CIRCULAR CARBON USAGE

OR

How I Learned to Stop Worrying and Love Carbon

Robert Palin – Managing director, Spaera

WHO WE ARE

Spaera consists of industry veterans from electric vehicles, motorsport, and logistics backgrounds

Our goal is to leverage experience from other industries to zero-emissions challenges in marine logistics




WHERE WE ARE

Shipping runs on carbon based fuels

HFO, VLSFO, MGO, MDO, LNG, LPG, Methanol

All in internal combustion engines

Combustion of these fuels leads to harmful emissions

From direct toxins like particulates and aromatic hydrocarbons, to sulphur oxides that cause acid rain and greenhouse gases

Emissions are causing the climate to change

Shipping contributes 1 billion tons of CO_2 emissions each year, approximately 3% of the world total

There is a push to change, but as little as possible

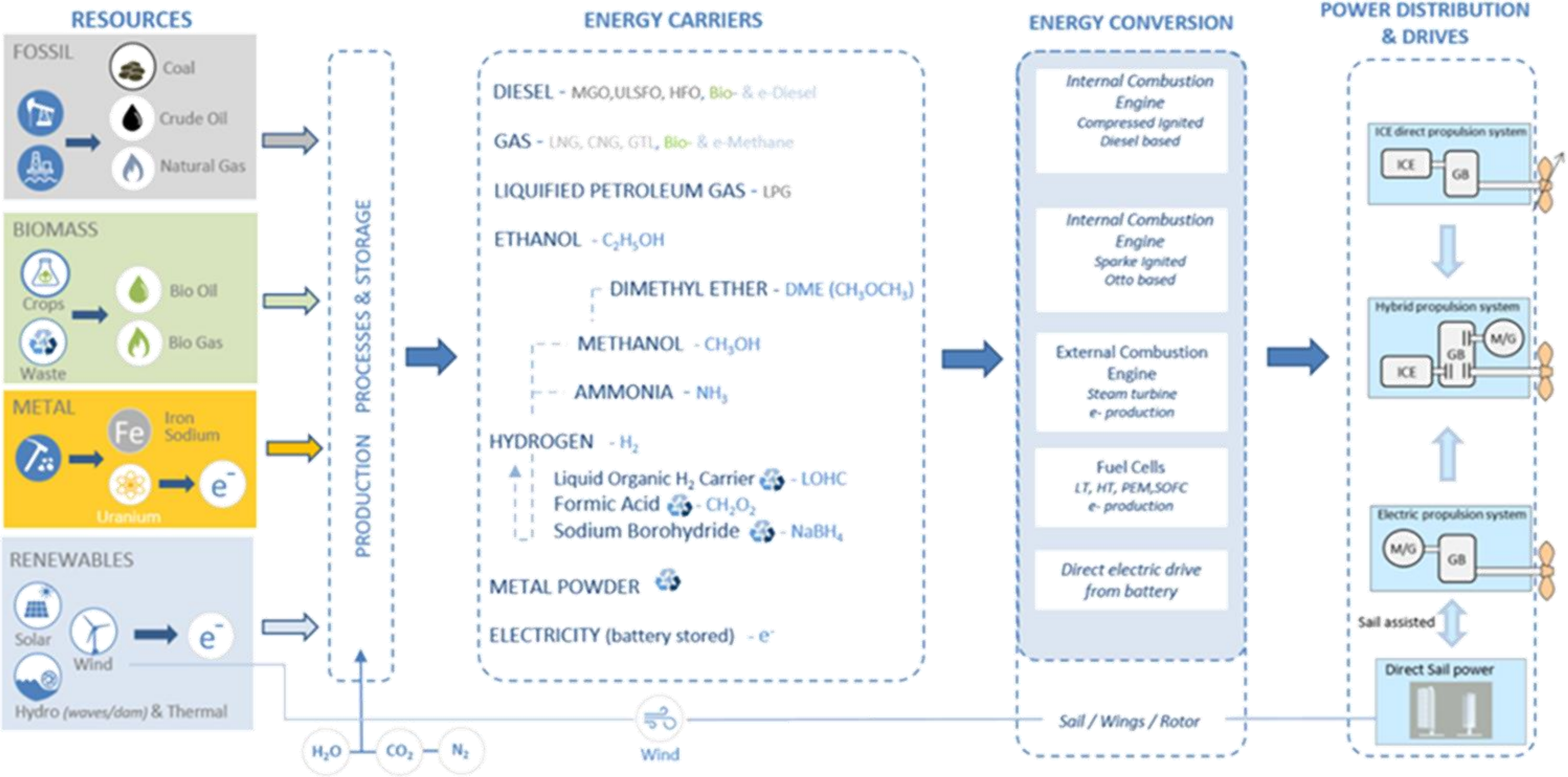
Changing only one piece of the puzzle means the new piece has to be the same shape

