METHANOL INSTITUTE

METHANOL AS A VESSEL FUEL & ENERGY CARRIER

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COO

INTERNATIONAL TANKER TECHNICAL FORUM
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SCIENCE PARK, SINGAPORE

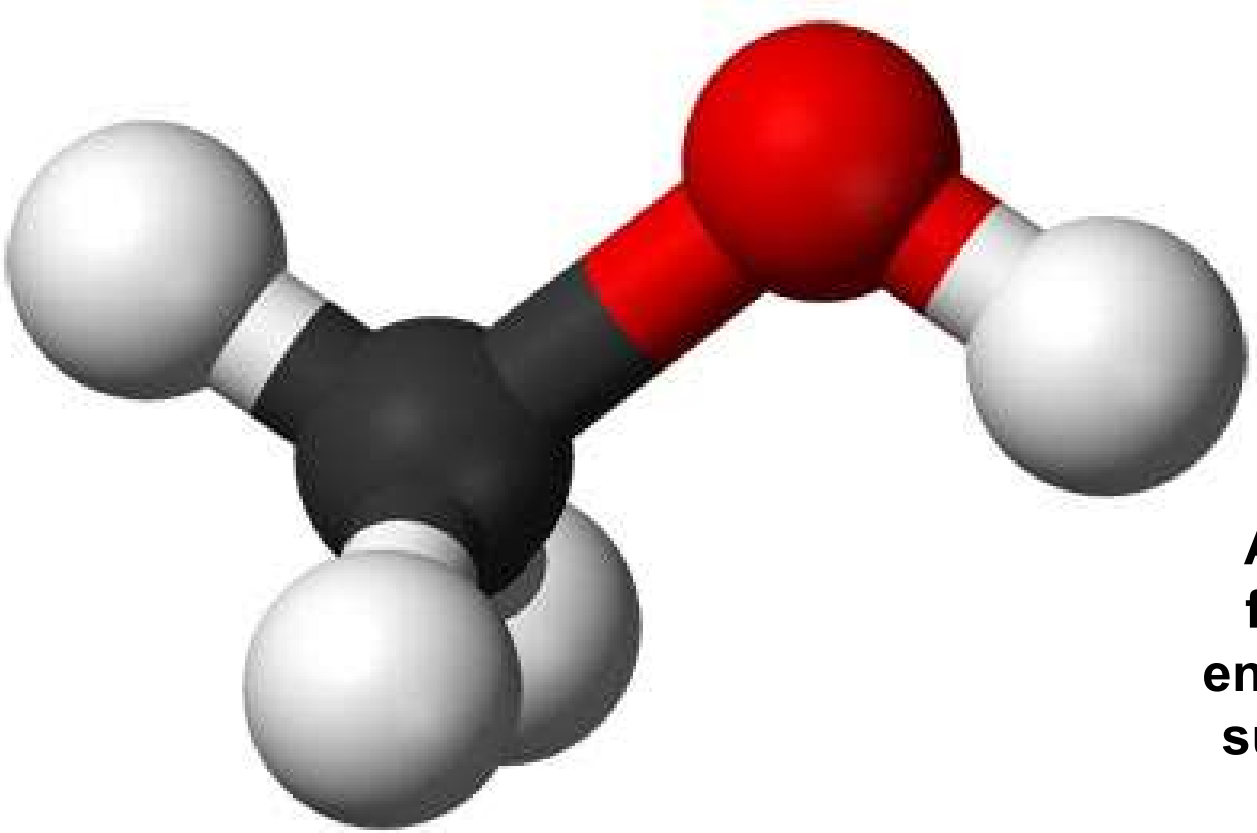
01 ABOUT MI

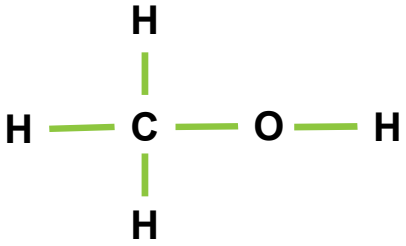
MEMBERS


Tier 1
MHTL
methanex
the power of agility
سابك
sabic
OCI
Tier 2
Qatar Fuel Additives Company Limited
MITSUBISHI GAS CHEMICAL AMERICA, INC.
ATLANTIC METHANOL
MITSUI & CO., LTD.
PETRONAS
Oman Methanol Company L.L.C.
Tier 3
Eni
Ecofuel
Sipchem
EXCELLENCE everywhere
G2XENERGY
JM
Johnson Matthey
Inspiring science, enhancing life
Mitsubishi International Corporation
Tier 4
FiTech
Advent
HELM PROMAN METHANOL
azelis
MOL
Mitsui O.S.K. Lines
Blue World
Technologies
CARBON RECYCLING INTERNATIONAL
GasTechno
ENERGY AND FUELS
HALDOR TOPSOE
SCC
SOUTHERN CHEMICAL CORPORATION
bse engineering
YCI METHANOL ONE
FUELFREEDOM
CHEAPER. CLEANER. AMERICAN-MADE.
Palcan
IGPMethanol
NW INNOVATION WORKS
Double Green Bridge
TRICON ENERGY
Element 1
Powering Innovation
IMTT
INTERNATIONAL-MATEX TANK TERMINALS
NAKHODKA FERTILIZER PLANT
quantiam technologies
CLARIANT
CoogeeChemicals
OLAHMOTORS
VITUSA PRODUCTS
INCORPORATED
solvadis
we do chemistry
Nebraska Public Power District
Always there when you need us

02 WHAT IS METHANOL?

SIMPLEST MOLECULE OF ALCOHOLS GROUP





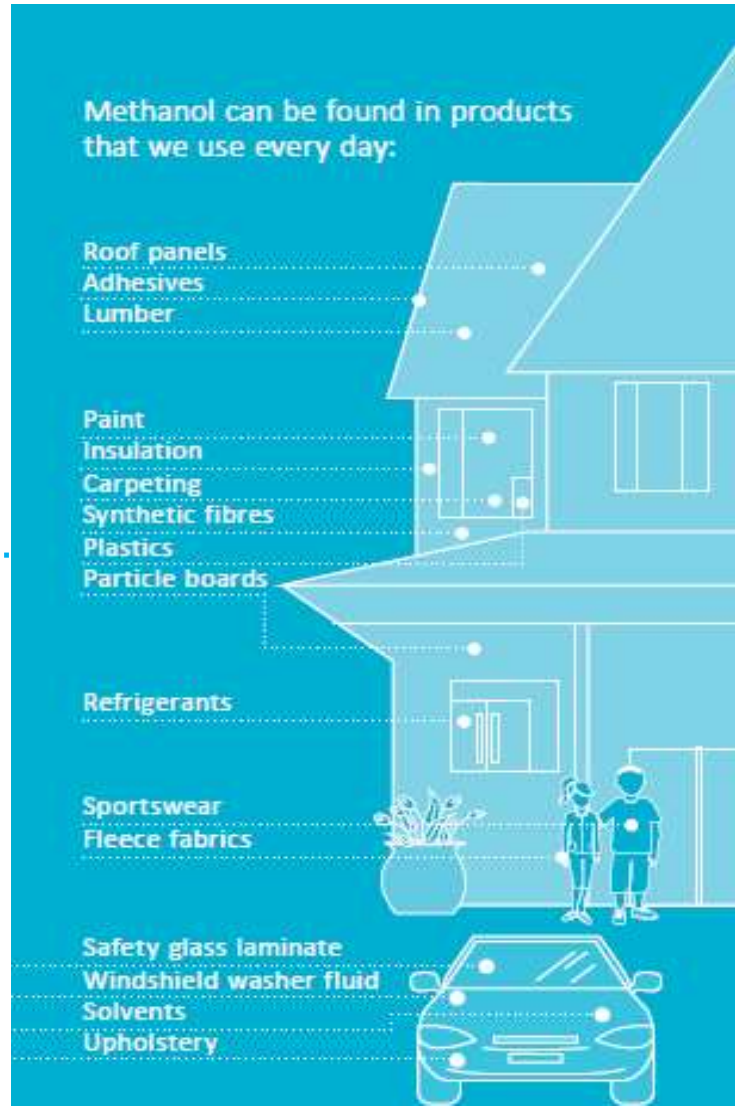
An efficient, universal, future-proof, and safe, energy carrier that can be sustainably produced in large quantities

METHANOL

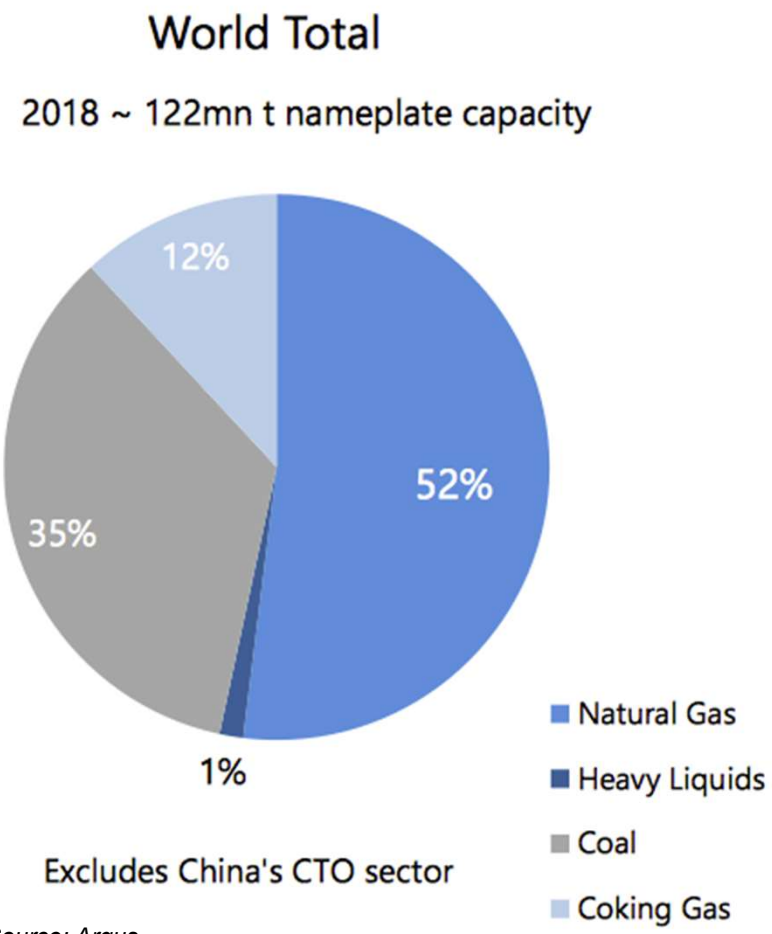
An essential ingredient of modern life

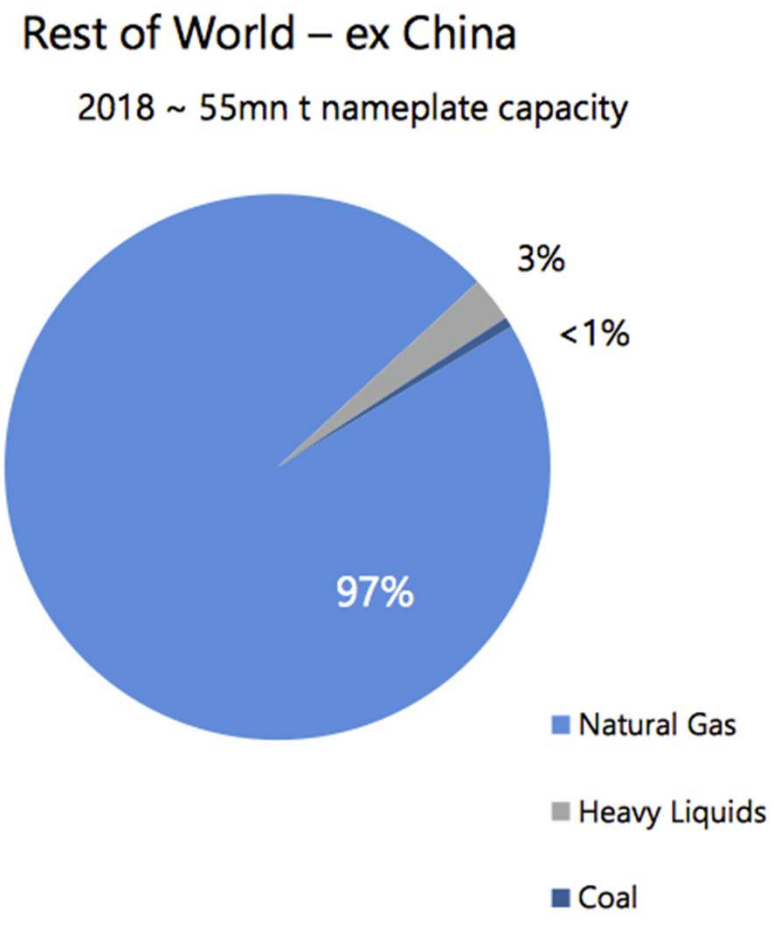
Energy/Fuel Substitution markets - represent the fastest growing demand segment for methanol (~45% demand)

