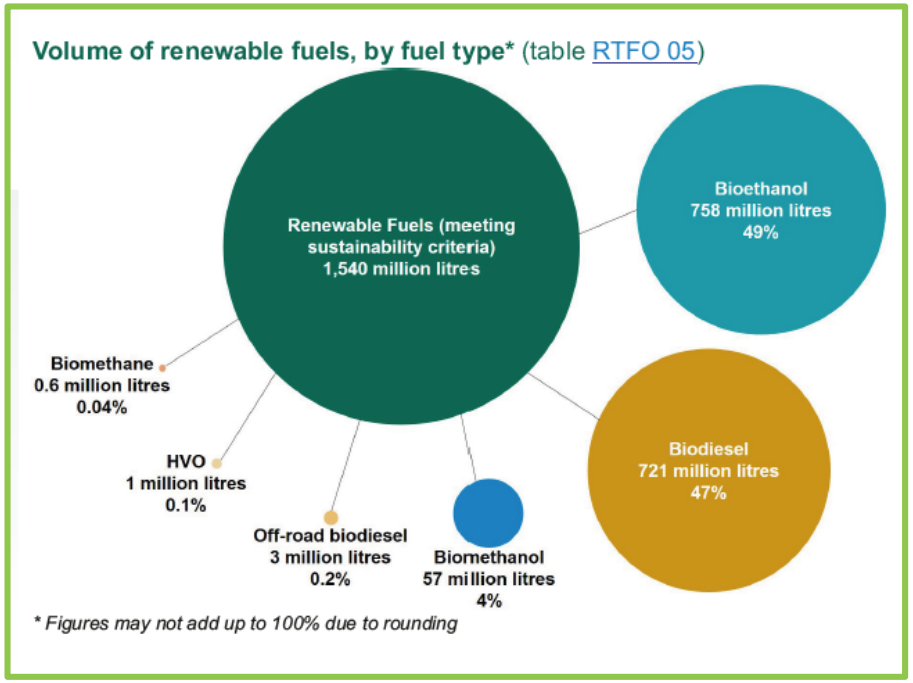
…Extensive technical literacy gained in the following areas

POSITIVE OUTCOMES

+ Distillation Properties
+ Water Solubility
+ Material Compatibility in
+ FFVs
+ Vehicle Emission Impacts *(e.g., HCHO standard adopted and easily complied with via close coupled catalysts)*
+ Octane Effects
+ Blending Vapor Pressure
+ Toxicity of Vapors
+ Risk Mitigation *(e.g., flame arrestors, anti-siphoning devices)*

UK BioMethanol Blending

- UK Department of Transport: Renewable Transport Fuel Obligation Report – 1 February 2018
- Averages 1% methanol in summer, and 1.5% in winter
- Biomethanol 57 Million liters, or 4% of UK total renewable fuel use
- “The supply of biomethanol has been increasing in recent years to an all-time high in 2016/2017”



https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/681174/rtfo-year-9-report-6-revised.pdf

Italy M15/E5 Blending

- 21 November 2017: With Italian Prime Minister, the CEOs of Eni and Fiat Chrysler Automobile sign MOU for joint development of technology reducing CO2 of road transport vehicles
- Eni had developed an “A20” fuel blend of 15% methanol and 5% bioethanol
- New blend being demonstrated in 5 FCA Fiat 500 vehicles in Eni’s Enjoy car-sharing fleet

joint press release

Eni and FCA sign research agreement for joint projects to significantly reduce CO_2 emissions produced by road transport vehicles

https://www.eni.com/en_IT/media/2017/11/eni-and-fca-sign-research-agreement-for-joint-projects-to-significantly-reduce-co2-emissions-produced-by-road-transport-vehicles

