NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

Is methanol a future marine fuel for shipping?

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MESD | Centre of Excellence

Vision

A global translational research centre in maritime energy and sustainable development

Supported by

Mission

- To advance, develop and apply research aimed at improving efficiency of current maritime energy systems
- To minimize impact of maritime operations to the environment and to diversify energy sources towards sustainability
- To enable knowledge creation and translation of maritime technology by engaging global standard-setting authorities, government agencies, research institutions and industries
- To foster a multidisciplinary and collaborative culture for researchers in applied maritime energy & operation and to promote new energy, emission and operational solutions for the industry and Singapore

GHG reduction

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

NCCS
NATIONAL CLIMATE CHANGE SECRETARIAT
STRATEGY GROUP
PRIME MINISTER'S
OFFICE

IMO

- Both developing and developed countries.
- Long-term: global warming < 2°C above preindustrial levels, ambition < 1.5°C.
- Peaking of global emissions asap. Parties to update their climate pledges every five years.

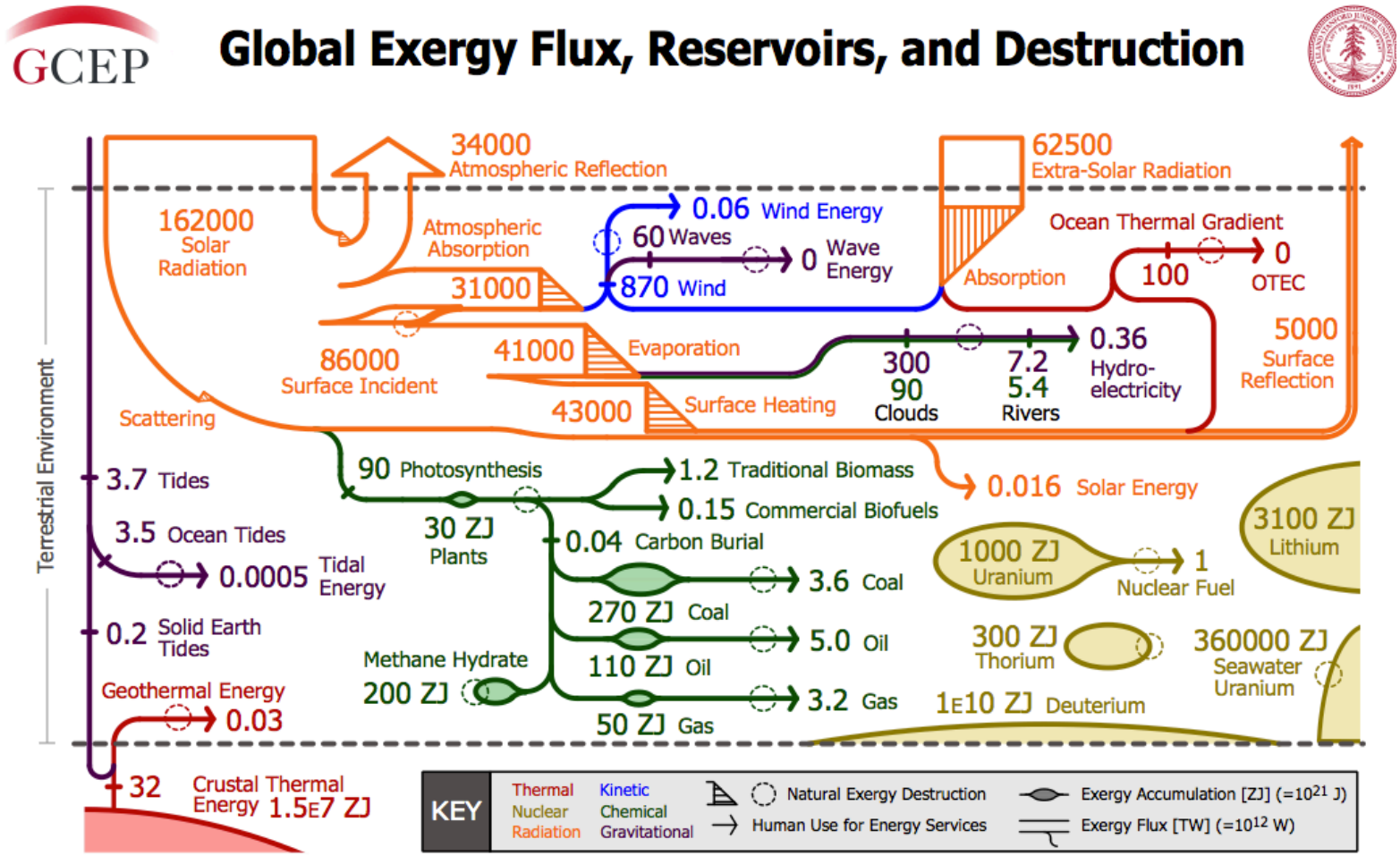
- To reduce emissions by 16% from business-as-usual (BAU) levels by 2020.
- To reduce Emissions Intensity(EI)* by 36% from 2005 levels by 2030, and stabilise emissions and try to peak around 2030.