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



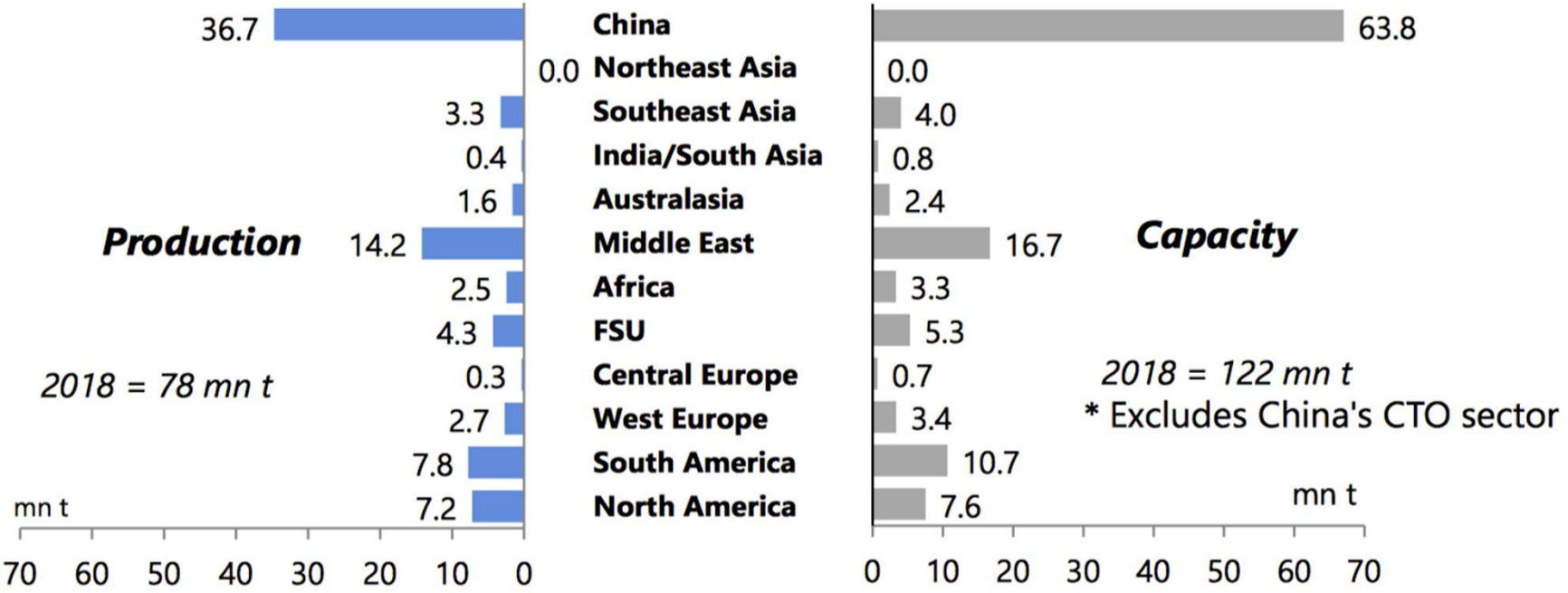
METHANOL PRODUCTION





Source: Argus

GLOBAL METHANOL PRODUCTION VS CAPACITY

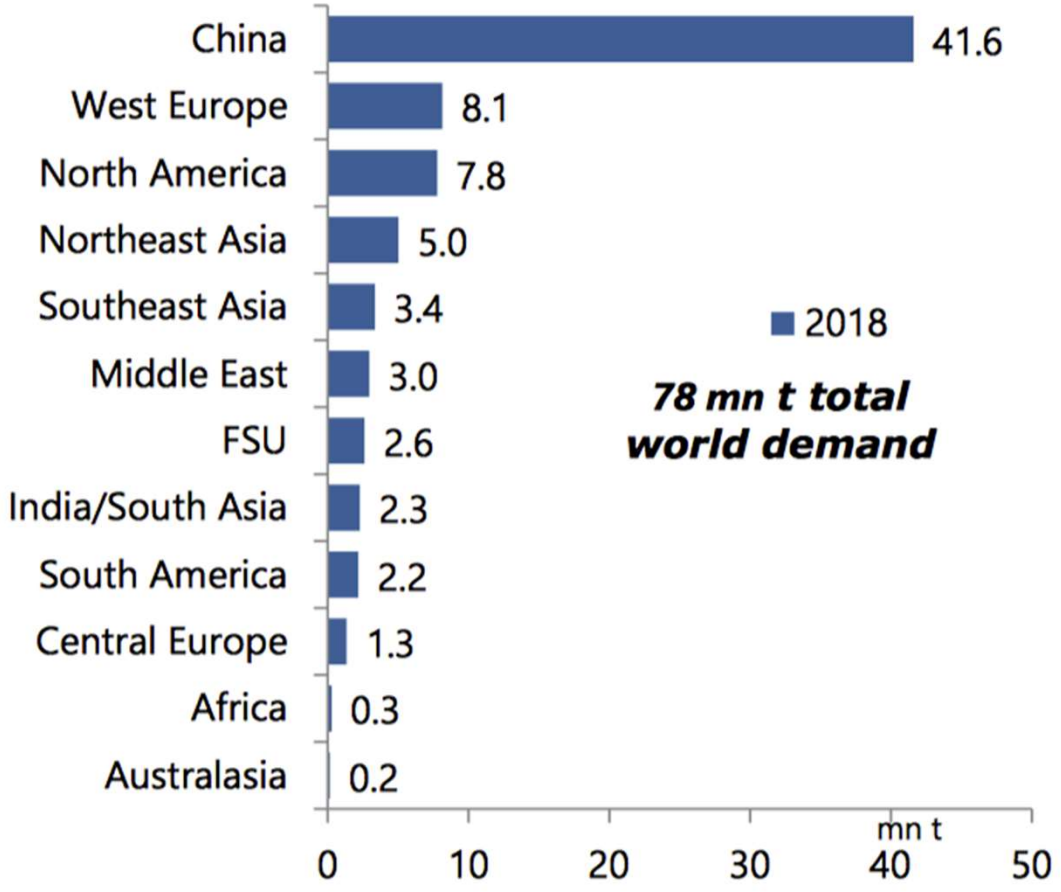


- Rest of world methanol production (excluding China) operates to best of abilities. Excess production from the rest of the world is exported to China
- China “generally” represents the high-cost methanol production bloc in the world and operates to meet China demand, less imports received from the rest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

Source: Argus

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, Momentive, 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**



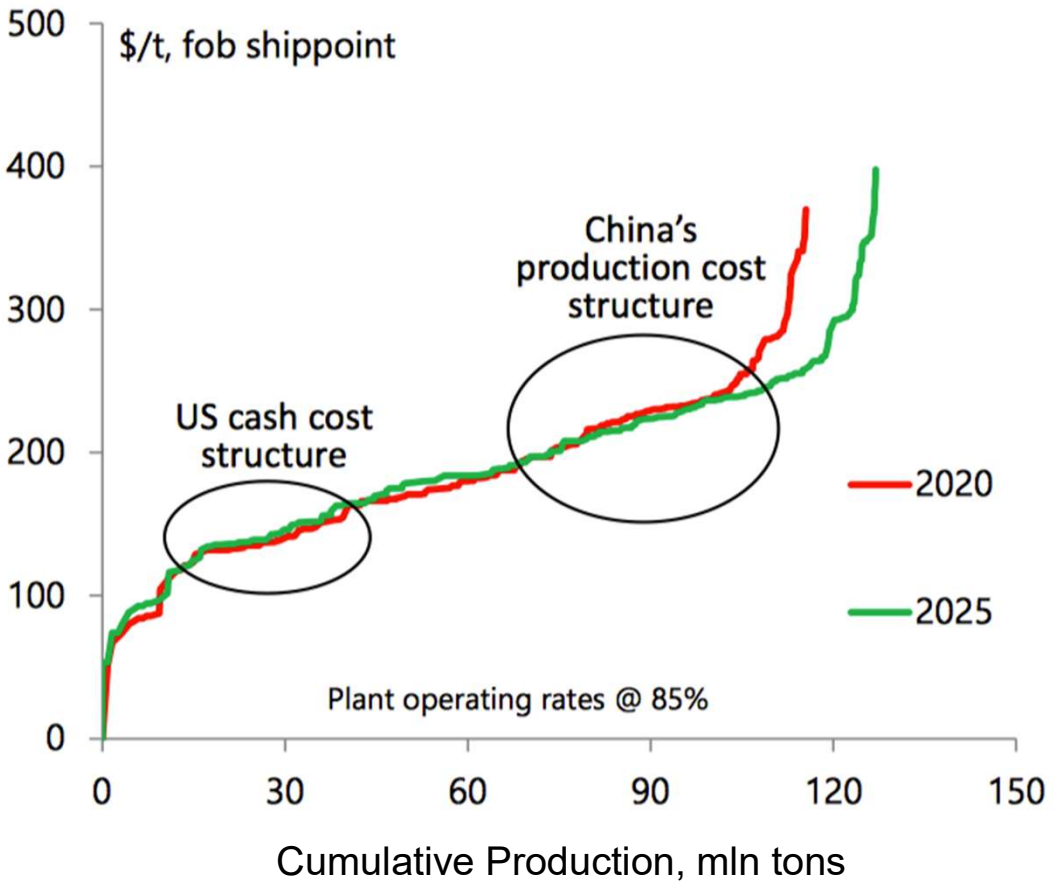
Source: Argus

***Excludes China's CTO sector**

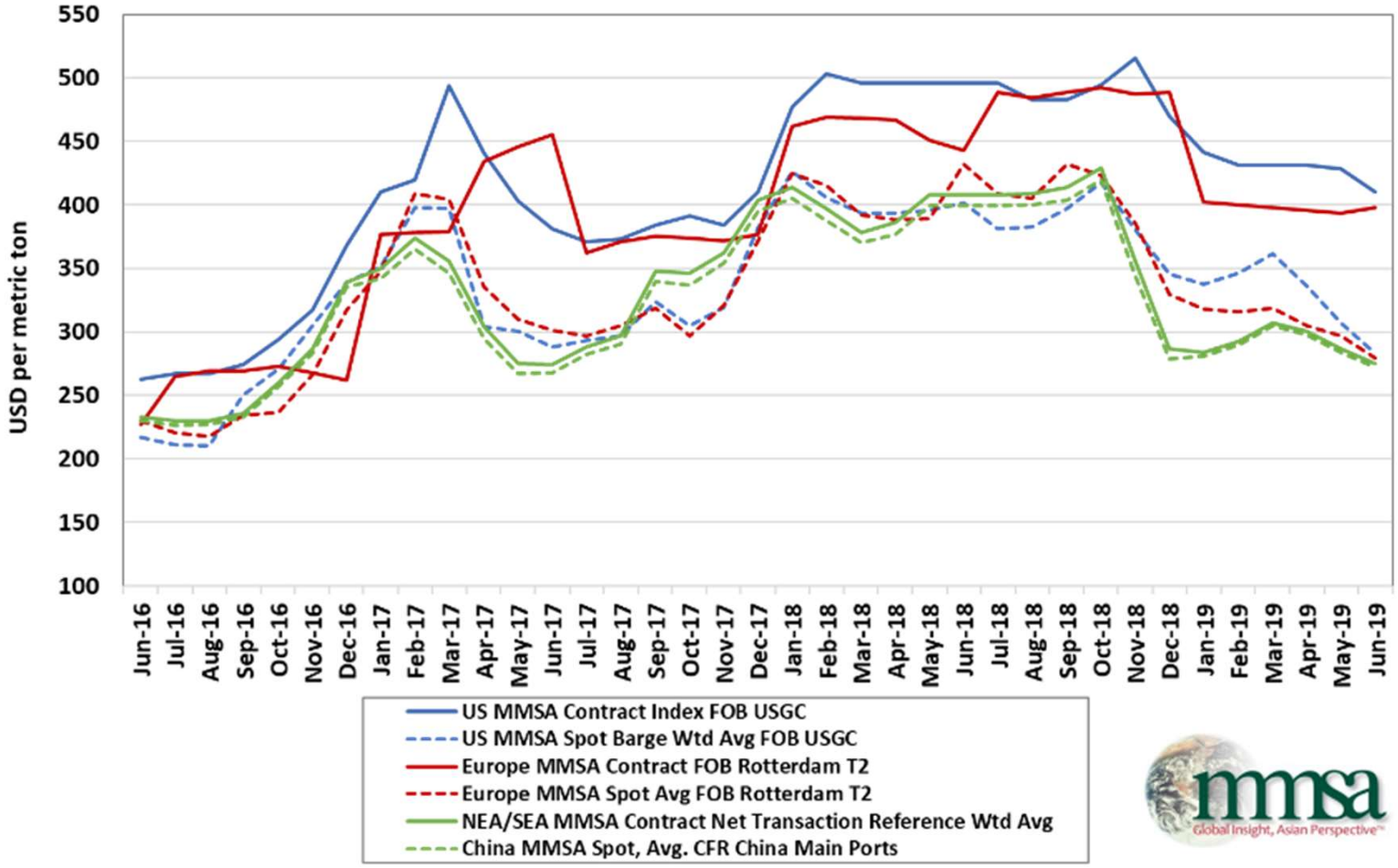
METHANOL INDUSTRY PRODUCTION CASH COST CURVES

- **Methanol industry cash cost curves well compressed**
  - Cash cost only, no depreciation, capital recovery or return
  - fob plant gate basis
  - Shipping to destinations can add $20-$60/t, depending on origin and destination
- **A slowly rising crude oil forecast drives little change in feedstock costs**
  - Industry incremental cash cost of production remains in a narrow band
  - Little opportunity to “driveup” the floor price of the high cost producer increment
- **The methanol industry continues to see robust growth**
  - ~4-5% into the next decade
  - China continues to dominate industry demand and production
  - Nominal 2-3 “world scale” methanol units needed per year to keep pace with demand growth