Solutions across disciplines & industries

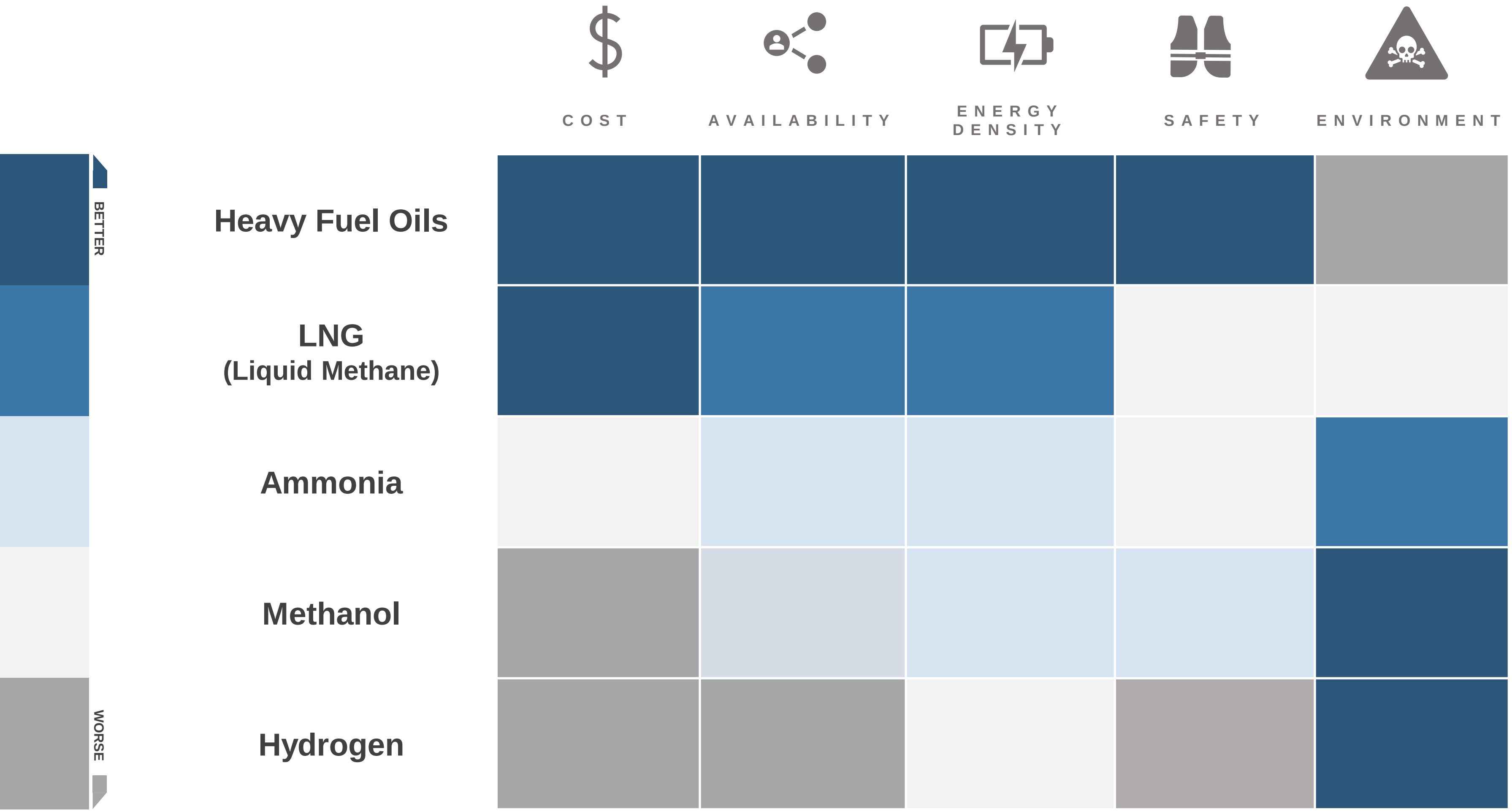
Some challenges already addressed in different applications

A bigger rethink of shipping’s energy is required

POWER PATHWAYS



ENERGY MEDIA TODAY



Heavy Fuel Oils: Stricter regulation on emissions, and potential Carbon taxes will make this unviable in future

LNG (Liquid Methane): Offers a small net benefit to GHG emissions, and limits stranded assets for established Oil Corps.

