Global Methanol Fuel Blending Expanding

With Crude Oil's Rise to $100 / Barrel

OMAN Fuel Blending Workshop
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Overview for Methanol Blending

- **Fuel Blend Preparation and Handling are similar for both Methanol and Ethanol**
- **Multi-Decade, Global Wide Experience with Methanol and Ethanol Fuel Blending**
- **Methanol Blending Expanding Economically with Crude oil near US$100**
- **Expanding Gasoline Supply with Methanol Blending is a Quicker and a Lower Cost Alternative to Expanding Oil Refinery Capacity**
- **Provides Benefits for Environmental Pollution and Health Risk**
- **Vehicles and Distribution Systems Compatible for Decades**
- **Water Entry into Gasoline Distribution System Easily Managed**

Decades of Methanol/Ethanol Blending Experience In Gasoline

Periods of High Crude Oil Prices are Main Driver for Expanding Methanol Blending
(but Government Subsides or BioFuel Mandates for Ethanol Blending)

1970's / 1980's	**Substitute for High Cost Petroleum in Conventional Vehicles** ***(M15 Trials & Commercialized M3/B3, M5/B5, & E10 Blends)***
1990's	**Adds Clean Burning Octane and Oxygen in Gasoline to Reduce Air Pollutions from "All" Model Gasoline Vehicles**
2000's	**Substitute for Higher Cost Petroleum in Conventional Vehicles** ***(Commercialized E15 in U.S. & M15 in China)***
Today & Future	**Methanol fuel supplies expanding via Lower Cost Natural Gas Supplies and Renewable Energy** ***(More M8-M15 trials being conducted in other countries)***

Later Fuel Standards Raise Allowable Methanol Content

- **Earliest commercial Fuel Standards in U.S. and in Europe started with nominal 3 vol % methanol plus 3% Cosolvent in gasoline as limited by pre-1975 vehicles**

- **Higher methanol content in gasoline now 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:

Pakistan, Israel, Trinidad, Australia, Others

Blending Methanol Is Lower Cost Option Than Importing More Gasoline

- **With crude oil market near $100 / bbl, the blending Methanol (with some ethanol cosolvent for phase stability) becomes a much lower cost gasoline supply extender than importing more gasoline supply.**

- **Ethanol is a low cost and effective co-solvent for methanol blends today, and is becoming cheaper as corn and world sugar prices continue to fall.**

- **Methanol Blends at about 135 RON (Research Octane Number), and M15 adds about 7 RONs to gasoline blending operations for added value.**