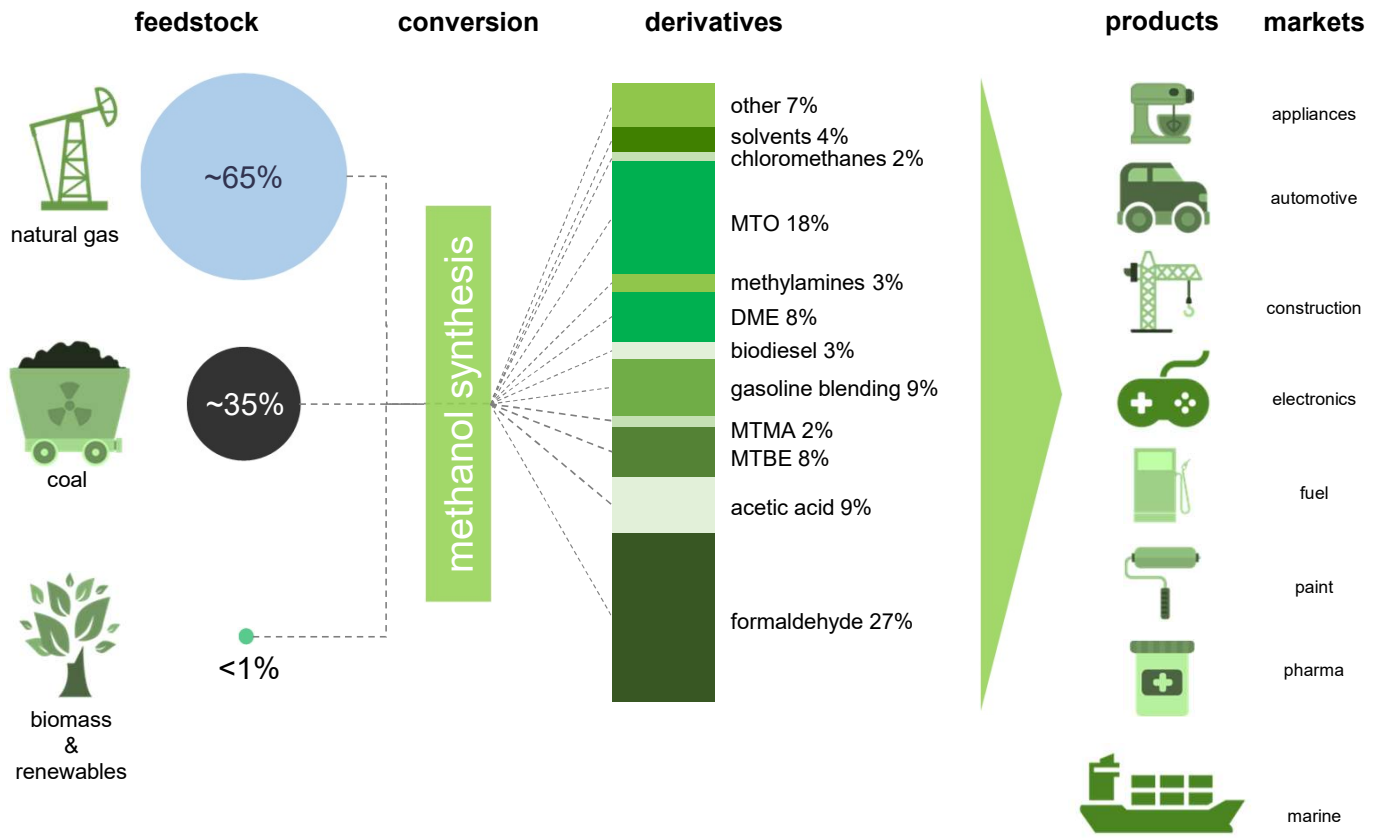
Source: Argus



METHANOL PRICING

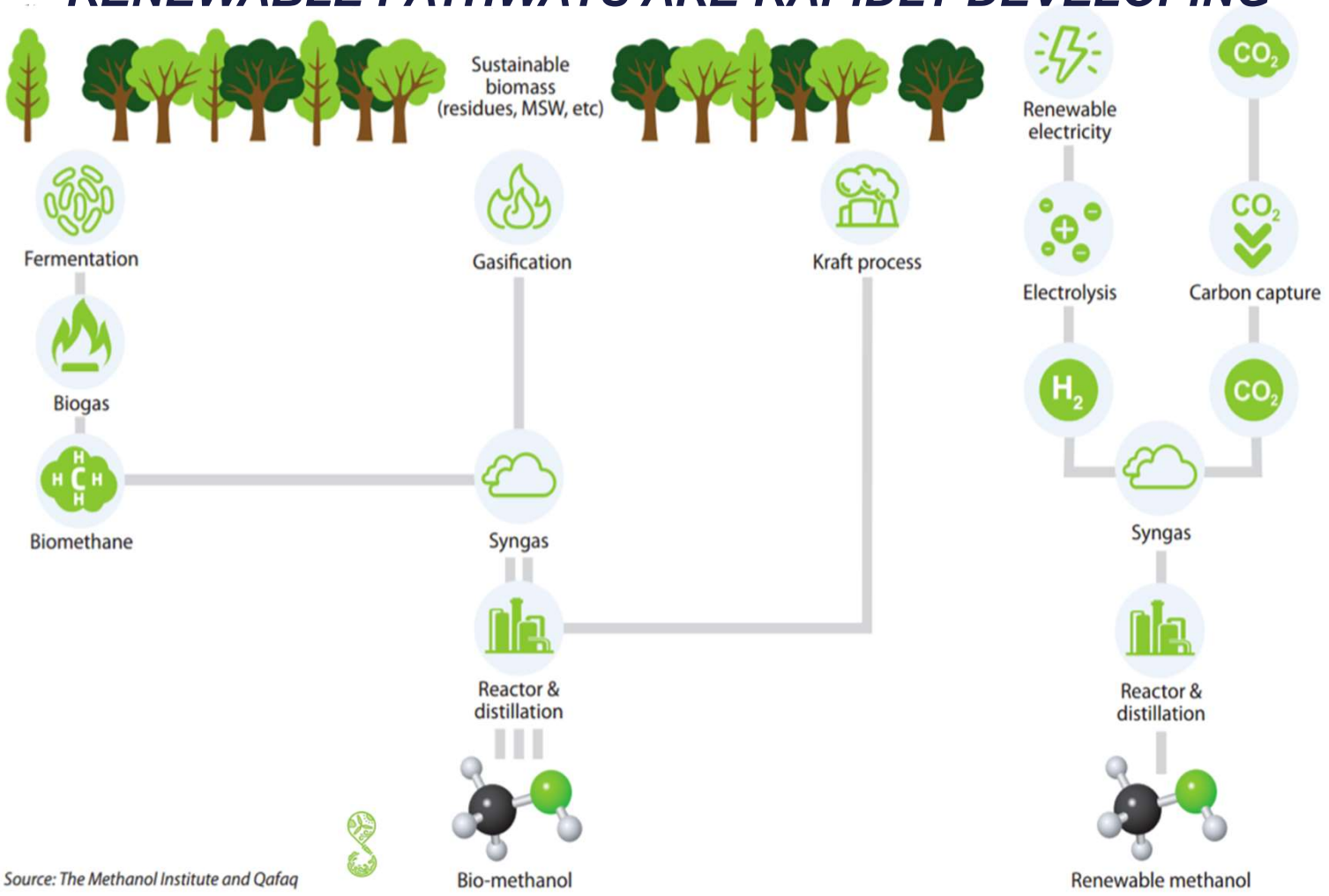


BROAD FEEDSTOCK RANGE, MANY APPLICATIONS



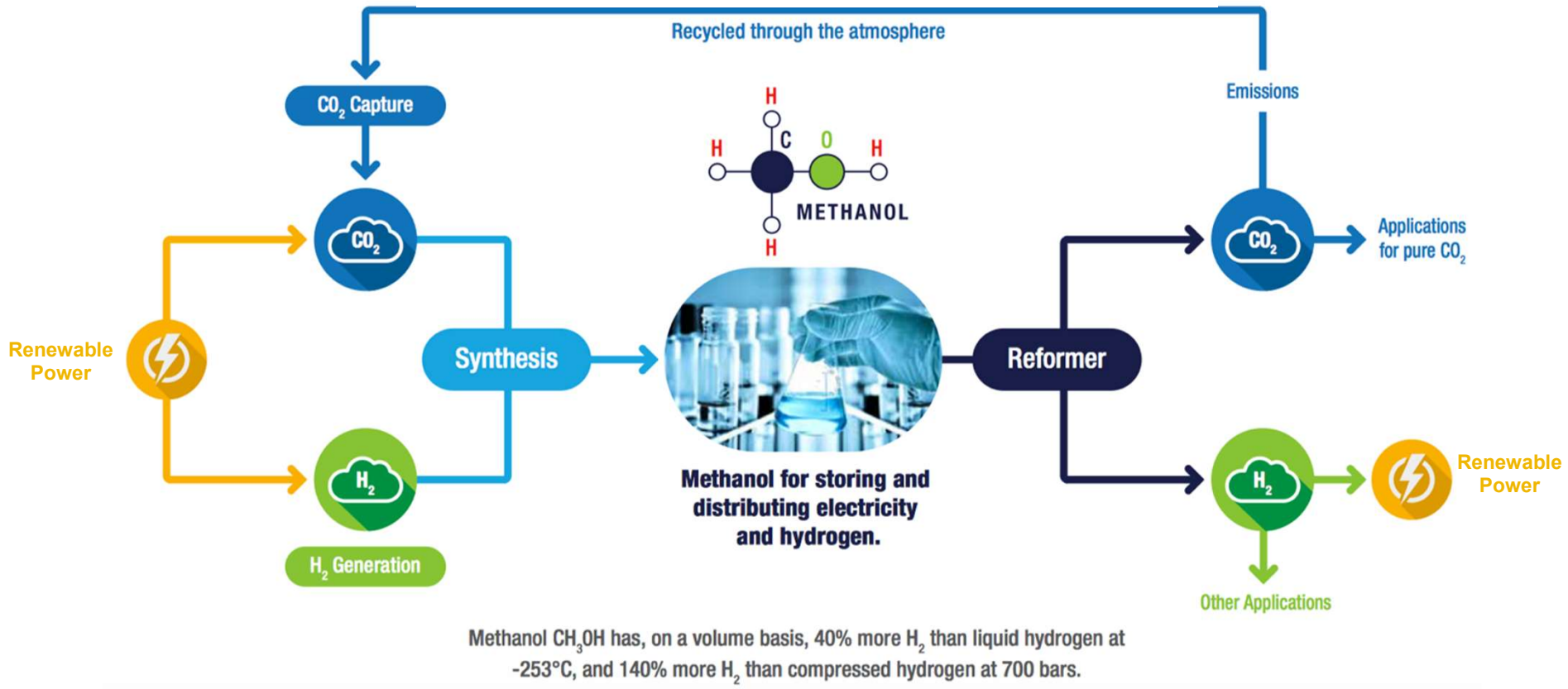
Source: IHS

RENEWABLE PATHWAYS ARE RAPIDLY DEVELOPING



Source: The Methanol Institute and Qafaq

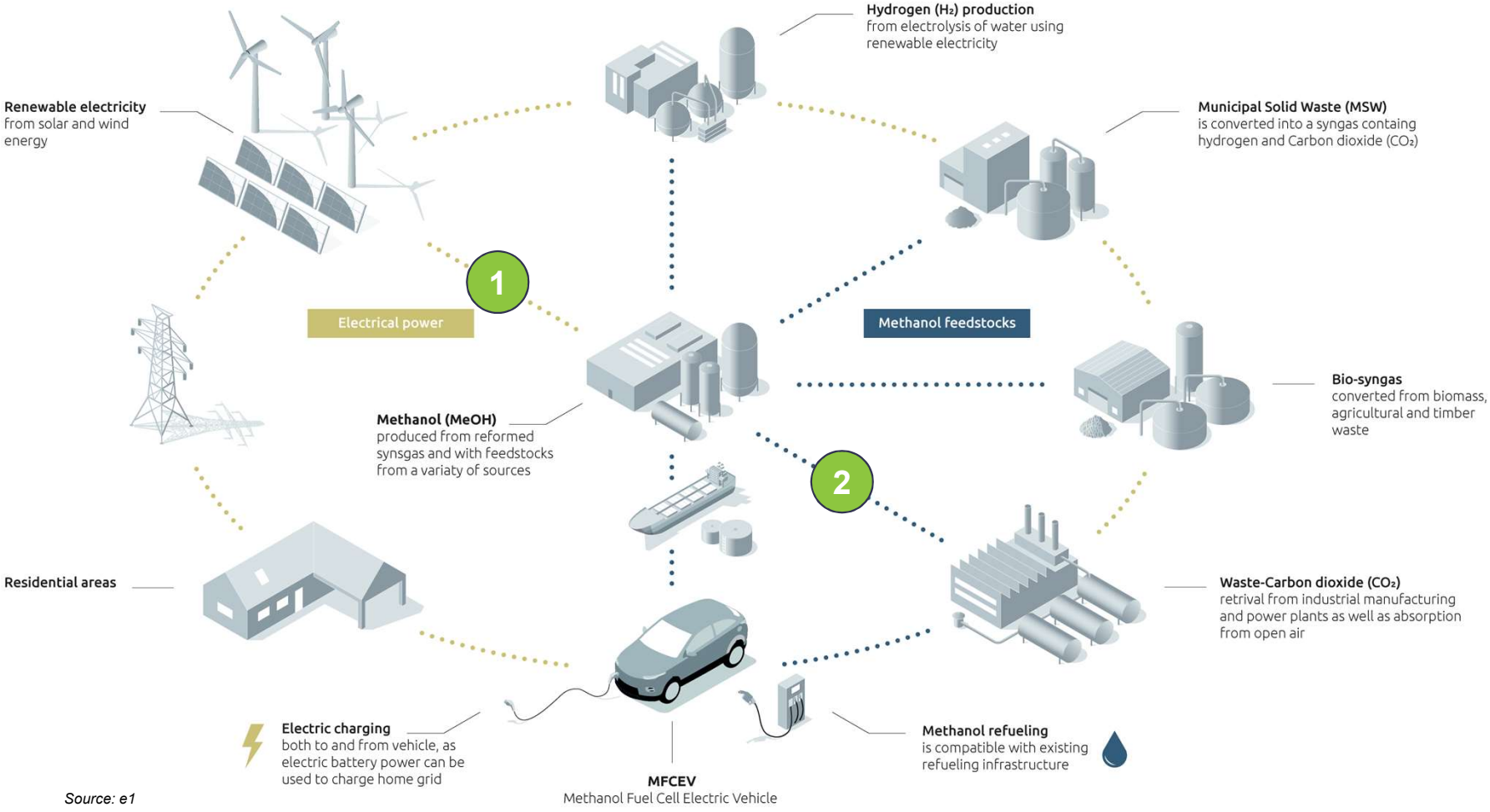
E-METHANOL: AN EFFICIENT ENERGY CARRIER



Methanol CH_3OH has, on a volume basis, 40% more H_2 than liquid hydrogen at -253°C, and 140% more H_2 than compressed hydrogen at 700 bars.