A20: a New Methanol-based Alternative Fuel

15% MeOH

5% bio-EtOH

80% Gasoline

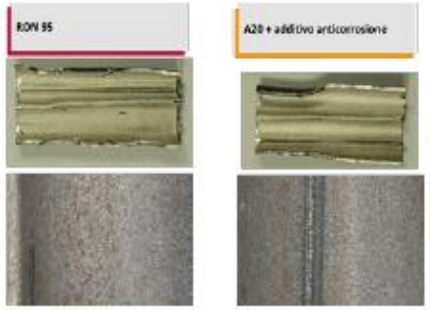
- Formula Cost Reduction
- "Transparent" to all the E10 car vehicles
- No-chemical corrosion problems
- No-phase separation (in the car tank and gas-station)

CUNA specification (NC 627-02 July 2018)

Property	Units	Limits MIN – MAX	
Research octane number, RON		100	
Motor octane number, MON		86	
Lead content	mg/l		5.0
Density (at 15 °C)	kg/m³	720.0	775.0
Sulfur content	mg/kg		10.0
Manganese content	mg/l		2.0
Nitrogen content	ppm		100
Oxidation stability	minutes	360	
Existent gum content (solvent washed)	mg/100 ml		5
Water content	% (m/m)		0.2
Oxygen content	%(m/m)		10.0
Methanol	%(V/V)	12.0	16.0
Ethanol + other Alcohols (C3-C4)	%(V/V)	4.0	6.0
Ethers (5 or more C atoms) other oxygenates	Volume blending of these components is restricted to 10.0 % (m/m) maximum oxygen content including methanol oxygen.		

CUNA NC 627-02 include also the evaporative class parameters to prepare A20 grade for summer, winter and transition period

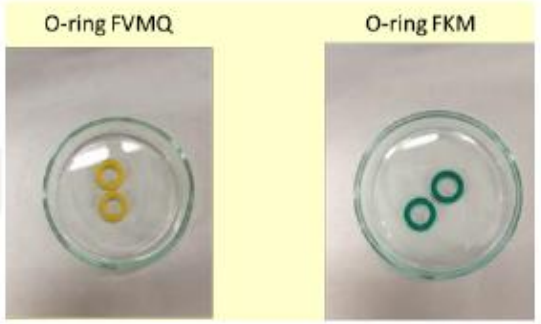
A20: Overall Transparency



After 1000 hours of test No evidence of corrosion-related criticalities for A20.

Metal tube

O-ring



All o-ring test shows No compatibility issue with A20

Plastic tube

For all types of tube tested, the ageing of A20 fuel does not lead to criticality in the mechanical behavior of the materials

Fuel system

Vehicle	Engine calibration	Air volume washed	Canister weight difference after cycle	Hot Soak	Day 1	Day 2	P. Factor	TOT
500 1.2 8v	4M10FVCS	231 L	34,1 g	HC 0,058 g	HC 0,598 g	HC 0,486 g	HC 2x0,120 g	HC 1,382 g

Vehicle test target : 2 g /test

A20 has positively passed the evaporative emission test

The results of the tests carried out so far confirm the compatibility of the fuel with FCA vehicles compliant with E10

Next step: On going process to check the compatibility to other carmakers and motorcycle manufacturers

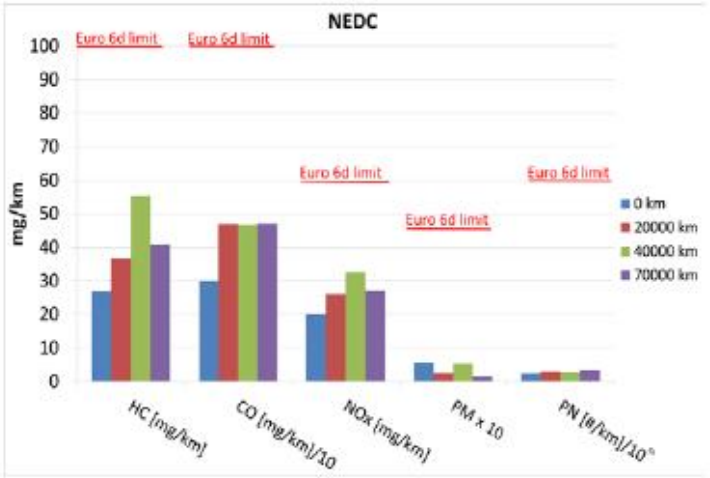
Fleet Test is On-going in Milan

Eni got approval from Italian Ministers to use A20 fuel for fleet tests as first step for selling into Italian market