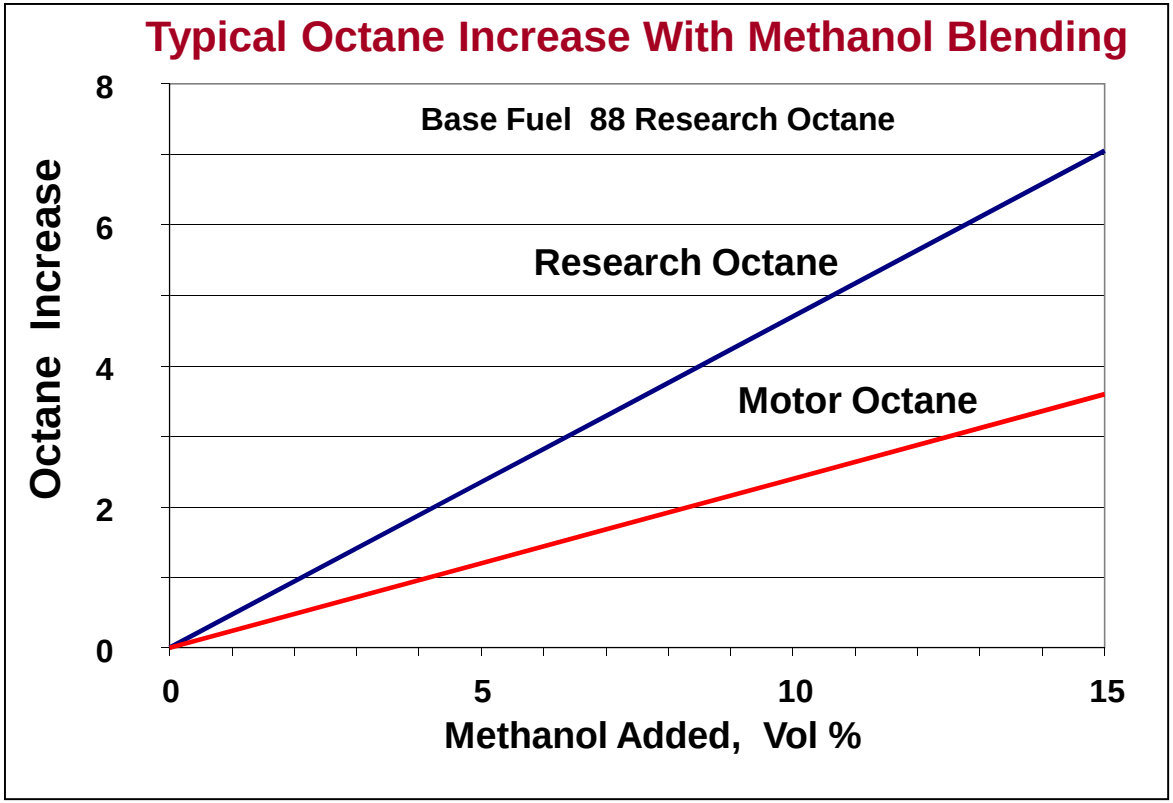
- **M15 fuel blending can potentially displace 8+ % of the petroleum gasoline supply, and reduce OMAN gasoline supply cost by approximately US$100 million per year.**

Methanol Blending Provides Multiple Savings of Petroleum Energy

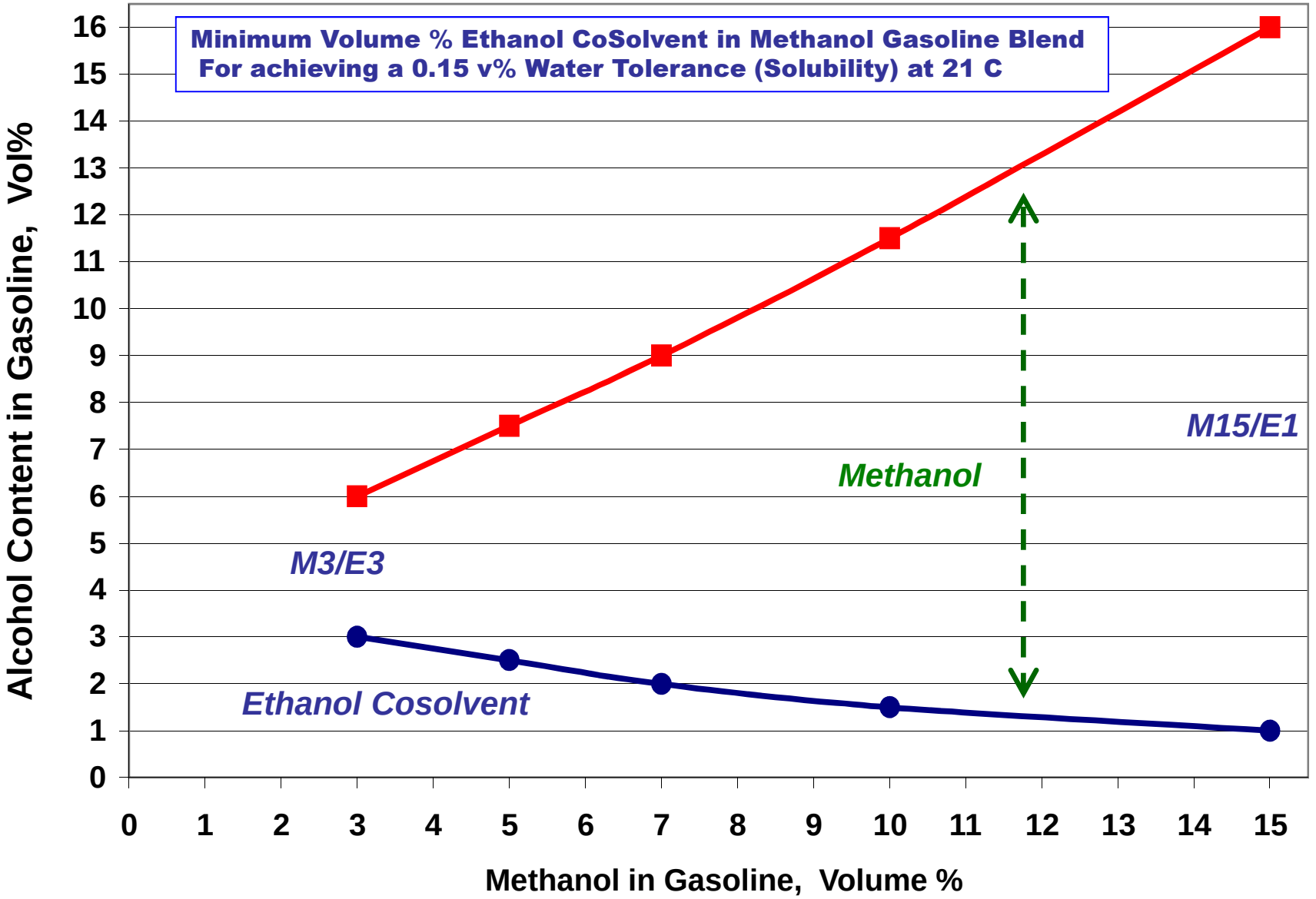
1. *Methanol's energy produced from non-petroleum energy sources (Nat. Gas, Coal and renewable energy sources)*

