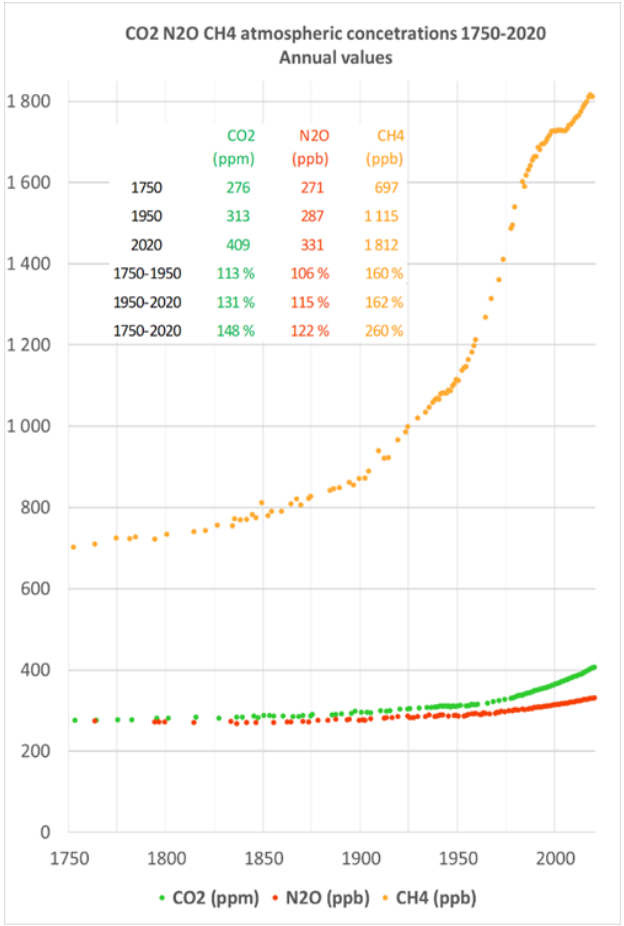
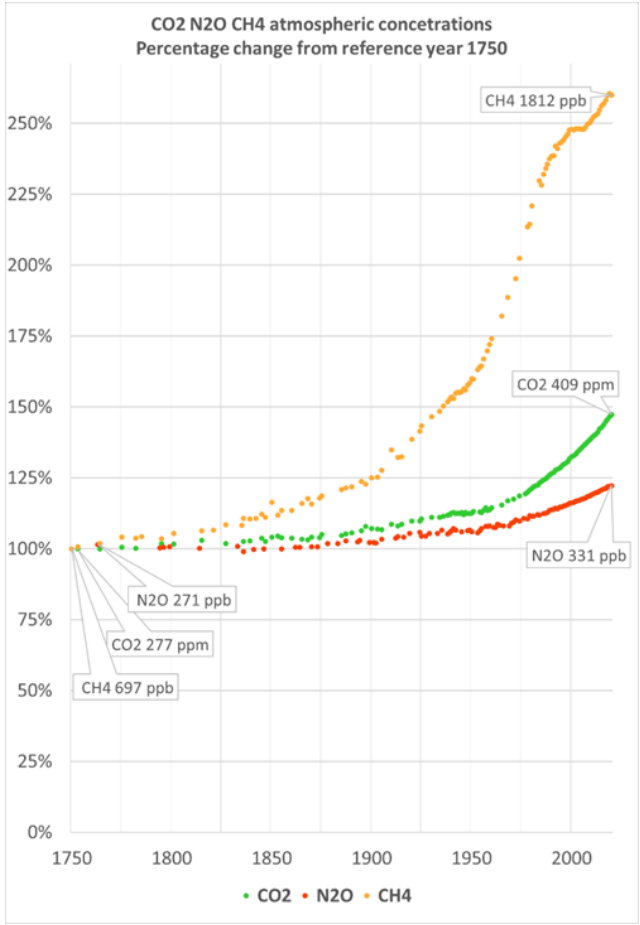
Natural propulsion for Transport & Shipping: potential and expectations in the present context

Guilhem Gaillarde
Head of Ships department, MARIN

Atmospheric gas concentrations of CO_2, N_2O and CH_4 from 1750 to 2020:



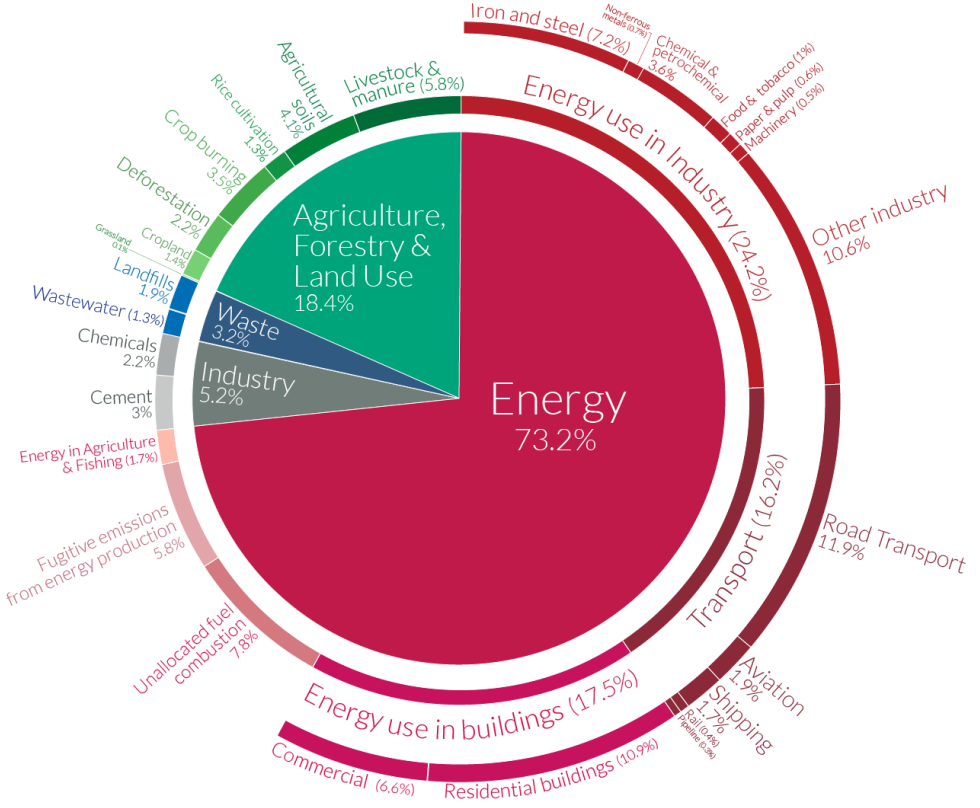


Data sources: Lindstad et al 2020 compiled based on MacFarling-Meure, C., et al. (2006); CSIRO Oceans & Atmosphere and the Australian Bureau of Meteorology (2020).