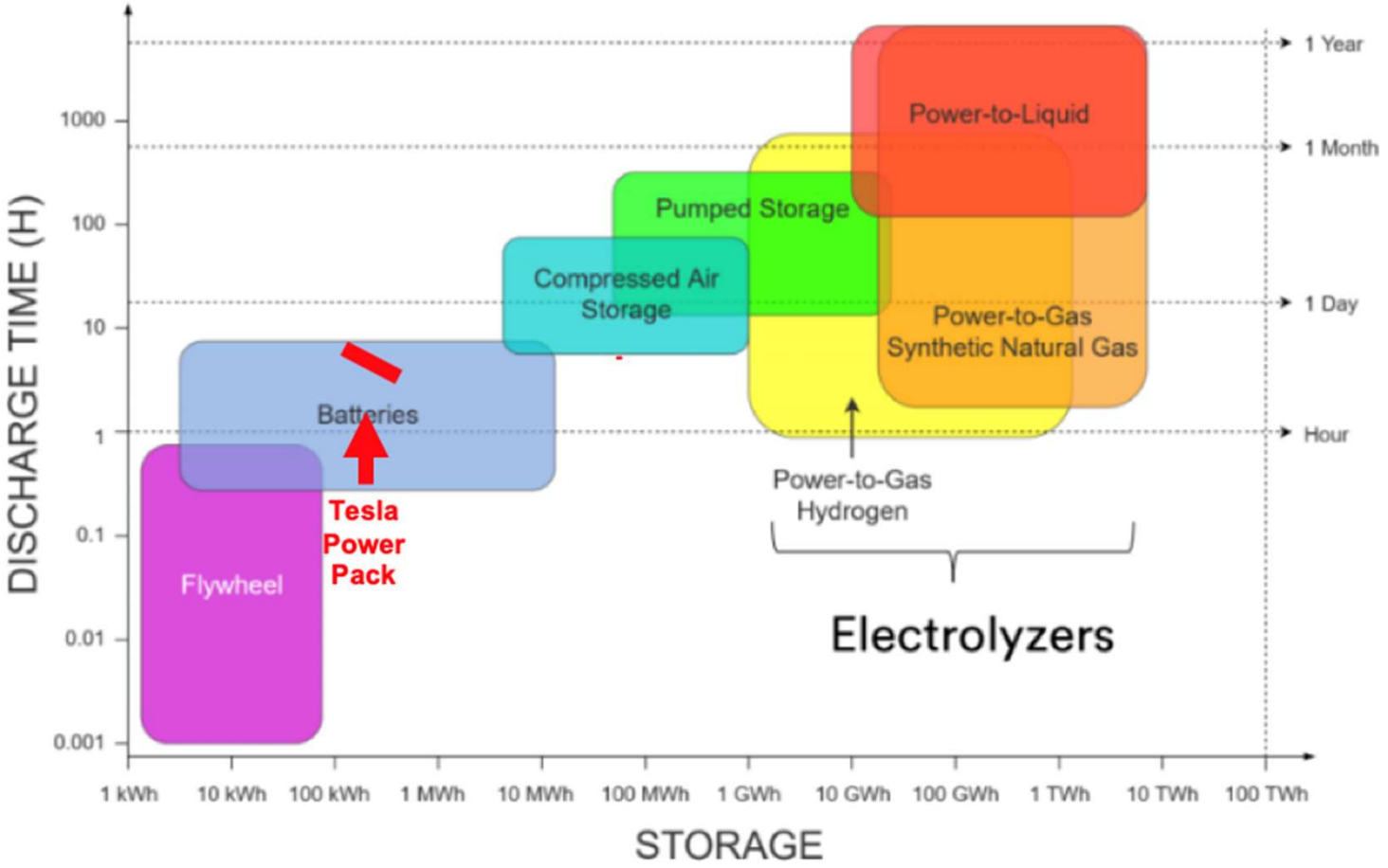
Source: Prof. SHIH Choon Fong, NTU, MI

E-METHANOL: IN PRACTICE



Source: e1

LIQUID RENEWABLE ENERGY STORAGE



Sources: *Laura Nereng, 3M, 2017;* ***Tesla July 2017 announcement extrapolation***

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**

03 METHANOL: SAFE & AVAILABLE

HAZARD COMPARISON

	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	H226: 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 P301+P310 IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician P302+P352 IF ON SKIN: Wash with plenty of soap and water 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 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 P233 Keep container tightly closed P240 Ground/bond container and receiving equipment P241: Use explosion-proof electrical/ventilation/lighting equipment P242 Use only non-sparking tools P243 Take precautionary measures against static discharge 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 P302+P352 IF ON SKIN: Wash with plenty of soap and water P303+P361+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 P314 Get medical advice/attention if you feel unwell P321: Specific treatment (see on this label) 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	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/lighting equipment P242 Use only non-sparking tools P243 Take precautionary measures against static discharge P261: Do not breathe 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 P303+P361+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 P314: Get medical advice/attention if you feel unwell P321: Specific treatment (see on this label) 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 classified as “not more dangerous” than other fuels such as gasoline or diesel – fuels largely familiar to most people

METHANOL POISONING CASE STUDY

Occupational Medicine, Volume 42, Issue 1, 1 January 1992, Pages 47–49, https://doi.org/10.1093/occmed/42.1.47
A. Downie ✉, T. M. Khattab, M. I. A. Malik, I. N. Samara
Published: 01 January 1992

Abstract

Methanol (CH_3OH) is a chemical feedstock of increasing importance as well as a commonly used solvent. In the early 1980s methanol production was introduced at a new petrochemical complex in the Saudi port of Jubail. A case is presented of a consultant supervising tank cleaning prior to methanol loading. He wore positive pressure breathing apparatus but no protective clothing. After 2–3 hours working in the confined space of the tank, he worked on deck and continued to wear his methanol-soaked clothing which eventually dried out. Visual symptoms of acute methanol toxicity presented some 8 hours after exposure. The appropriate treatment (with ethanol provided by the ship bond) was carried out in hospital and the individual recovered completely. Most reported cases of methanol toxicity are social in origin, arising from ingestion. This particular case, though unusual, does present some interesting lessons.

Easy and reliable treatment to full recovery with either ethanol (orally) or fomepizole (injected)

Source: Malcom Pirnie Inc

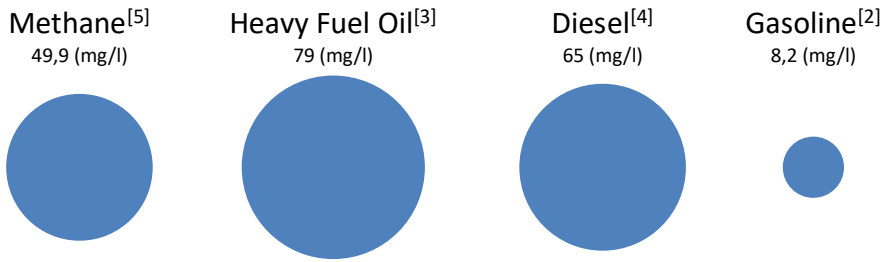
SAFER FOR THE ENVIRONMENT

LC50, LC = LETHAL CONCENTRATION FISH

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

Safer than Diesel by a factor of 240 times

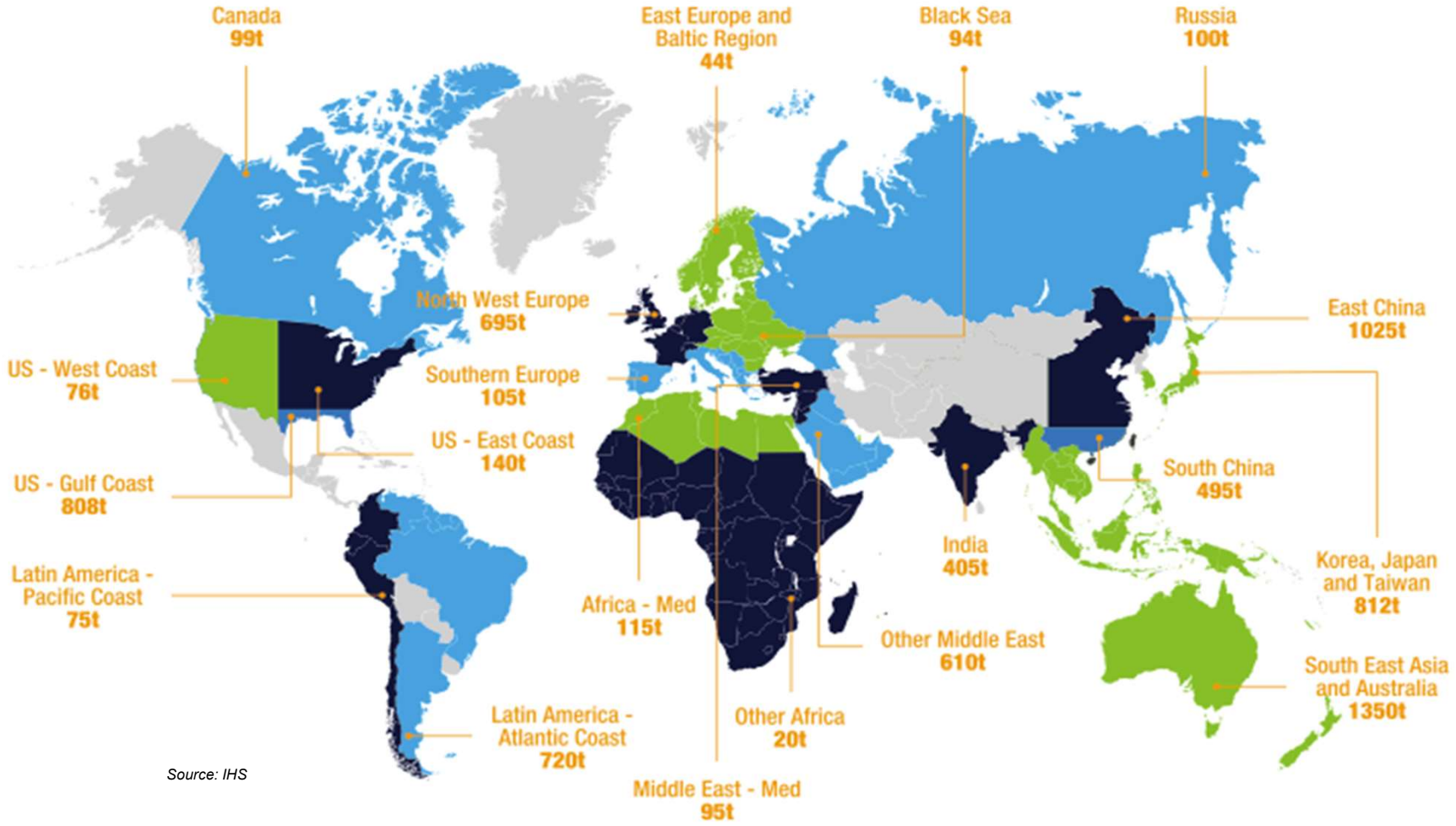
Methanol[1]
15,400 (mg/l)