- Carbon intensity to decline through EEDI for new ships
- Further decline by at least 40% by 2030, pursuing 70% by 2050, compared to 2008.
- To peak GHG emissions asap and to reduce it by at least 50% by 2050 (compared to 2008).

The ambition: Significant GHG reduction under BAU

Source: "Singapore's Climate Action Plan: Take Action Today, For a Carbon-Efficient Singapore"
IMO MEPC 72, "Report of the Working Group on Reduction of GHG emissions from ships", 12th April 2018

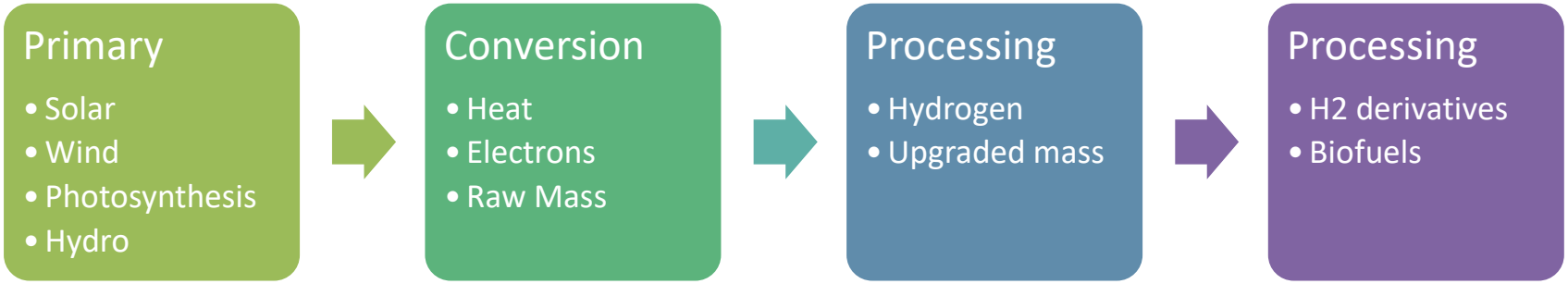
Global energy flow



Source: W. Hermann, "Quantifying global exergy resources", Energy, 31(12), 2006, p. 1690

World consumption in 2013 is 18 TW year or 0.57 ZJ, total shipping consumed 0.332 TW year in 2014

Renewable energy conversion



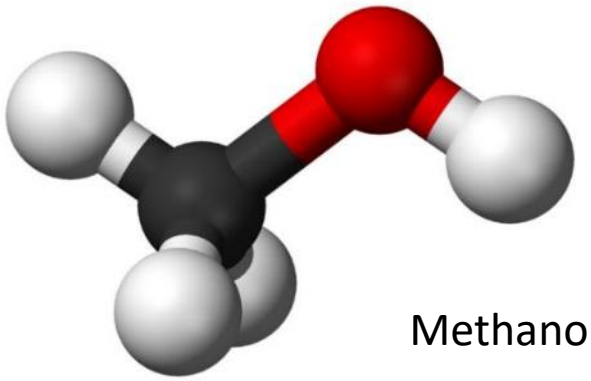
Loss of energy and mass

Good overall conversion efficiency
Abundance of raw feedstocks
Net reduction of GHG emission
…