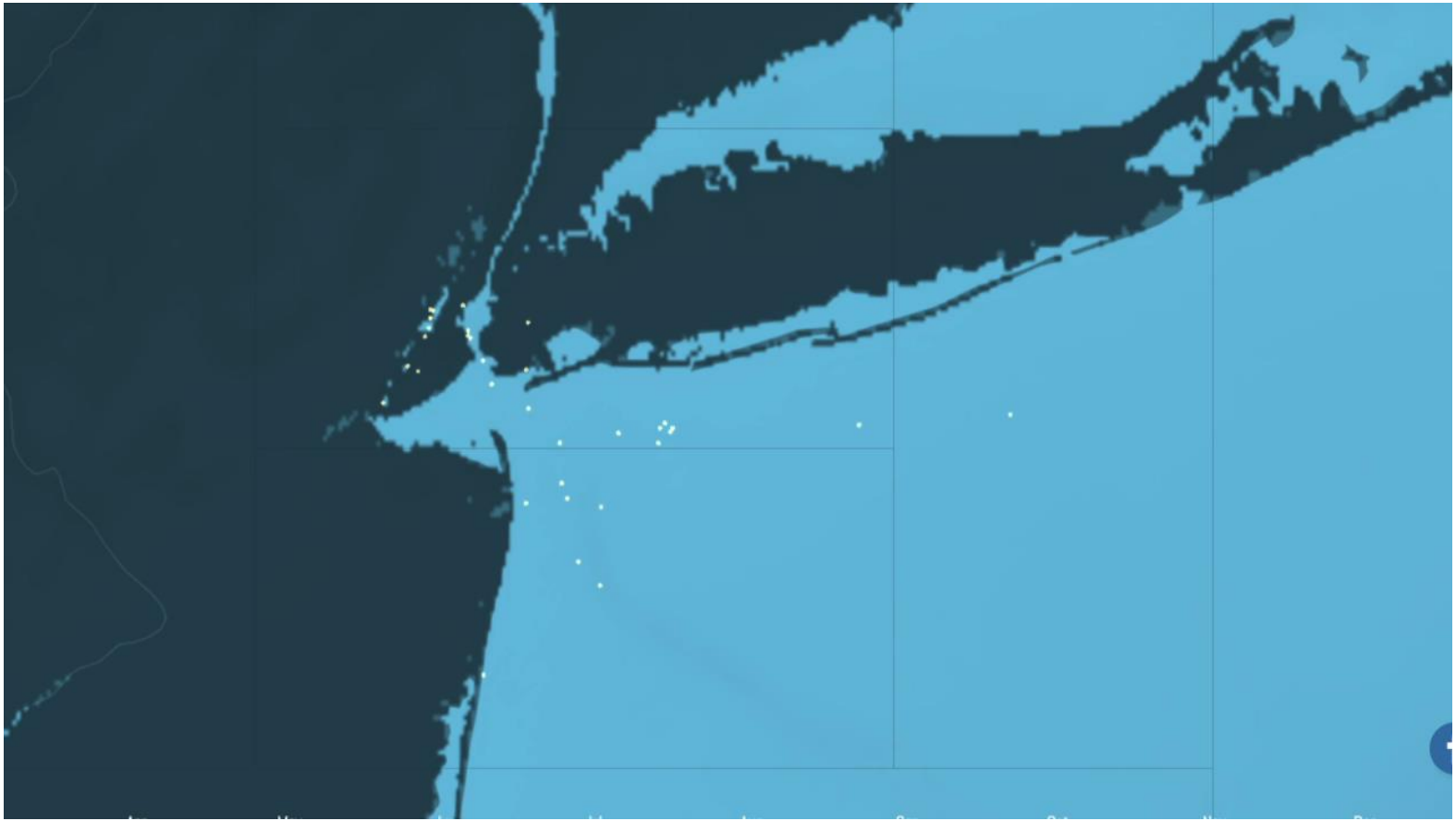
Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).



ENERGY CARRIERS

DIESEL - MGO,ULSFO, HFO, Bio- & e-Diesel - $C_{12}H_{23}$

METHANE - LNG, CNG, GTL, Bio- & e-Methane - CH_4

LIQUIFIED PETROLEUM GAS – LPG - C_3H_8, C_4H_{10}

ETHANOL - C_2H_5OH

- DIMETHYL ETHER - DME - CH_3OCH_3
- METHANOL - CH_3OH
- AMMONIA - NH_3

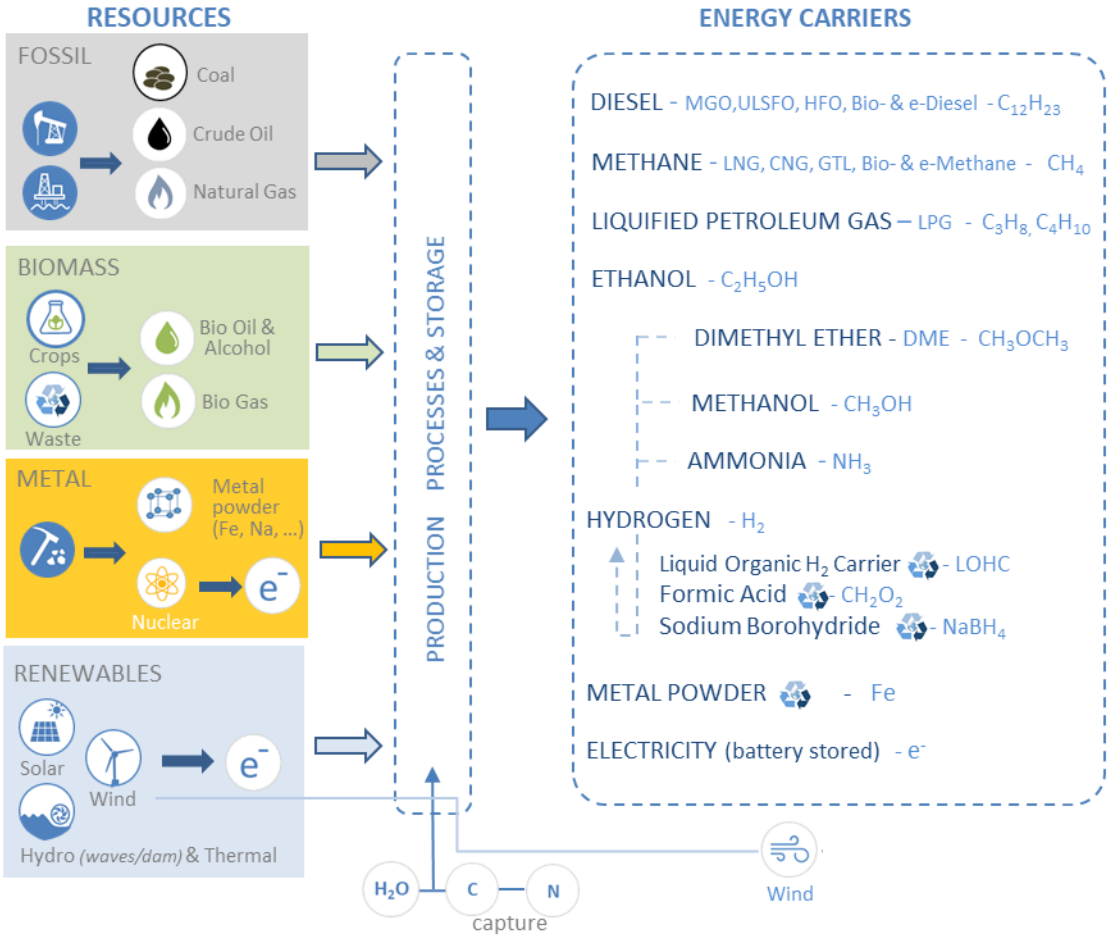
HYDROGEN - H_2

- Liquid Organic H_2 Carrier - LOHC
- Formic Acid - CH_2O_2
- Sodium Borohydride - $NaBH_4$