[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

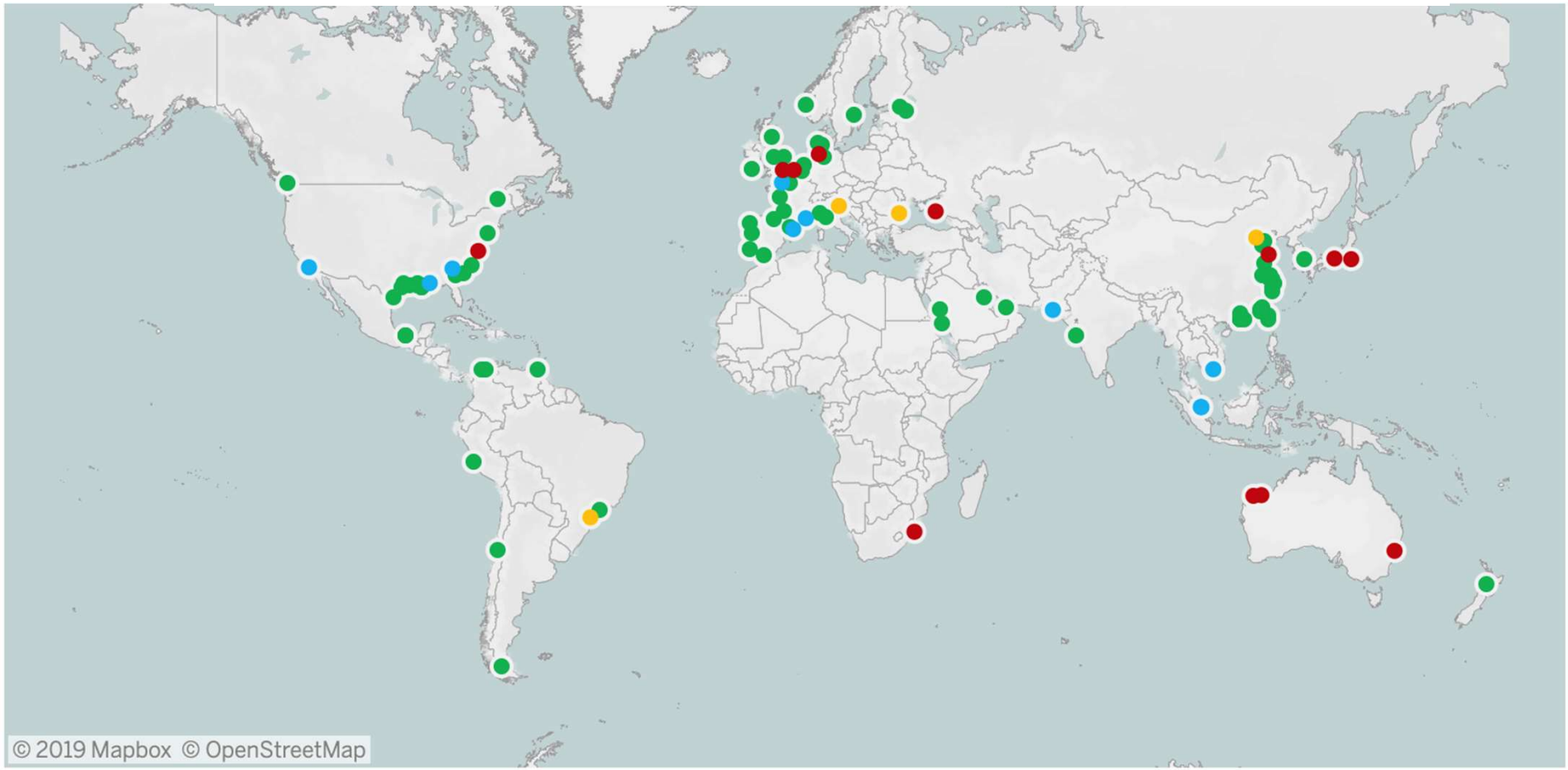
Additional Source: Meyer-Werft

METHANOL IS WIDELY AVAILABLE



Source: IHS

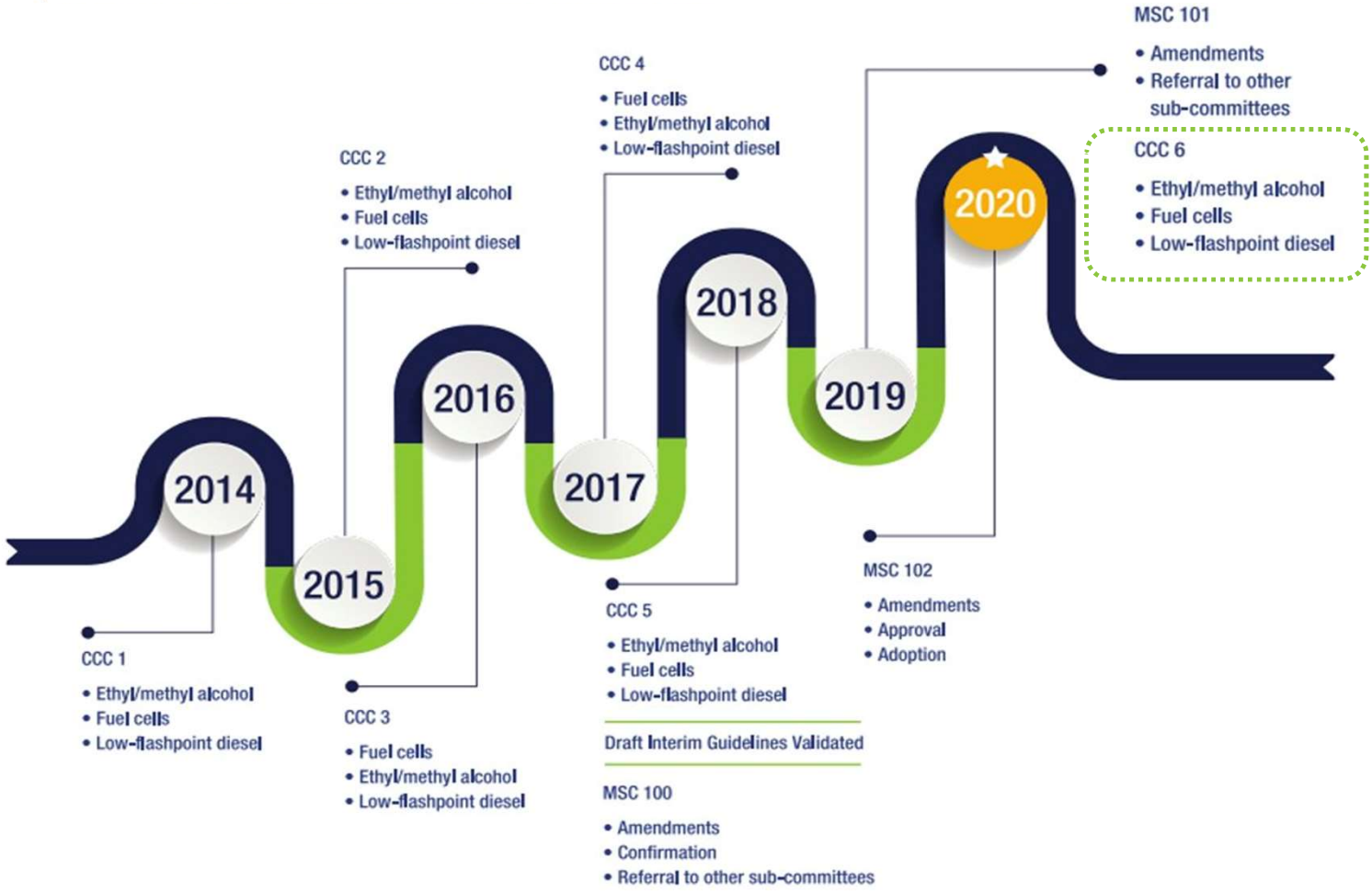
METHANOL AVAILABLE IN OVER 100 PORTS TODAY



https://public.tableau.com/profile/quantzig#!/vizhome/MethanolAvailabilityDataTopGlobalMaritimePorts/MethanolFuelAvailabilityatPorts

04 METHANOL BUNKERING

PROGRESSION OF GUIDELINES FOR METHANOL



METHANOL FUELLED VESSELS AND PILOTS

	DUAL FUEL			FUEL CELL		PROJECT | R&D
						
Quantity	8 + 3	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, WL, Marinvest, Mitsui, NYK	Stena Line	MI/SMA ScandiNaos	Innogy HTWG Konstanz	Viking Line	SUMMETH/MARTEC, Lean Ships, Methaship, Billion Miles[1], FiTech[2], IWAI[3], PCG Product Vessel[4], NTU[2], GMM, Fastwater, Port of Rotterdam Barge, Jupiter, Paxell, Methanex Fishing[5]
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[1]China/SG, [2]EU/China/SG, [3]India, [4]Malaysia, [5]China

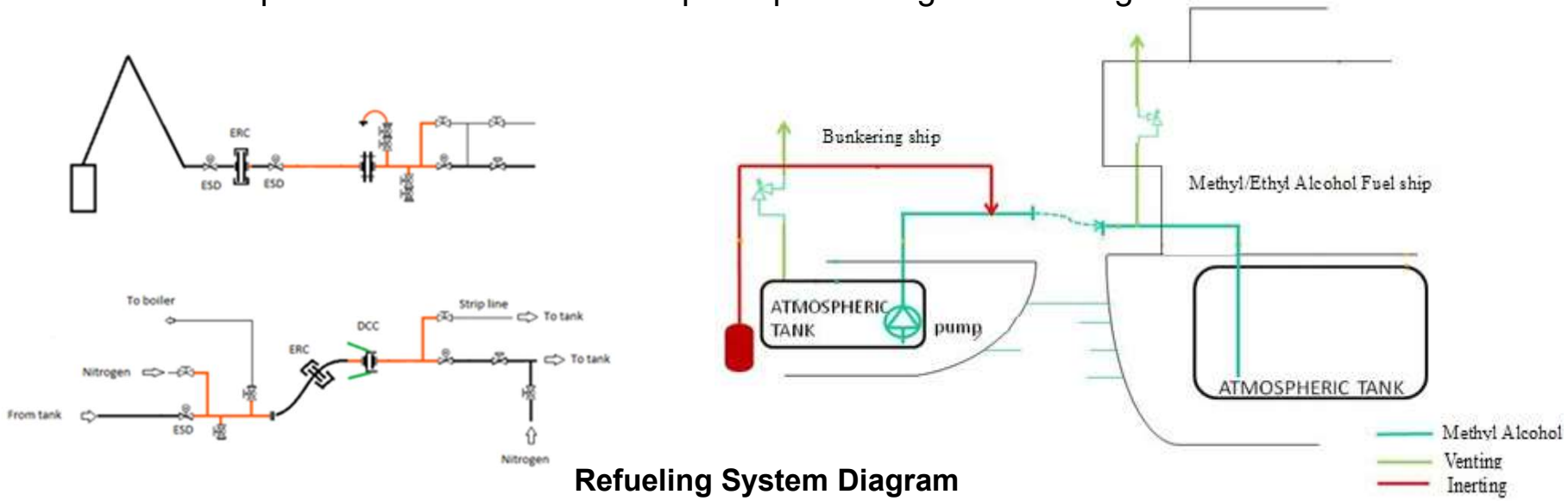
BUNKERING TECHNICAL CONSIDERATIONS

- **Refueling station**
  - Refueling station should be located on open deck for natural ventilation
  - There should be a device for safe disposal of leaked fuel, and skirting and collection tray below the joint for safe collection
  - Monitor and control the refueling from a safe location (equipped with overfill alarm and automatic cutoff to monitor bunker level and overfill)
  - **Personnel protection (shower and eyewash station for emergency use must be available)**


Stena Germanica Methanol Refueling

BUNKERING TECHNICAL CONSIDERATIONS

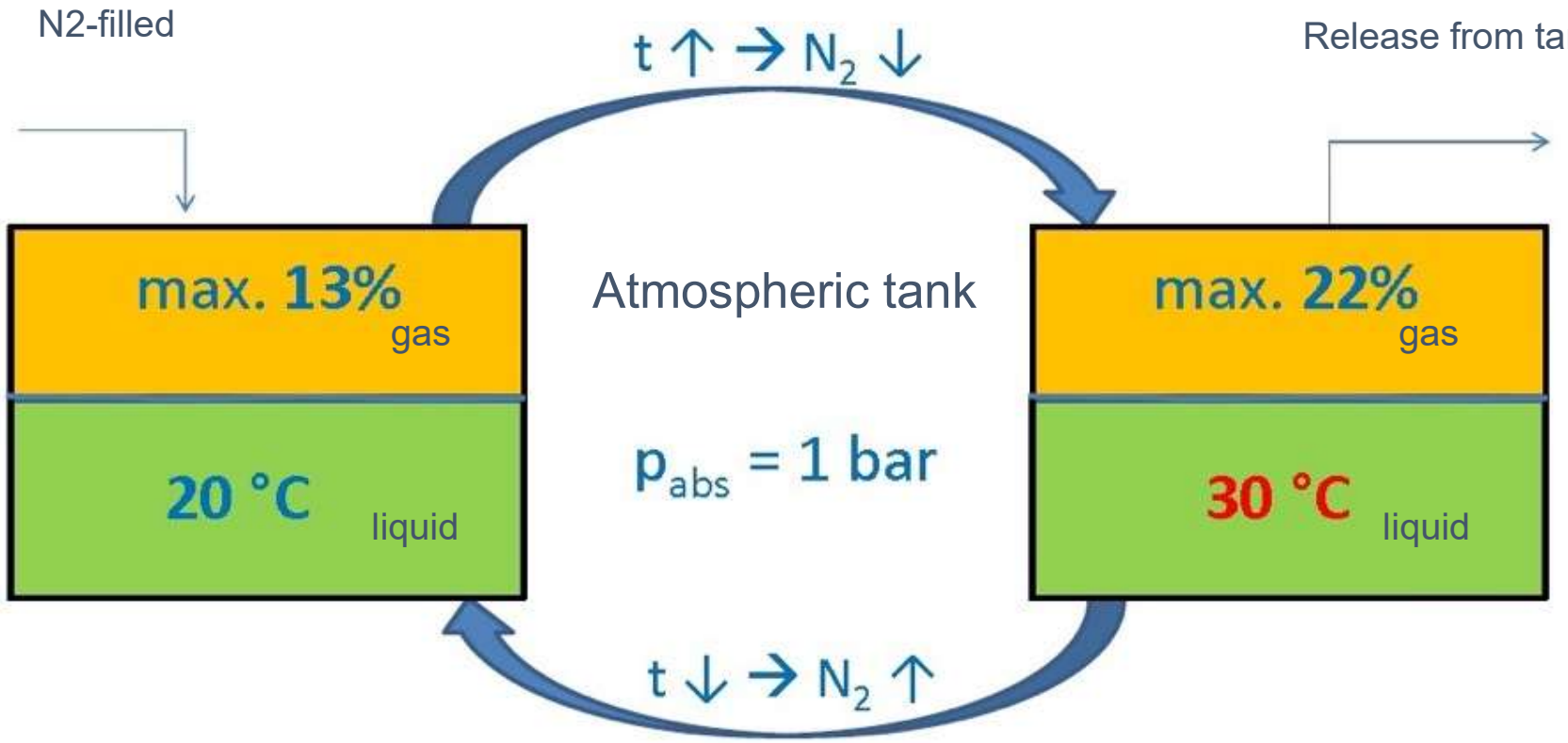
- **Refueling system**
  - Every refueling line near the shore connector should be fitted with a manual shutoff valve and a remote shutoff valve connected in series
  - Should be able to perform gas inerting and degassing of the refueling line
  - Should be equipped to purge the fuel from the refueling line after refueling
  - The ship should be equipped with refueling ESD cut-off system, which can be operated from the ship to be refueled or from the place performing the refueling