2. *Methanol's oxygen in gasoline improves engine combustion efficiency which further reduces vehicle's petroleum energy consumption*

3. *<u>Supplying external octane sources to petroleum refinery improves Gasoline Yield</u> & Methanol contributes the highest octane per unit of energy supplied*



Need for Ethanol Cosolvent Decreases with Higher Methanol Content



Methanol's High Octane Further Expands Gasoline Supplies

- Lower cost, cleaner burning octane Improver is used to replace costlier, dirtier octane aromatics in gasoline, or to upgrade low cost, low octane naphtha to gasoline.

  - Every ton of methanol blended into gasoline supplies can also upgrade octane of 1.5 tons of low cost naphtha into gasoline for a total net gain of 2.0 tons of 92 RON gasoline supply. (potential 25+% supply increase with added octane from M15)

  - Faster option to expand gasoline supply than using capital investments to expand refineries.

- Blending cleaner-burning methanol adds oxygen, volatility and clean octane to gasoline which

  - reduces vehicle exhaust emissions which decreases air pollution from gasoline vehicles

  - improves combustion efficiency that raises methanol's net energy contribution from 50% of gasoline energy equivalent up to 55+% which further lowers vehicle's CO2/km emissions

  - adds octane to refiner's gasoline supplies which increases reformate volume yields from refiner's naphtha reformer, and also reduces fuel consumption with lower severity operation

- Methanol's Vapor Pressure (VP) increase in gasoline can be offset by removing butanes if necessary. Like ethanol, a VP waiver (increases) can be used with modern vehicles with injector systems that pressurize the fuel system.

OMAN 2015 Potential Cost Savings with M15 Gasoline

M15 Blending Reduces Petroleum Gasoline Volumes and Lowers Gasoline Supply Cost

	Annual Volume		Market Cost		Annual Costs	
	Million BBLS	Million Gallons	USD $ / Ton	USD $ / Gal	USD $ Million	Rial OMR Million
Gasoline Prem 95	24.67	1,036	855	2.40	2,491	958
M15 Gasoline :						
Methanol 15%		155	350	1.05	164	63
Gasoline 85%		951		2.40	2,285	879
Cost of M15 Gasoline		1,106			2,449	942
Added Octane Credit of Methanol		155	x	0.40	(62)	(24)
Net Cost of M15 Gasoline					2,387	918
M15 Total Cost Potential "Savings"					104	40

