



## ***Methanol Applications for Sustainability Seminar***

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Development (AP/ME)**

***September 17, 2019***

***Salalah, Oman***

# MEMBERS

## Tier 1



## Tier 2



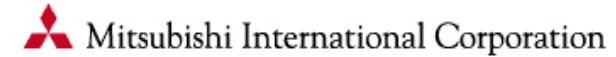
شركة قطر الإضافات البترولية المحدودة  
Qatar Fuel Additives Company Limited



## Tier 3



Ecofuel



## Tier 4



Advent



HALDOR TOPSOE



NAKHODKA  
FERTILIZER PLANT



CLARIANT



CoogeeChemicals

OLAHMOTORS

Nebraska Public Power District

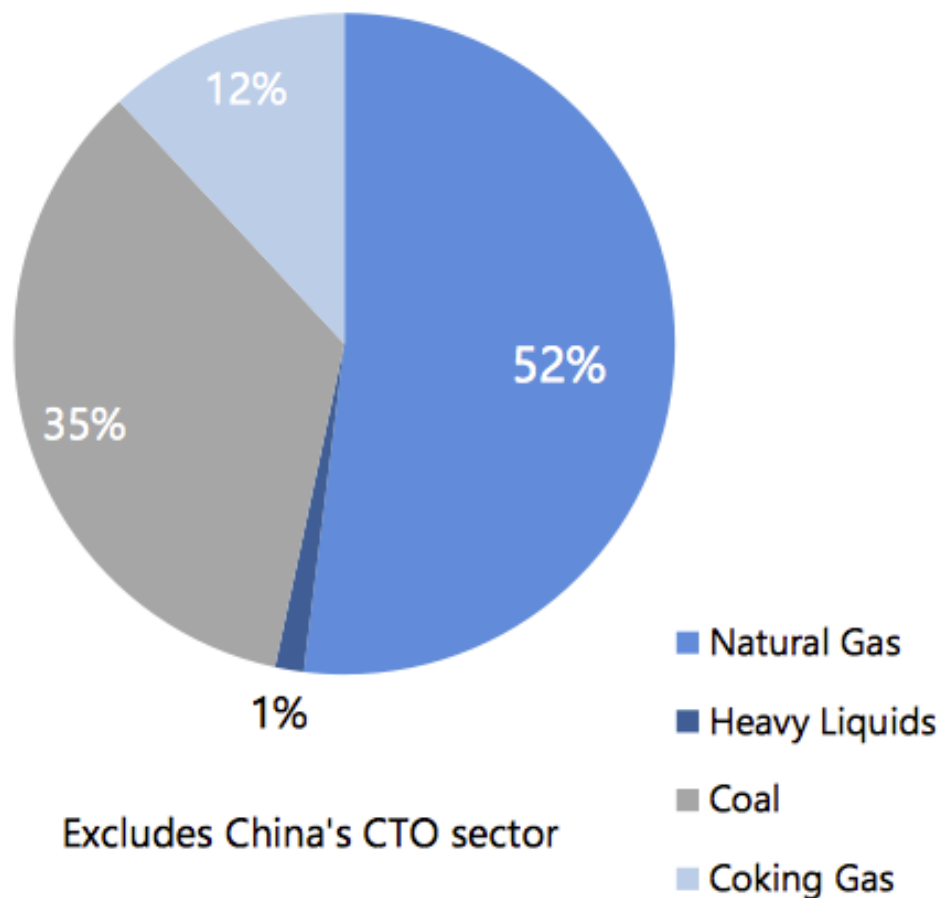
# METHANOL SUPPLY & DEMAND

01

# METHANOL PRODUCTION

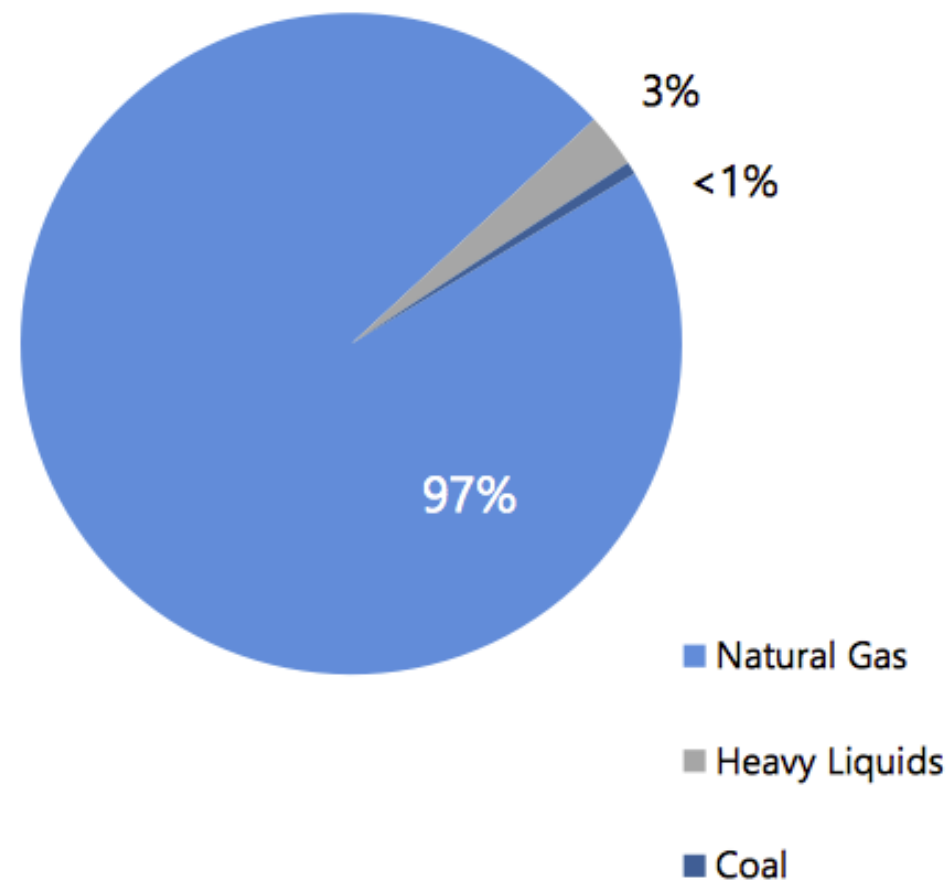
## World Total

2018 ~ 122mn t nameplate capacity



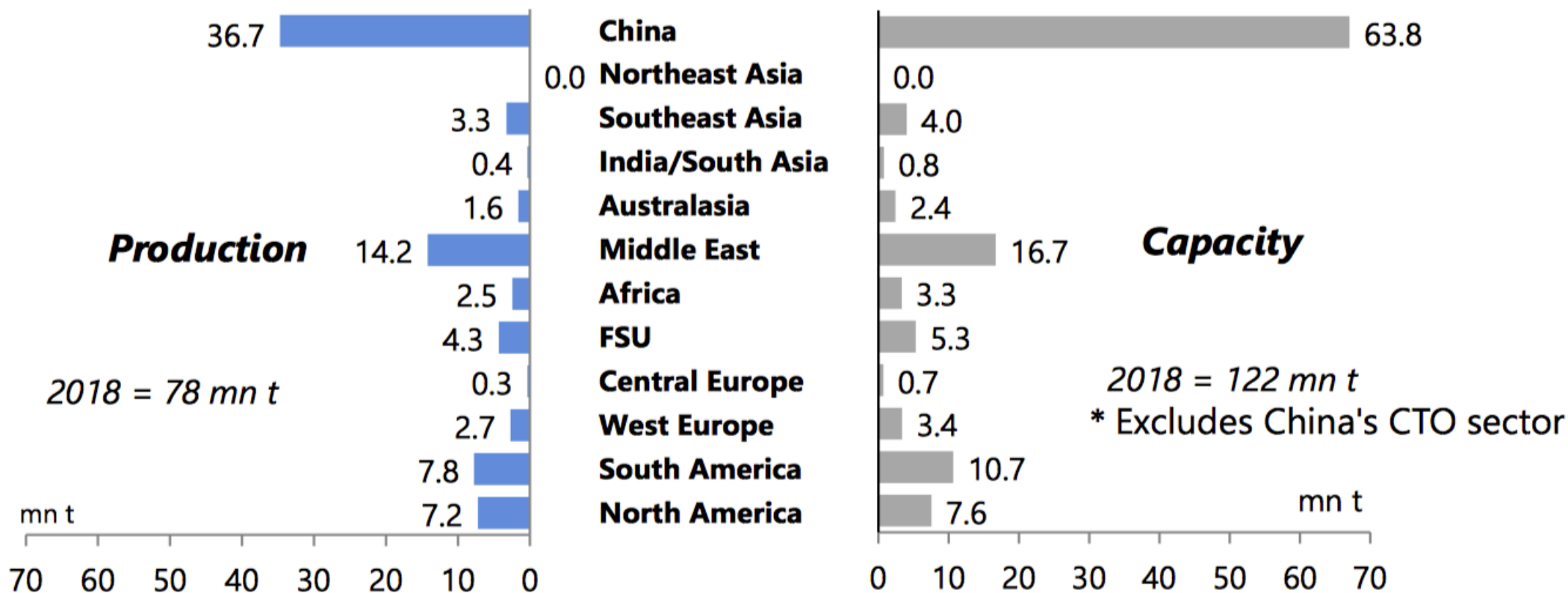
## Rest of World – ex China

2018 ~ 55mn t nameplate capacity



Source: Argus

# GLOBAL METHANOL PRODUCTION VS CAPACITY



- Rest of world methanol production (excluding China) operates to best of abilities. Excess production from the rest of the world is exported to China
- China “generally” represents the high-cost methanol production bloc in the world and operates to meet China demand, less imports received from the rest of the world
- Industrial scale since 1923 (BASF)