Refueling System Diagram

FUEL STORAGE

Proportion of gaseous methanol depends on the rate of evaporation

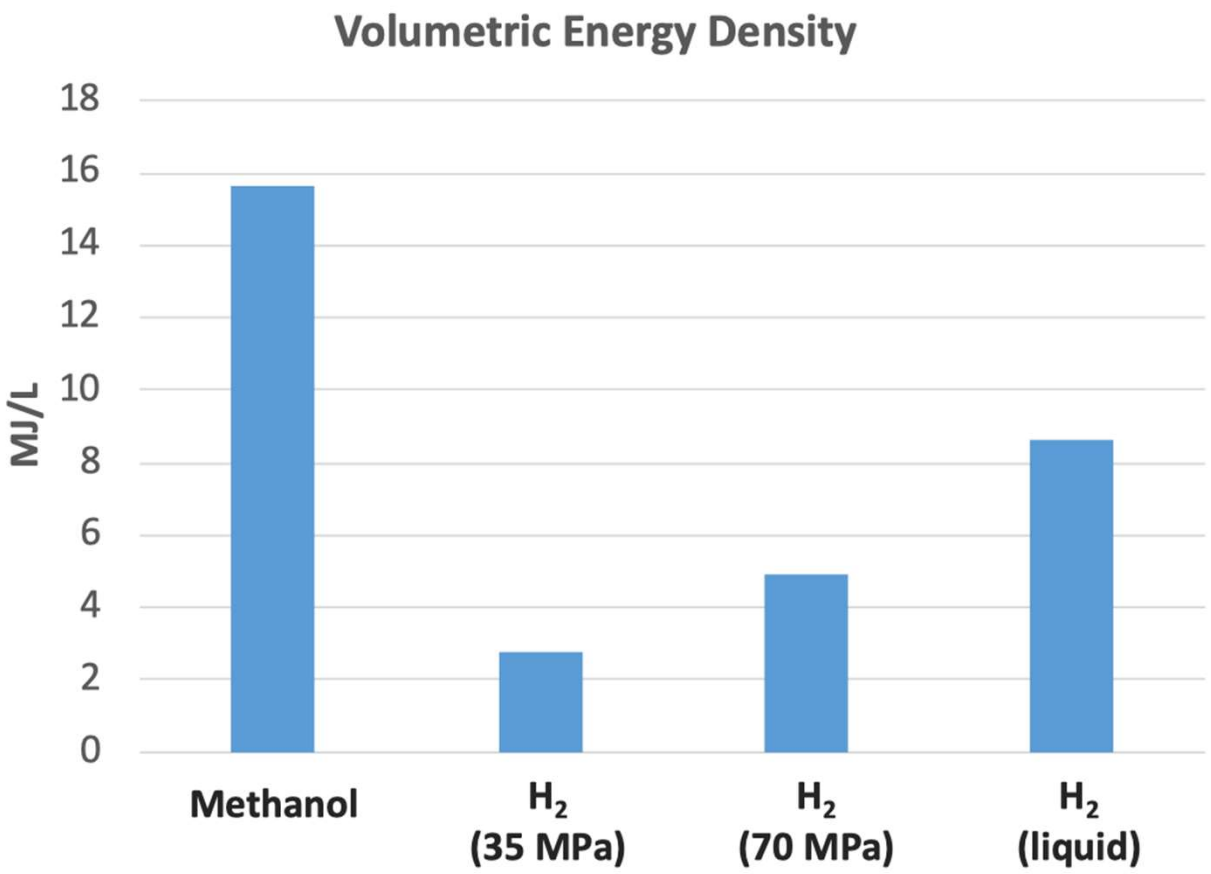


Evaporation is not boiling; it is a very slow process!

05 FUEL CELLS AND METHANOL AS A HYDROGEN CARRIER

METHANOL ENERGY DENSITY

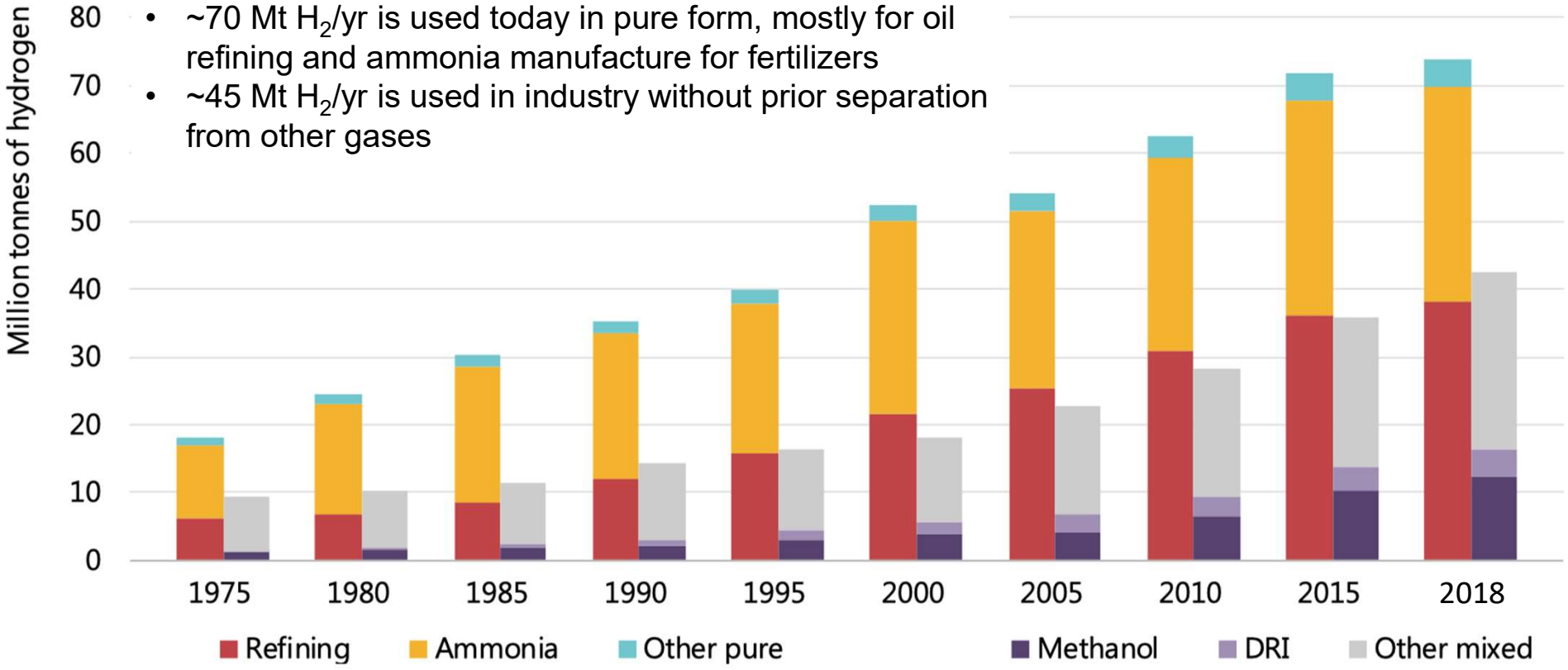
- High density H_2 storage remains a significant challenge for transportation solutions
- Storage options typically require large-volume systems that store H_2 in gaseous form
- On a volume basis, methanol has almost 6X the energy density of compressed H_2 (350 bar or 35 Mpa)



Source: MI, e1

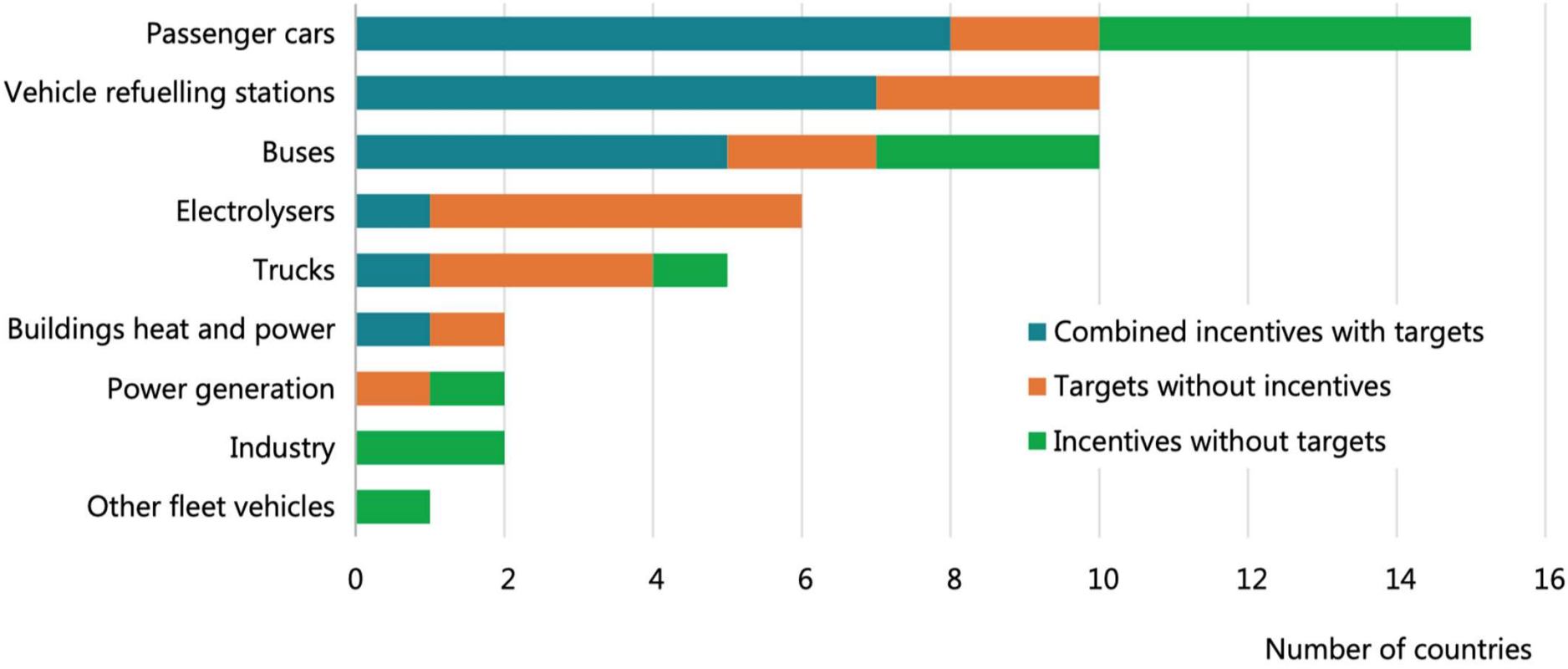
H_2 PRODUCTION

- ~70 Mt H_2/yr is used today in pure form, mostly for oil refining and ammonia manufacture for fertilizers
- ~45 Mt H_2/yr is used in industry without prior separation from other gases



Notes: DRI = direct reduced iron steel production. Refining, ammonia and "other pure" represent demand for specific applications that require hydrogen with only small levels of additives or contaminants tolerated. Methanol, DRI and "other mixed" represent demand for applications that use hydrogen as part of a mixture of gases, such as synthesis gas, for fuel or feedstock.

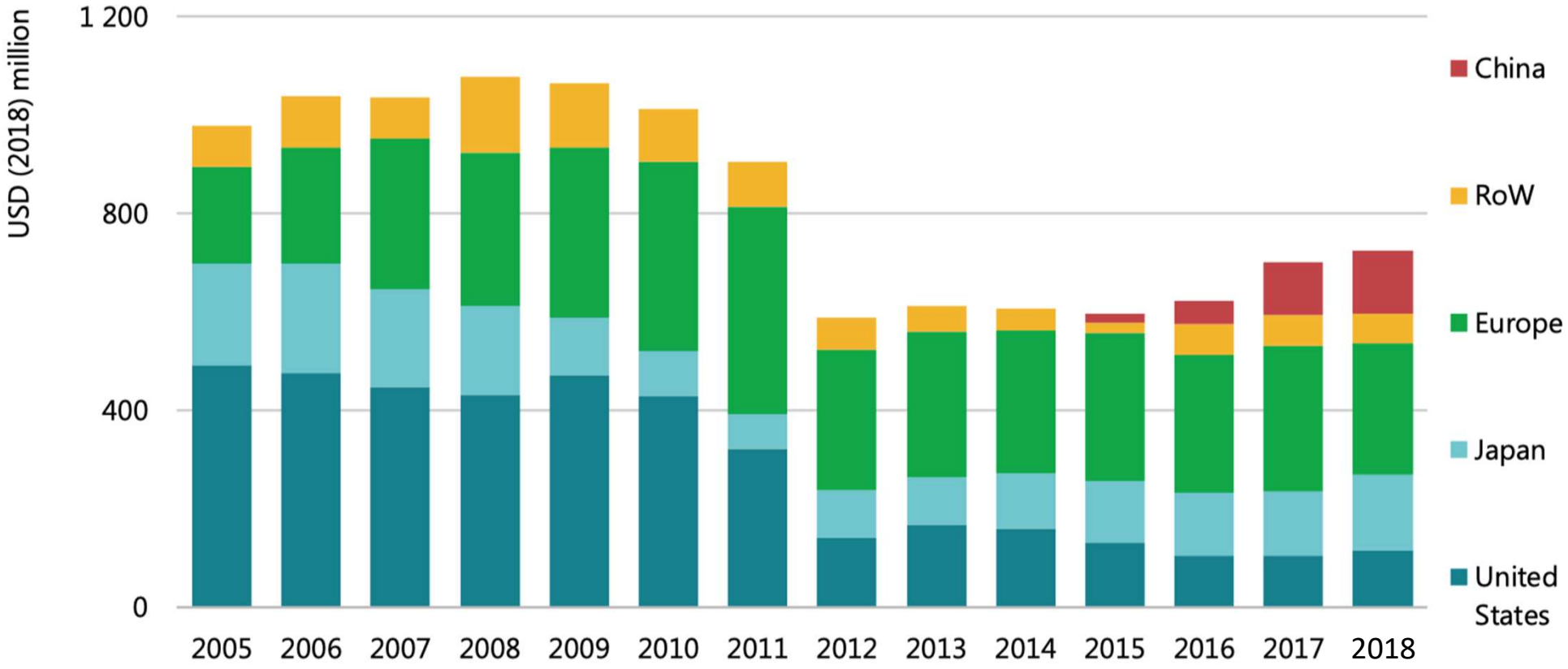
POLICIES SUPPORTING H_2 DEPLOYMENT BY APPLICATION



Note: Based on available data up to May 2019.

Source: IEA analysis and government surveys in collaboration with IEA Hydrogen Technology Collaboration Programme; IPHE (2019), *Country Updates*.

GOVERNMENT R&D BUDGETS FOR H_2 AND FUEL CELLS



Notes: Government spending includes European Commission funding, but does not include sub-national funding, which can be significant in some countries. 2018e = estimated; RoW = rest of world.

