Creating a world
fit for the future

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New opportunities in electrofuels for shipping

Environmental Defense Fund workshop
"Navigating towards zero-carbon future"

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Ricardo Energy & Environment's Vision:

We want to create a world where everyone can live sustainably

Our Mission:

Solving the world's most pressing energy and environmental challenges

This presentation draws on a Ricardo report "Sailing on Solar" for Environmental Defense Fund Europe

- Ash, N. and Scarbrough, T., 'Sailing on solar: Could green ammonia decarbonise international shipping?', Environmental Defense Fund, London, 2019.
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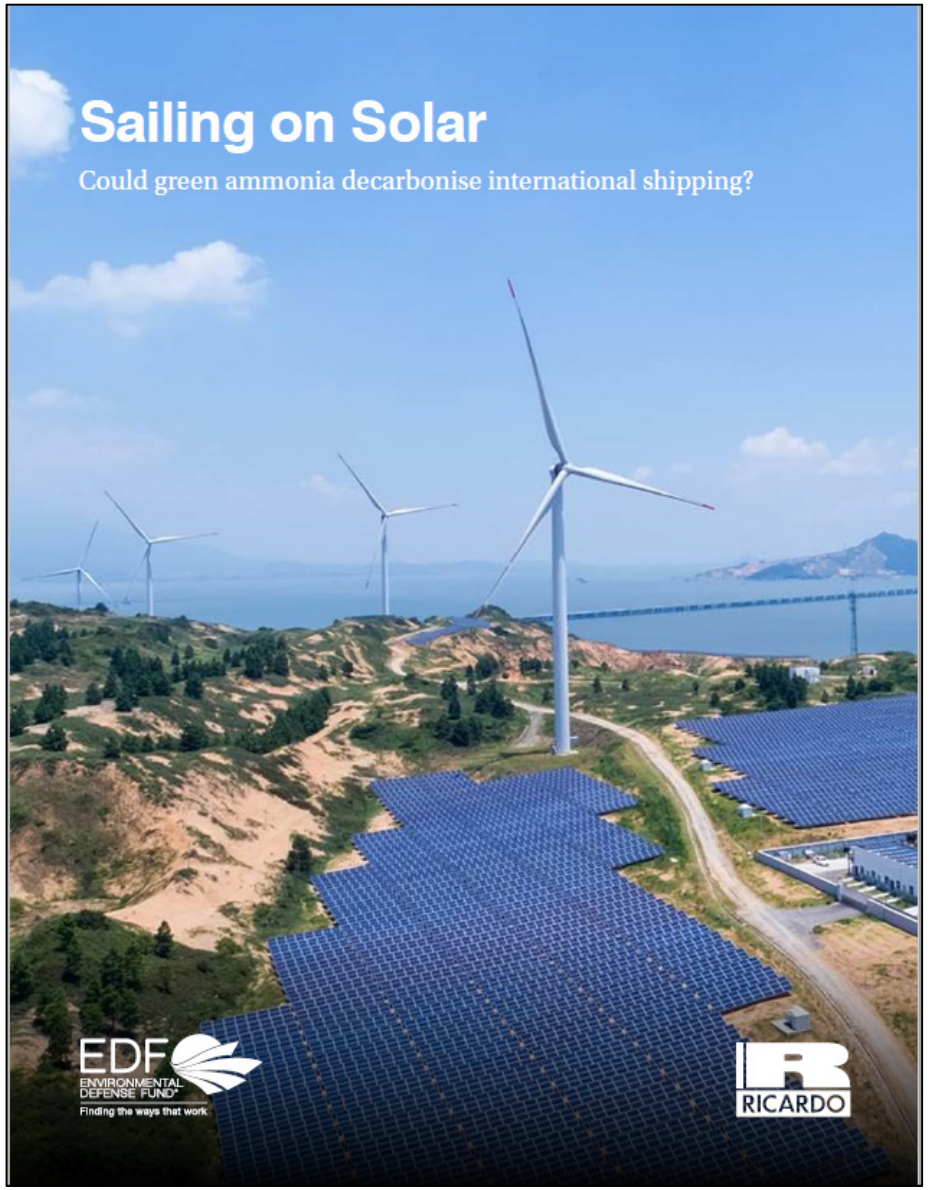
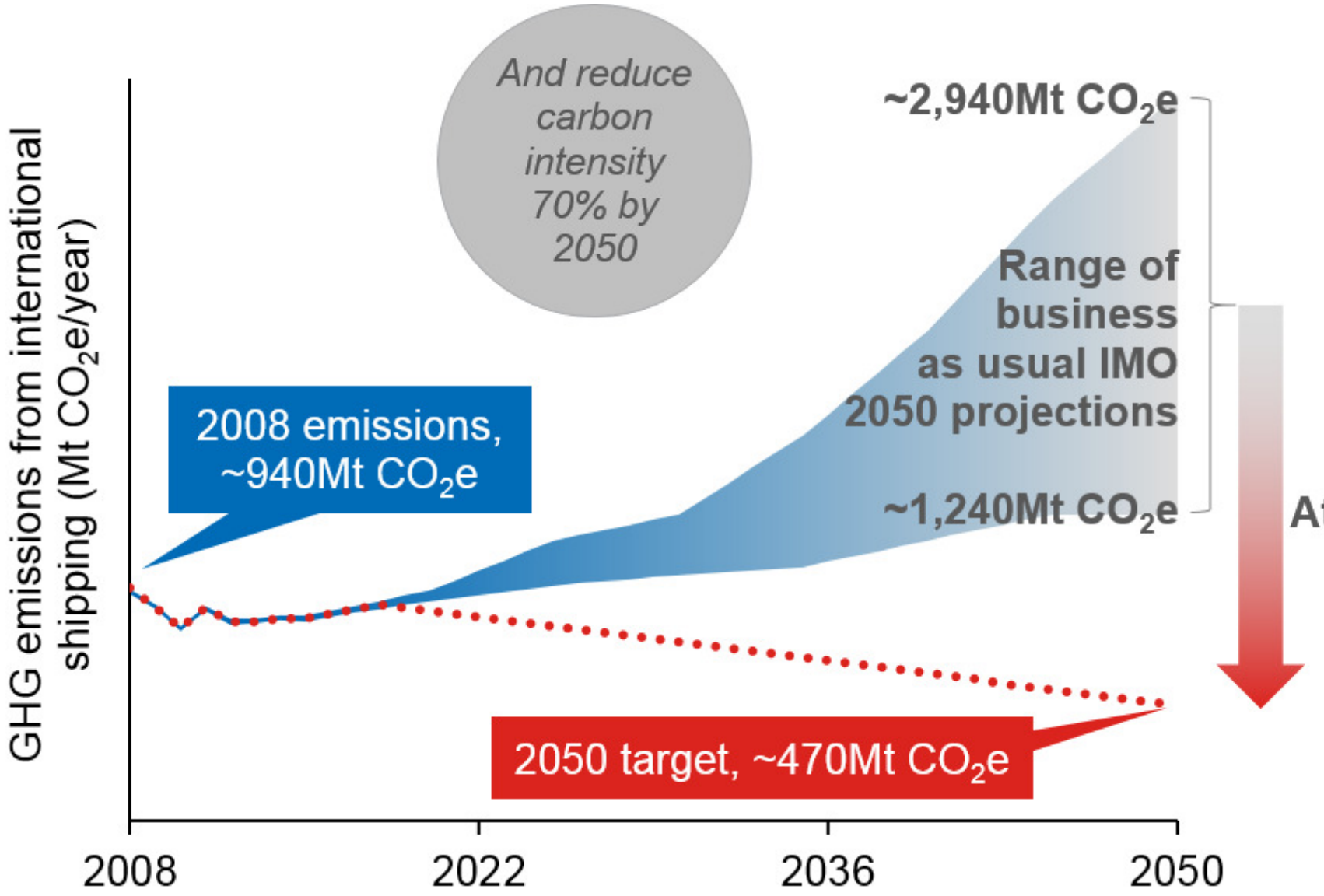
- Available for download: https://europe.edf.org/news/2019/02/05/shipping-can-reduce-climate-pollution-and-draw-investment-developing-countries