Source: Argus

# METHANOL PRODUCTION IN OMAN



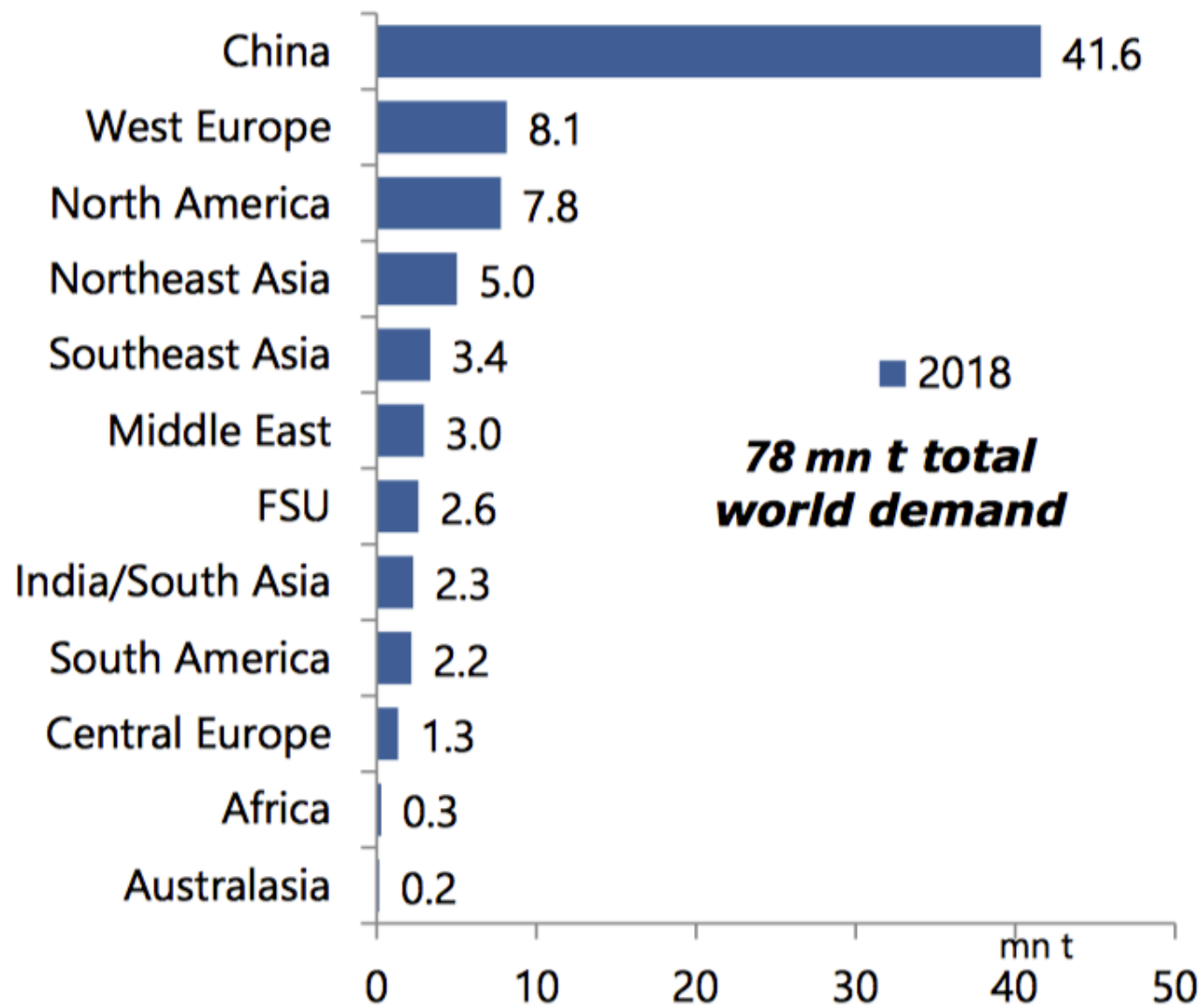
**Nameplate Capacity: 1.3MMT/Year**



**Nameplate Capacity: 1.15MMT/Year**

# GLOBAL METHANOL DEMAND BY COUNTRY/REGION

- China dominates global methanol industry demand – 54% in 2018
- W Europe and N America compete for the 2nd and 3rd spots – top three accounting for 75% of total
- Concentrated consumer base, ~30% of demand from top 25 consumers
  - Main consumers are large, global chemical companies and China MTO producers: BASF, Momenite, Celanese, BP, Dow/Dow Corning, Lucite, Evonik, LyondellBasell, SABIC, Sinopec, Ningbo Fund, Jiangsu Sailboat, etc
- Industry growth expected at 4.5% per year. The equivalent of 2 world scale methanol units



\*Excludes China's CTO sector

Source: Argus



# METHANOL

## An essential ingredient of modern life

Energy/Fuel substitution markets - represent the fastest growing demand segment for methanol (~45% demand)

Chemical markets - essential ingredient used in countless industrial and consumer products (~55% demand)



Methanol can be found in products that we use every day:

Roof panels  
Adhesives  
Lumber

Paint  
Insulation  
Carpeting  
Synthetic fibres  
Plastics  
Particle boards

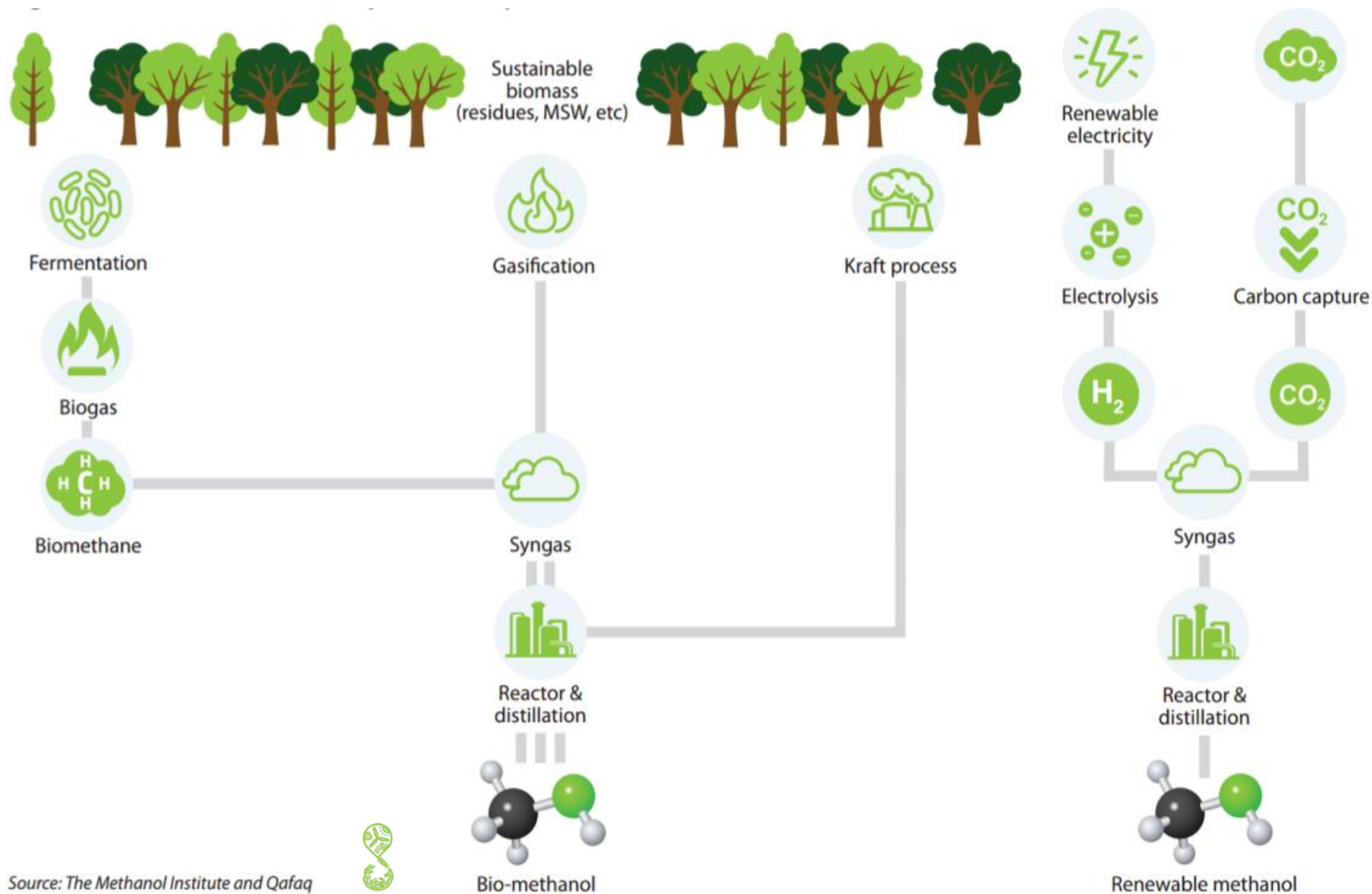
Refrigerants

Sportswear  
Fleece fabrics

Safety glass laminate  
Windshield washer fluid  
Solvents  
Upholstery



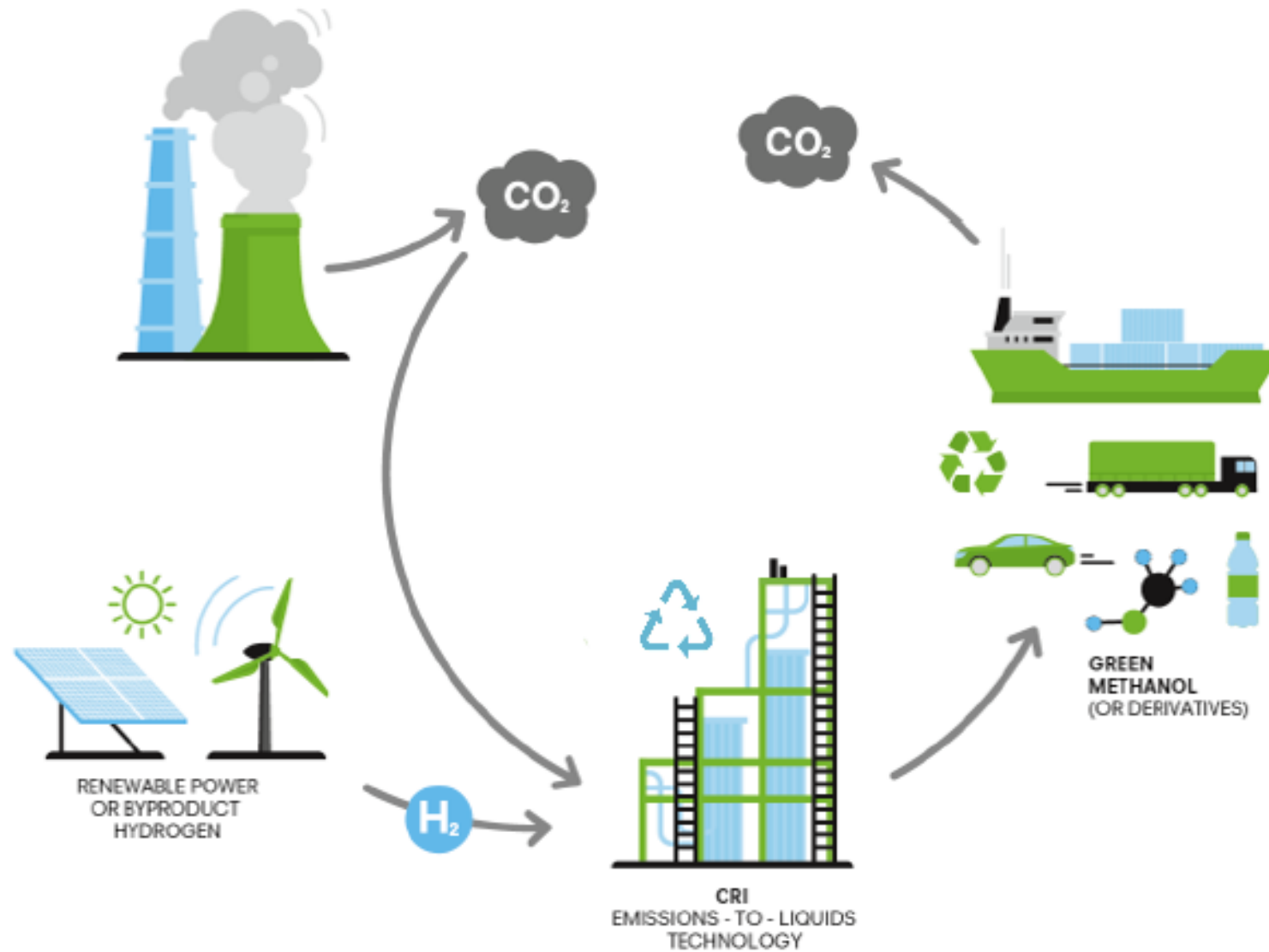
# RENEWABLE PATHWAYS ARE RAPIDLY DEVELOPING