Source: IEA (2018a), *RD&D Statistics*.

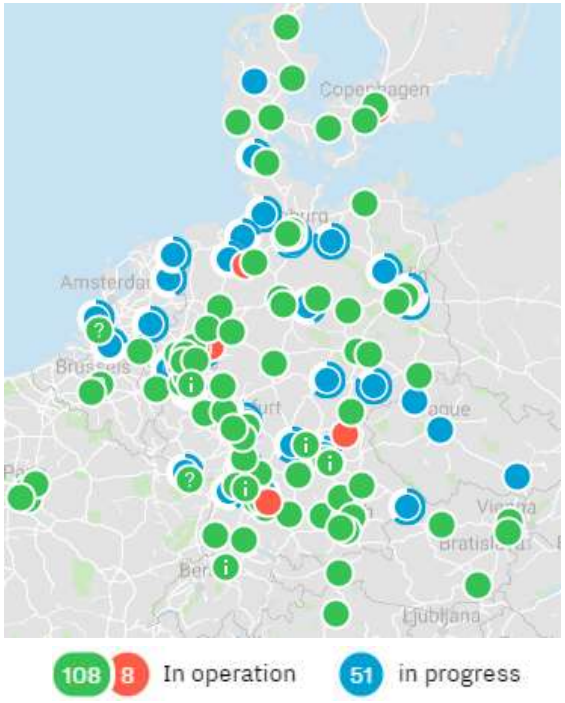
EARLY DEVELOPMENTS FOR METHANOL FUEL CELLS

- **April 2002:** California Fuel Cell Partnership opens methanol fueling station in Sacramento
  - 2,000-gallon above-ground tank and dispenser for a mere $45,000
  - Features included a “non-drip” methanol fueling nozzle

- **June 2002:** Daimler’s NECAR 5 drives San Francisco to Washington, DC – 16 days and 3262 miles

H_2 REQUIRES NEW DISTRIBUTION INFRASTRUCTURE

- **H_2 fueling grid will be extended**
- **Few stations in operation**



Source: C_3 mobility

- **H_2 will be a central component of "CO_2 neutral mobility" over the long term**
  - H_2 is the cheapest chemical energy carrier
  - H_2 is widely used already (mainly from NG)
  - Fuel storage & distribution is challenging
  - Available applications are very rare but will increase (fuel cell or combustion engine)
  - **Long term: Renewable H_2 will be available in large amounts for energy transport**

	Fuel costs	Availability	Technology Readiness Level	Fuel distribution	Compatibility with existing vehicles
Hydrogen	**+**	**o**	**+/o**	–	–

LOGISTICS: METHANOL VS H_2

- **Gaseous H_2:**
  - **40 ton transport tanker truck**
  - **500 kg** H2 delivered @ 200 bar

- **H_2 as Methanol:**
  - **40 ton transport tanker truck**
  - **3,600 kg** of H2 delivered at STP

Source: Paul Wubben

GOVERNMENT R&D BUDGETS FOR H_2 AND FUEL CELLS

COMPARATIVE INFRASTRUCTURE CAPEX

	Liquid Fuels	Electricity	Hydrogen
Daily Miles Enabled by Typical Current Station*	500,000	4,800	9,000
Stations Needed to Achieve Energy Equivalent Throughput Capacity	1	104	56
Cost Per Current Station	$200,000	$80,000	$2,500,000
Cost Per Equivalent Station	$200,000	$8.3 million	$139 million
Cost for 10,000 Station National Network	$2 billion	$83 billion	$1.4 trillion

** Gasoline Benchmark: 600,000 gallons / month, average 25 mpg*
** Level 3 EV Recharging Benchmark: 200 miles / EV; 1.5 hours for full charge; 2 plugs per station; 24 cars per day*
** Hydrogen "Nano-Station" Benchmark: 150 kg/day; 60 miles / kg.*

** Gasoline Benchmark: 600,000 gallons / month, average 25 mpg; equivalent to 1,000 kg/hour*
** Level 3 EV Recharging Benchmark: 200 miles / EV; 1.5 hours for full charge; 2 plugs per station; 24 cars per day*
** Hydrogen "Nano-Station" Benchmark: 150 kg/day; 60 miles / kg.*
** Hydrogen Gasoline-Equivalent Station: 1,000 kg/hour capacity; either 35' high above ground storage or 50+ MW on-site electrolysis. The permiting of either of these options in congested urban areas is highly doubtful if not impossible.*

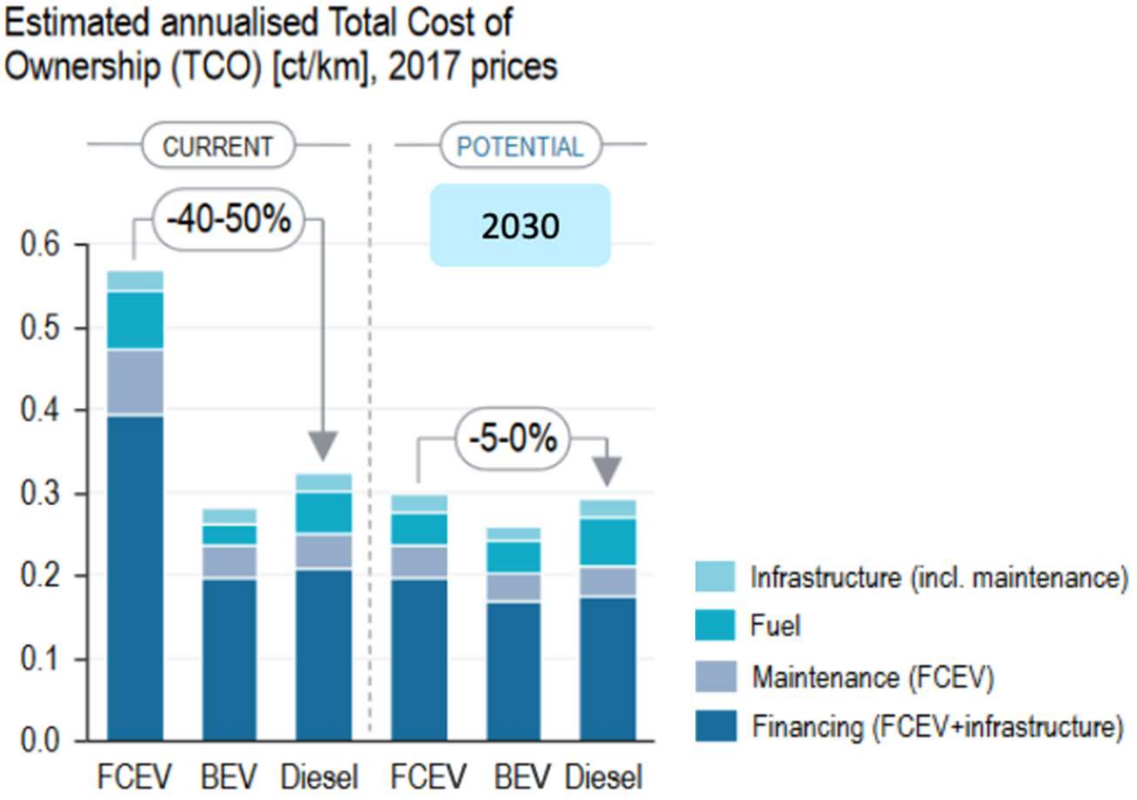
Source: Paul Wubben

COST OF H_2 COMING DOWN BUT INFRA COSTS STILL HIGH

FC cars are projected to achieve cost parity with diesel at commercial production volumes at a H_2 cost of €5/kg

Clean H_2 as a feedstock can reach parity with fossil-based inputs once the cost of carbon is included

Source: e1



Adapted from "Development of business cases for Fuel Cell and Hydrogen applications for Regions and Cities", 2017, Roland Berger for the FCH-JU

METHANOL: A HYDROGEN CARRIER FOR FUEL CELLS

- Blue World Technologies (Denmark)
- Palcan (China)
- Horizon Energy Systems (Singapore)
- Oneberry (Singapore)
- Altergy (USA)
- Serenegy (Denmark)
- SFC Energy (Germany)
- Toshiba (Japan)
- Ultracell (USA)
- e1 (USA)

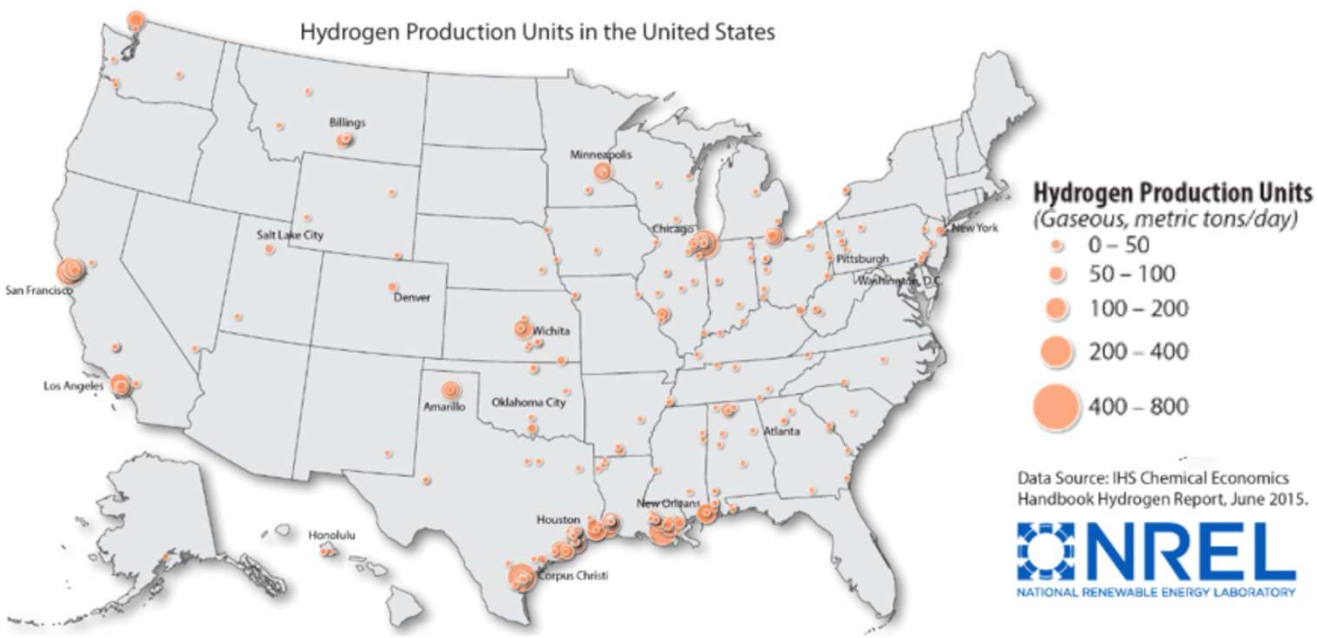






WHAT IS HYDROGEN?

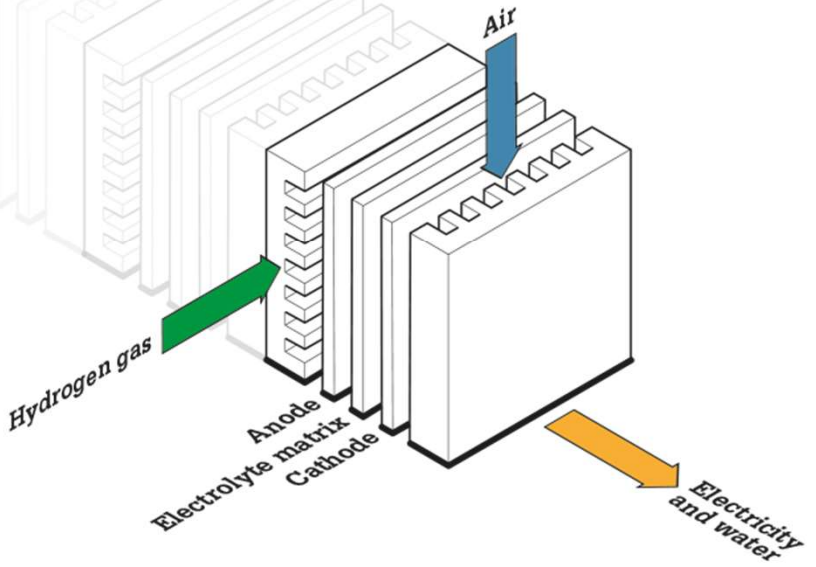
- Hydrogen is the **simplest element in the universe**
- Hydrogen is a chemical element with the symbol H and atomic number 1. With just one proton and one electron, it is the **most common element** in the universe
- **Highest calorific value** of 150 KJ/g among all the “fuels”
- Cheaper than gasoline or diesel
- **1 kg of hydrogen contains 33.33 kWh of usable energy**, whereas petrol and diesel only hold about 12kWh/kg (see www.h2data.de). In terms of volumetric energy density however, hydrogen is outperformed by liquid fuels



U.S. annual hydrogen production	Largest Users in the U.S.			
10 million metric tons	Petroleum Processing	68%	Fertilizer Production	21%

WHAT ARE FUEL CELLS?