METAL POWDER - Fe

ELECTRICITY (battery stored) - e^-

Wind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FOSSIL
Coal
Crude Oil
Natural Gas
BIOMASS
Crops
Waste
Bio Oil & Alcohol
Bio Gas
METAL
Metal powder (Fe, Na, ...)
Nuclear
RENEWABLES
Solar
Wind
Hydro (waves/dam) & Thermal
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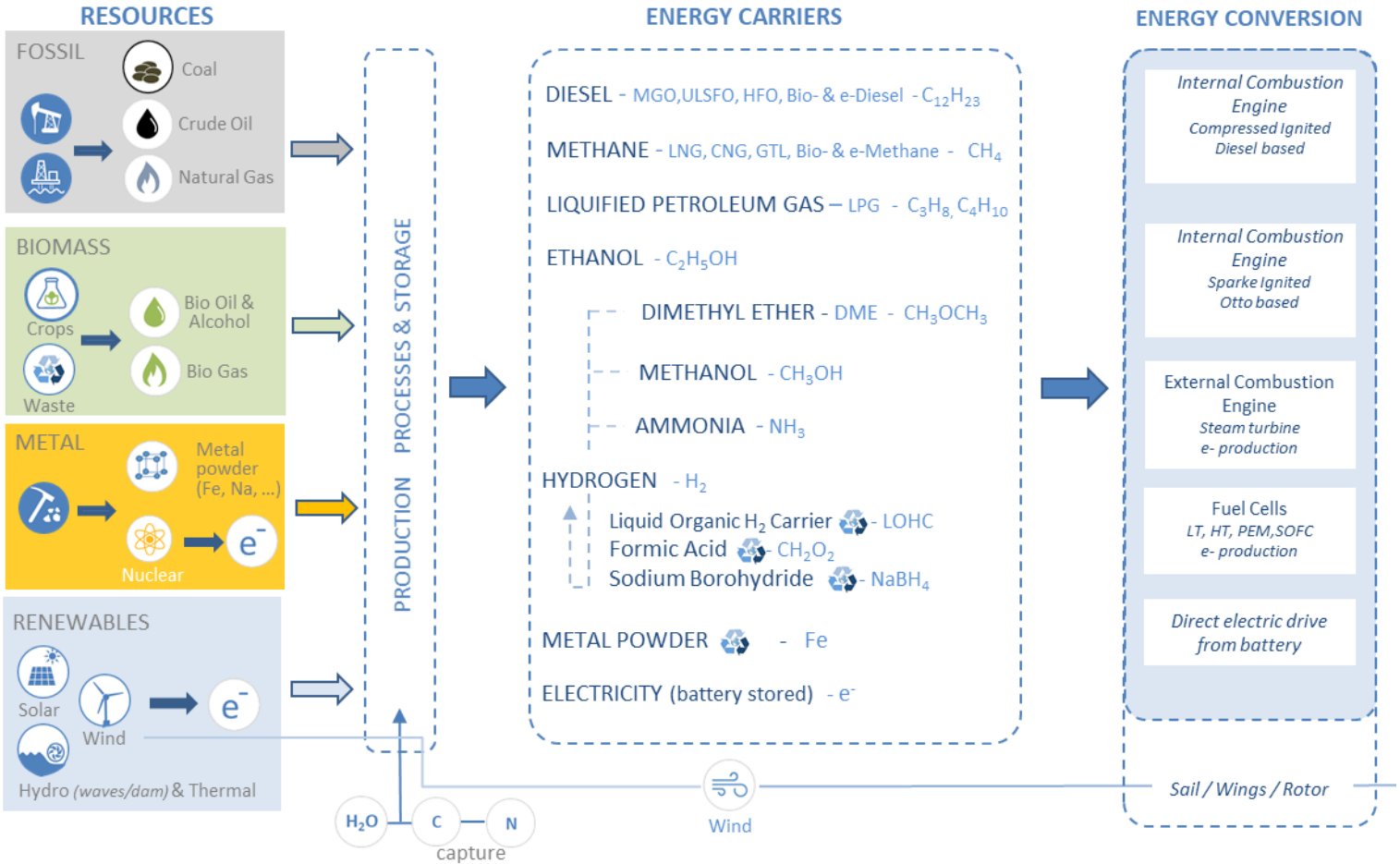
METAL POWDER - Fe
ELECTRICITY (battery stored) - e^-
H_2O
C
N
capture
Wind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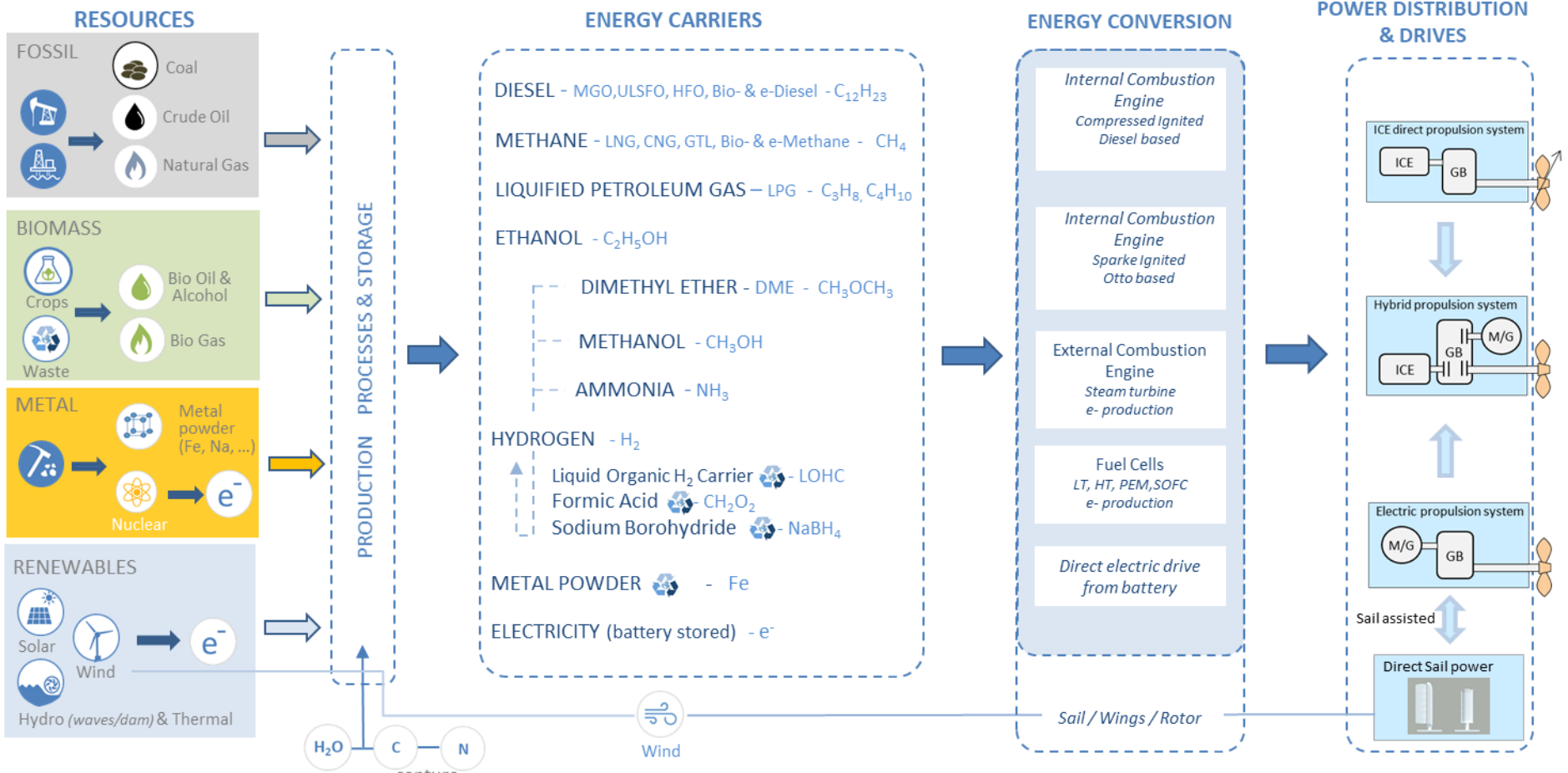
Internal Combustion Engine
Compressed Ignited
Diesel based
Internal Combustion Engine
Sparke Ignited
Otto based
External Combustion Engine