Source: The Methanol Institute and Qafq



# RENEWABLE METHANOL CIRCULAR ECONOMIES



Source: Carbon Recycling International

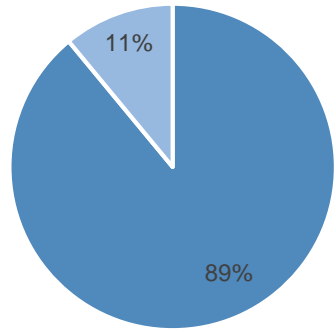
# RENEWABLE/BIO METHANOL PROJECTS



# EMERGING METHANOL ECONOMIES

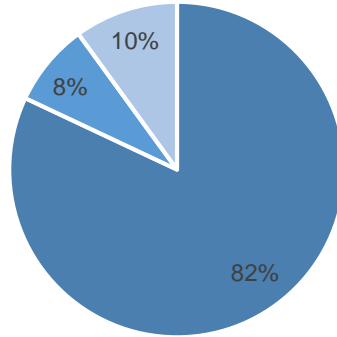
02

# CHINA METHANOL PRODUCTION AND ENERGY SECURITY



■ Dedicated ■ Ammonia Combined

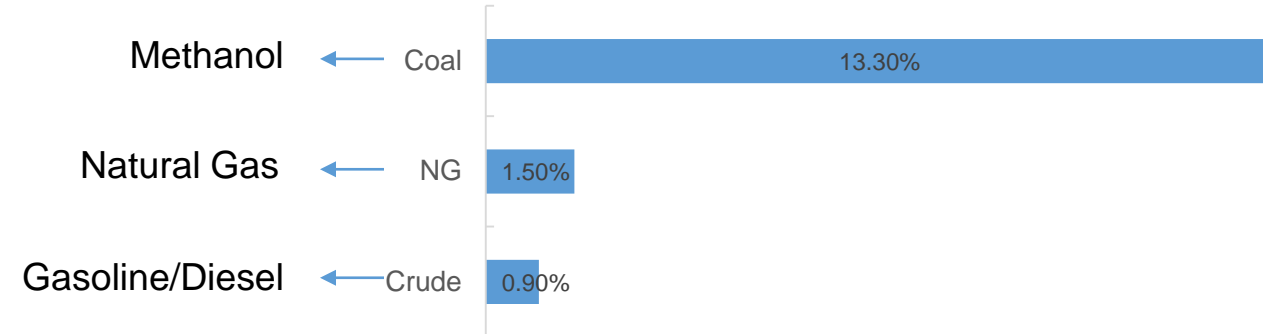
Source: CNFIA Statistics



■ Coal ■ NG ■ Coking Gas

- China methanol production capability: 84.32 MMTs, mainly dedicated coal to methanol projects
- New NG stock feed methanol project suspended, coking gas limited by steel industry
- Advanced coal gasification and world scale methanol production

## China Domestic Energy Resources in Global Share



Source: BP analytical Statistics

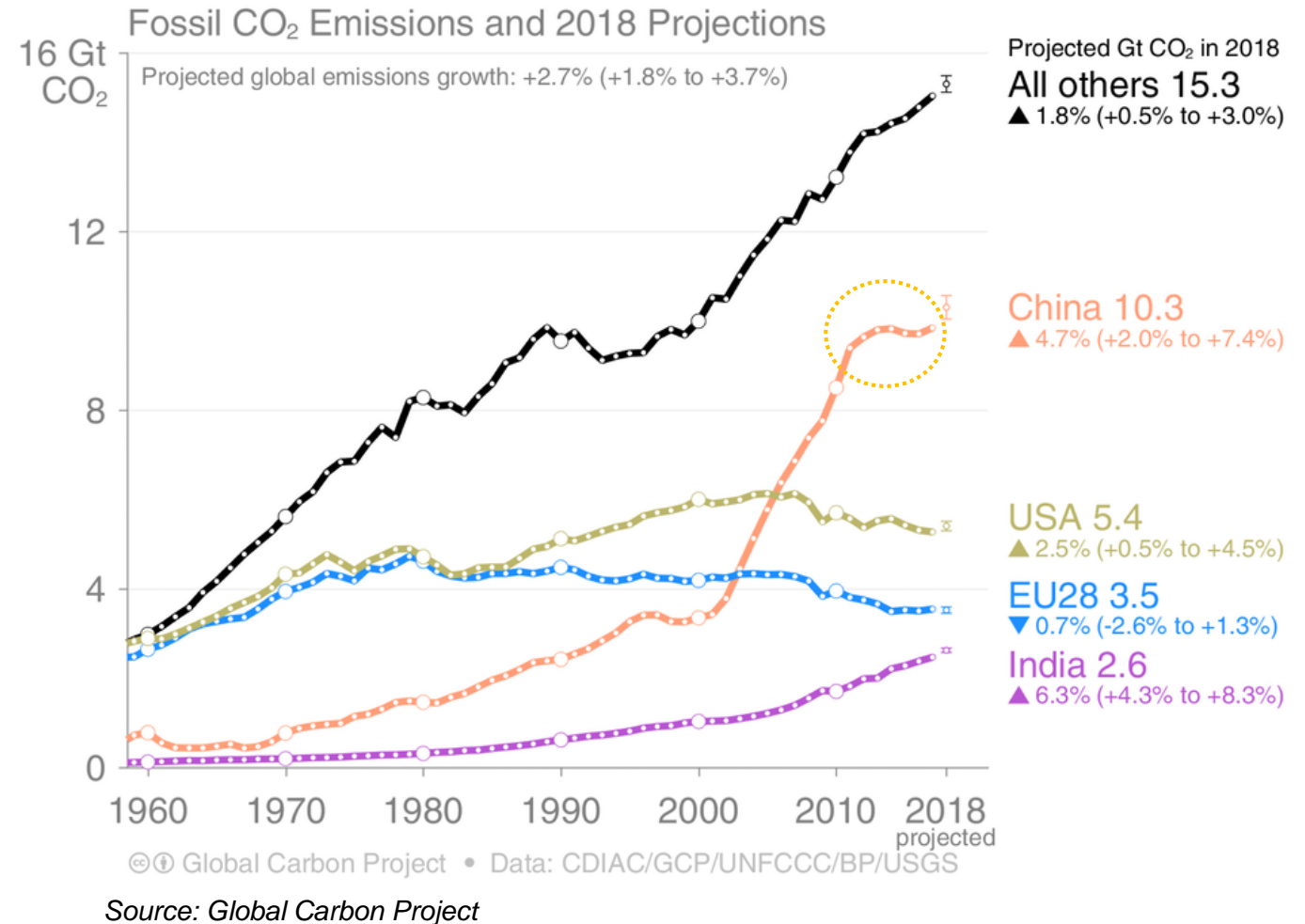
- China: coal reserve rich country (115bln tons) with scarce crude (2bln tons) and NG reserves
- Increasing concerns of energy security, mainly crude, over 70% oversea import
- Methanol imports ~8 MMTs in recent years, import only ~11%
- China Vehicle Population in 2018: 240 mln, consuming 100 MMTs gasoline and 140 MMTs diesel



# CHINA'S POLICIES ON EMISSIONS AND AIR QUALITY

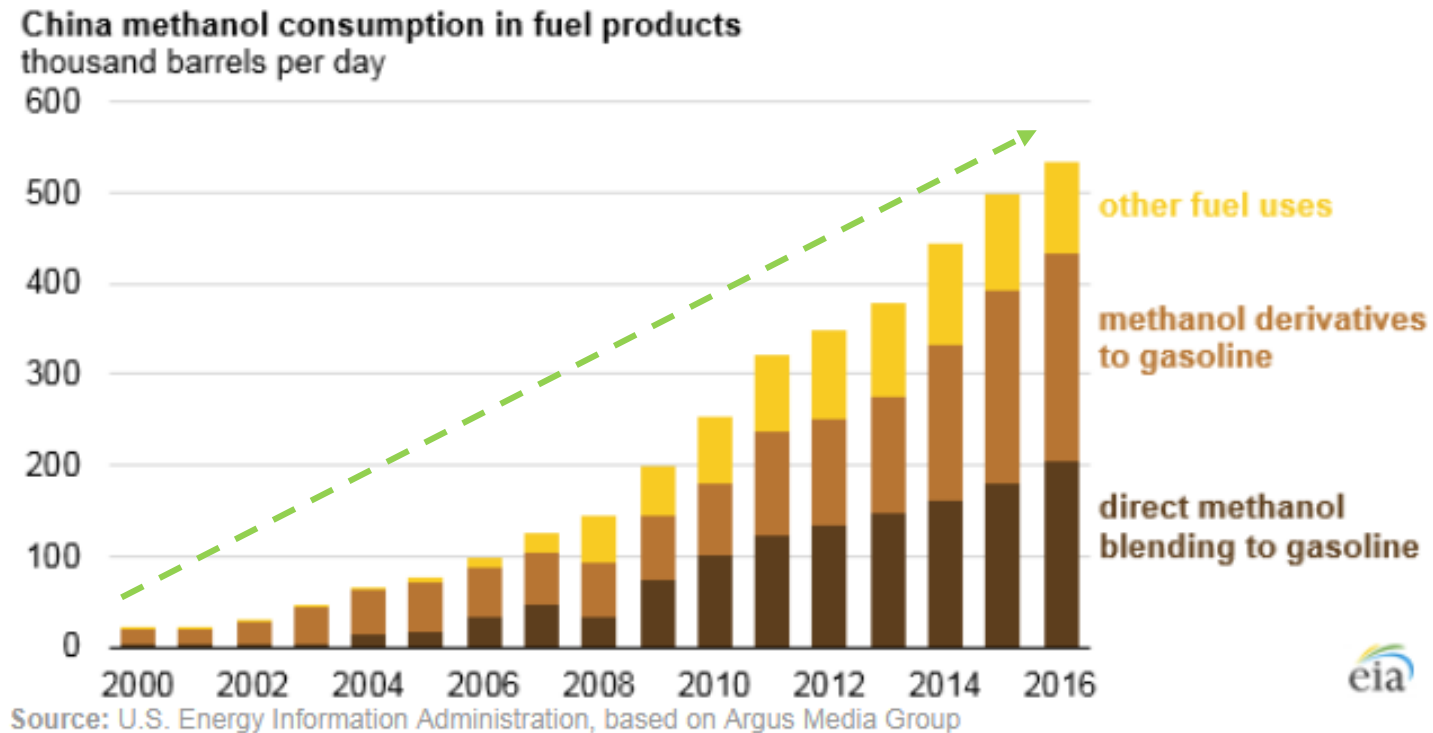
- Ten measures of Air Pollution Control
- Air Pollution Control Action Plan
  - Measures aimed to set limits to air pollution
  - Banned the burning of coal in urban areas with some coal-fired power plants shutting
  - Provide state/provincial support to new energy and energy-efficient technologies

**Methanol became a cost-efficient alternative fuel as it can be domestically produced and has clean-burning properties.**