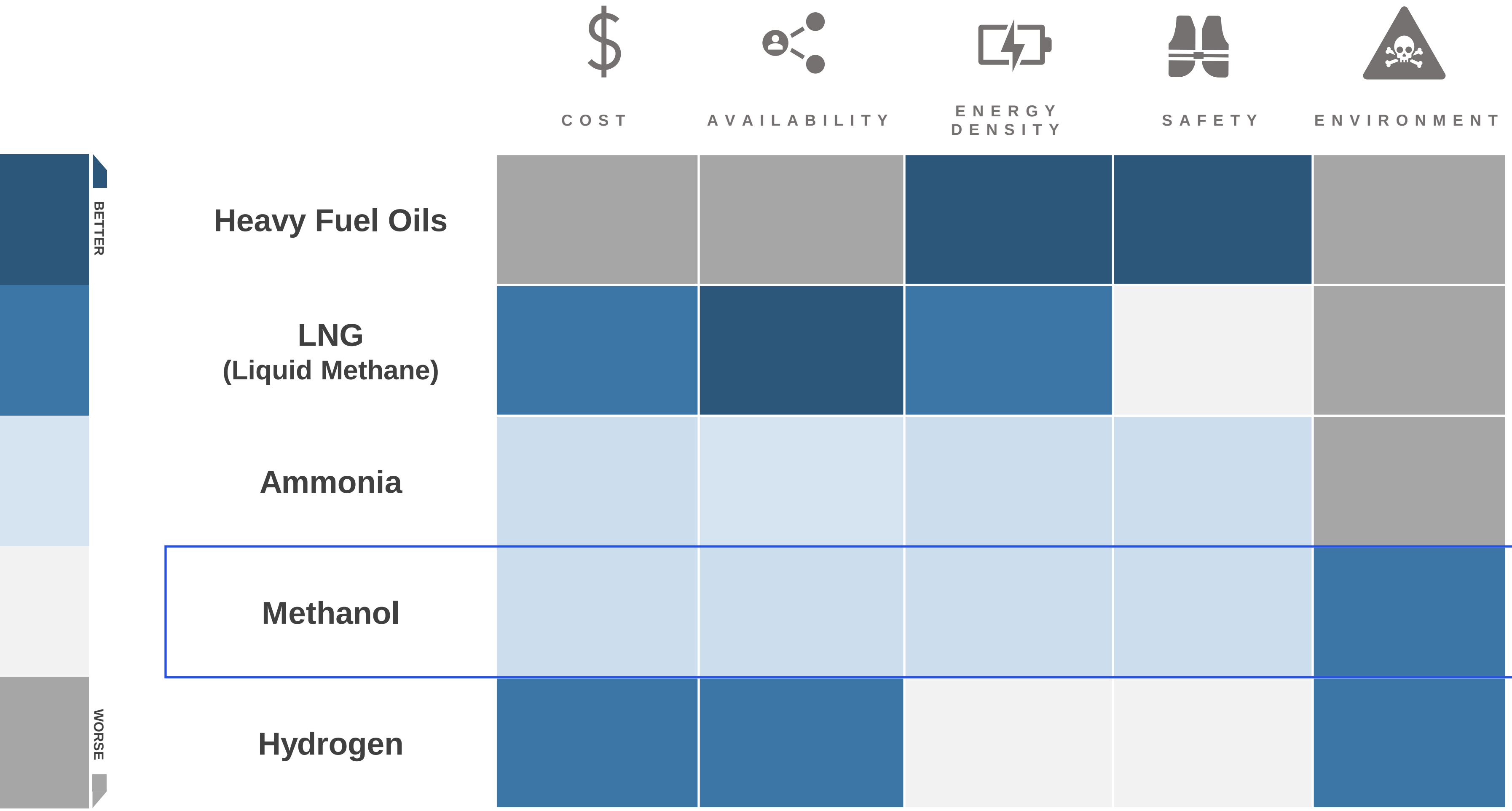
Ammonia: There is an established infrastructure for production & transport, but inefficient & toxic

Methanol: Carbon cycle control will be an important feature in future, but availability is scalable

Hydrogen: Requires substantial investment in infrastructure,& storage tech but is potentially the ‘cleanest’ of all

Currently fossil fuels win by virtue of their low cost, relative safety, and wide availability

ENERGY MEDIA TOMORROW



Stricter regulation on emissions, and potential Carbon taxes will make this unviable in future

Offers a small net benefit to GHG emissions, and limits stranded assets for established Oil Corps

There is an established infrastructure for production & transport, but inefficient & toxic

Simple to produce, store, and transport, but carbon cycle control will be an important factor

Requires heavy investment in infrastructure & storage tech but offers maximum green potential

All energy carriers must be synthesised in future, and methanol as a carrier for hydrogen makes the most sense.

WHY “DECARBONISATION” IS A MISNOMER

GHGs & GWPs

There are many, many substances classed as GreenHouse Gases, or GHGs

GHGs can have widely varying climate impacts, over different timescales

The fuels used by shipping generate several of them, with some not containing any carbon, but being far more potent than CO_2

What we want is really “de-GHG-isation”

Compound	Chemistry	GWP_{100}	GWP_{20}
Carbon Dioxide	CO_2	1	1
Nitrous Oxide	N_2O	298	268
Methane (Nat. Gas)	CH_4	34	86
Black carbon (particulates)	Varies	~460	~1600
Hydrogen	H_2	11	33
Sulphur Dioxide	SO_2	-40	-140
Sulphur Hexaflouride	SF_6	23,500	17,500

GWP_{100} is the Global Warming Potential of a substance over 100 years, normalized to CO_2 as a value of 1

GWP_{100} is the most relevant for relatively permanent climate impacts, but GWP_{20} is sometimes used to grade short-term impacts, to prioritise measures we can take now, buying time for more wholesale changes later

EEXI, EEDI, CII, & OTHER BAD SCRABBLE HANDS

New emissions regulations focus purely on CO_2

Ships could get excellent scores on these metrics, even if they emitted other potent GHGs