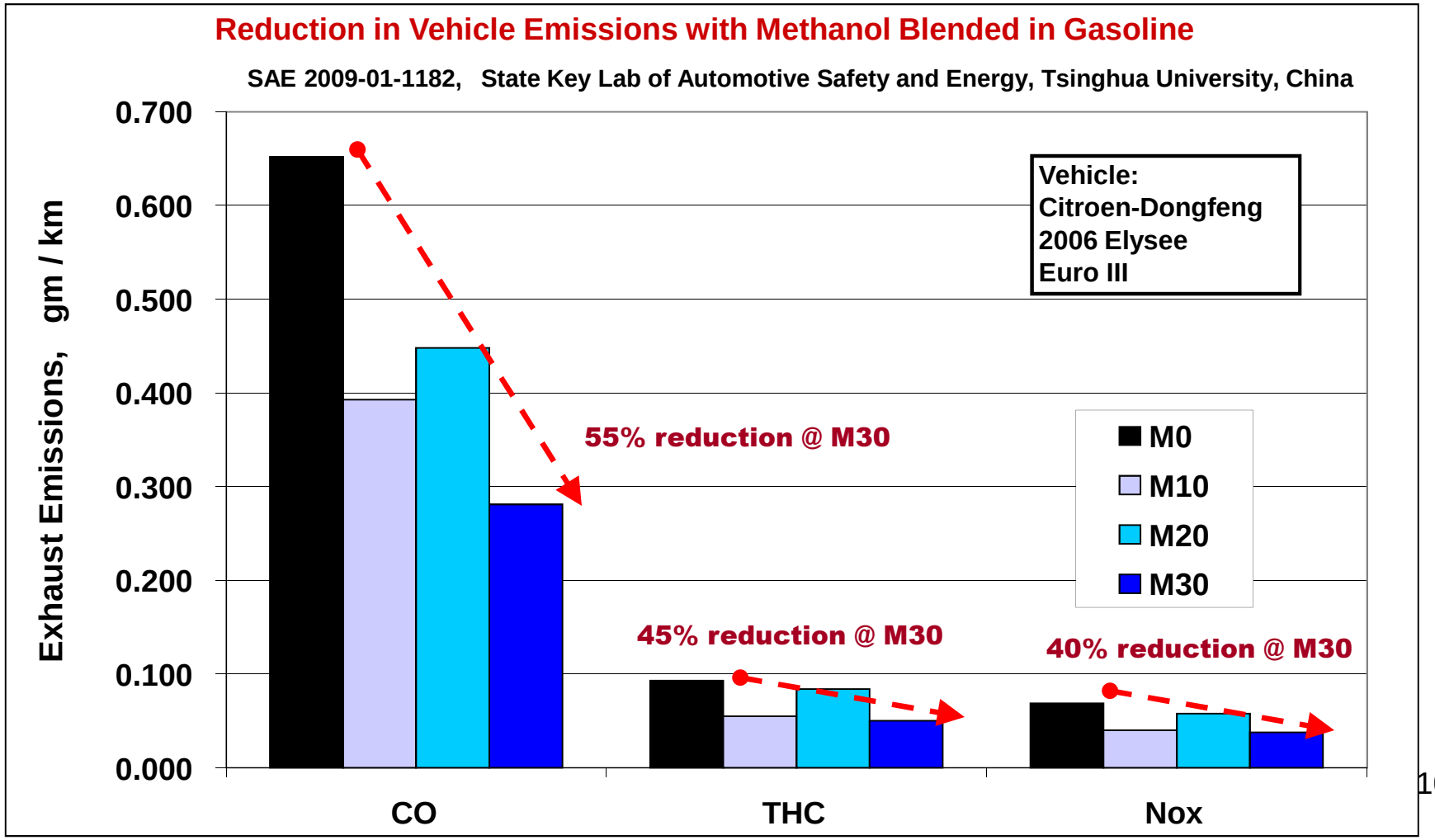
Gasoline Volume Reduction	85	
Percent Reduction	*8.3*	*%*