# CHINA'S CONSUMPTION OF METHANOL AS FUEL (2016)

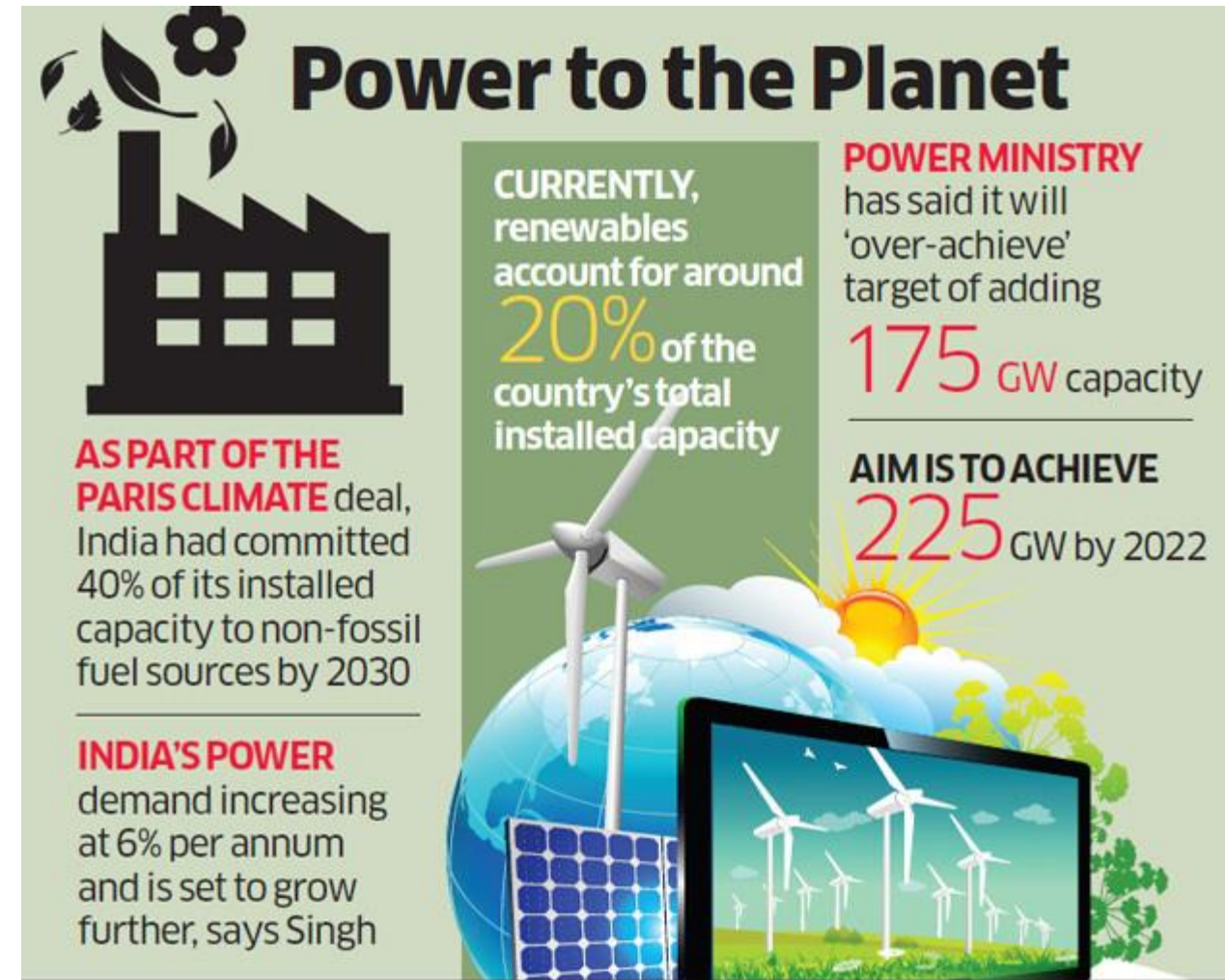
China's use of methanol in liquid fuels has grown rapidly since 2000



**Methanol became a cost-efficient alternative fuel as it can be domestically produced and has clean-burning properties.**

# INDIA'S ENERGY SECURITY CHALLENGES

- Government keen on cutting India's oil import bill
  - India's reliance on imported oil has grown to a multi-year high of 83.7% in 2018/19 due to consumption growth
- Natural gas imports also rising
  - Energy industry (23%) competes with fertilisers (28%), city gas distribution (CGD) entities (16%), refineries (12%), and petrochemicals (8%)
- Paris Agreement commitment: produce 40% of electricity from non-fossil fuel sources
- Need to bolster country's long-term energy security as the world's third largest energy consumer while increasing renewable sources in energy mix.



Source: <https://economictimes.indiatimes.com/industry/energy/power/renewables-to-account-for-55-of-total-installed-capacity-by-2030-rk-singh/articleshow/64737298.cms>

# INDIA'S METHANOL POLICY ASPIRATIONS

- September 2015: NITI Aayog formed the Methanol Economy Expert Group
- 2018: Methanol M15 Guidelines published
- 2018: IRCClass published Guidelines for Methanol Fueled Vessels
- 2019: Methanol economy roadmap proposed to Indian parliament
- Launching Projects:
  - M15 fuel blending (through ARAI)
  - Inland waterways (through IWAI)
  - Cook stoves (in Assam)
  - Remote power generation
- Looking into producing methanol from biomass/agricultural waste



भारतीय अन्तर्देशीय जलमार्ग प्राधिकरण  
**Inland Waterways Authority of India**  
Ministry of Shipping, Government of India



# METHANOL APPLICATIONS

03



# METHANOL APPLICATIONS



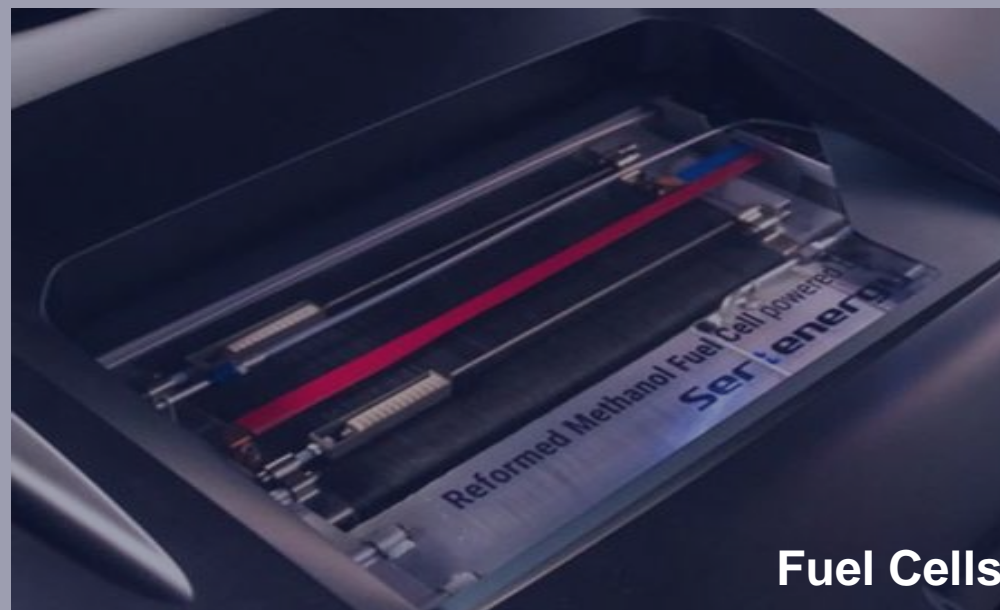
Land Transport Fuel



Marine Fuel



Industrial Boilers



Fuel Cells



Cookstoves

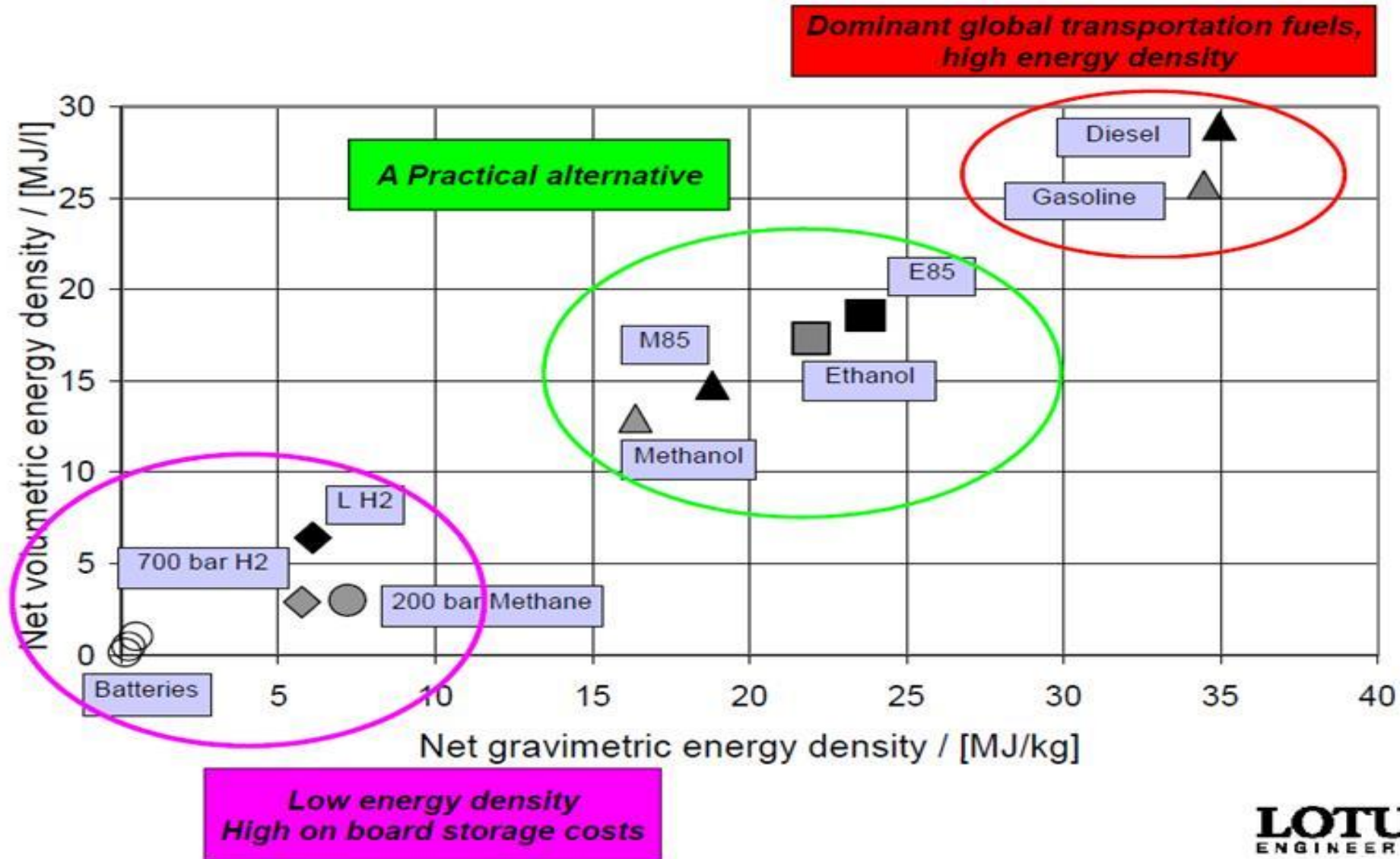


# LAND TRANSPORT FUEL



04

# PRACTICAL LIQUID FUEL



**LOTUS**  
ENGINEERING



# METHANOL AS A LAND TRANSPORT FUEL

## Low-level gasoline blending (M15 – 25)

- No changes needed to vehicle
- ~75% of cars manufactured by international automakers are compatible with low-level blends
- Long history of M15 blending in China from 1980s
- Estimated 7 MMT of methanol consumed in M15 blends in China



## High-level blending/methanol vehicles (>M85)

- Requires dedicated vehicles
- Few changes required to existing vehicle technologies
- Only in Chinese market, R&D started in late 1980s
- Geely has a 300,000/year production capacity for M100 cars