It would be better to generalize the emissions factor to include a broader range of GHGs

EEXI [g/ton·mile]=

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}\right) + \left\{\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) \cdot C_{FAE} \cdot SFC_{AE}\right\} - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot V_{ref}}$$

Concept formula

$$\text{EEXI [g/ton·mile]} = \frac{CO_2 \text{ Conversion factor} \times \text{SFC [g/kW·h]} \times \text{Engine Power [kW]}}{\text{Capacity [ton]} \times \text{EEXI Speed [knots]}}$$

CO_2 emissions (gram) from a ship when ship sail transport 1 (ton) cargo for 1 (nautical mile)

CO_2 Conversion factor (C_F)	C_F corresponds to the fuel used when determining SFC (DM grade: 3.206)
SFC	Fuel consumption at 75%MCR (M/E), at 50%MCR (A/E)
Engine Power	75% of the rated installed power (MCR) (In case of EPL, 83%MCRlim)
Capacity	Deadweight (For containerships, 70% of the deadweight)
EEXI Speed (V_{ref})	Ship speed at 75%MCR under the draught condition corresponding to the capacity

$$C_{Eff} = [GWP_{CO_2} \times MassFraction_{CO_2}] + [GWP_{N_2O} \times MassFraction_{N_2O}]$$
$$+ [GWP_{SO_2} \times MassFraction_{SO_2}] + [GWP_{Particulates} \times MassFraction_{Particulates}]$$
$$+ [GWP_{NH_3} \times MassFraction_{NH_3}] + [GWP_{CH_4} \times MassFraction_{CH_4}]$$
$$+ [GWP_{H_2} \times MassFraction_{H_2}]$$

BETTER SYSTEM DRIVERS

WORKING PAPER 2022-34

OCTOBER 2022

How updating IMO regulations can promote lower greenhouse gas emissions from ships

Authors: Bryan Comer, Ph.D. and Bharadwaj Sathiamoorthy

Table 4. Carbon factors when calculating attained EEDI using TTW or WTW CO_2e.

		TTW			WTW		
Fuel	**Engine**	**CO_2**	**CO_2e100**	**CO_2e20**	**CO_2**	**CO_2e100**	**CO_2e20**
LNG	HPDF 2-stroke	2.750	2.864	2.965	3.280	3.940	5.008
	LPDF 2-stroke	2.750	3.308	4.244	3.280	4.385	6.288
	LPDF 4-stroke	2.750	3.854	5.758	3.280	4.930	7.801
MeOH	2-stroke or 4-stroke	1.375	1.375	1.375	1.738	1.825	1.976
MGO	2-stroke	3.206	3.284	3.357	3.782	4.007	4.340
	4-stroke	3.206	3.408	3.802	3.782	4.130	4.785
HFO	2-stroke	3.114	3.316	3.710	3.545	3.874	4.495
	4-stroke	3.114	3.457	4.219	3.545	4.015	5.004

New analysis by the ICCT demonstrates the error in these metrics

Comparisons the EEDI of container & cruise vessels across different energy media reveals the potency of misdirection from incomplete GWP accounting

Their recommended updates to the metrics make a profound difference to the future feasibility of the range of energy media options

The evolution of a system is driven by its forcing functions, such as regulations, technology, politics, and market forces

We need to be careful to establish mindful metrics that guide the system to a healthier state

REFRAMING THE QUESTION

FOSSILS

In the fossil fuel age, we lean on the robust & reliable power of our stored energy to overcome the elements on our journey

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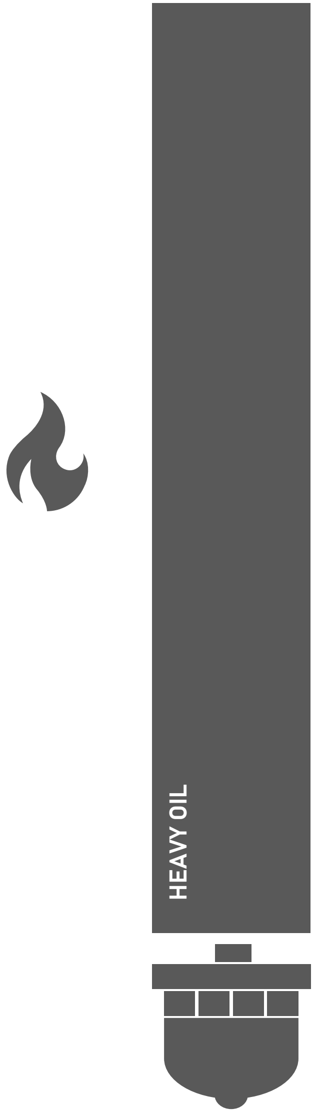
In times past we used to leave port with none of the energy required for the voyage, & the elements were our precious, if fickle allies

SPAERA's APPROACH IS DIFFERENT

FOSSILS



Vessels today are 100% reliant on heavy fuel oils, currently cheap and widely available, but highly polluting and facing strong consumer and legislative push back