Methanol Blending Reduces Vehicle Exhaust Emissions

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

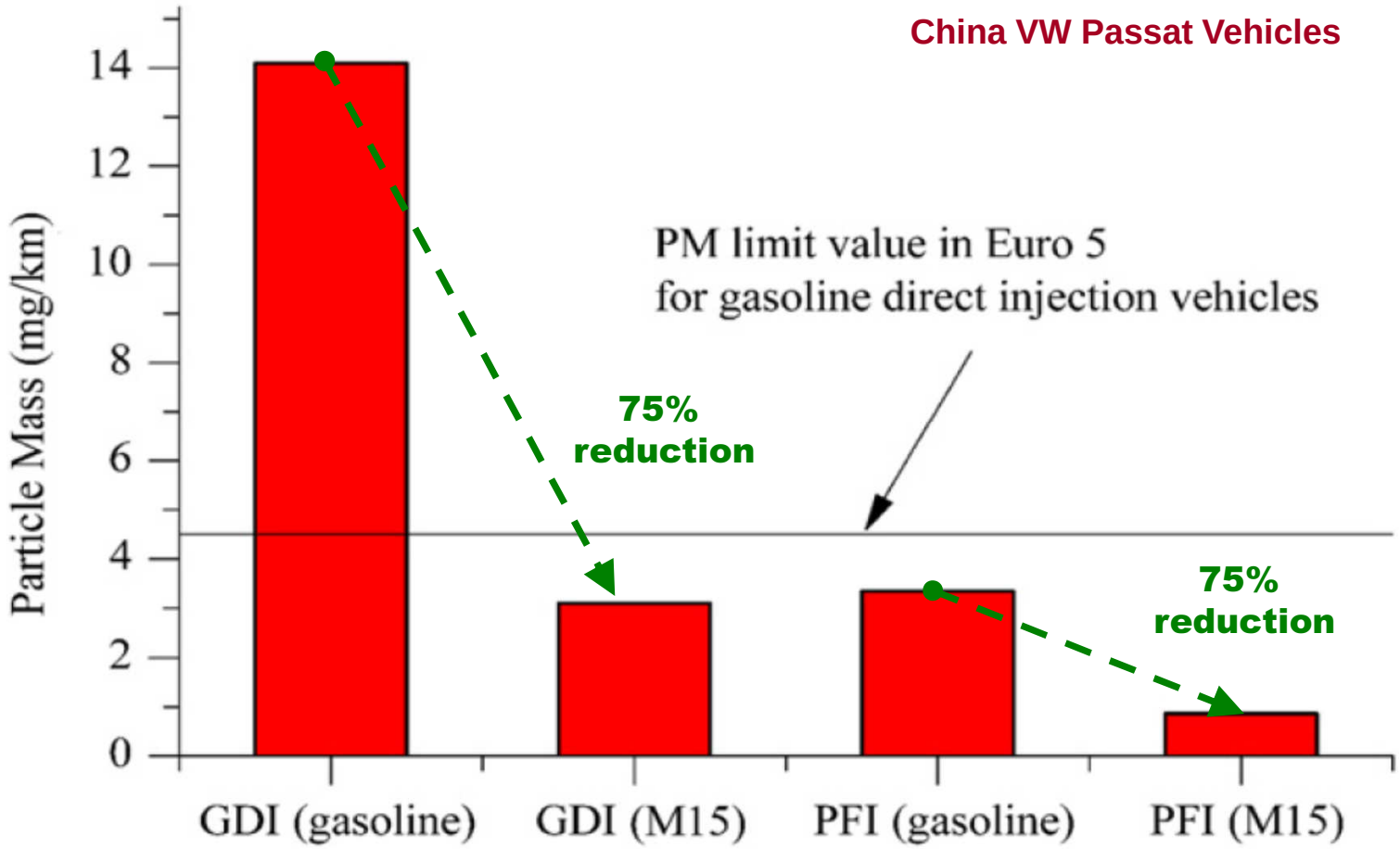
- reduces vehicle exhaust emissions that reduces air pollution from Mobile Sources

- improves combustion efficiency that raises methanol's net energy contribution from 50% of gasoline energy equivalent up to 55+% which further lowers vehicle's CO2/km