More ready to use

Good/acceptable energy density
Compatible with existing energy infrastructure
…

Methanol as the candidate



Methanol

- ✓ The simplest form of alcohol
- ✓ Produced from any feedstock capable of generating syngas
  - o Non-renewable feedstock
  - o Renewable feedstock
  - o Waste stream
- ✓ Global name plate capacity ~ 150 million tons per year*
- ✓ Room temperature liquid
- ✓ Established transportation and distribution infrastructure
- ✓ Clean combustion
- ✓ Acceptable energy density
- ✓ Fully degradable in nature
- ✓ No global warming potential

*Source: Argus Global Methanol Report, issue 19-18, 3rd May 2019

Potential demand

Methanol as an alternative to marine bunker fuel

370 mn t/yr world bunker consumption

Energy equivalent

725 mn t/yr

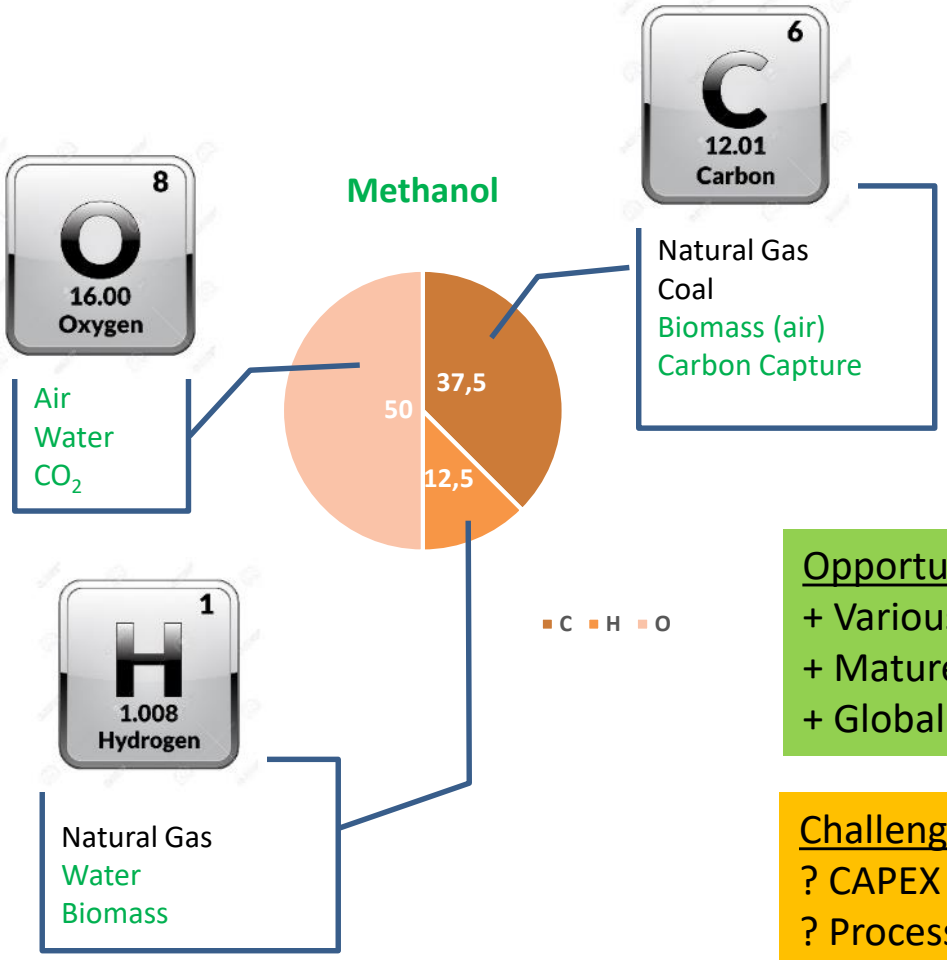
Gap does exist

80 mn t/yr world demand (2018)