# INTERNATIONAL EXPERIENCE

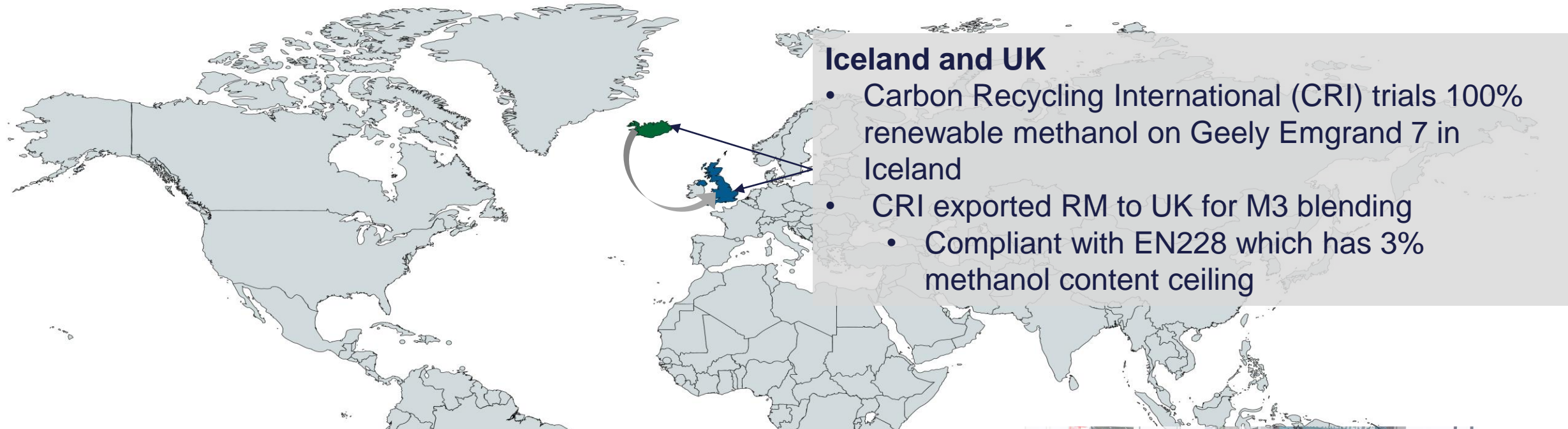
## China

- Long history of methanol-gasoline blends in the lower levels
- Methanol commonly found in gasoline across the country
- 8 Ministries published a policy paper in 2019 to promote M100 cars
- 5-year projection (from 2019): 50,000 M100 cars, trucks, and buses consuming >500k MT/year





# INTERNATIONAL EXPERIENCE



## Iceland and UK

- Carbon Recycling International (CRI) trials 100% renewable methanol on Geely Emgrand 7 in Iceland
- CRI exported RM to UK for M3 blending
  - Compliant with EN228 which has 3% methanol content ceiling



# INTERNATIONAL EXPERIENCE

## Italy

- Eni and Fiat Chrysler Automobiles (FCA) collaborated on A20 fuel (M15 + E5)
- Trialed on 5 Fiat 500 cars used for car sharing in 2018
- Compliant with Euro 6 standard and 3% reduction of tailpipe emissions

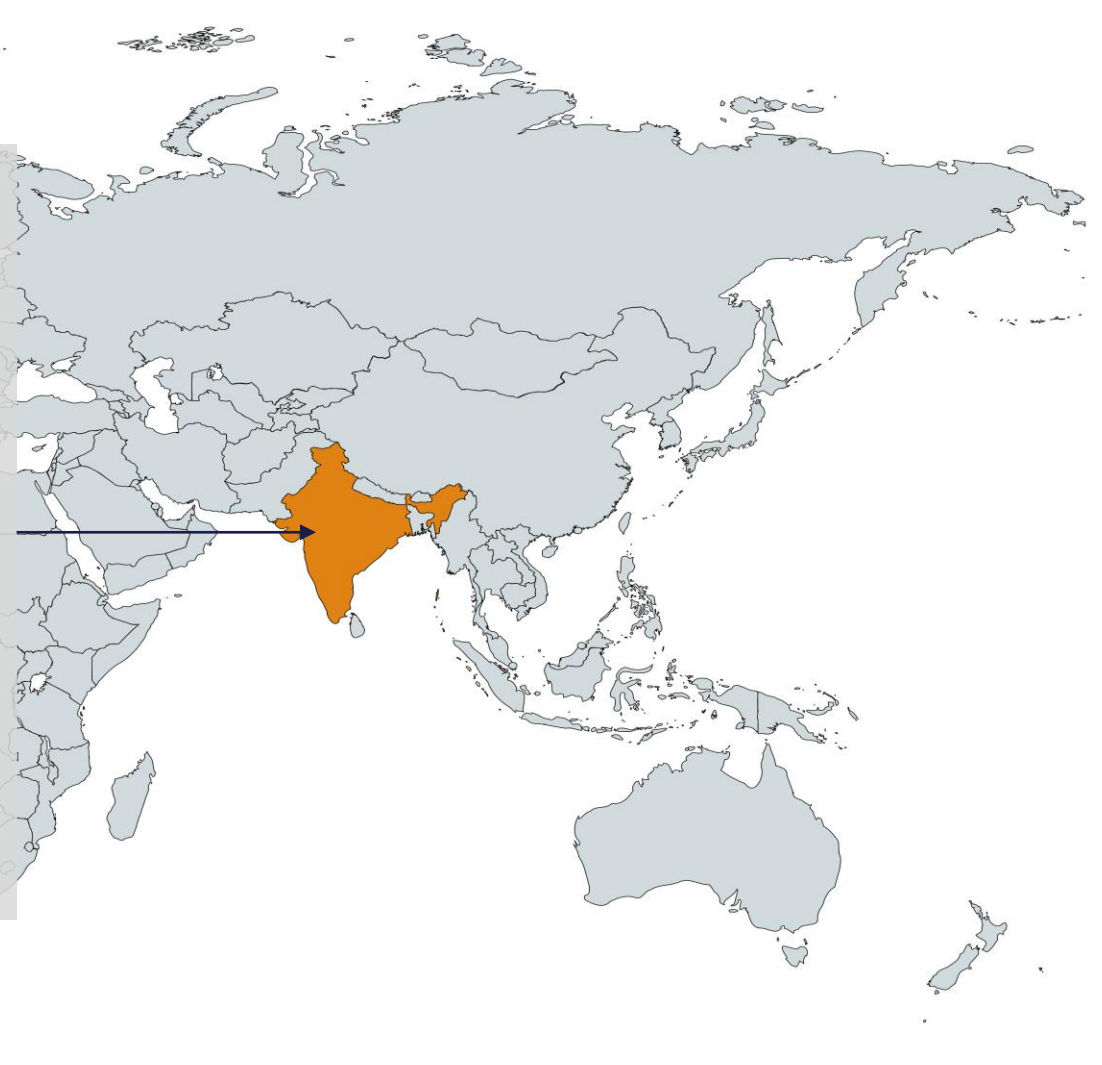




# INTERNATIONAL EXPERIENCE

## India

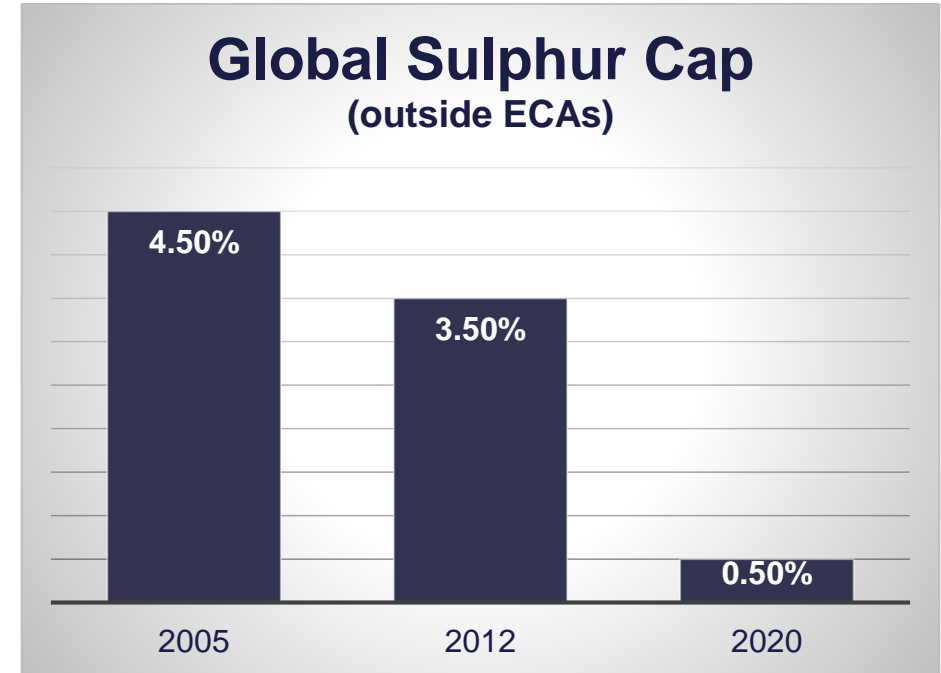
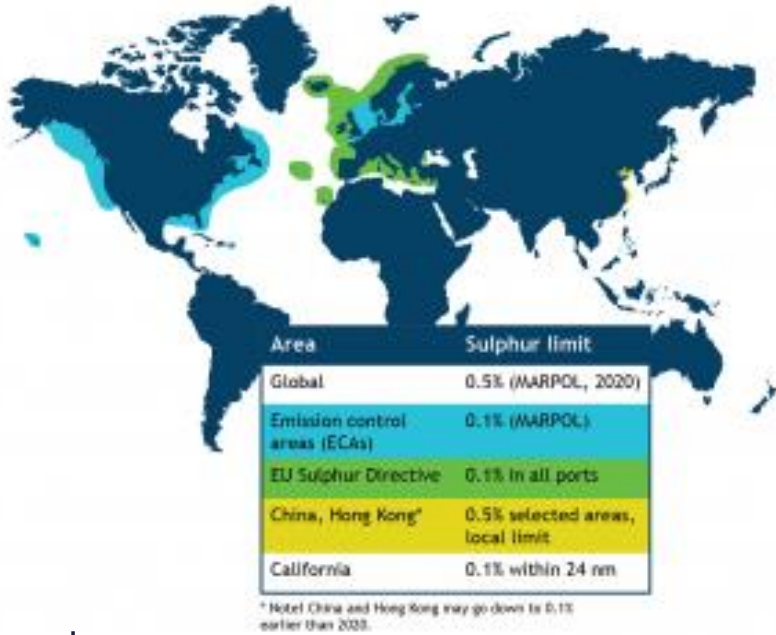
- Methanol M15 guidelines published in 2018
- Launched M15 research project with Automotive Research Association of India (ARAI)
- M15 research results positive:
  - Lower emissions from vehicles
  - Compliant with cars (not 2/3-wheelers) with minor modifications to some components
- Waiting on government funds to launch field trials
- Stakeholders keen on methanol as ethanol aspirations were largely unsuccessful
- Beyond Bharat Stage VI market will open up to new fuels due to cost



# MARINE FUEL

05

# SULPHUR CAP



International Convention for the Prevention of Pollution from Ships (MARPOL)

ECAs first introduced with sulphur content limit of 1 %

Global sulphur limit of 0.5%, effective January 2020

Annex VI Prevention of Air Pollution from Ships entered into force

Sulphur content lowered to 0.1% in ECAs

?