Methanol Blending Greatly Reduces Vehicle's Particulate Emissions

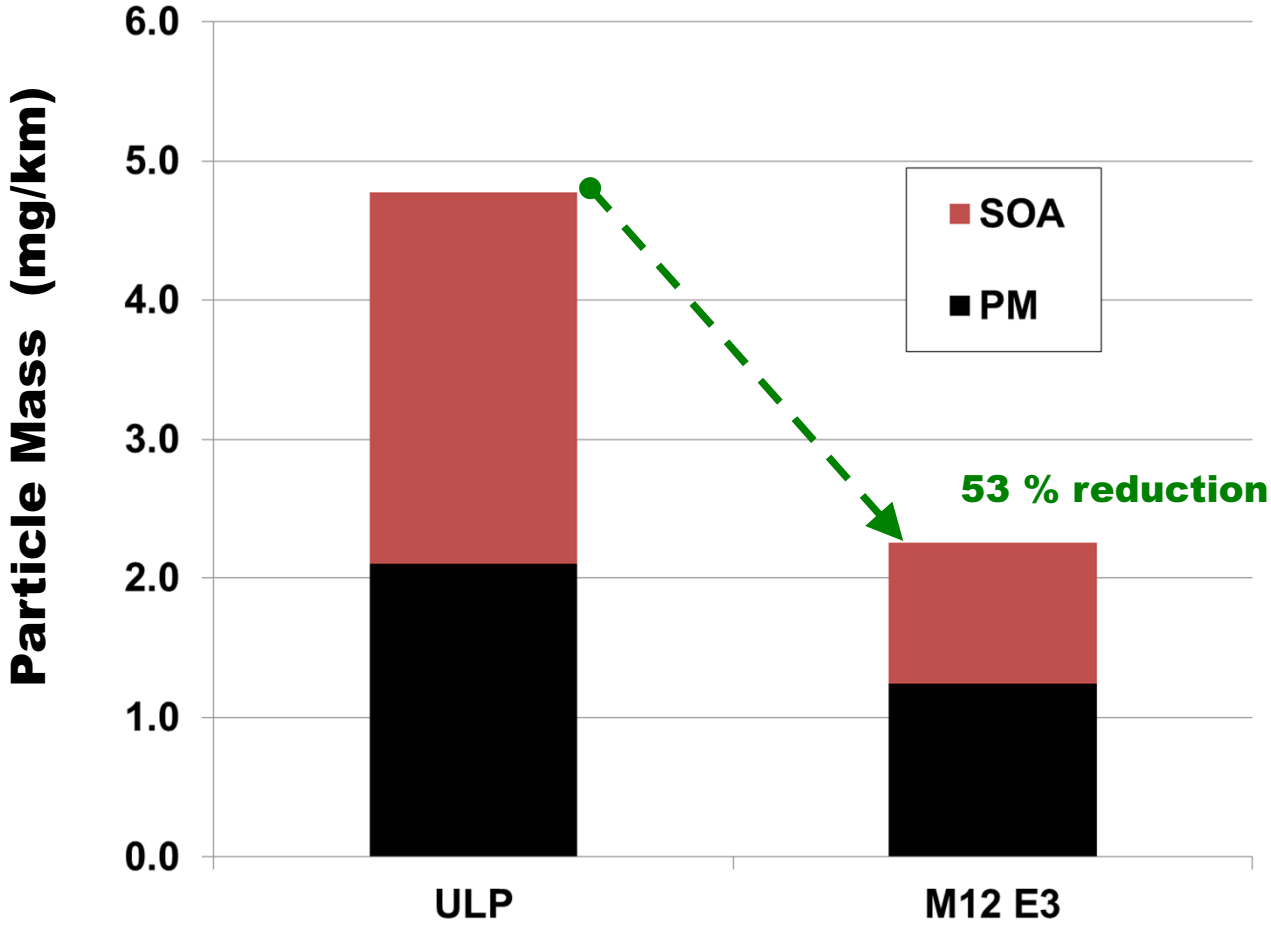
- **M15 Blend Reduces PM Emissions in Exhaust from PFI and the newer GDI Vehicles**



Source: ***National Lab of Auto Performance and Emission Test, Beijing Institute of Technology, Journal of Aerosol Science 57 (2013) 22–31***