In November 2017 the fleet tests started on Enjoy car sharing vehicles (n.5 Fiat 500) constantly monitored and refueled by the Enjoy team on a Eni station c/o Milan

Endurance test

- The car subjected to accumulation has run 100,000 km. All the controls (emissions, etc.) have been successful



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

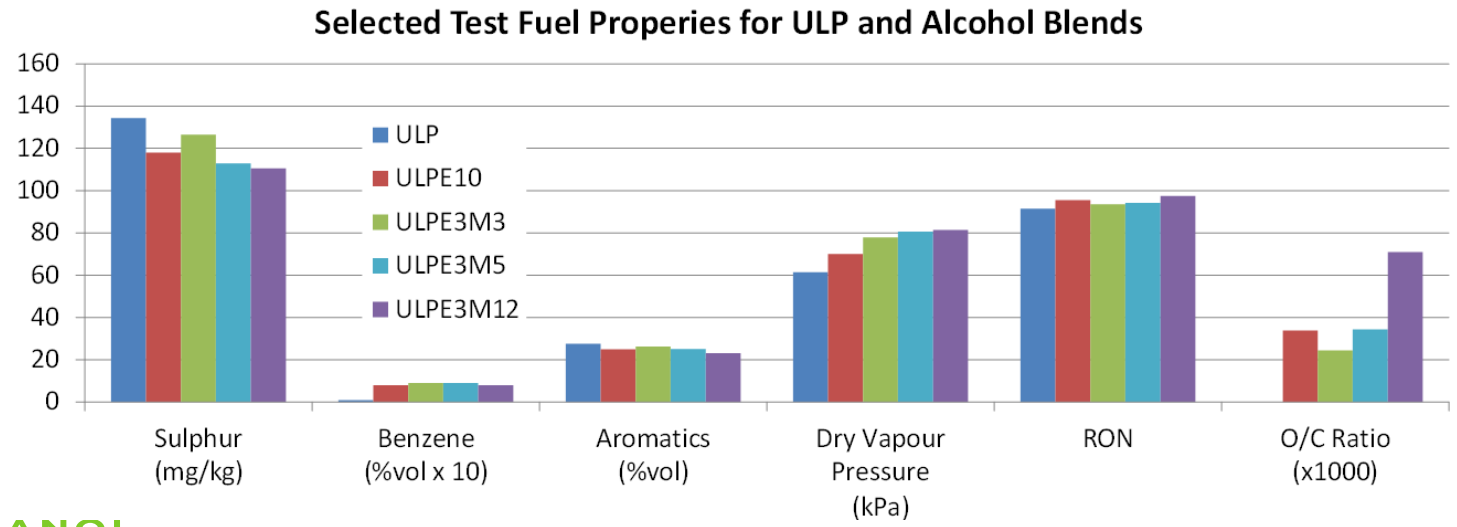
METHANEX ABENGOA natgasoline MH ePURE GEM FUEL

Denmark: Methanol Fuel Cell EV Range Extender

- Green Methanol Infrastructure consortium opened the first methanol fuel pump in Europe
- Cars/vans use Serenergy RMFC technology as range extender and CRI methanol as fuel
- Increasing range of battery powered vehicles from 200 to 800 kilometers
- Serenergy fuel cells also in Gumpert RG Nathalie, a methanol fuel cell powered electric supercar with a 1,200 km (745 mile) range and a top speed of 300 km/h (186 mph)