- A follow-up report on green electrofuels (hydrogen, ammonia and methanol) will be published soon



Efficiency gains will be insufficient.
Zero carbon fuels are required to meet and exceed the 2050 decarbonisation target



"a 50% total cut by 2050 can realistically only be achieved with the development and widespread use, by a large proportion of the fleet, of zero CO_2 fuels"

– International Chamber of Shipping, 2018

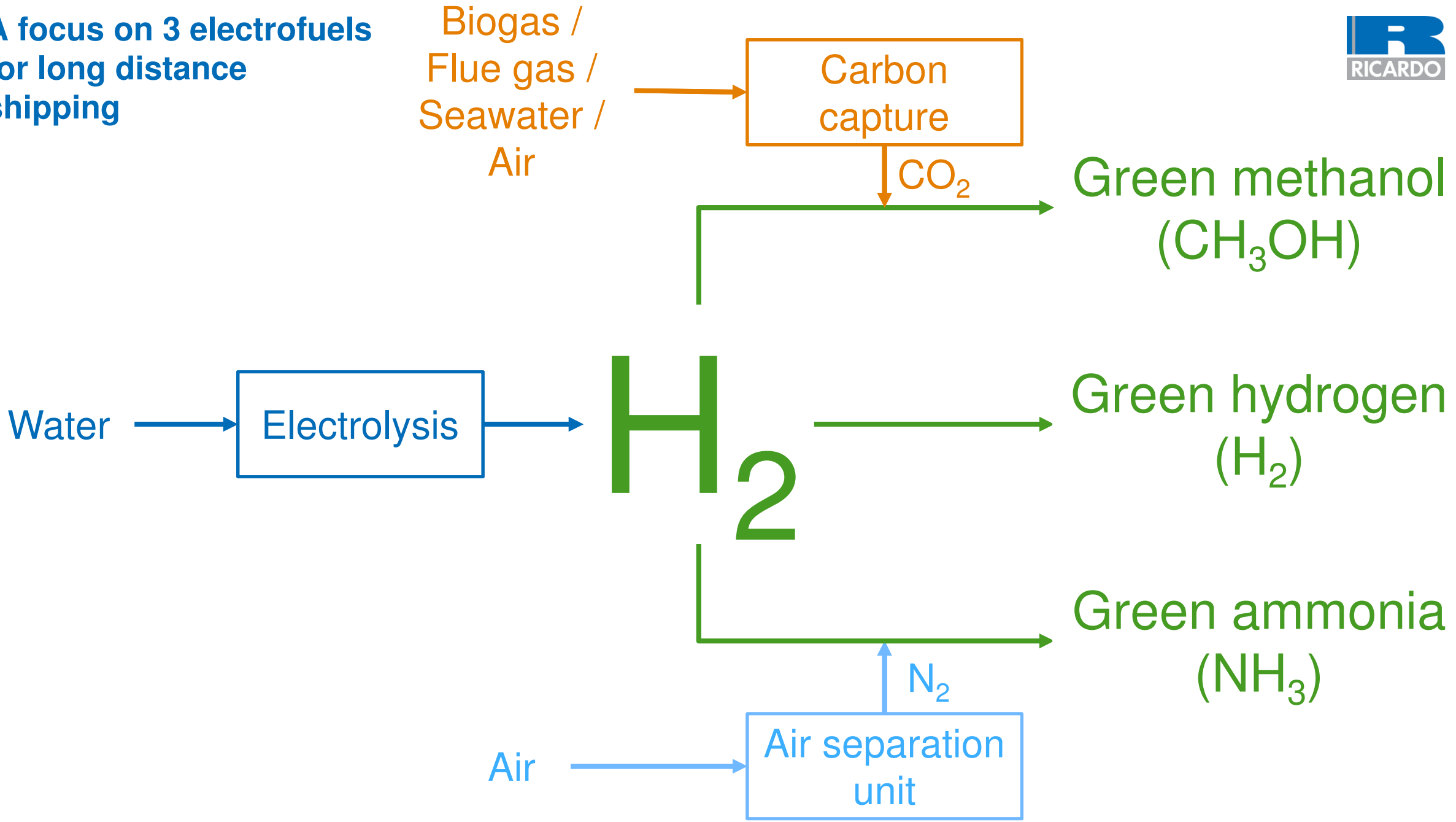
What are “green” electrofuels?