Methanol Blending Greatly Reduces Vehicle's "Total" PM Emissions

- M12 E3 Blend Reduces "primary" PM Emissions in Exhaust from GDI Vehicles
- Reduces Aromatics in Exhaust which also reduce secondary organic aerosols (SOA)



Data Source: ***ORBITAL Report: Vehicle Emissions from GEM Blends, MY2012 Ford Mondeo Zetec EcoBoost, Australia, November 2014***

Methanol Fuel Blends Compatible with Vehicle Fuel Systems

- **Material Compatibility with M15 blends well studied since early 1980's**

- **Compatible non-metal materials identified and also upgraded in vehicle fuel systems since early 1980's.**

- **Small amounts of fuel corrosion inhibitors used in methanol fuel blends to mitigate corrosion of metal parts in the vehicle fuel system.**

- **In early 1990's, the SAE (Society of Automotive Engineers) issued recommended guidelines that used M15 fuel for screening for compatible vehicle fuel system materials (elastomers, plastics, and metals components) in all new vehicles and replacement parts.**

Cosolvent Ethanol Provides Cost-Effective Water Solubility and Phase Stability for Methanol Fuel Blends

- **Adding small amounts of ethanol to methanol fuel blends adds sufficient "water tolerance" (gasoline water solubility) to adsorb normal water infiltration, and thereby prevent possible phase separation during normal commercial fuel use.**

- **Initial system preparation first requires removal of excess water from the collection low points before introducing methanol blends. Water tolerance of methanol fuel blends then keeps system "water free" in properly maintained systems.**

- **Years of commercial experience with both methanol and ethanol fuel blends in many market regions support that a water tolerance property of 0.15 volume percent will provide adequate phase stability when following good "water management" practices in the gasoline distribution system.**

Three Entry Options for Blending Methanol into Gasoline Distribution Systems

Fuel Methanol Contains Co-solvent alcohol and Corrosion Additives

- ***Refinery Blending*** conducted during the 1980's. Methanol blended during the gasoline blending operations and the methanol fuel blends shipped in product distribution pipelines to product truck loading terminals. One fuel methanol storage tank located at the refinery.

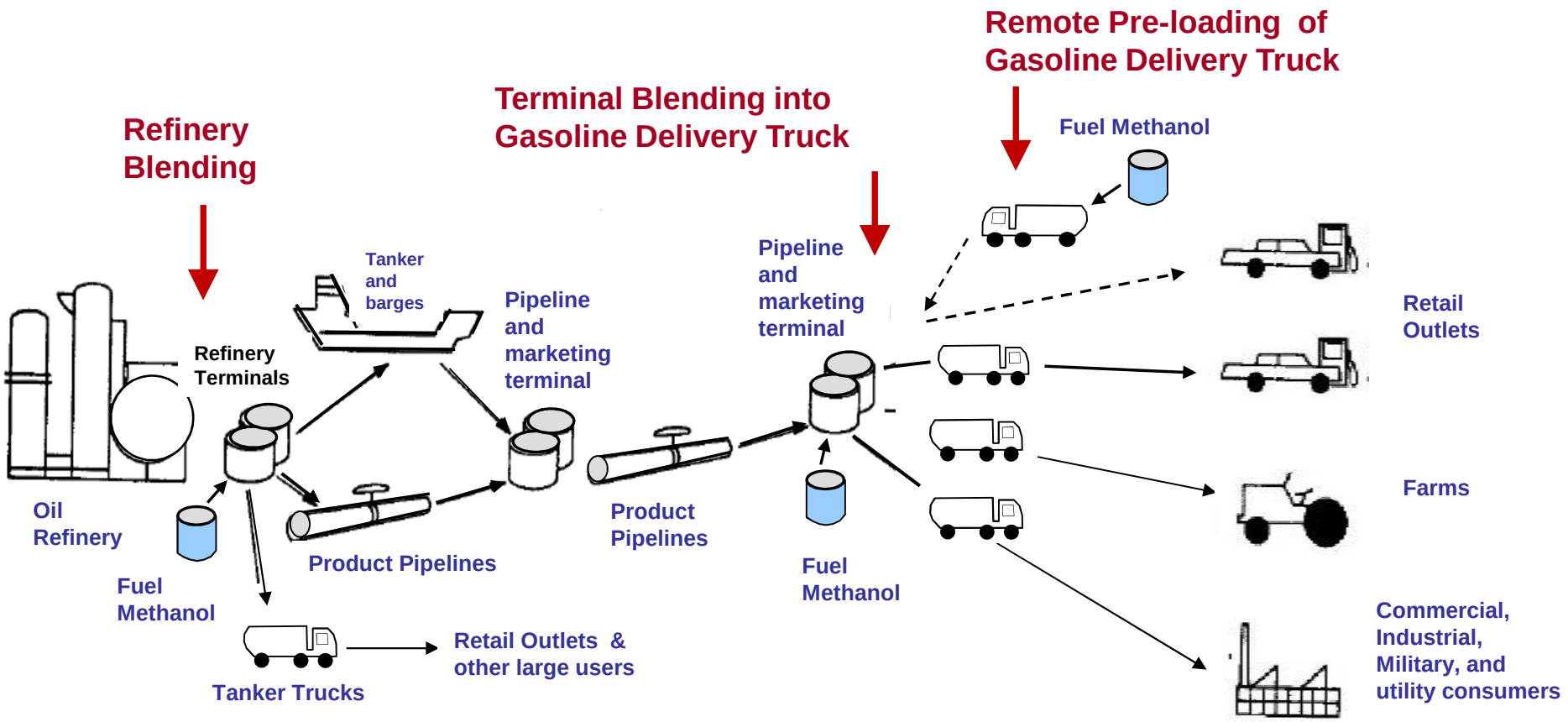
- ***Gasoline Terminal blending*** of methanol when loading gasoline into tanker truck for refilling the gasoline stations. A fuel methanol storage tank located at each product terminal.