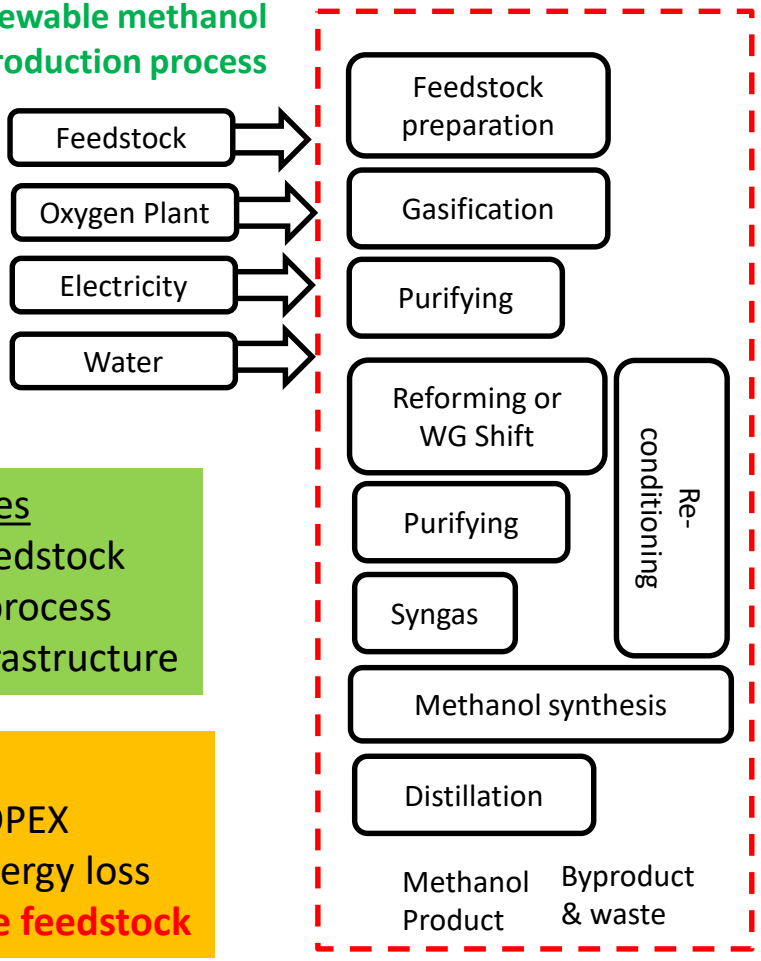
150 mn t/yr world name plate capacity (2018)

Source: Argus White Paper: "Emerging Opportunities for methanol and the effect on market dynamics", 2019 Argus Media group

Methanol production



Renewable methanol production process



Opportunities
+ Various feedstock
+ Matured process
+ Global infrastructure

Challenges
? CAPEX & OPEX
? Process energy loss
? **Renewable feedstock**

Feedstock, feedstock, feedstock

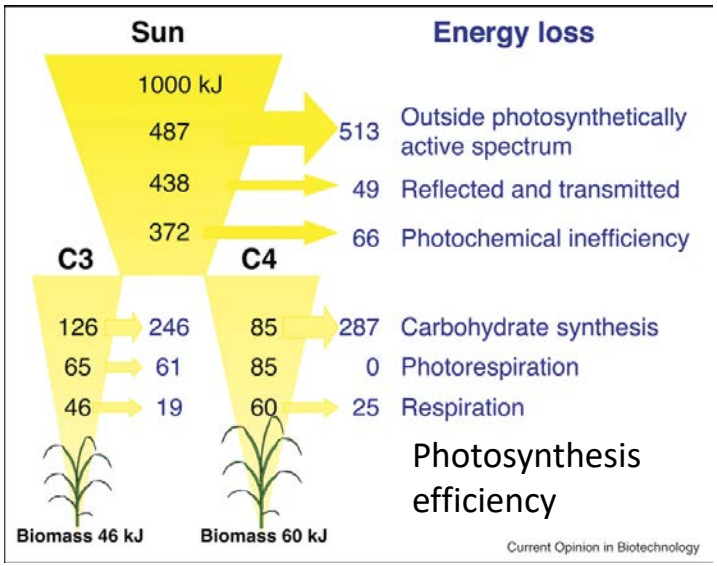


Photo-synthesis is the King

- ✓ **Self-supporting**
- ✓ **Self-propagating**
- ✓ **Good overall efficiency**
- ✓ **Multi-purpose products**

Source: Xin-Guang Zhu, Stephen P Long, and Donald R Ort, What is the maximum efficiency with which photosynthesis can convert solar energy into biomass? , Current Opinion in Biotechnology 2008, 19:153–159.