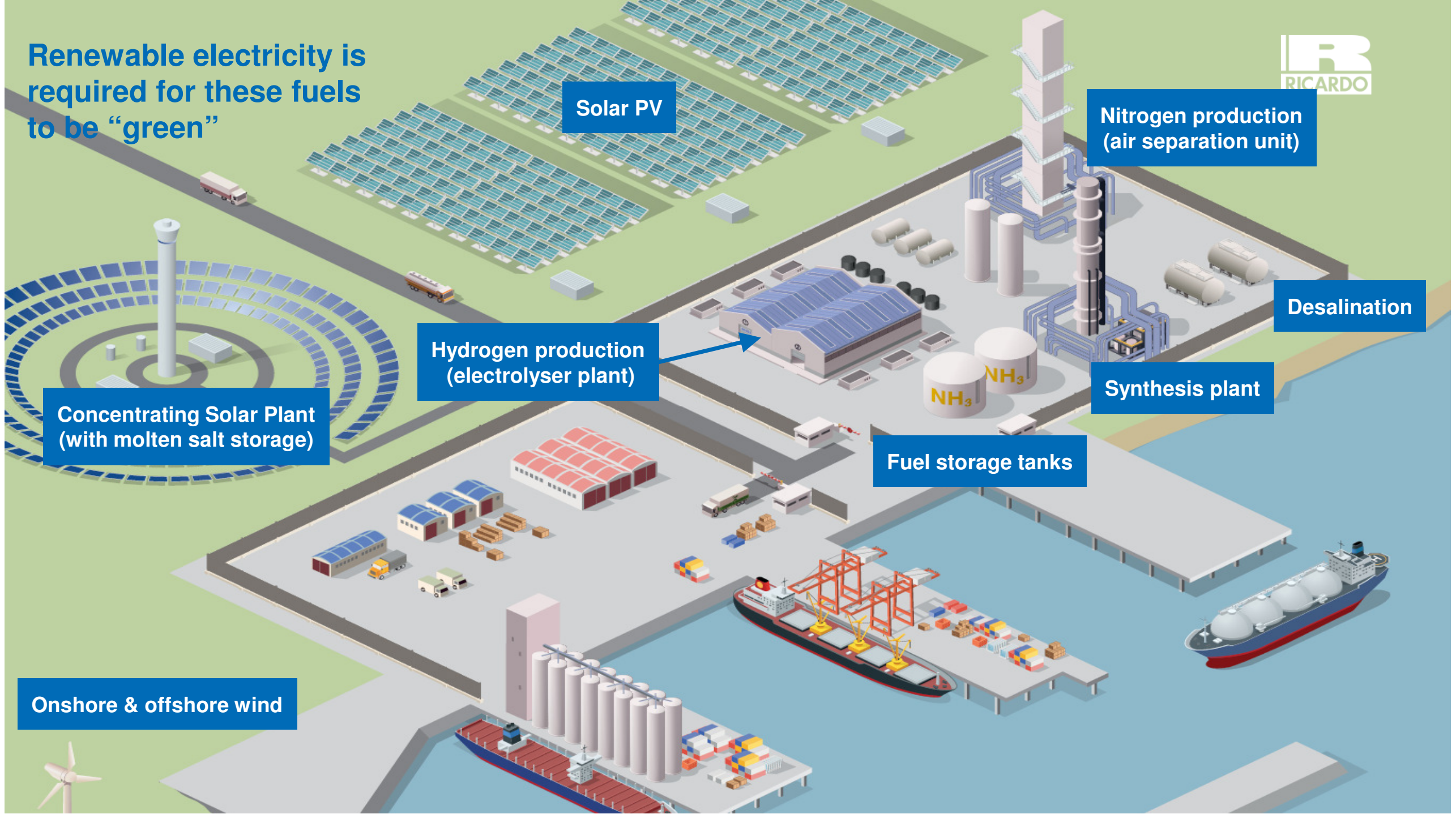
“Electrofuels” (or e-fuels) are a type of synthetic fuel that rely on electrolysis of water to produce hydrogen.