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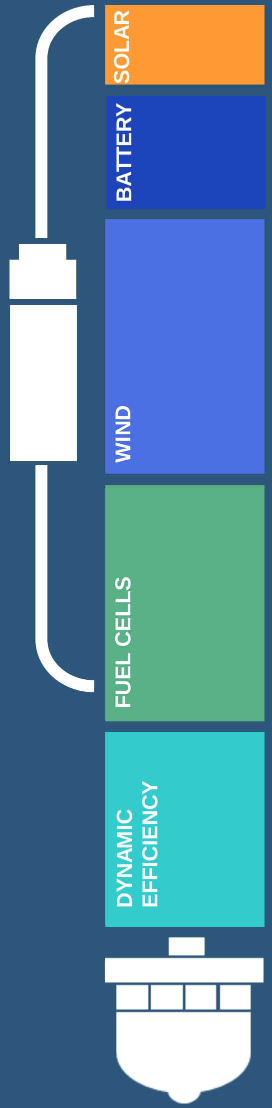
Electricity as the common medium allows multiple energy sources to be easily unified



Solar cells on free deck space provide auxiliary power

Batteries act as a buffer between electrical energy inputs & outputs

Adjustable wing-sail technology, aided by satellite weather data and route-mapping provides up to 50% of propulsion, and can enable onboard electricity generation

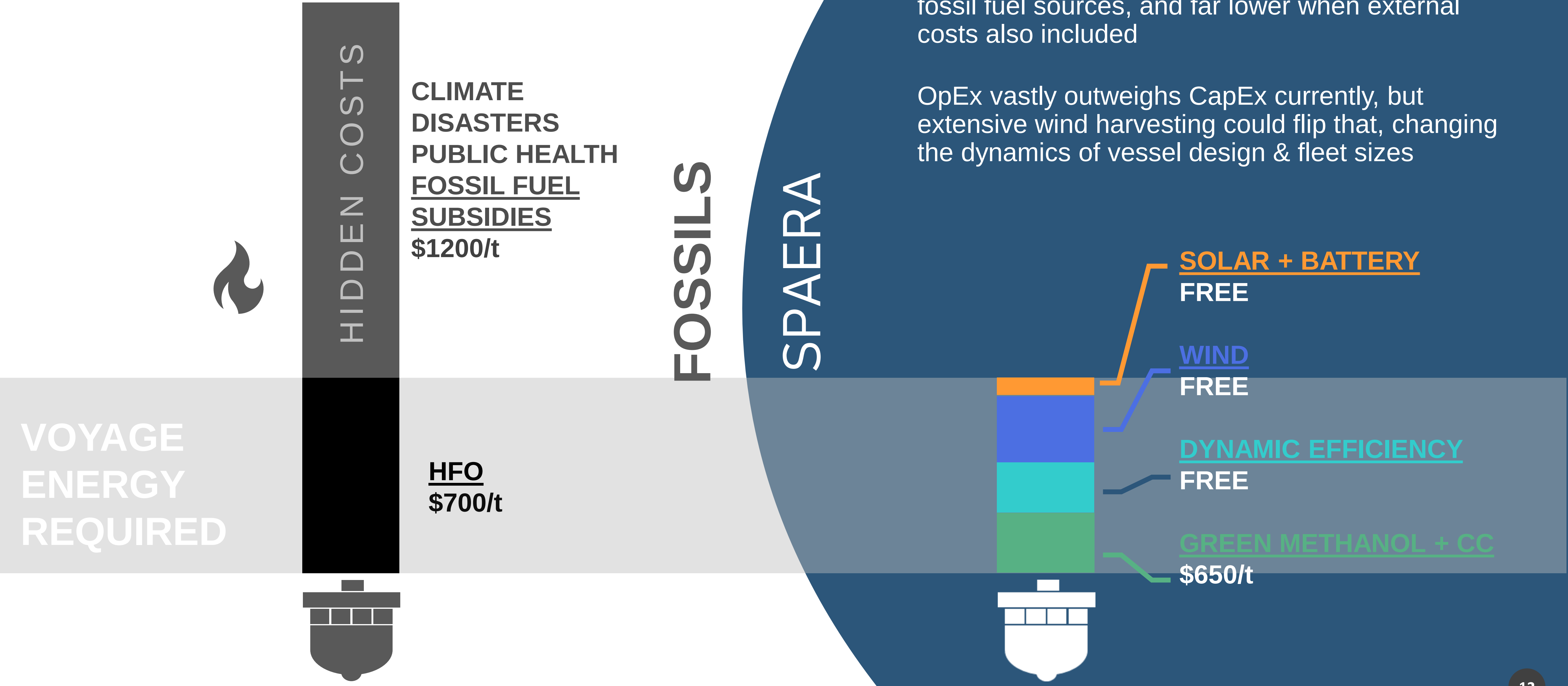
Green Methanol (with CO_2 recovery, storage, & reuse) will bridge the gaps in harvested renewable energy

Hydrodynamic & aerodynamic efficiency improvements will significantly reduce overall energy requirements