Steam turbine
e- production
Fuel Cells
LT, HT, PEM,SOFC
e- production
Direct electric drive from battery
Sail / Wings / Rotor
Wind
H_2O
C
N
capture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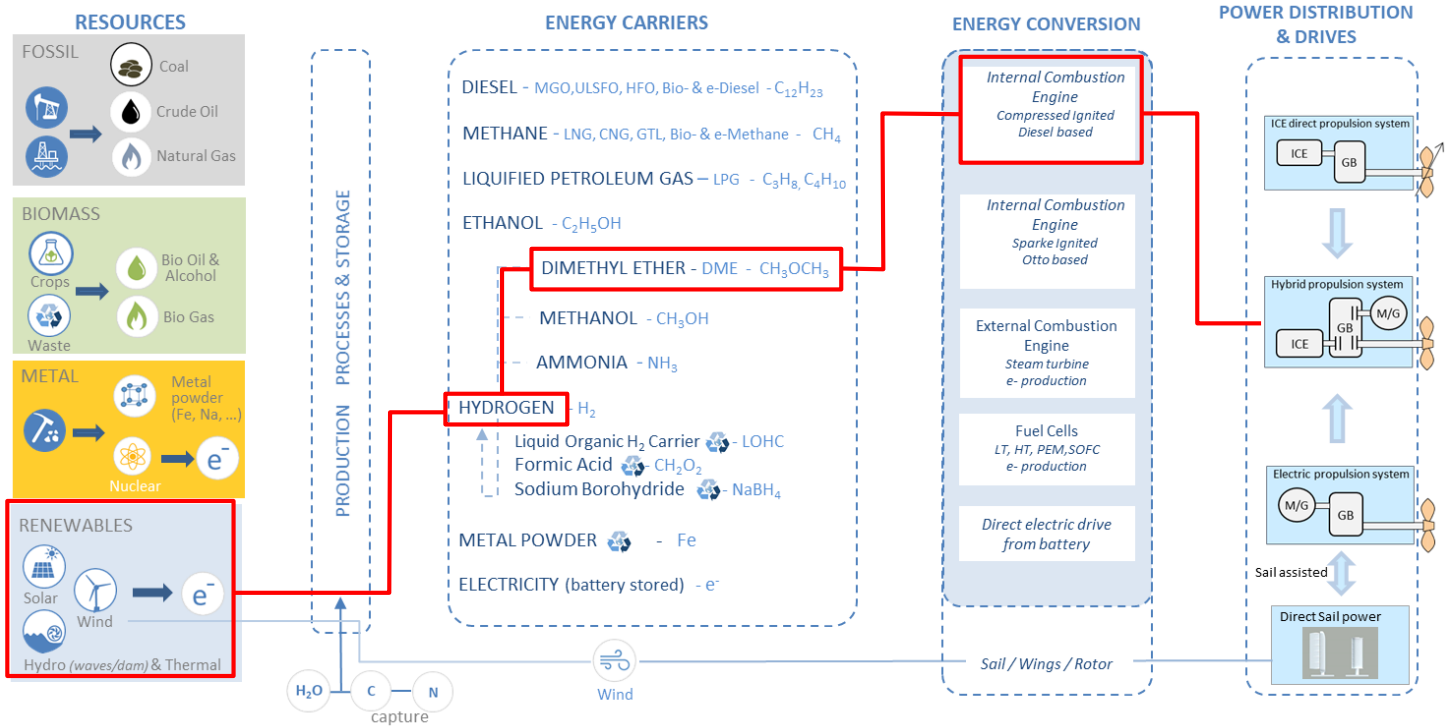
ICE direct propulsion system
ICE
GB
Hybrid propulsion system
ICE
GB
M/G
Electric propulsion system
M/G
GB
Sail assisted
Direct Sail power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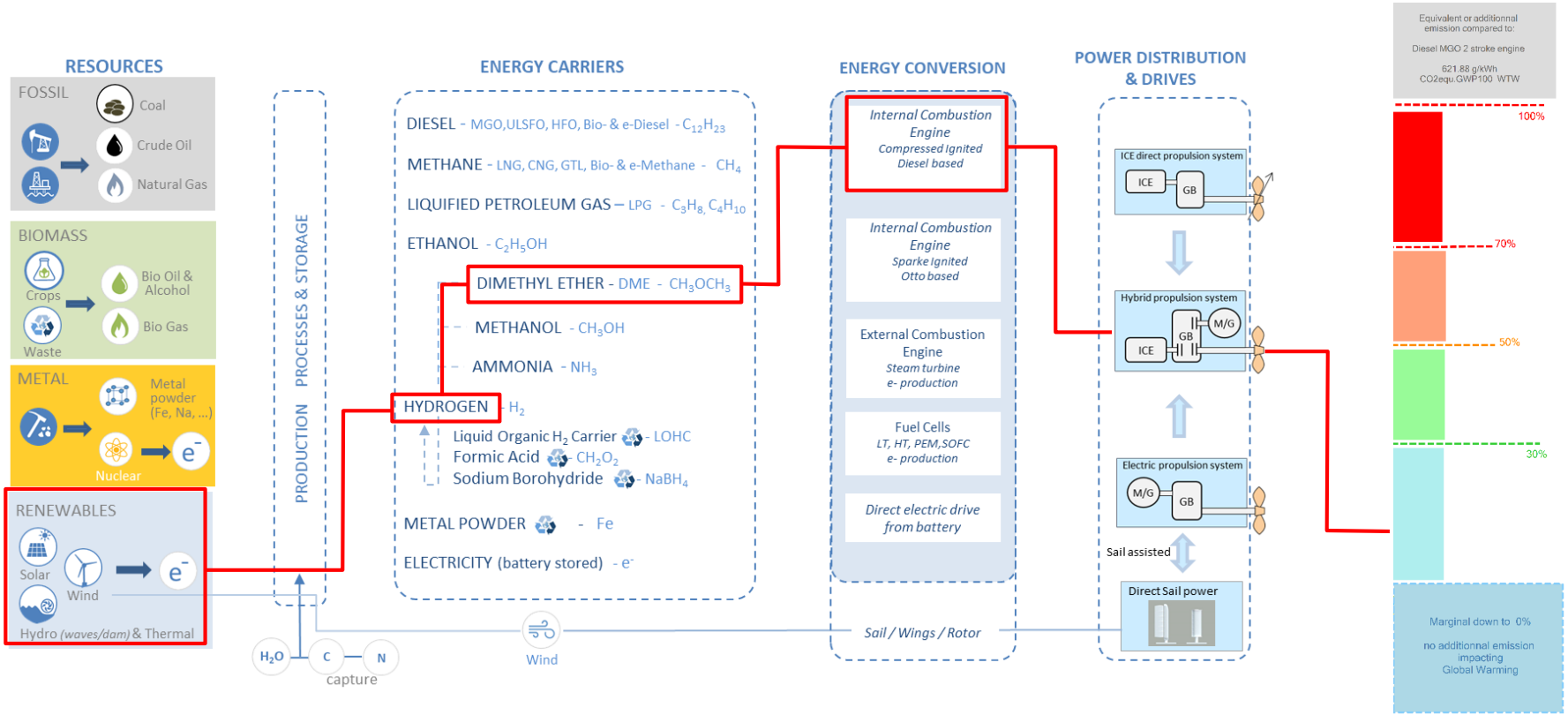
Sail assisted
Direct Sail power
GHG Emissions
WTW CO_2eq. GWP100 [g/kWh]
WELL TO TANK
TANK TO WAKE
WELL TO WAKE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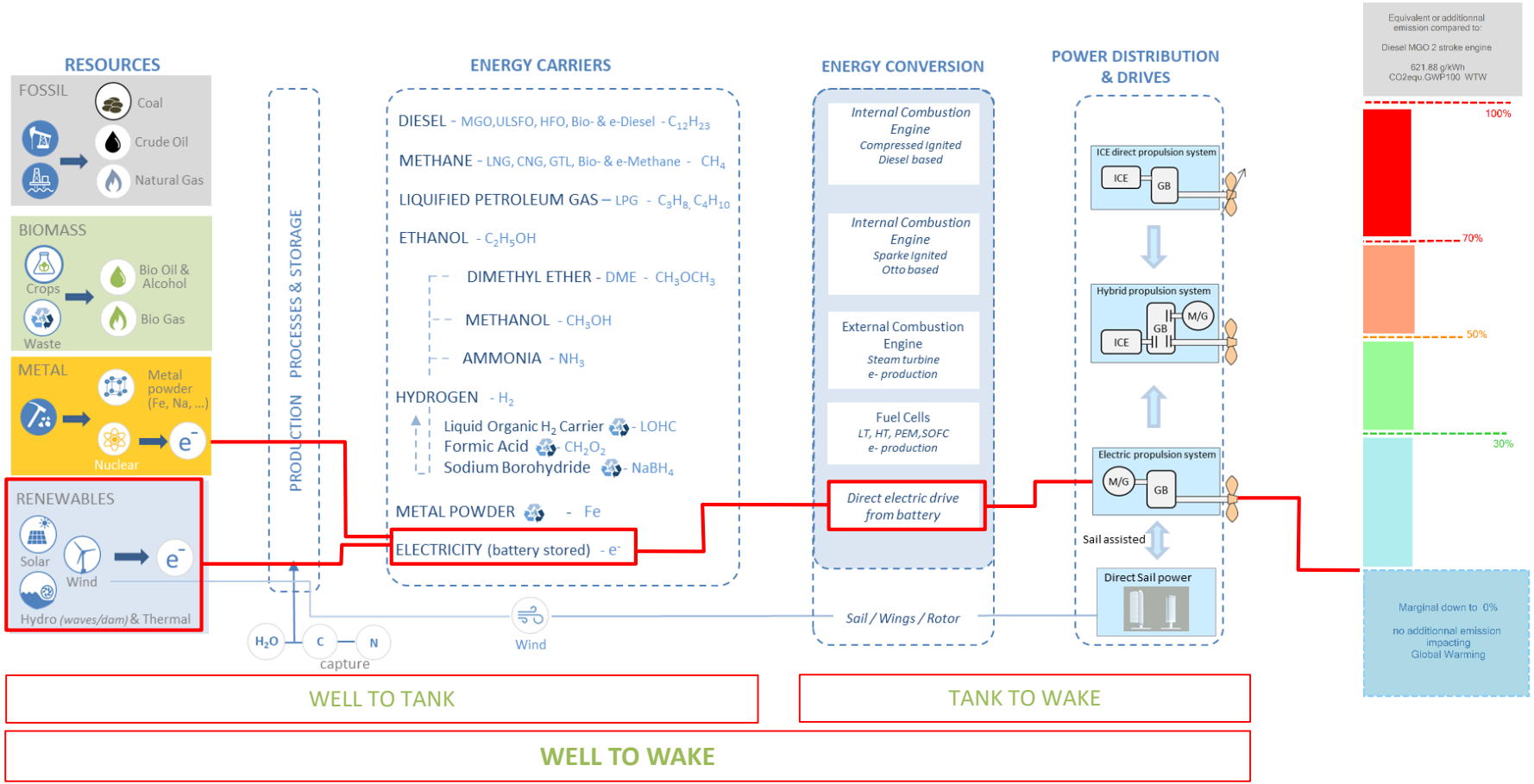
621.88 g/kWh