Other molecules can be added to the hydrogen to create different fuels.

The prefix “green” indicates that they are produced using renewable energy rather than derived from fossil fuels.

A focus on 3 electrofuels for long distance shipping




Renewable electricity is required for these fuels to be “green”
Solar PV
Nitrogen production (air separation unit)
Desalination
Hydrogen production (electrolyser plant)
Synthesis plant
Concentrating Solar Plant (with molten salt storage)
Fuel storage tanks
Onshore & offshore wind
NH3
NH3
RICARDO

Each of the electrofuels has its pros and cons

	Green Hydrogen	Green Ammonia	Green Methanol
Carbon-emitting	No	No	Yes
Temperature for liquid storage	- 253 °C	- 33 °C (or 10 bar)	Ambient
Compatibility with existing bunkering infrastructure	Low (requires refrigerated tanks)	Low (requires refrigerated tanks)	Minor modifications required
Electricity required to produce enough fuel for one day's sailing of a Panamax container vessel*	1.3 GWh	1.4 GWh	1.6 GWh (biogas source) 1.7 GWh (flue gas source) 1.8 GWh (seawater source) 2.0 GWh (air source)

Best performing Acceptable Problematic

*** Electricity consumption based on Ricardo calculations with CO_2 capture consumptions from Van-dal & Bouallo (2013)**

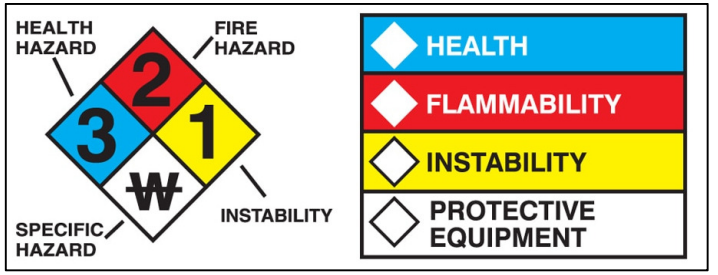
Each of the electrofuels has its pros and cons (cont.)

	Green Hydrogen	Green Ammonia	Green Methanol
Storage volume compared to marine gas oil for a fixed energy content*	x7.6	x4.1	x2.3
Requires co-firing with liquid fuel in compression ignition engines	Yes	Yes	Yes
Requires co-firing with another fuel in spark ignition engines	No	Yes – hydrogen or liquid fuel	No