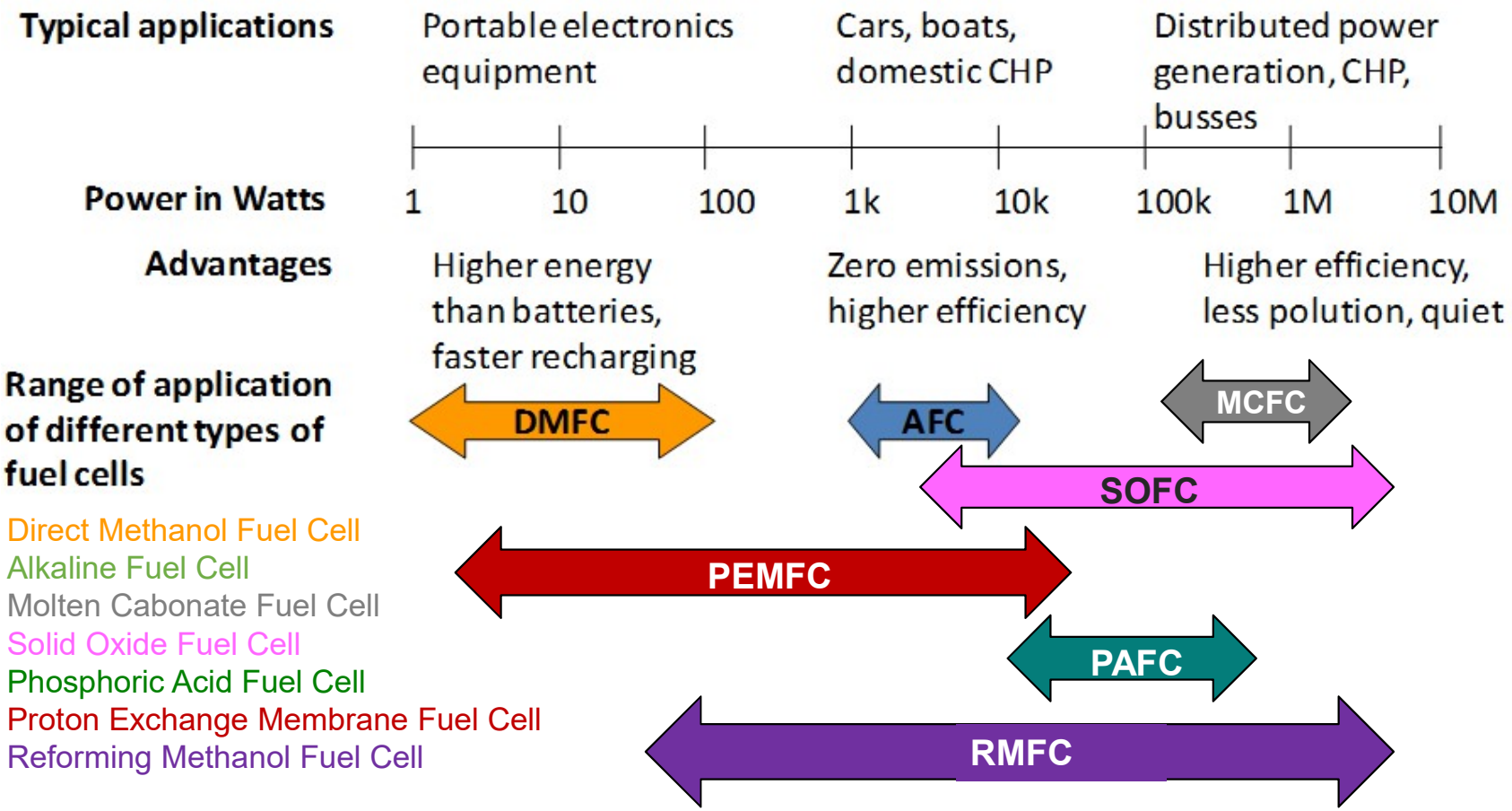
- High efficiency power generation with water as the only emission
- Converts chemical energy directly into electrical energy via an electrochemical reaction, similar to a battery
- Batteries consume their electrodes when they produce electricity and must therefore be discarded or recharged
- Fuel cells, on the other hand, produce electrical energy as long as fuel is added in the form of hydrogen and oxygen
- Fuel cells have a broader field of application than any other available source of energy and can be manufactured for small units that produce only a few watts, up to major power stations generating megawatts



Compared to a combustion engine, which is also powered by a reaction between fuel and oxygen, higher power efficiency is achieved. While the combustion engine's thermomechanical process means that a large part of the energy is always consumed as heat, the fuel cell's reaction takes place at a significantly lower temperature. In contrast to the combustion engine, water and heat are the only emissions generated by a fuel cell

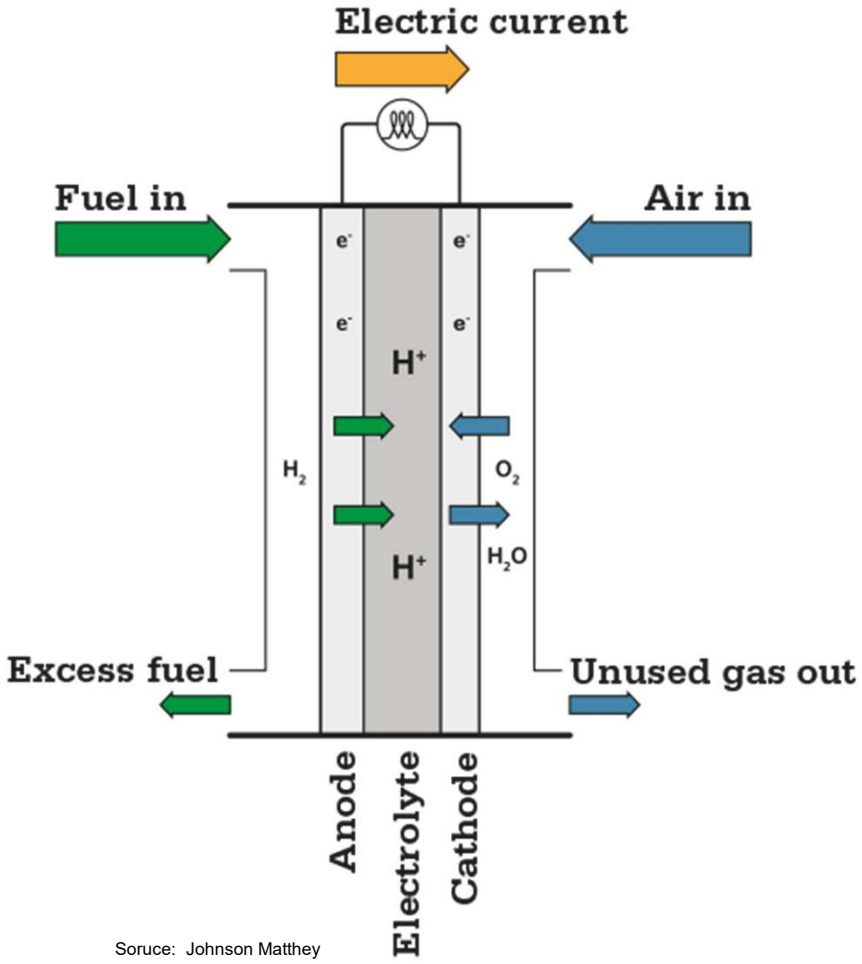
Source: PowerCell

TYPES OF FUEL CELLS



Soruce: J. Larminie, A. Dicks, Fuel Cell Systems Explained, Wiley, 2nd edition, 2003

KEY COMPONENTS OF A FUEL CELL



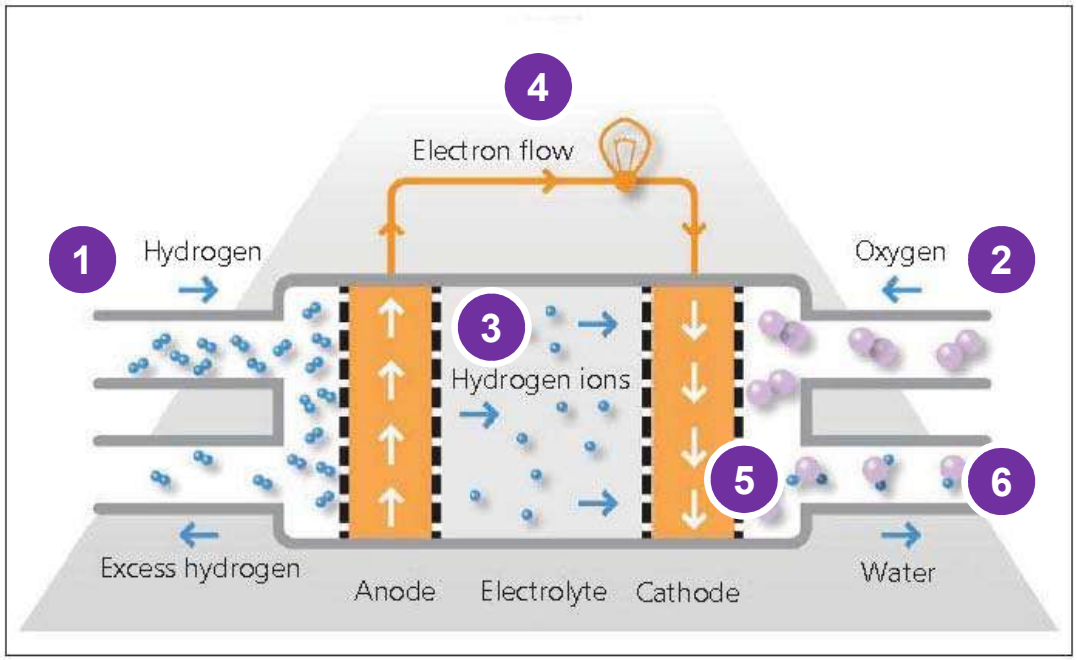
Soruce: Johnson Matthey

The fuel cell's key components are:

- An anode, cathode and electrolyte
- The electrolyte largely determines the properties of the fuel cell
- Proton Exchange Membranes (PEM), with ion-conducting polymer membrane as the electrolyte, are common
- PEM fuel cells operate at a relatively low temperature (<100°C) and therefore have valuable rapid start-up and response times
- PEM fuel cells have the highest power density of all fuel cell types and are thereby significantly smaller and lighter than other versions

CHEMICAL REACTION

1. When in operation, the anode is fed with fuel in the form of hydrogen (H_2)
2. Simultaneously, the cathode is continuously fed with air (O_2)
3. The hydrogen molecules are oxidised at the anode, forming hydrogen ions and electrons
4. The electrons transfer through the external electrical circuit, which connects the anode and cathode, to generate electricity
5. Meanwhile, the hydrogen ions are transported via the electrolyte to the cathode, where they combine with the oxygen molecules to form water and heat
6. The result is electricity, water and the heat generated by the reaction. Since the fuel cells are liquid cooled, the heat can e.g. be used to heat buildings



Soruce: Johnson Matthey

REFORMER

- If the fuel is not hydrogen, but a hydrocarbon such as methanol, ethanol, diesel, biogas or natural gas, the fuel cell system, in addition to air supply components, cooling system and power conditioning, also requires a reformer system

- The reformer system consists of the reformer, which converts the original fuel to a hydrogen containing gas, and a clean-up system, which removes CO and sulphur from the gas to make it appropriate for the fuel cell

Soruce: PowerCell

CHINA FUEL CELL PIVOT

- March 2018: MIIT releases plans for hydrogen fuel cell promotion as “new energy vehicles”
- China now has just 1,500 FCVs and 23 hydrogen fuelling stations
- Targets: 2020 – 5,000 FCVs; 2025 – 50,000 FCVs; 2030 – 1mln FCVs
  - USA 1,000 hydrogen fuelling stations and 1mln FCVs by 2030
  - Japan 80 hydrogen fuelling stations by 2021
- Pivot away from EV subsidies and moving support to hydrogen fuel cells
- Emphasis on commercial vehicles: buses & trucks, long-haul

HYBRID INNOVATION: AIWAYS/GUMPERT RG 'NATALIE'

- AIWays: Gumpert RG Nathalie
- Reformed Methanol Fuel Cell electric supercar
- 1,200 km range > 2X Toyota or Hyundai H_2 models (550km range)
- top speed 300 kph > 2X Toyota or Hyundai models (157kmh)

ON-BOARD H_2 GENERATION FOR MARINE VESSELS

- **Storing compressed H_2 onboard a vessel requires 15X more space than liquid methanol paired with a hydrogen generator**

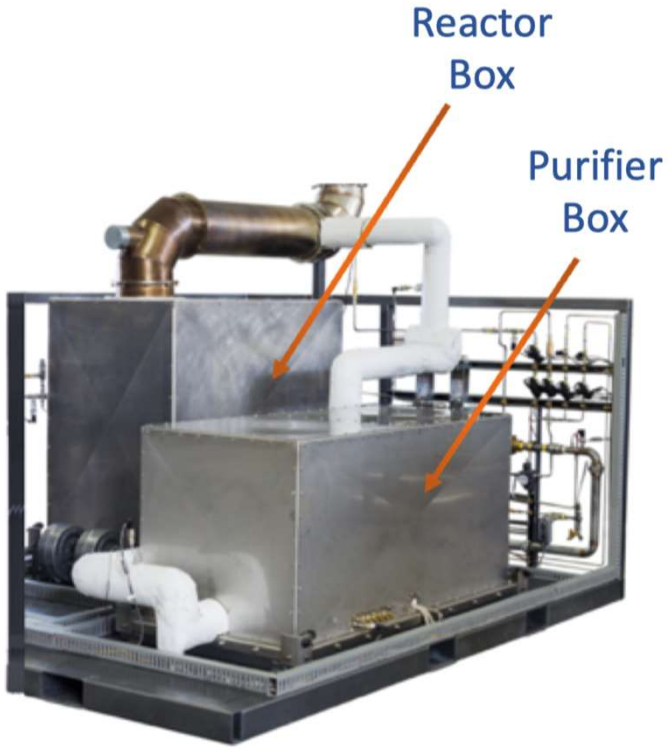
1 MW for 1 day	
Compressed Hydrogen	309 m^3
Liquid Methanol + M-Series	20 m^3

1 MW for 10 days	
Compressed Hydrogen	3,090 m^3
Liquid Methanol + M-Series	200 m^3

25% Fuel Cost Reduction vs Diesel

Source: e1, EIA

- **Mature technology:** 20 years, multiple lines
- **Scaleable:** to 300kW
- **>99.97% purity:** <0.2ppm CO & CO_2
- **Feed:** Methanol + DI water



SUMMARY

- **Physical characteristics of methanol are highly competitive or surpass other alternative fuels, across a range of applications**
- **Application design, whether retrofit or new build are simple, advantageous, practical and understandable – whether for ships, boilers, kilns, fuel cells 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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