SPAERA'S COSTS ARE DIFFERENT

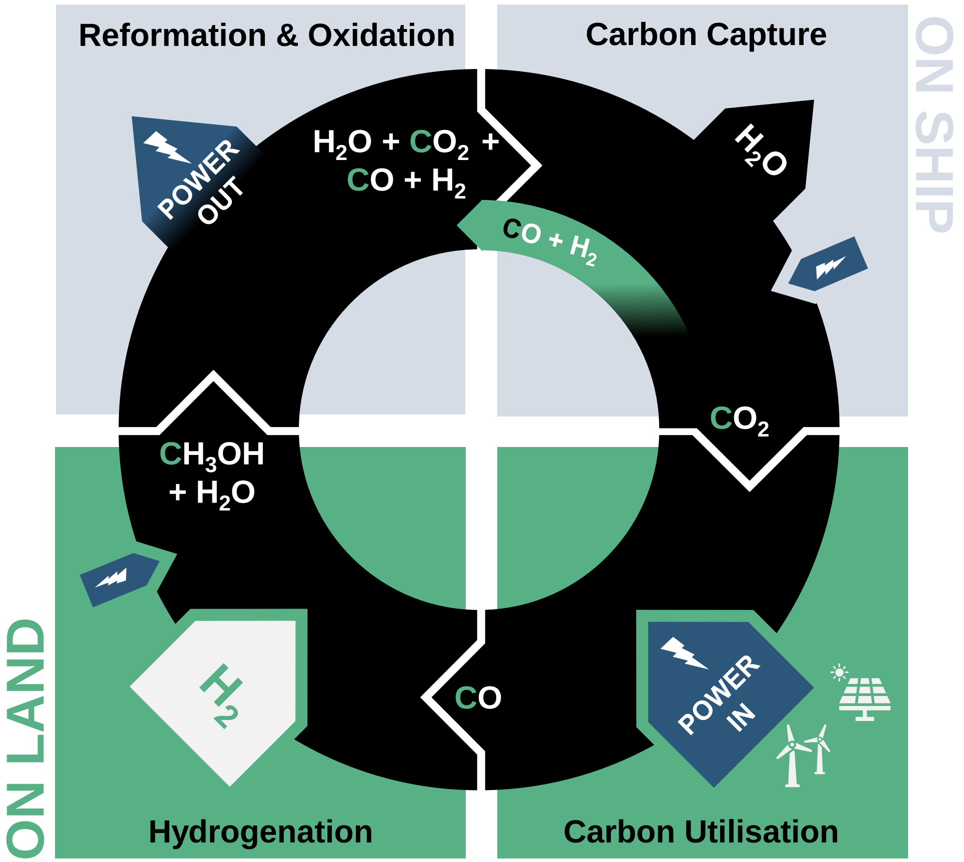
Operating costs can be comparable or lower than fossil fuel sources, and far lower when external costs also included

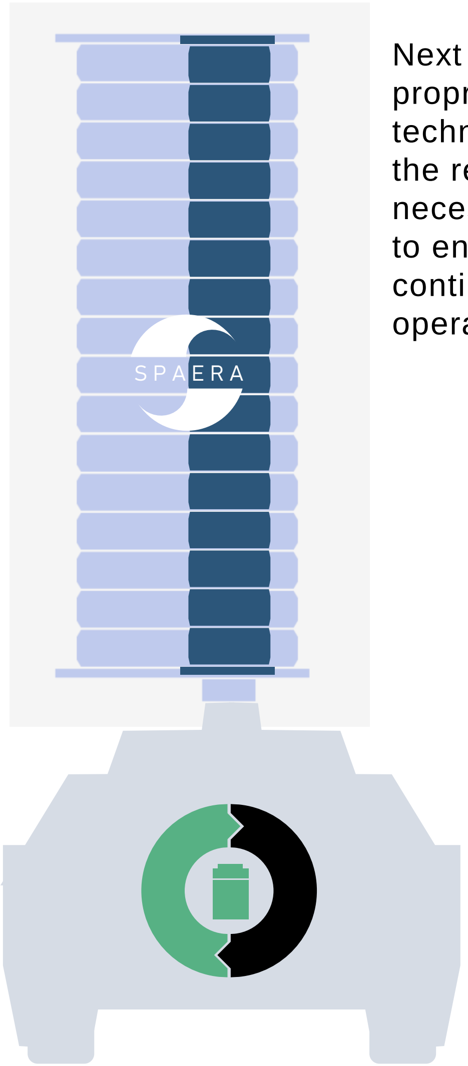
OpEx vastly outweighs CapEx currently, but extensive wind harvesting could flip that, changing the dynamics of vessel design & fleet sizes



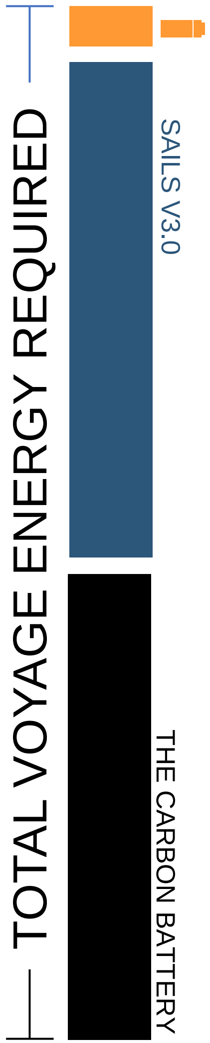
CARBON BATTERY

The C-Battery: a perpetual closed loop use of carbon, via hydrogenation into methanol and discharging via fuel cell to electricity. The only other outputs and inputs are water.