Best performing Acceptable Problematic

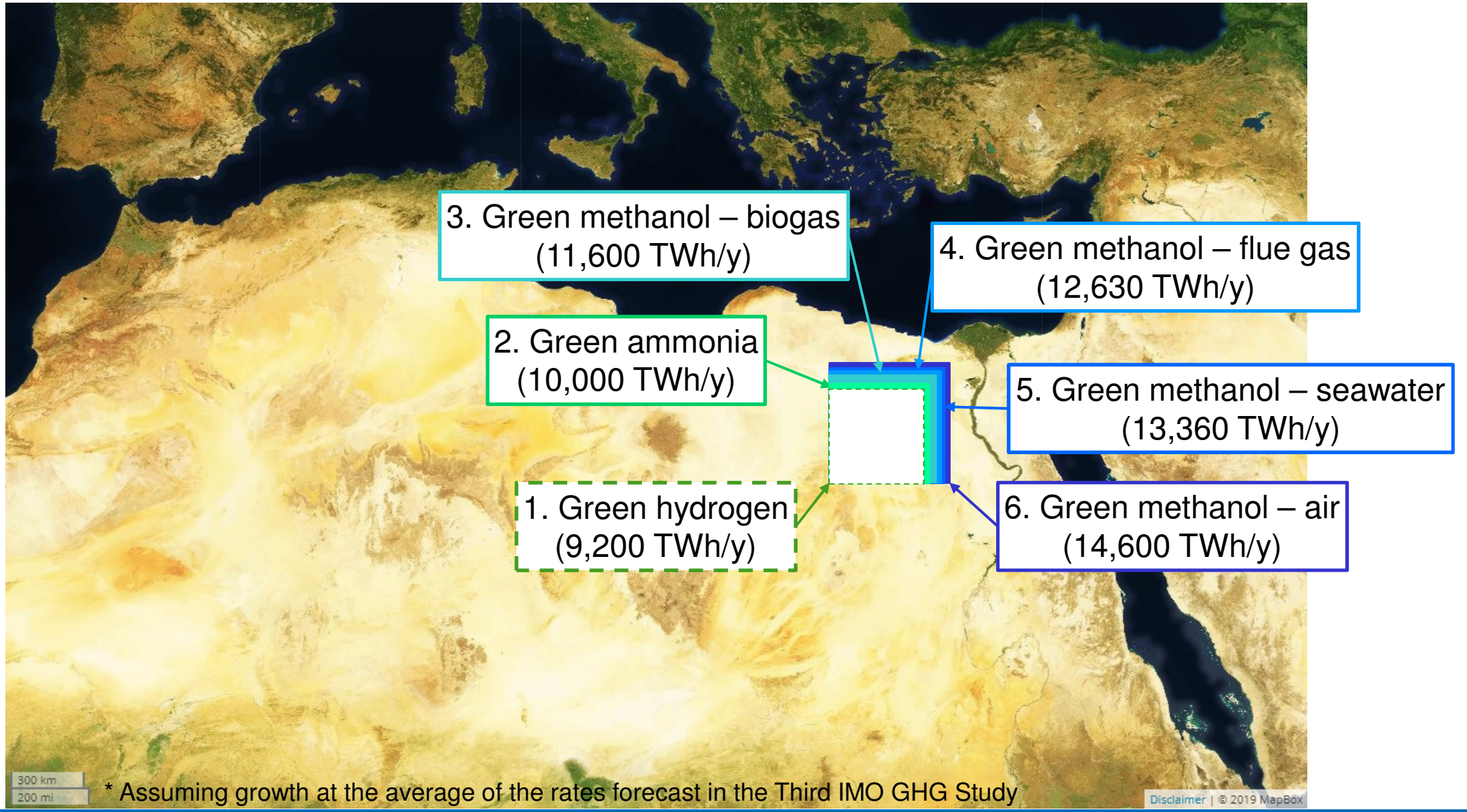
***Tank volumes for ammonia, hydrogen account for insulation ("system-level" densities).**
Ammonia: Ricardo calculations based on expected design of ammonia storage tanks (inner tank, insulation, outer)
Hydrogen: Minnehan and Pratt (2017), Comer (2019)