Australia Methanol Fuel Blending

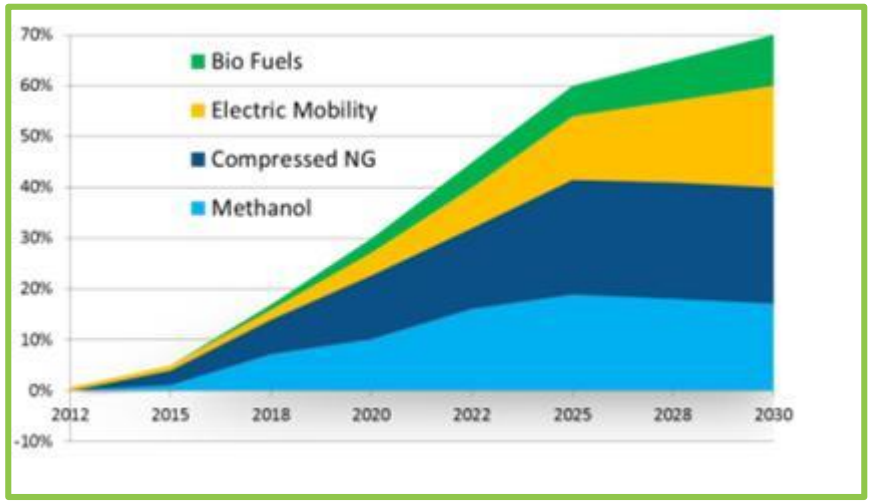
- Methanol Fuels being commercialized in Australia
  - Project led by Coogee. Methanex is a partner
  - Methanol excise tax free status for 10 years (~A38c/litre)
  - Successful road trials and testing programs completed
  - **Commercial roll out of GEM 8 (M5/E3) on hold pending methanol plant restart: GEM15 & GEM56 in the future**