Table 1 Global biomass potential (EJ)

	Dedicated crops	By-product, residual, manure	Forestry	Organic waste	Total
2012	3.5	2.1	48.9	1.7	56.2
2035	30	34	78	8	150

Potential supply

1.782 TW year

4.756 TW year

Total shipping Demand (2014)

0.332 TW year

Source: "Global biomass potential towards 2035", WBA fact sheet, March 2016

Energy yield of biomass

129~438 GJ/ha.a

Methanol

Catalytical reaction

268~364 GJ/ha.a

Biogas

Fermentation

114~221 GJ/ha.a

Ethanol

Fermentation

~166 GJ/ha.a

Palm oil

Extraction

Miscanthus

Maize

Sugar cane

Oil palm

Emerging energy crops

These two herbaceous crops almost reach the theoretical photosynthesis efficiency of C4 plants, providing the enormous potential for future biomethanol production.

Creeping river grass
(Echinochloa polystachya)

Photo source: https://www.researchgate.net/figure/Figura-4-A-canarana-Echinochloa-polystachya-Foto-Sammya-DAngelo_fig19_326752415

Up to 99 tons dry mass/ha.yr

> 2 X productivity of Miscanthus

Data source: Piedade M T F, et al, Journal of Ecology, 1991, 72(4): 1456

King grass
(Pennisetum americanum × P. purpureum)

Photo source: http://www.tropicalforages.info/key/forages/Media/Html/entities/pennisetum_purpureum.htm

Up to 79 tons dry mass/ha.yr

~ 2 X productivity of Miscanthus

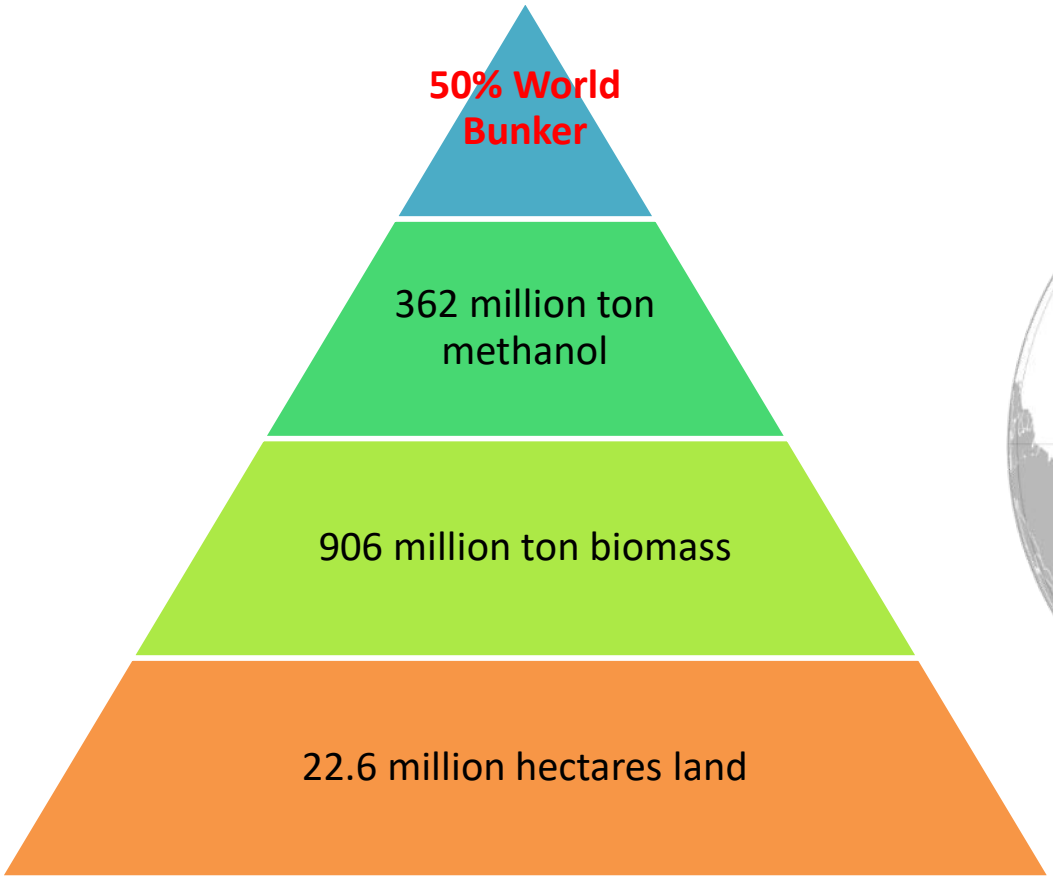
Data source: Zhang X.F. et al, Journal of Biomass and Bioenergy, 2014, 67: 179-187