- ***Preloading Gasoline Tanker Truck at Remote Fuel Methanol Terminal*** then top-off with appropriate gasoline mix into the tanker truck at gasoline terminal. Remote storage tank may be leased for the fuel methanol storage.

Methanol Fuel Blending at Three Possible Locations Along the Gasoline Supply Chain for Fuel Quality Controls

- Global blending experience developed procedures for maintaining fuel quality in gasoline distribution systems

- Water Management and Compatibility Monitoring Starts at Methanol Blending Point



Methanol Blends Have Lower Environmental and Health Risks

- **TVL (threshold limit values) for methanol vapor is only slightly lower than gasoline; U.S. DOE considers gasoline to be overall more hazardous to health than methanol**

- **U.S. EPA's Office of Pollution Prevention and Toxics consider methanol to be essentially non-toxic for aquatic species tested. Methanol has negligible bioaccumulation and is relatively non-toxic to ecological receptors.**

- **Methanol spills to the soil, groundwater and surface water will quickly biodegrade both in aerobic and anaerobic conditions, and thereby are not expected to persist in the environment.**

- **Methanol exhibits a lower toxicity to both human and indigenous microbes than conventional gasoline; therefore, methanol appears to be more environmentally benign compared to gasoline.**

Source: "Evaluation of the Fate and Transport of Methanol in the Environment", Malcolm Pirnie, Inc., Oakland, Calif., January 1999

35+ Years of Global Experiences with Methanol Gasoline Blends

- **Methanol fuel blends first successfully commercialized in late 1970's**
- **With Crude Oil now near $100 / bbl, methanol fuel blending becomes very economical**
- **Up to 25+% gasoline supply expansion at minimal investment when using M15's octane contribution to upgrade low cost naphtha to 95 RON gasoline**
- **Methanol gasoline blends provide air pollution reduction from vehicles, and with low exposure risks in the environment**
- **Quality M15 blending with corrosion inhibitors and co-solvent alcohols produces "stable" gasoline fuel, and protects fuel system metals in vehicles**
- **Ethanol is low cost and effective co-solvent for methanol blending**
- **Water monitoring in gasoline distribution system maintains performance quality of methanol gasoline blends to the consumer's vehicle**

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