Next generation proprietary sail technology provides the remaining necessary energy to enable trans continental operation



WIND-ASSISTED CARBON BATTERY POWERTRAIN

We want to introduce the closed loop **carbon battery (c-battery),** where carbon atoms are charged with hydrogen, and discharged via a chemical reaction with the fuel cell, producing electricity.

On the **ship**, methanol[(1)] is converted into electrical energy via a solid oxide fuel cell[(2)].

Emissions of water, carbon dioxide, carbon monoxide & hydrogen pass through a membrane system[(3)], returning unspent carbon monoxide and hydrogen to the fuel cell[(4)] for efficiency.

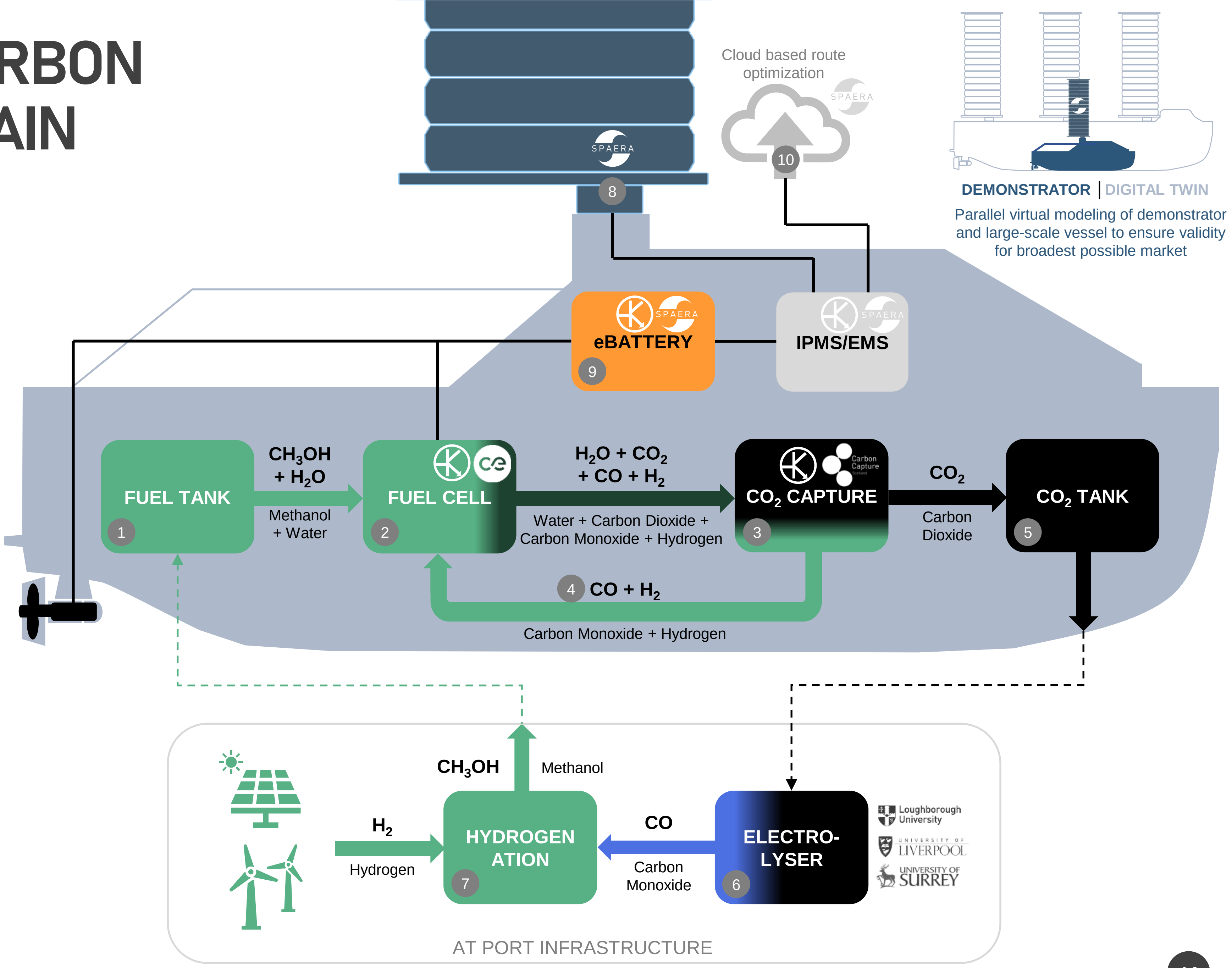
Remaining carbon dioxide and water mixture is condensed, dried and compressed for storage on the vessel[(5)].