CO2equ.GWP100 WTW
100%
70%
50%
30%
Marginal down to 0%
no additionnal emission impacting Global Warming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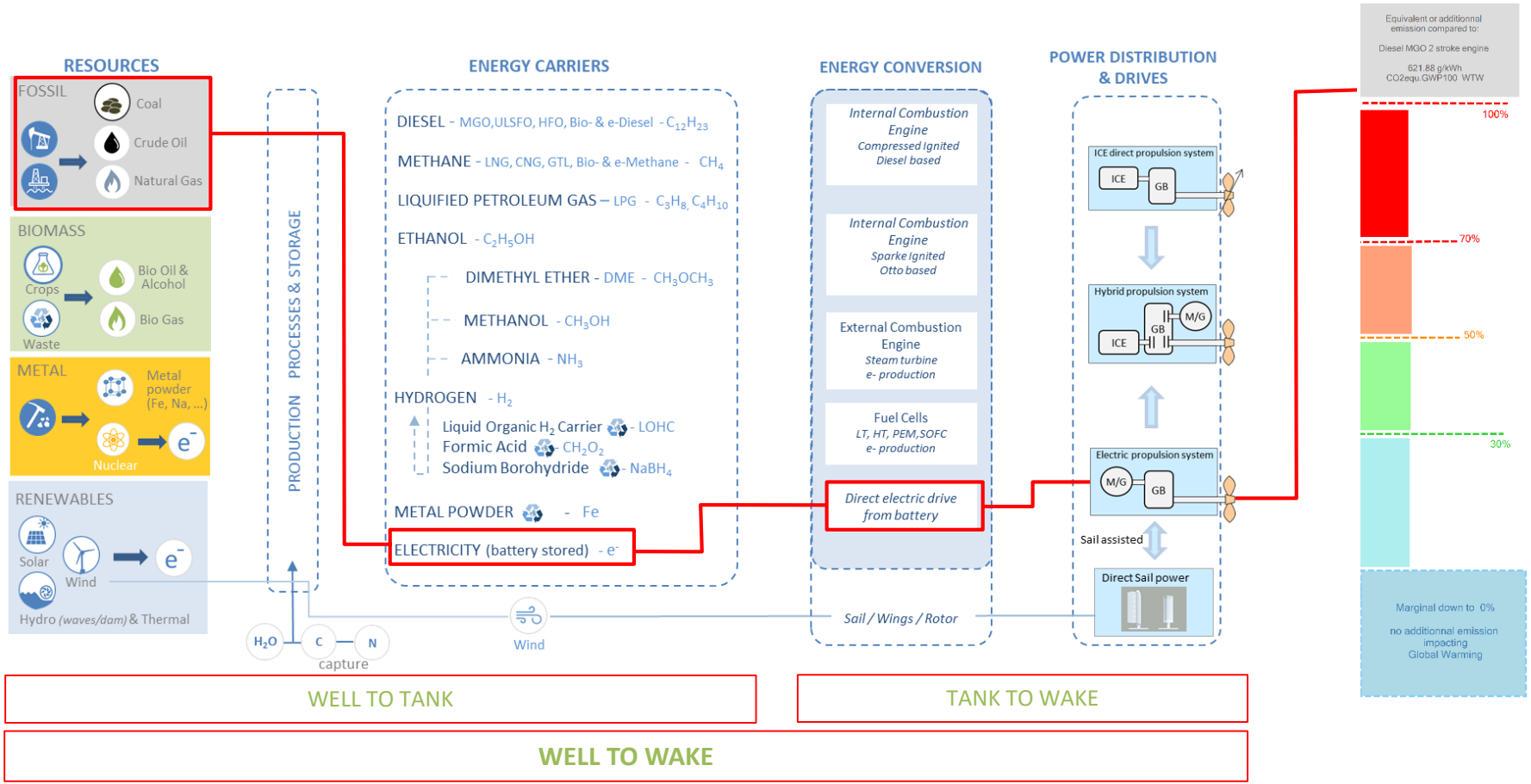
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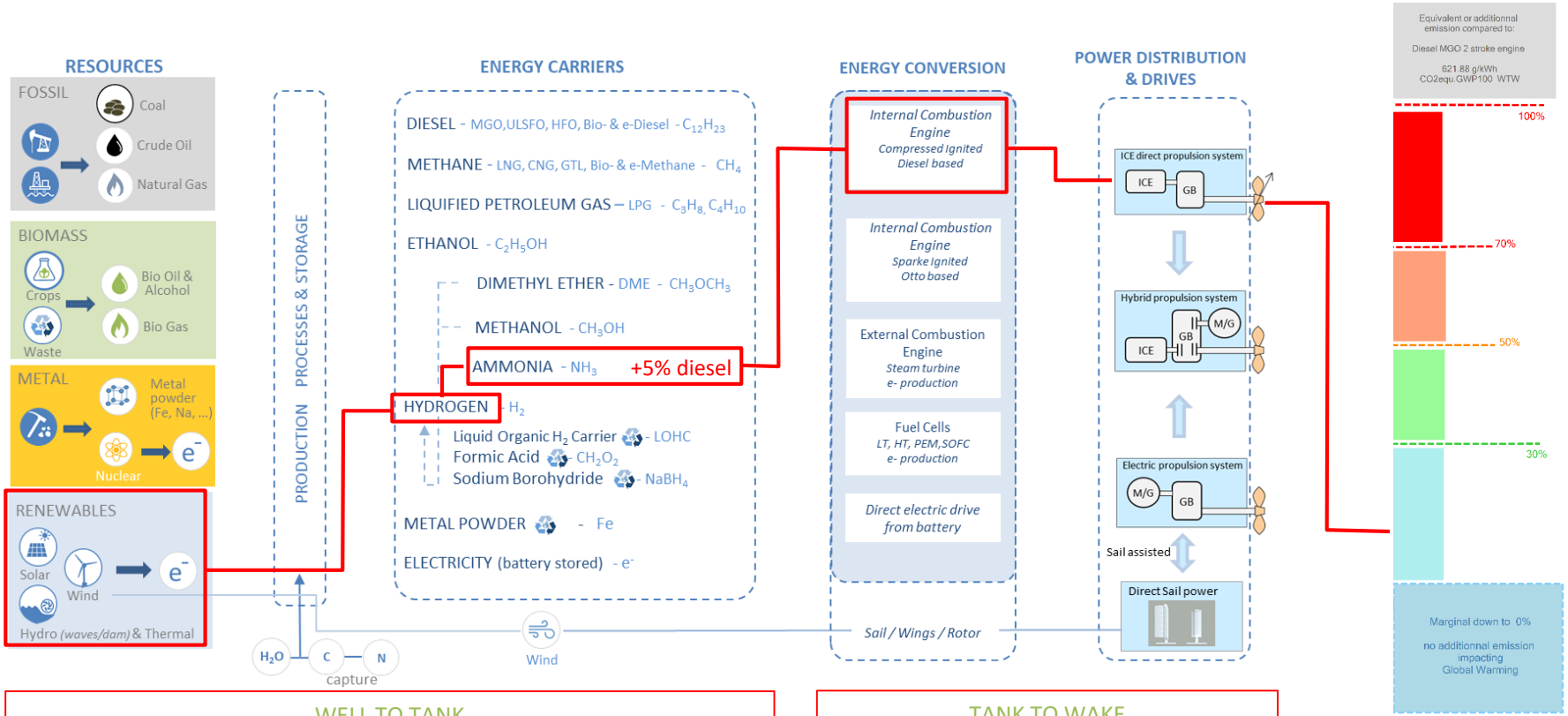
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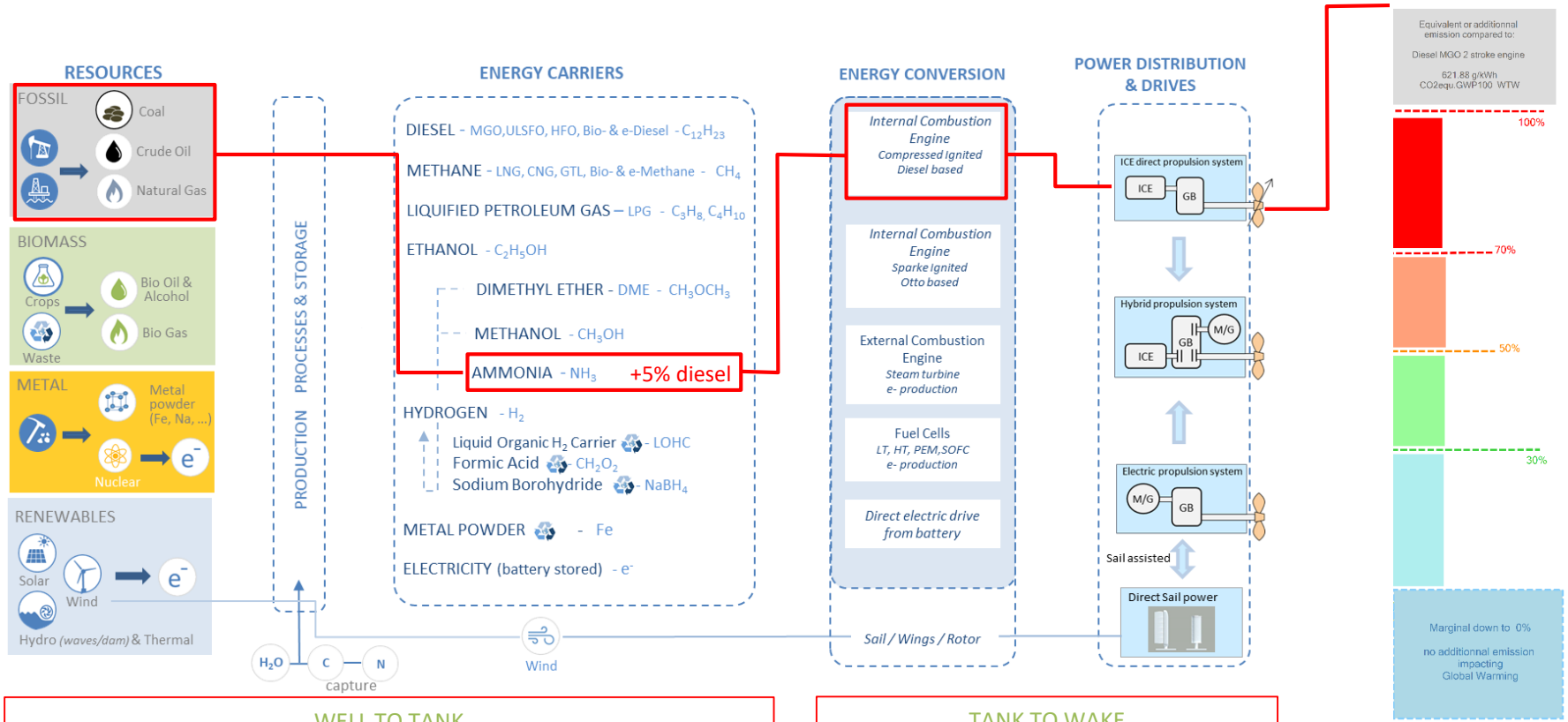
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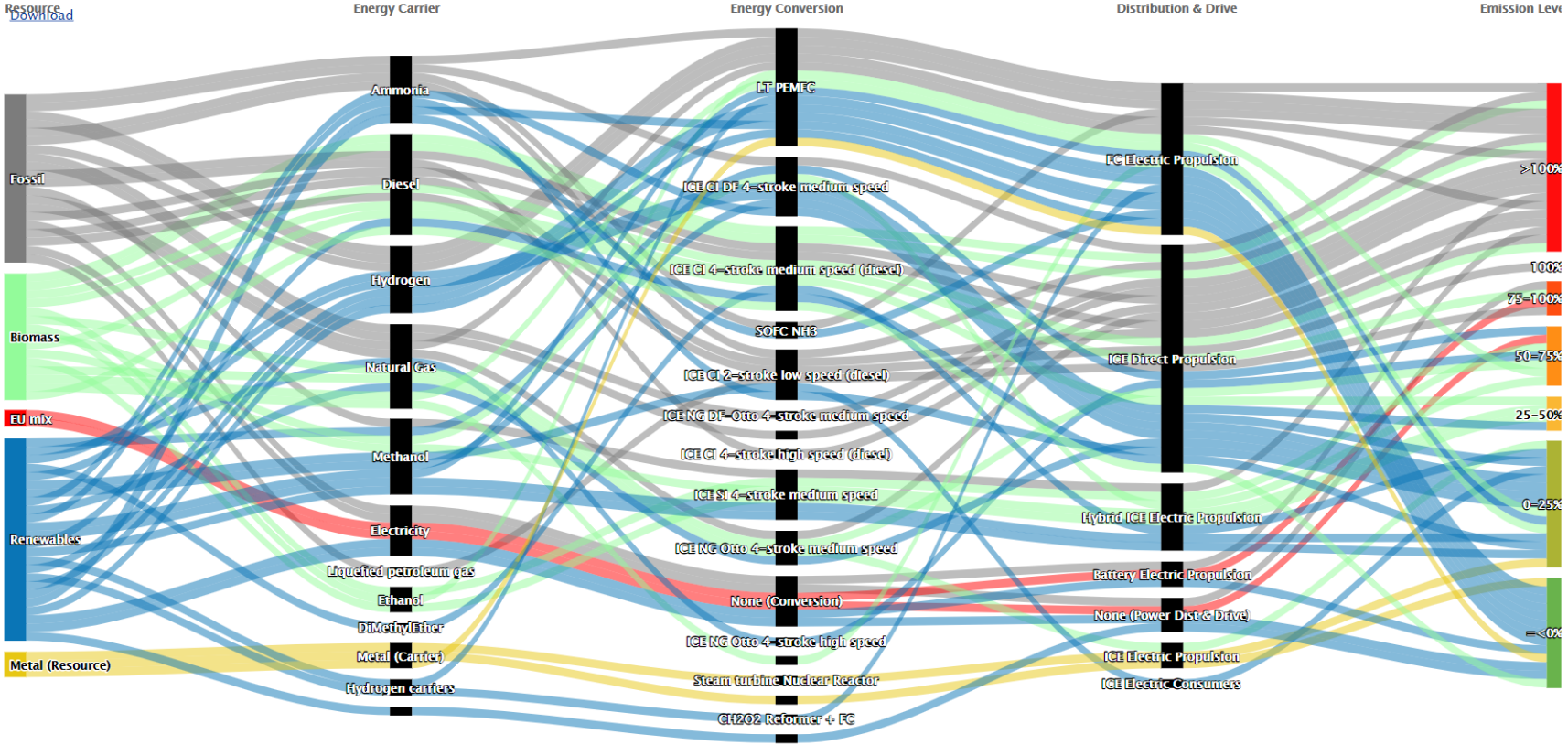
Resource
Download
Energy Carrier
Energy Conversion
Distribution & Drive
Emission Leve
Fossil
Biomass
EU mix
Renewables
Metal (Resource)
Ammonia
Diesel
Hydrogen
Natural Gas
Methanol
Electricity
Liquefied petroleum gas