All fuels are hazardous, but the types of hazard vary



	MGO	LNG	Green Methanol	Green Ammonia (liq.)	Green Hydrogen (liq.)
Physical hazards	• Flammable (2)	• Flammable (4) • Gas under pressure	• Flammable (3)	• Flammable (1) • Gas under pressure	• Flammable (4) • Gas under pressure
Health hazards	• Acute toxicity • Aspiration hazard • Skin corrosion • Carcinogenic • Organ toxicity		• Acute toxicity • Specific target organ toxicity	• Acute toxicity • Skin corrosion	
Env. hazards	• Toxic to aquatic life			• Toxic to aquatic life	
Summary US NFPA704	2 / 1 / 0	4 / 3 / 0	3 / 1 / 0	1 / 3 / 0	4 / 3 / 0 / CRYO

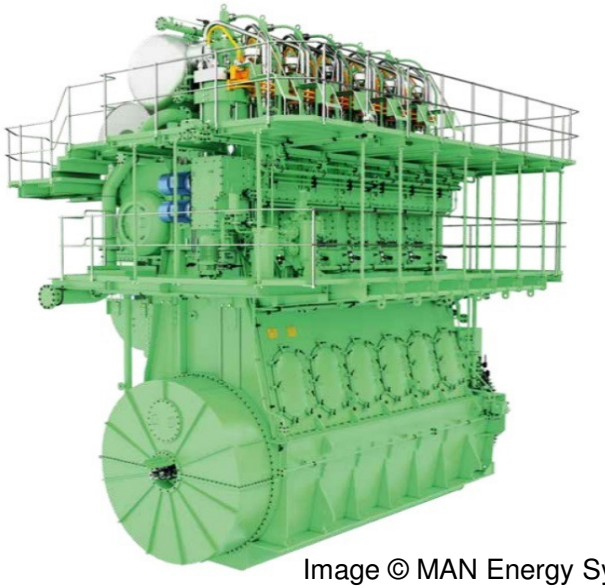
The land area required for solar electricity to produce green electrofuels for the international shipping fleet in 2050* is not excessive



* Assuming growth at the average of the rates forecast in the Third IMO GHG Study