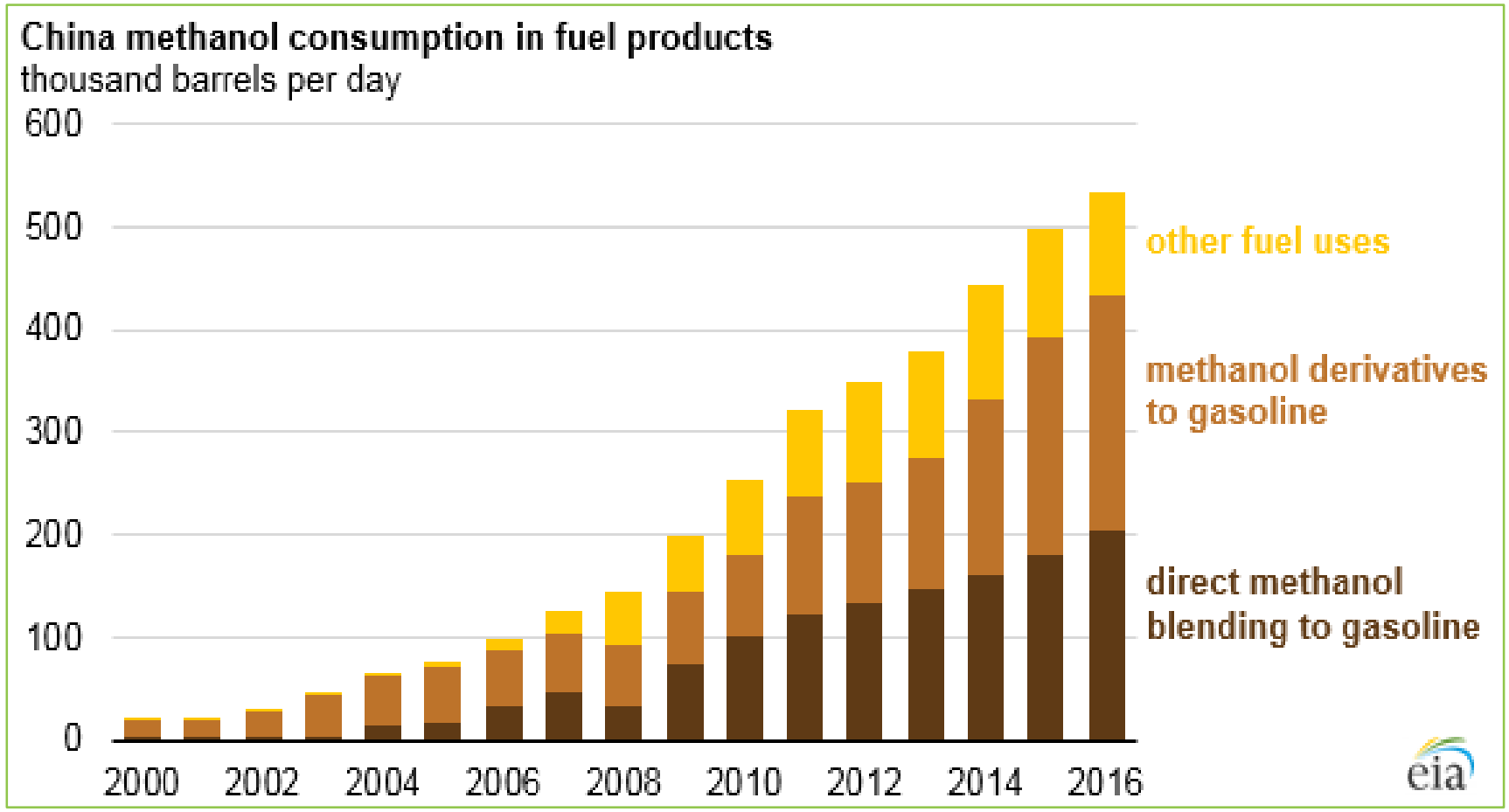
Driven by the pure power of methanol

Israel Methanol Fuels Demonstrations

- Prime Minister Netanyahu established Fuel Choices Initiative
- Driven 1,000,000 kms on M15 fuels with improved power and torque
- In 2016, Israel adopted national standard for M15 fuels
- Fiat marketing M15 car in Israel, and Dor Chemicals has introduced M15 retails pumps



China Leading World in Methanol Fuel Use



https://www.eia.gov/todayinenergy/detail.php?id=30072

China Methanol Fuel Status

2009

China adopted national standards for M85 and M100

2012

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.

2014

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

180,000

Vehicles converted to methanol fuel, mostly taxis.

Geely M100 Vehicles

- China's Geely Automotive Holdings is global leader in the commercialization of M100 vehicles
- Geely has two methanol engine and five methanol vehicle manufacturing bases, with an annual methanol vehicle production capacity of 300,000 - 500,000 cars
- Now introduced M100 bus, long-haul truck and medium-duty truck