Ethanol
DiMethylEther
Metal (Carrier)
Hydrogen carriers
LT PEMFC
ICE CI DF 4-stroke medium speed
ICE CI 4-stroke medium speed (diesel)
SOFC NH3
ICE CI 2-stroke low speed (diesel)
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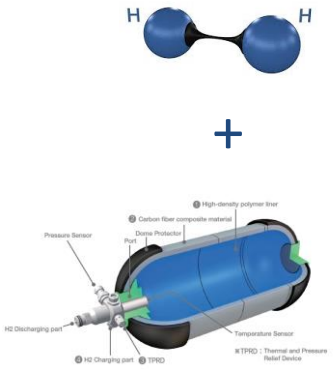
ICE CI 4-stroke high speed (diesel)
ICE SI 4-stroke medium speed
ICE NG Otto 4-stroke medium speed
None (Conversion)
ICE NG Otto 4-stroke high speed
Steam turbine Nuclear Reactor
CH2O2 Reformer + FC
FC Electric Propulsion
ICE Direct Propulsion
Hybrid ICE Electric Propulsion
Battery Electric Propulsion
None (Power Dist & Drive)
ICE Electric Propulsion
ICE Electric Consumers
>100%
100%
75-100%
50-75%
25-50%
0-25%
=<0%