Four co-benefits of decarbonising shipping with green electrofuels

1. Electrofuels could drive investment in renewables



2. The deployment pathway can begin using existing and familiar technologies (i.e. internal combustion engines)

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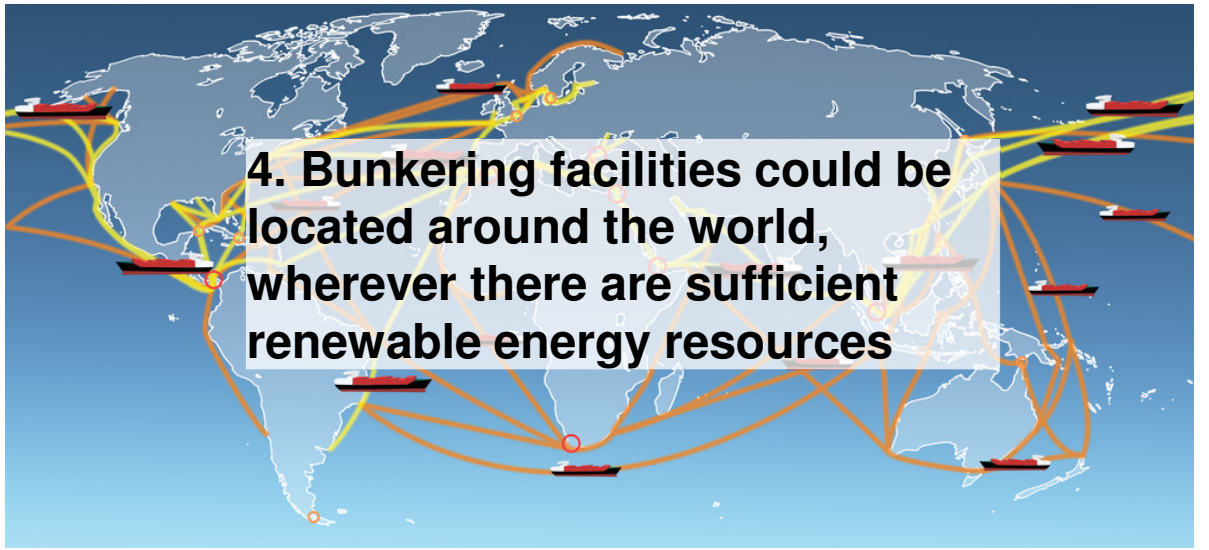
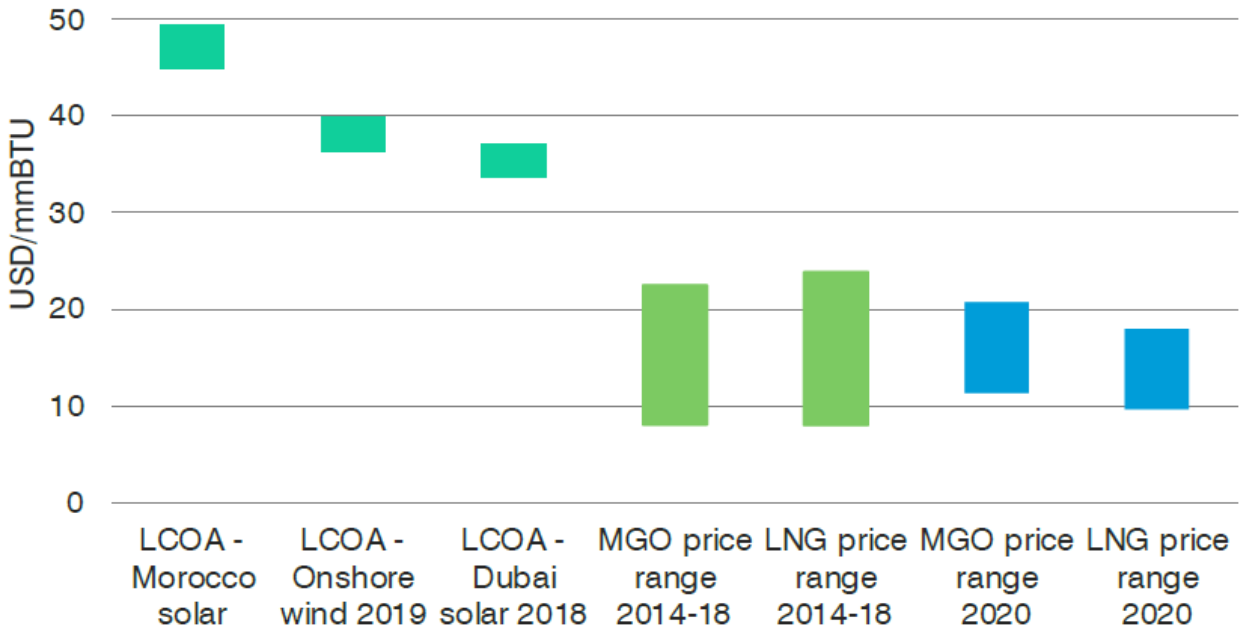
3. There are established safety protocols for storing and transporting the fuels



4. Bunkering facilities could be located around the world, wherever there are sufficient renewable energy resources

Topics for further discussion



Electrofuels are not currently cost competitive with the status quo shipping fuels

- Incentives, taxes, levies to achieve price parity with fossil fuels
- Encouraging research and development
- Certification of ***green*** electrofuels to differentiate from fossil-derived synthetic fuels
- Chicken/egg –
  Sufficiently distributed infrastructure
- Retrofit options –
  Including where to put the fuel tanks
- Pathway to regulatory approval and ship certification

Thank you

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