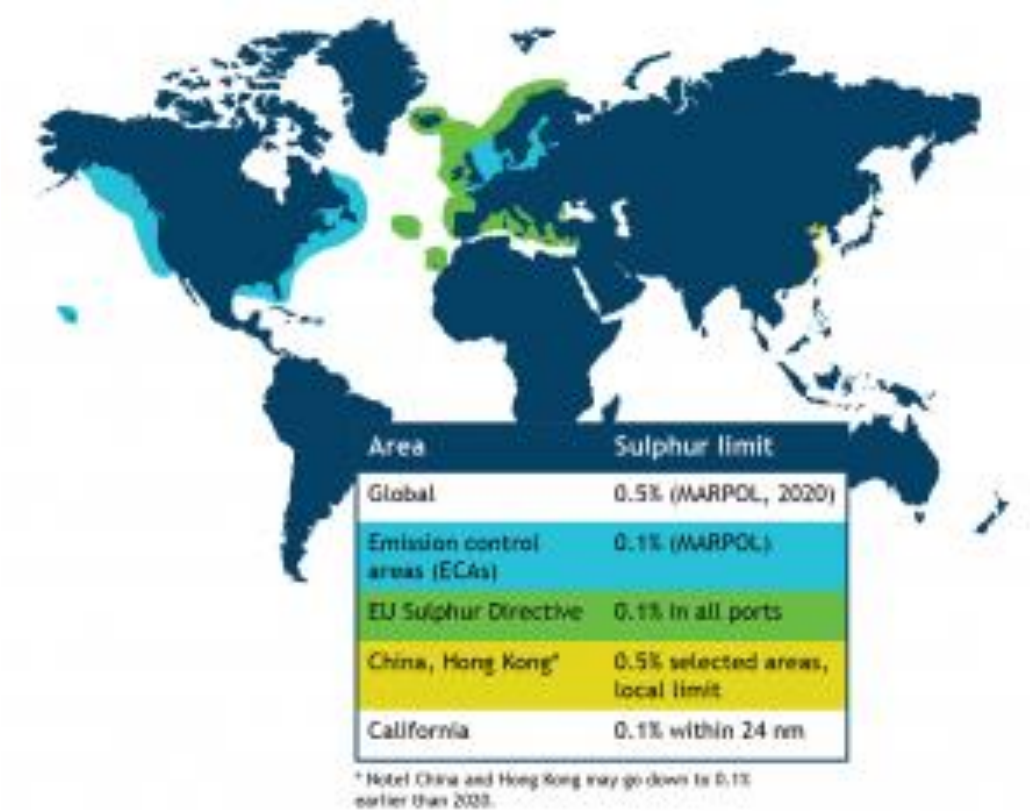
India: Roadmap to Methanol Economy

- September 2015, NITI Aayog formed Methanol Economy Expert Group
- September 2016, MI jointly organized Methanol Economy International Seminar held in Delhi
- M15 rollout in January 2019
- NITI Aayog has plan to replace 20% of crude imports from methanol, reducing fuel costs by 30%

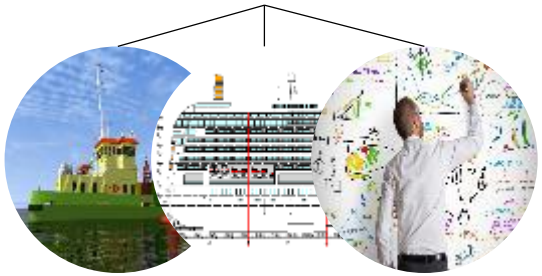
05 MARINE FUELS

Emissions regulations driving market

- The International Maritime Organization has adopted emission regulations transforming the shipping industry
- In 2020, global SOx reductions take effect
- By 2050, greenhouse gas emissions must be cut in half



Examples of vessels running on methanol

DUAL FUEL			FUEL CELL		PROJECT and R&D
					
7x - **+4**	1x	1x	2x	1x	
chemical tankers	ROPAX ferry	Pilot boat	Tourist boat	Ferry	Cruise ships, fishing boat, barge, dredge, a.o.
MOL, WL, Marinvest	Stena Line	MI/SMA ScandiNaos	Innogy HTWG Konstanz	Viking Line	SUMMETH/MARTEC, Lean Ships, Methaship, Billion Miles, FiTech, India, PCG Product Vessel, NTU Test Bed Port of Rotterdam Barge
2 stroke MAN	4 stroke Wärtsila	high speed Scania, Weichai	Serenergy fuel cell stacks		SI hybrid, dual fuel, etc.
new build	retrofit	retrofit	retrofit	retrofit	new build & retrofit

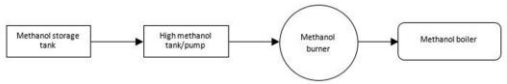
Methanol bunkering easy and clean

- Liquid at atmospheric pressure
- Available in many ports around the world and along rivers
- Low infrastucture cost
- Flexible, modular system
- Environmentaly friendly as it’s **biodegradable**

06 OTHER MARKETS

Methanol Industrial Boilers in China

- Industrial boilers are widely used for heating and industrial stream
- Many cities in China prohibiting use of coal and diesel fuels
- Capacity ranged from 1 to 20 ton/hour
- One steam ton capacity consumes 110 kg of methanol, and runs 24/7
- Methanol fuel is used neat or as blend with diesel fuel
- Standards developed with MI and Methanex support
- ***Estimated more than 1000 units, consuming over 2 MMTs methanol in 2017***
- ***Growing to 5 MMT in 5 years***



https://www.methanol.org/energy/boiler-cookstoves/

Methanol Cook Stoves in China

- **Different types methanol cook stoves:** Single heating, stir fry, steaming
- Widely used in restaurants, central kitchens, mainly cost-driven
- Simple storage and transportation, filling the gap of pipeline NG supply
- Fuel: 100% methanol to methanol blends usually with water
- ***Market for Cooking Application estimated over 5 MMTs in China in 2017***
- ***Growing to 7-8 MMT in 5 years***