# ROAD TO 2050

## IMO Initial Strategy on the Reduction of GHG Emissions adopted at MEPC 72 (April 2018)

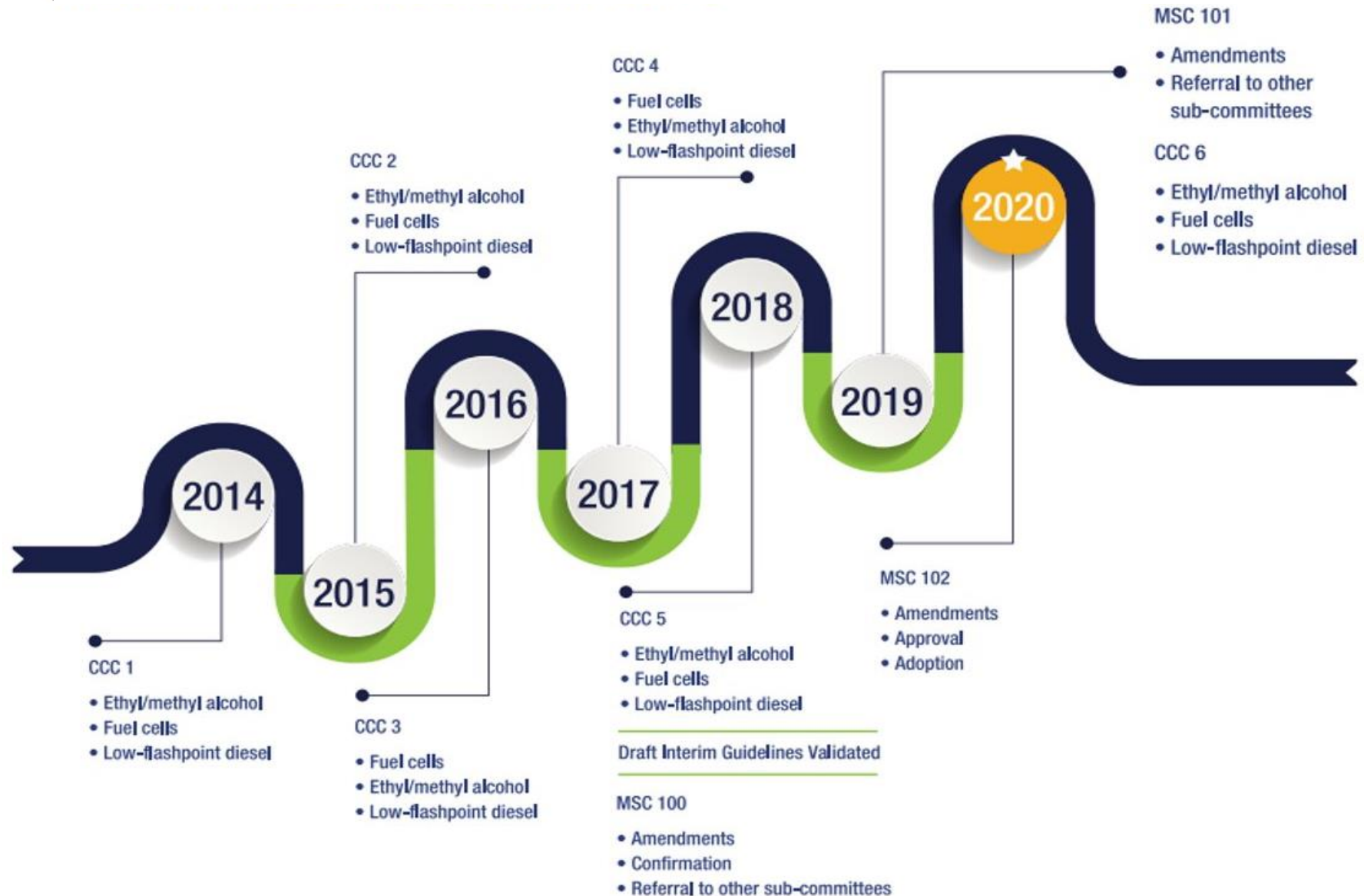
Level of ambition of Initial Strategy.

Carbon intensity of ships to decline through implementation of further phases of energy efficiency design index (EEDI) for new ships.







Reduce CO<sub>2</sub> emissions per transport work, as an average across international shipping by at least 40% by 2030, and 70% by 2050, compared to 2008.

Peak GHG emissions from international shipping ASAP, and reduce total annual GHG emissions by at least 50% by 2050 compared to 2008

# PROGRESSION OF GUIDELINES FOR METHANOL



# METHANOL FUELLED VESSELS AND PILOTS

	DUAL FUEL			FUEL CELL		PROJECT   R&D
						
Quantity	9 + 2	1	1	2	1	+4
Vessel Type	Chemical tankers	ROPAX ferry	Pilot boat	Tourist boat	Ferry	Cruise ships, fishing boats, barges, dredges, others
Owner	MOL, W-L, Marininvest, Methanex, Mitsui, OIIO, NYK	Stena Line	MI/SMA ScandiNaos	Innogy HTWG Konstanz	Viking Line	SUMMETH/MARTEC, Lean Ships, Methaship, Billion Miles <sup>1</sup> , FiTech <sup>2</sup> , IWA <sup>3</sup> , PCG Product Vessel <sup>4</sup> , NTU <sup>2</sup> , GMM, Fastwater, Port of Rotterdam Barge, Jupiter, Paxell, Methanex Fishing <sup>5</sup>
Engine Type	2 stroke MAN	4 stroke Wärtsila	high speed Scania, Weichai	Serenergy fuel cell stacks		SI hybrid, dual fuel, etc.
Design	new build	retrofit	retrofit	retrofit	retrofit	new build & retrofit

All projects are based in the EU unless noted otherwise<sup>1</sup>China/SG, <sup>2</sup>EU/China/SG, <sup>3</sup>India, <sup>4</sup>Malaysia, <sup>5</sup>China

# HAZARD COMPARISON

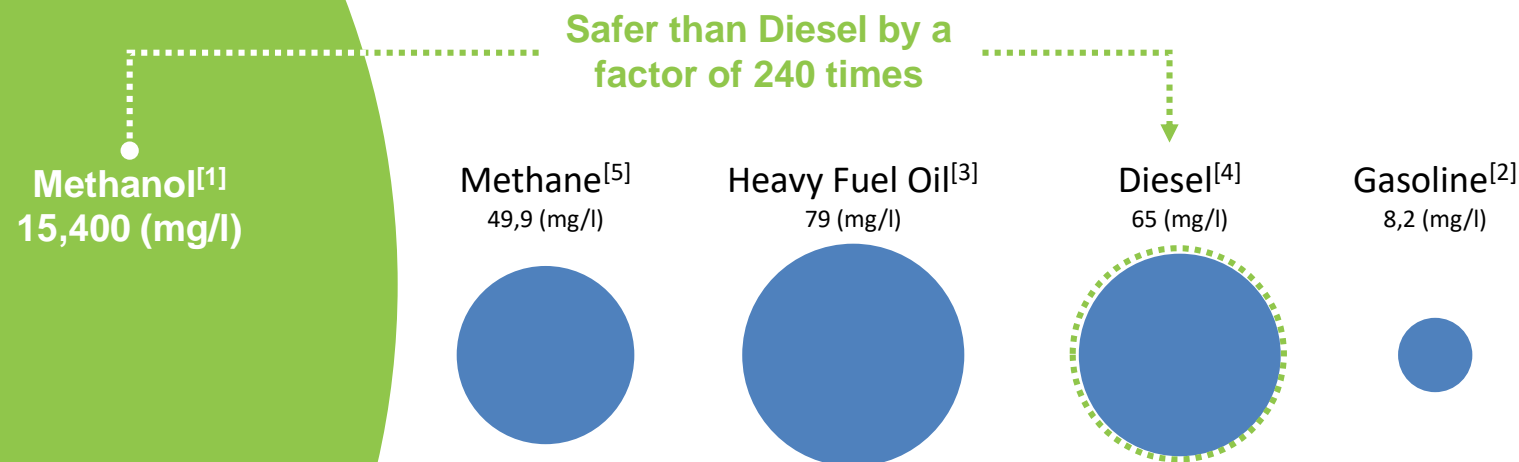
	METHANOL	DIESEL	GASOLINE
Hazard pictograms (CPL)			
Signal word: (CPL)	Danger	Danger	Danger
Hazard statements (CPL)	<p>H220: Highly flammable liquid and vapour.</p> <p>H301: Toxic if swallowed.</p> <p>H311: Toxic in contact with skin.</p> <p>H331: Toxic if inhaled.</p> <p>H370: Causes damage to organs.</p>	<p>H220: Flammable liquid and vapour.</p> <p>H304: May be fatal if swallowed and enters airways.</p> <p>H315: Causes skin irritation.</p> <p>H332: Harmful if inhaled.</p> <p>H351: Suspected of causing cancer.</p> <p>H373: May cause damage to organs through prolonged or repeated exposure.</p> <p>H411: Toxic to aquatic life with long lasting effects.</p>	<p>H220: Extremely flammable liquid and vapour.</p> <p>H304: May be fatal if swallowed and enters airways.</p> <p>H315: Causes skin irritation.</p> <p>H360: May cause genetic defects.</p> <p>H370: May cause cancer.</p> <p>H381: Suspected of damaging fertility or the unborn child.</p> <p>H400: May cause drowning or distress.</p> <p>H411: Toxic to aquatic life with long lasting effects.</p>
Precautionary statements (CLP)	<p>P201: Read carefully before use.</p> <p>P202: Do not handle until you have read and understood the label.</p> <p>P203: Keep away from heat/sparks/open flames/hot surfaces. – No smoking.</p> <p>P210: Keep away from heat/sparks/open flames/hot surfaces. – No smoking.</p> <p>P211: Keep container tightly closed.</p> <p>P212: Use explosion proof electrical/lighting equipment.</p> <p>P213: Use only non-sparking tools.</p> <p>P215: Take precautionary measures against static discharge.</p> <p>P221: DO NOT breathe dust/fume/gas/vapour/spray.</p> <p>P241: Wash hands thoroughly after handling.</p> <p>P271: DO NOT eat, drink or smoke when using this product.</p> <p>P273: Avoid release to the environment.</p> <p>P280: Wear protective gloves/protective clothing/eye protection/face protection.</p> <p>P301+P312: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.</p> <p>P302+P352: IF ON SKIN: Wash with plenty of soap and water.</p> <p>P303+P361+P353: IF ON SKIN (or hair): Remove contaminated clothing and shoes.</p> <p>P304+P340: IF INHALED: Remove person to fresh air and keep at rest in a position comfortable for breathing.</p> <p>P305+P351+P338: IF EYES ARE CONTAMINATED: Flush eyes with water for several minutes. Call a POISON CENTER or doctor/physician if you feel uneasy.</p> <p>P312: Call a POISON CENTER or doctor/physician if you feel uneasy.</p> <p>P313: Do NOT induce vomiting.</p> <p>P332+P313: IF skin irritation occurs: Get medical advice/attention.</p> <p>P370+P378: In case of fire: Use water spray or foam for extinction.</p> <p>P501: Dispose of contents and container in accordance with local/regional/national/international regulations.</p>	<p>P201: Read carefully before use.</p> <p>P202: Do not handle until you have read and understood the label.</p> <p>P203: Keep away from heat/sparks/open flames/hot surfaces. – No smoking.</p> <p>P210: Keep away from heat/sparks/open flames/hot surfaces. – No smoking.</p> <p>P211: Keep container tightly closed.</p> <p>P212: Use explosion proof electrical/lighting equipment.</p> <p>P213: Use only non-sparking tools.</p> <p>P215: Take precautionary measures against static discharge.</p> <p>P221: DO NOT breathe dust/fume/gas/vapour/spray.</p> <p>P241: Wash hands thoroughly after handling.</p> <p>P271: DO NOT eat, drink or smoke when using this product.</p> <p>P273: Avoid release to the environment.</p> <p>P280: Wear protective gloves/protective clothing/eye protection/face protection.</p> <p>P301+P312: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.</p> <p>P302+P352: IF ON SKIN: Wash with plenty of soap and water.</p> <p>P303+P361+P353: IF ON SKIN (or hair): Remove contaminated clothing and shoes.</p> <p>P304+P340: IF INHALED: Remove person to fresh air and keep at rest in a position comfortable for breathing.</p> <p>P305+P351+P338: IF EYES ARE CONTAMINATED: Flush eyes with water for several minutes. 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Methanol classified as “not more dangerous” than other fuels such as gasoline or diesel – fuels largely familiar to most people