Production cost

Table 2 Comparison of biomethanol production cost

Feedstock	Conversion process	Capacity (tonnes/day)	Cost year	Production cost ($/GJ)	Fossil methanol price ($/GJ)
Forest residue	SilvaGas process	2000	2008	14.48	16.7 ~ 41.8 ($333~832/ton)
Forest residue	RENUGAS process	2000	2008	22.67	16.7 ~ 41.8
Maize residue	Gasification	18.8~3792	2008	21.6~29.5	16.7 ~ 41.8
Pine wood	Gasification	2400	2012	~ 20	22.1~24.2 ($439~482)
Wood	Gasification and water electrolysis	890	2010	18.7	16.7~23.1 ($333~459/ton)
CO_2 and hydrogen	CO_2 capture from power plant hydrogenated with H_2 from water electrolyser	890	2010	33.8	16.7~23.1
Animal manure	Biogas upgrading and water electrolysis	2.85	2010	34.52	16.7~23.1
Animal manure	Biogas upgrading and water electrolysis	59.3	2010	21.03	16.7~23.1
Animal manure	Biogas upgrading and water electrolysis	37.1	2010	22.74	16.7~23.1
Wood	Gasification and water electrolysis (20% wind penetration)	1053	2010	19.6	16.7~23.1
Wood	Gasification and water electrolysis (50% wind penetration)	1053	2025	23.0	n.a.

Enough land?


50% World Bunker
362 million ton methanol
906 million ton biomass
22.6 million hectares land


Republic of Ghana

Future is in the eyes of the beholder

Carbon Capture by DAC (direct air capture)

Renewable Biomass Feedstock

Renewable Electrons

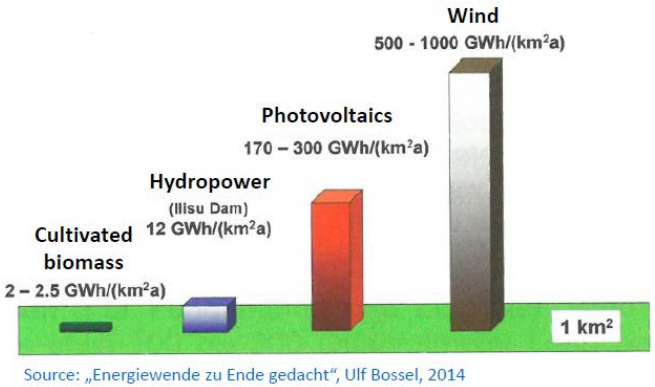
Carbon feedstock

Carbon & hydrogen feedstock

Hydrogen feedstock

Modular methanol plant

Future is in the eyes of the beholder



Source: „Energiewende zu Ende gedacht", Ulf Bossel, 2014

- ✓ Combination of largely existing technologies to use solar energy to recycle atmospheric carbon dioxide into a liquid fuel.
- ✓ H_2 from electrolysis of seawater (solar PV or wind)
- ✓ CO_2 extracted from sea water instead of DAC
- ✓ Seventy of these artificial islands would make up a single facility of approximately 1 km^2
- ✓ Output from 3.2 million floating islands would exceed the total global emissions from fossil fuels