Methanol a Hydrogen Carrier for Fuel Cells

- Horizon Energy Systems (Singapore)
- Oneberry (Singapore)
- Altergy (USA)
- Palcan (China)
- Serenegy (Denmark)
- SFC Energy (Germany)
- Toshiba (Japan)
- Ultracell (USA)
- Blue World Technologies (Denmark)

07 CONTACTS

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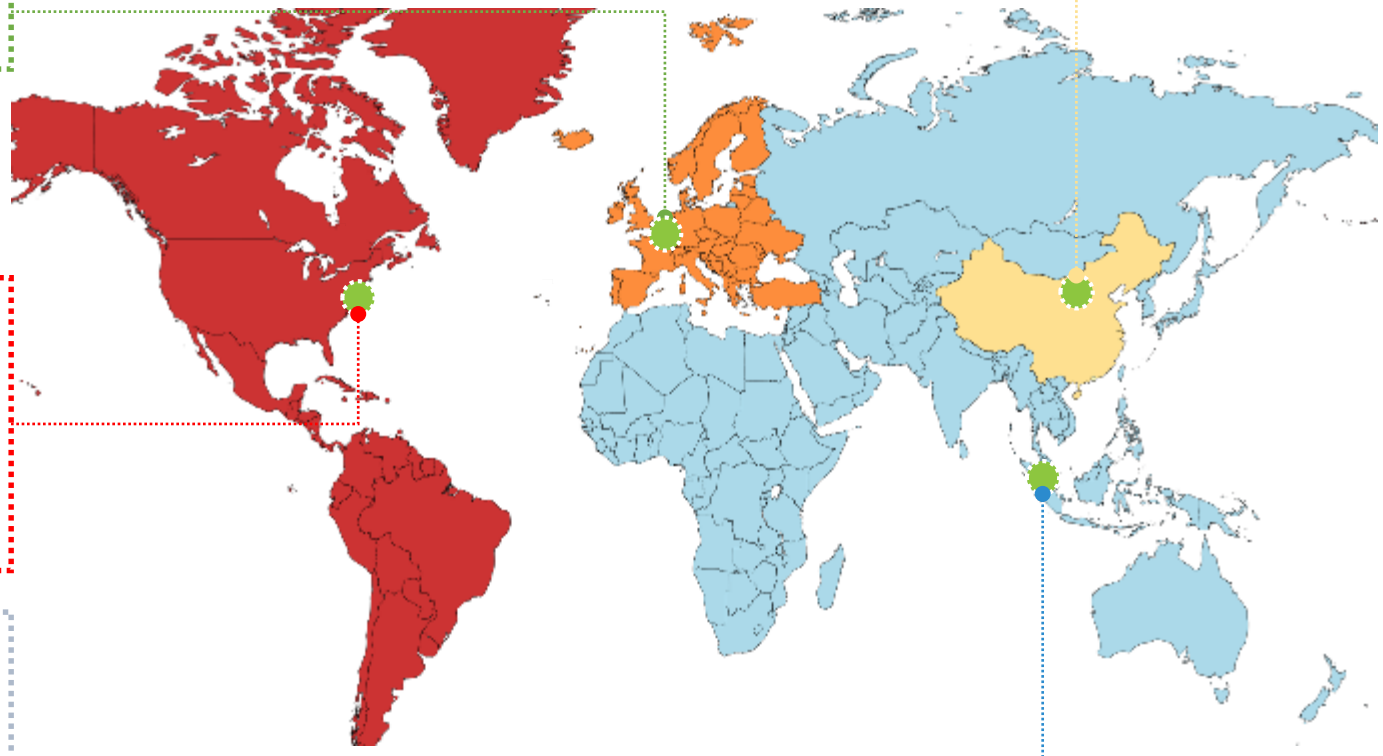

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