# SAFER FOR THE ENVIRONMENT

## LC50, LC = LETHAL CONCENTRATION FISH

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



<sup>[1]</sup> ECHA, European Chemicals Agency, registration dossier Methanol

<sup>[2]</sup> Petrobras/Statoil ASA, Safety Data Sheet, ECHA registration dossier Gasoline

<sup>[3]</sup> GKG/ A/S Dansk Shell, Safety Data Sheet

<sup>[4]</sup> ECHA, European Chemicals Agency, registration dossier Diesel

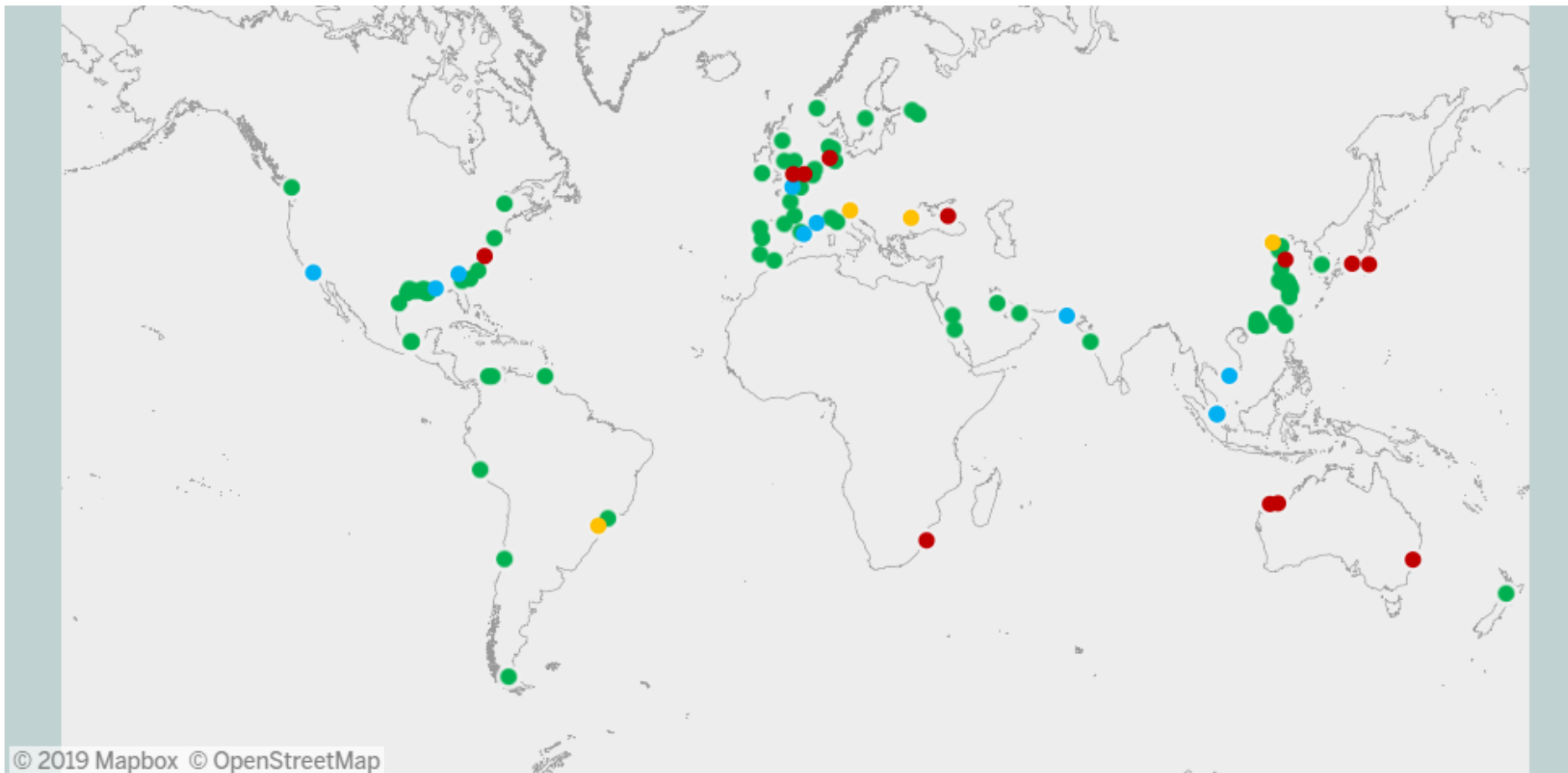
<sup>[5]</sup> ECHA, European Chemicals Agency, registration dossier Methane

*Additional Source: Meyer-Werft*



# METHANOL IS WIDELY AVAILABLE AT PORTS

## Methanol Fuel Availability at Ports



Yellow square: Ports with confirmed methanol capacity (provided by ports directly)

Red square: Ports with no methanol capacity

Blue square: Ports with private bulk liquid storage

Green square: Ports with confirmed methanol supply/storage (provided by suppliers operating at the port)

## ***BROADLY, METHANOL IS...***

- A cost effective and “future proof” fuel which can be produced from a variety of feedstocks – to include renewables
- One of the top 5 seaborne chemical commodities – safely handled for over 50 years
- A lower cost alternative for converting vessels, boilers and other power sources to methanol – minimal and economically viable without subsidies
- Widely available and alleviates many infrastructure and safety limitations both on land and at sea, trading within a narrower price range than competing fuels
- Not as well understood as a fuel, even though it has similar handling characteristics as distillate fuel



# FUEL CELLS

06

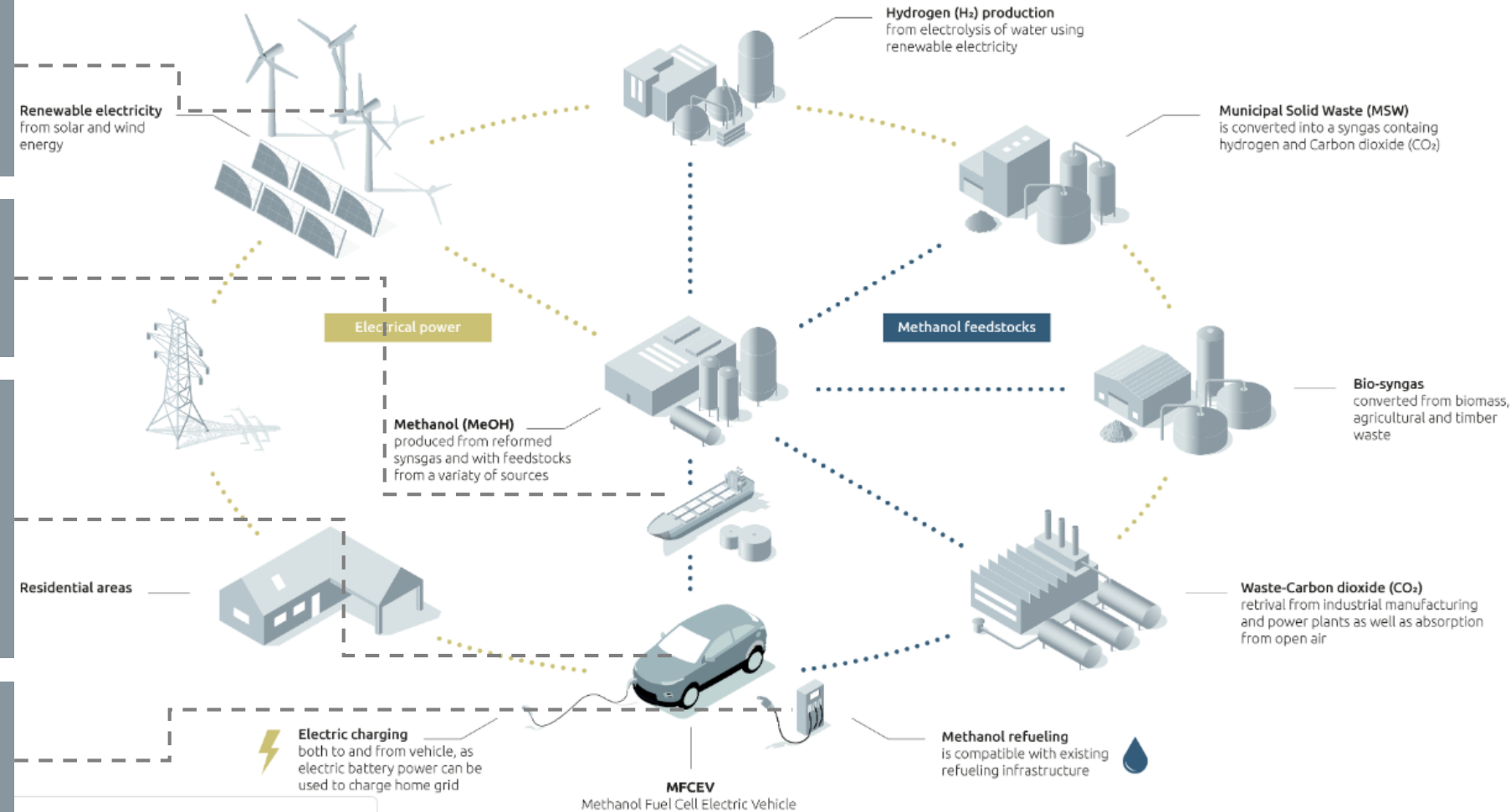
# WHY METHANOL IN FUEL CELLS

Methanol can be produced efficiently from renewable electricity, providing a long term storage solution.

Physical characteristics make distribution and transport cost-efficient.

Can be converted to electricity in fuel cells on board vehicles with minimal emissions. No NO<sub>x</sub>, SO<sub>x</sub>, or PM. 80% reduction in CO<sub>2</sub> emissions.

Compatible with existing distribution and refueling infrastructure





# METHANOL FUEL CELLS

## 2 types of methanol fuel cells

1. Direct Methanol Fuel Cell
  - Uses methanol without reforming
  - Methanol can react at the cell electrodes without reforming technology
2. Reformed Methanol Fuel Cell
  - Requires a reformer which converts methanol into hydrogen
  - Hydrogen is reacted in the fuel cell to produce power

**Methanol ( $\text{CH}_3\text{OH}$ ) is a better carrier of hydrogen than hydrogen.**

- It is liquid at ambient temperature and pressure
- Has more hydrogen atoms in one molecule compared to  $\text{H}_2$