At **port**, the compressed carbon dioxide is converted into carbon monoxide via an electrolyser[(6)]. This is mixed with green hydrogen in a hydrogenation reactor[(7)] to produce fresh methanol, ready to refuel our vessel.

To reduce the amount of methanol required, high performance Wind Assisted Propulsion[(8)] is employed – capable of providing up to 100% of propulsive force in certain conditions.

An electrical battery[(9)] will also be employed to act as a buffer between available wind power and fuel cell power delivery

Proprietary software will be developed to optimize performance of the system holistically, integrating real time environmental data[(10)] to optimize route and schedule, providing the maximum possible efficiency.



SPAERA Vision – Project Lovelock

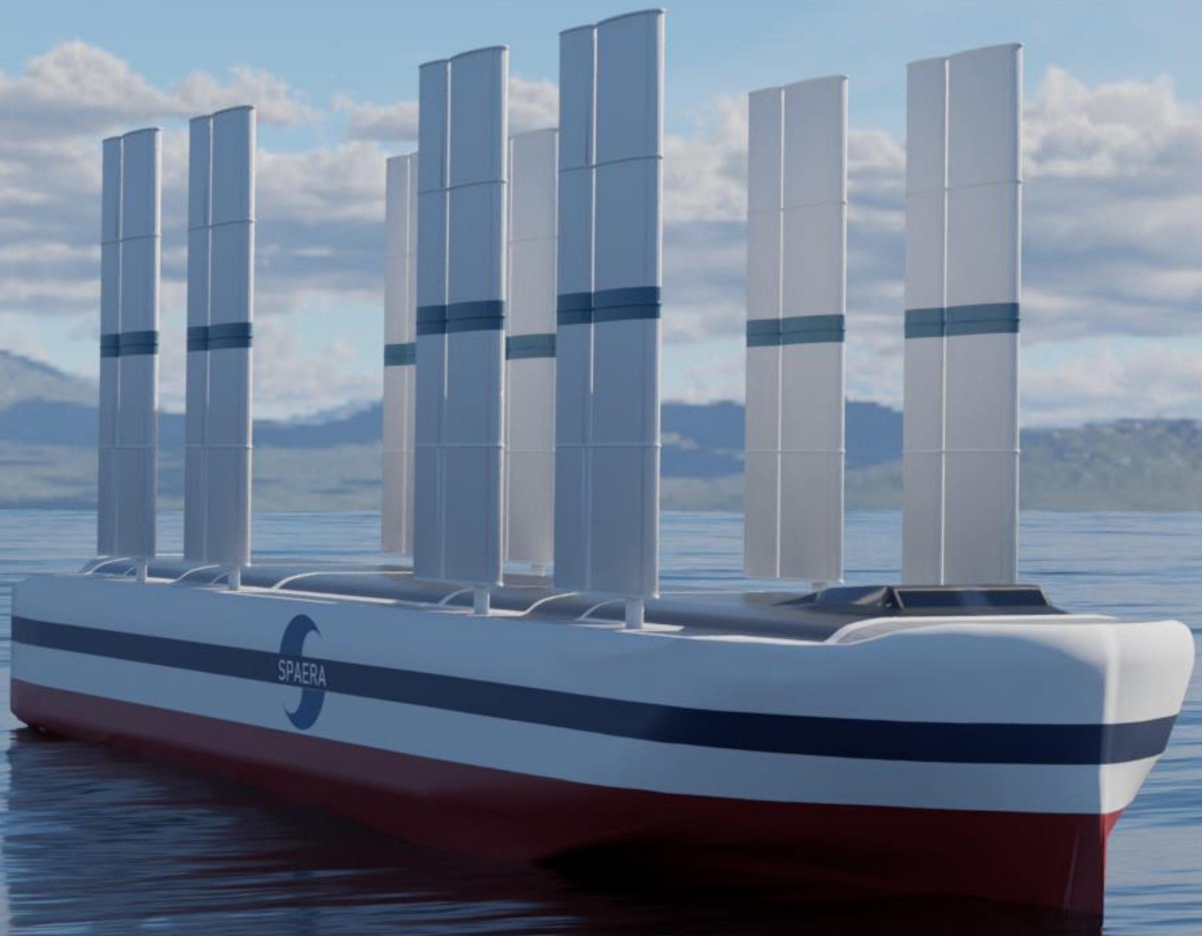
**Project Lovelock Phase 4:
Fully capable car transporter**

Efficient hull & body design with holistically integrated wind-assistance

Zero-emission fuel cell powertrain

Intelligent, connected energy harvesting, storage, & management

Smart route planning, & inventory management



Zero-emission vehicle & container carrier

- 200 m OAL, 49 m beam, ~12,000 DWT
- Capacity of 4000 cars
- Configurable for 4000TEU
- 9.5 MW Hydrogen Fuel Cell powertrain
- Collapsible Rigid wing-sails for wind-assisted propulsion
- Solar panels & batteries for auxiliary power

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THANK YOU

For more information, please contact us

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