Source: Scot Snowden, Forbes, science report on Giant Floating Solar Farm, 14th June 2019
Methaship project presentation, Methanol Technical Workshop, Copenhagen, 20 March 2018

Methanol powered ships

1

2

3

4

5

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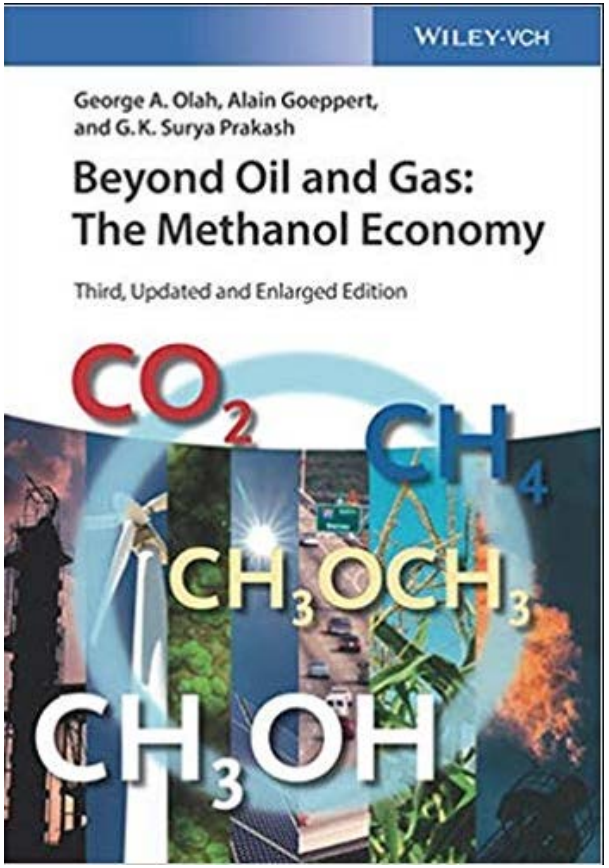
Methanol powered ships

Table 3 Methanol Powered Ships

S/N	Vessel Name	Company	Vessel Type	Ignition Type	Total Engine Power (kW)	DWT (Tons)	Remarks
1	Mari Couva	NYK	Oil/Chemical Tanker	CI, slow speed, 2 stroke	7,180	49,000	New Build
2	Mari Kokako	IINO Kaiun Kaisha & Mitsui	Oil / Chemical Tanker	CI, slow speed, 2 stroke	7,180	49,000	New Build
3	Lindanger	Waterfront Shipping	Oil / Chemical Tanker	CI, slow speed, 2 stroke	10,320	49,999	New Build
4	Leikanger	Waterfront Shipping	Oil / Chemical Tanker	CI, slow speed, 2 stroke	10,320	49,999	New Build
5	Mari Jone	Marinvest	Oil / Chemical Tanker	CI, slow speed, 2 stroke	10,320	49,999	New Build
6	Mari Boyle	Marinvest	Oil / Chemical Tanker	CI, slow speed, 2 stroke	10,320	49,999	New Build
7	Taranaki Sun	MOL	Oil / Chemical Tanker	CI, slow speed, 2 stroke	10,320	51,447	New Build
8	Manchac Sun	MOL	Oil / Chemical Tanker	CI, slow speed, 2 stroke	10,320	51,458	New Build
9	Cajun Sun	MOL	Oil / Chemical Tanker	CI, slow speed, 2 stroke	10,320	51,458	New Build
10	Stena Germanica	Stena Lines	RO-Pax	CI, 4 stroke, medium speed	24,000	10,670	Retrofit

When it becomes a sure thing

- ✓ Generation of biomass & renewable electrons
- ✓ Disruptive methanol production technology
- ✓ Cost reduction of carbon capture
- ✓ Solar, wind and nuclear energy to kick in
- ✓ Offshore production & bunkering facility



Thank you

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For more information, please visit MESD website http://coe.ntu.edu.sg/MESD_CoE