**Oorja DMFC**



**e1 Hydrogen Reformer**

# FUEL CELL APPLICATIONS



Remote Power Generation



Telecom Towers



Security Installations



Military Applications

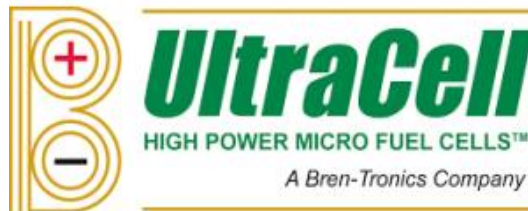


Range Extender in Automobiles



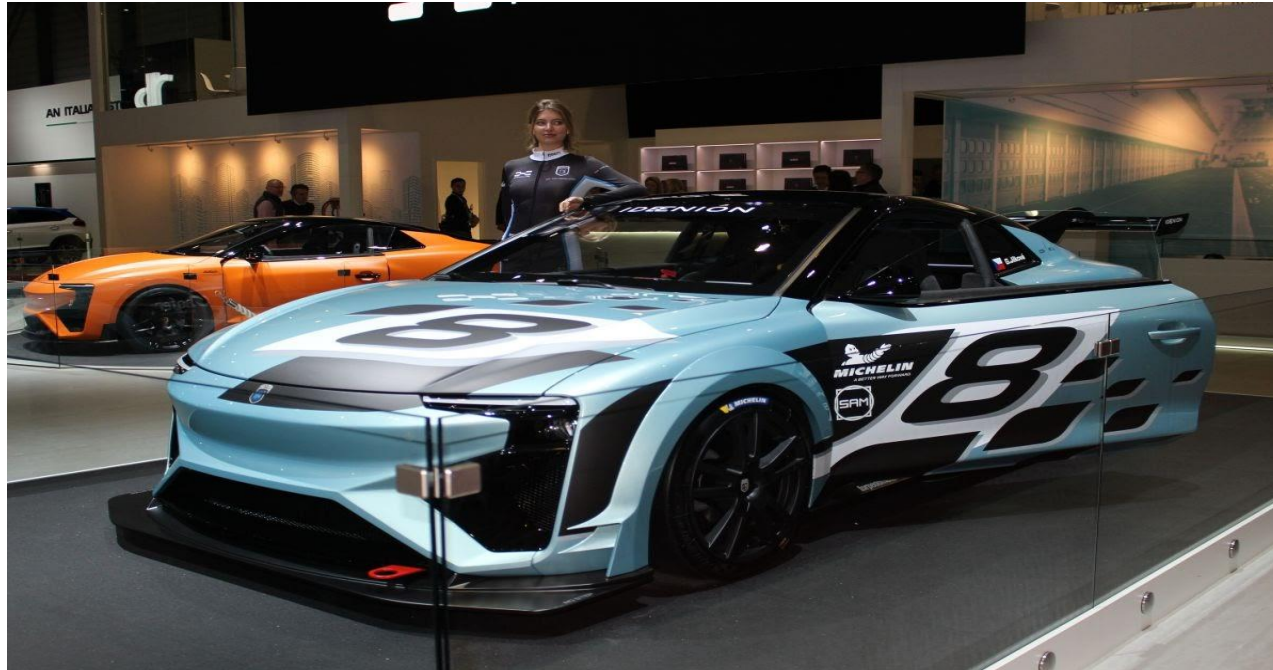
Propulsion for Marine Vessels

## GLOBAL INDUSTRY GAINING TRACTION





# HYBRID INNOVATION: AIWAYS/GUMPERT RG 'NATHALIE'



## AIways: Gumpert RG Nathalie

Reformed Methanol Fuel Cell Electric Supercar

1,200 km Range

Top speed 300 km/h



A photograph of an industrial boiler system. The boiler is a large, horizontal, cylindrical vessel with a dark grey front door. To the left of the door, there are two white electrical control panels mounted on a metal stand. To the right of the door, there is a large, orange, L-shaped burner assembly. The boiler is surrounded by a network of pipes, some painted yellow and others red. A yellow ladder is visible on the left side of the boiler. The background shows more industrial equipment and a concrete floor.

# INDUSTRIAL BOILERS

07

# METHANOL FUELED INDUSTRIAL BOILERS

- Industrial boilers are widely used for heating and industrial stream
- Many cities in China prohibit the use of coal and diesel
- Capacity ranges from 1 to 20 steam tons/hour
- In continuous cycle on full load, one steam ton of capacity consumes 110 kg of methanol
- Methanol fuel is used neat or emulsified (typically to 25%)
- Standards developed with MI and Methanex support
- *Currently close to 1500 units, consuming over 3M mtpa*
- *Forecasted to consume 5M mtpa by 2022*

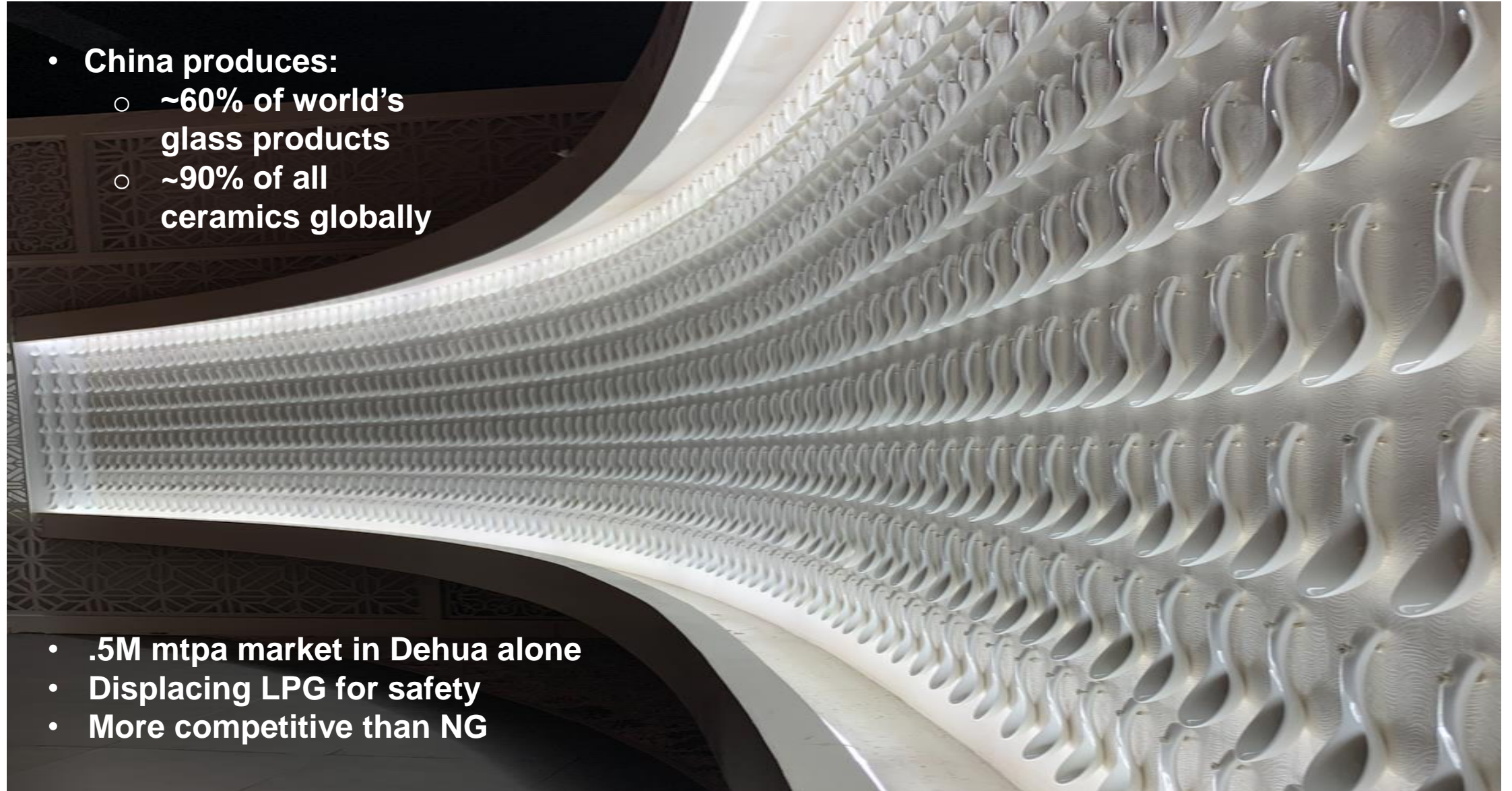




# METHANOL FUELED CERAMIC KILNS

- China produces:
  - ~60% of world's glass products
  - ~90% of all ceramics globally

- .5M mtpa market in Dehua alone
- Displacing LPG for safety
- More competitive than NG



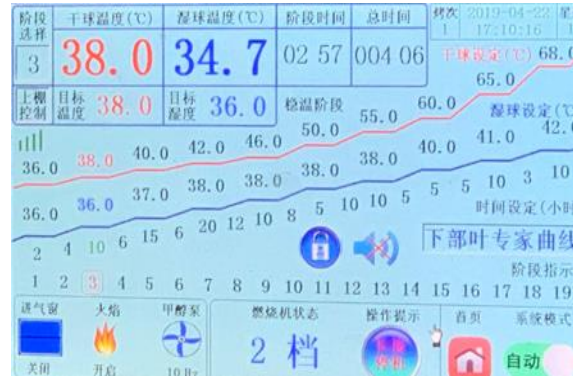
# METHANOL FUELED CERAMIC KILNS



- 3-yr pilot reference
- 4 MT/month average consumption with less air intake
- Underground storage with day tank buffer
- 3 to 6 cubic meters kiln capacity
- Retrofit kit includes:
  - Tank
  - Burners
  - Controls
  - CPU
  - Waste Heat Recovery
  - RMB 10,000 (USD\$ 1,500)
- Higher achieved temperatures with methanol – to 1400°C
- Similar price but safer than LPG, which is registering on average of one explosion weekly – often with fatalities



# METHANOL FUELLED TABACCO DRIERS



1 out of every 3 Cigarettes globally are consumed in China

- RMB1.7 trln profits + tax collected by government annually
  - Equal to military spending budget
  - More than Sinopec and CNOC combined contributions to state treasury



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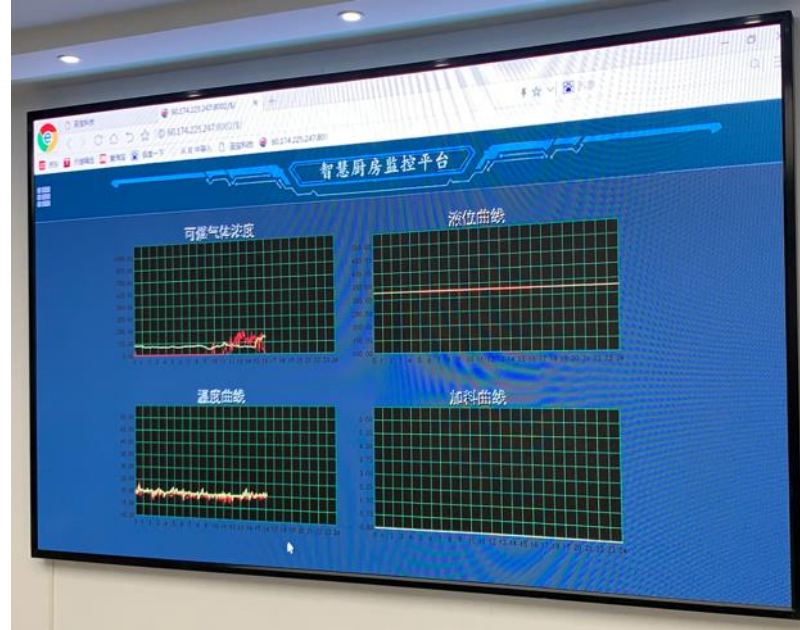
# METHANOL FUELED COOK STOVES

- *Current market consuming over 5 M mtpa*
- *Forecast to reach 7-8 M mtpa by 2022*



# METHANOL FUELED COOK STOVES

- Single heating, stir fry, steaming
- Widely used in restaurants, central kitchens, mainly cost-driven
- Simple storage and transportation, filling the gap when NG supplied by pipeline is cost prohibitive
- Fuel: 100% methanol to methanol blends usually with water (to 40%)





## ***SUMMARY***

- **Application design, whether retrofit or new build are simple, advantageous, practical and understandable – whether for ships, boilers, kilns, or cars**
- **Compelling emissions reduction properties in all cases**
- **Superior Life Cycle Analysis (LCA) advantage when combined with CCI technology or when renewably produced**
- **Infrastructure is a key enabler for methanol's uptake as a fuel due to storage and handling being no more complicated than other liquid fuels**
- **More visibility over long-term pricing than competitive fuels**

# THANK YOU



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