ENERGY CARRIER MAIN PHYSICAL PROPERTY

ENERGY DENSITY

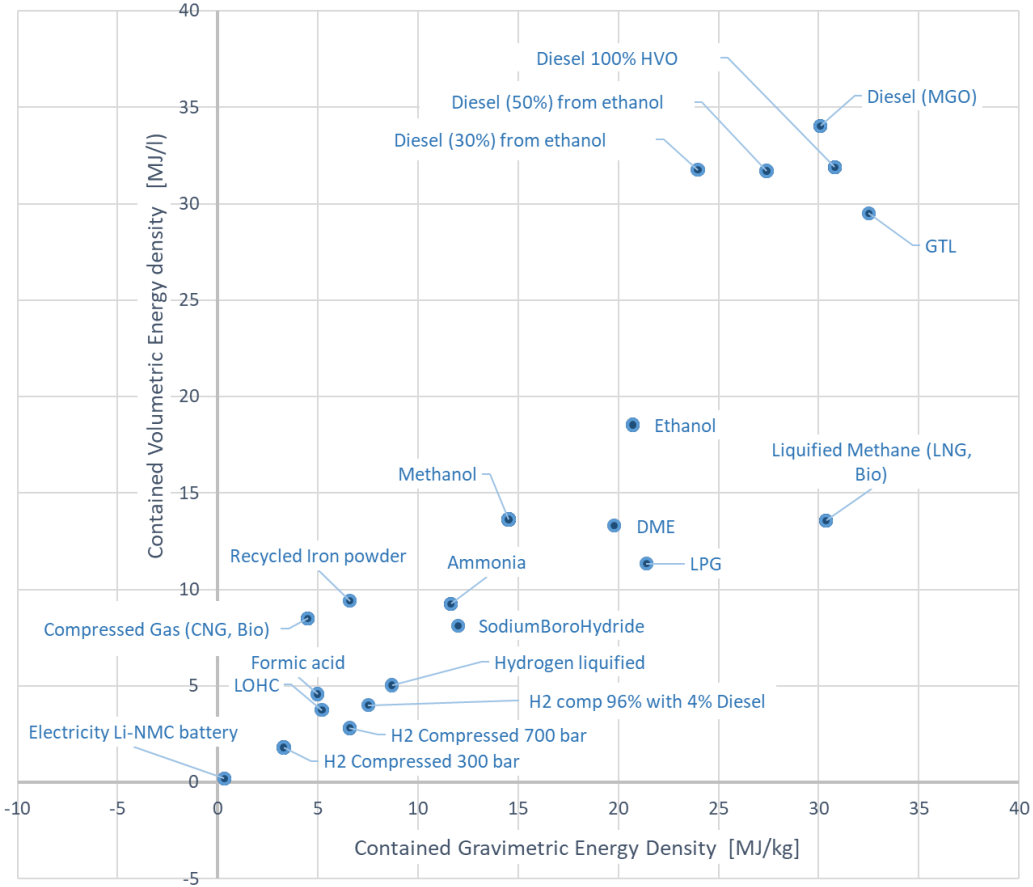
Contained energy density:

Weight (or volume) of the molecule & its containment system



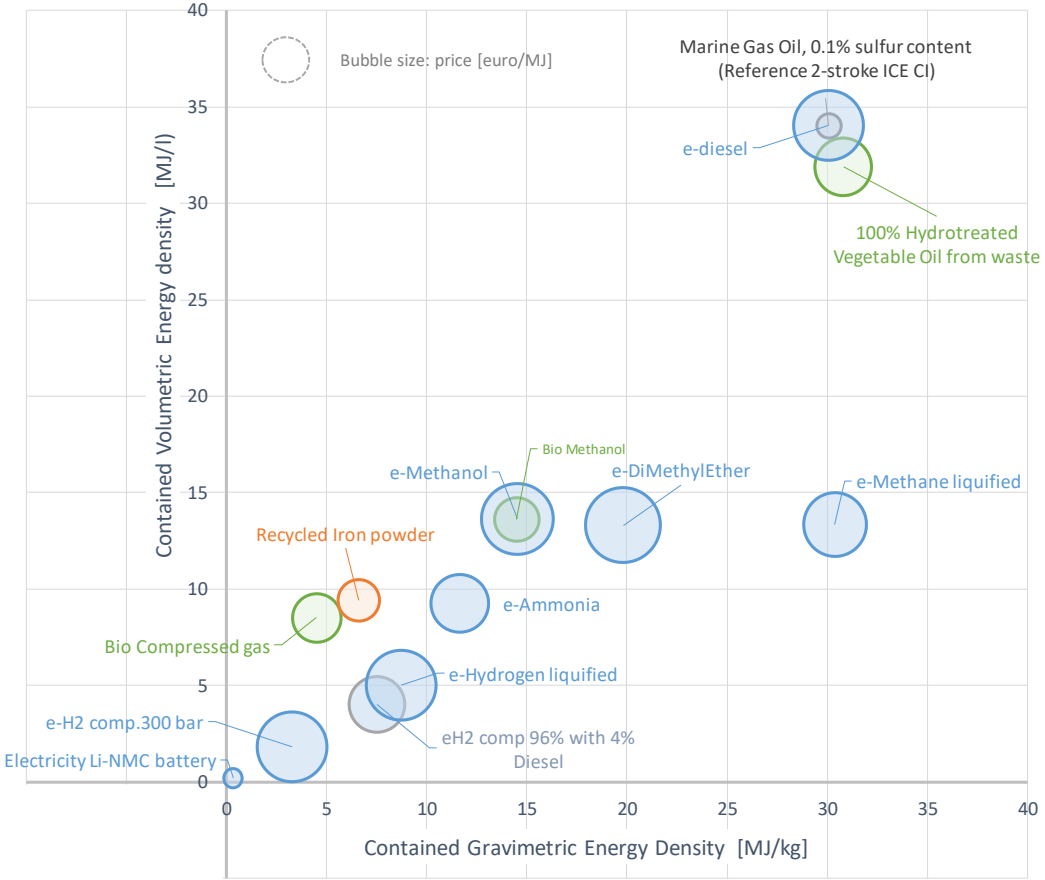
Contained Energy Density of energy carriers (volumetric & gravimetric)

Weight & Volume of the containment system is included in the density



Physical properties of Sustainable Alternative Energy Carriers & price per energy unit

Selection of the solutions matching de 70% emission reduction



Physical properties of Sustainable Alternative Energy Carriers & price per energy unit

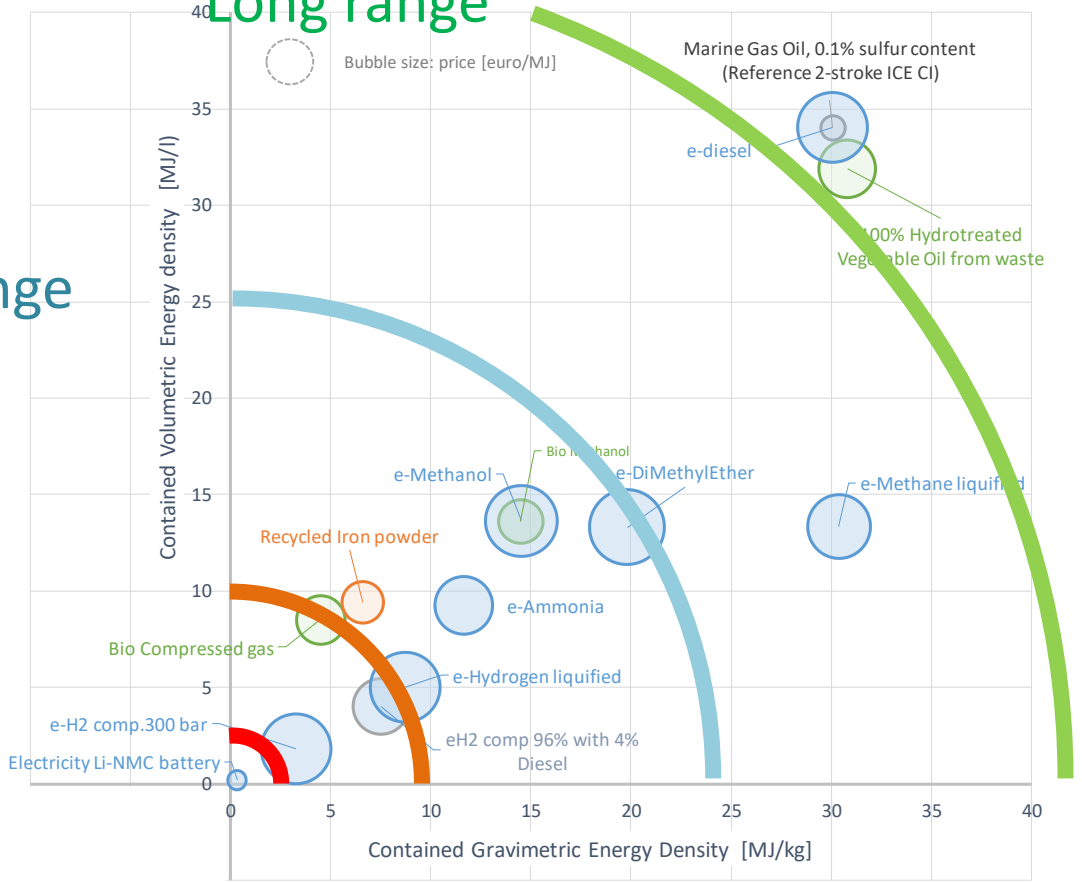
Selection of the solutions matching de 70% emission reduction

Long range

Mid range

Short range

Low autonomy

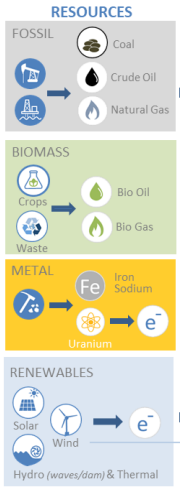


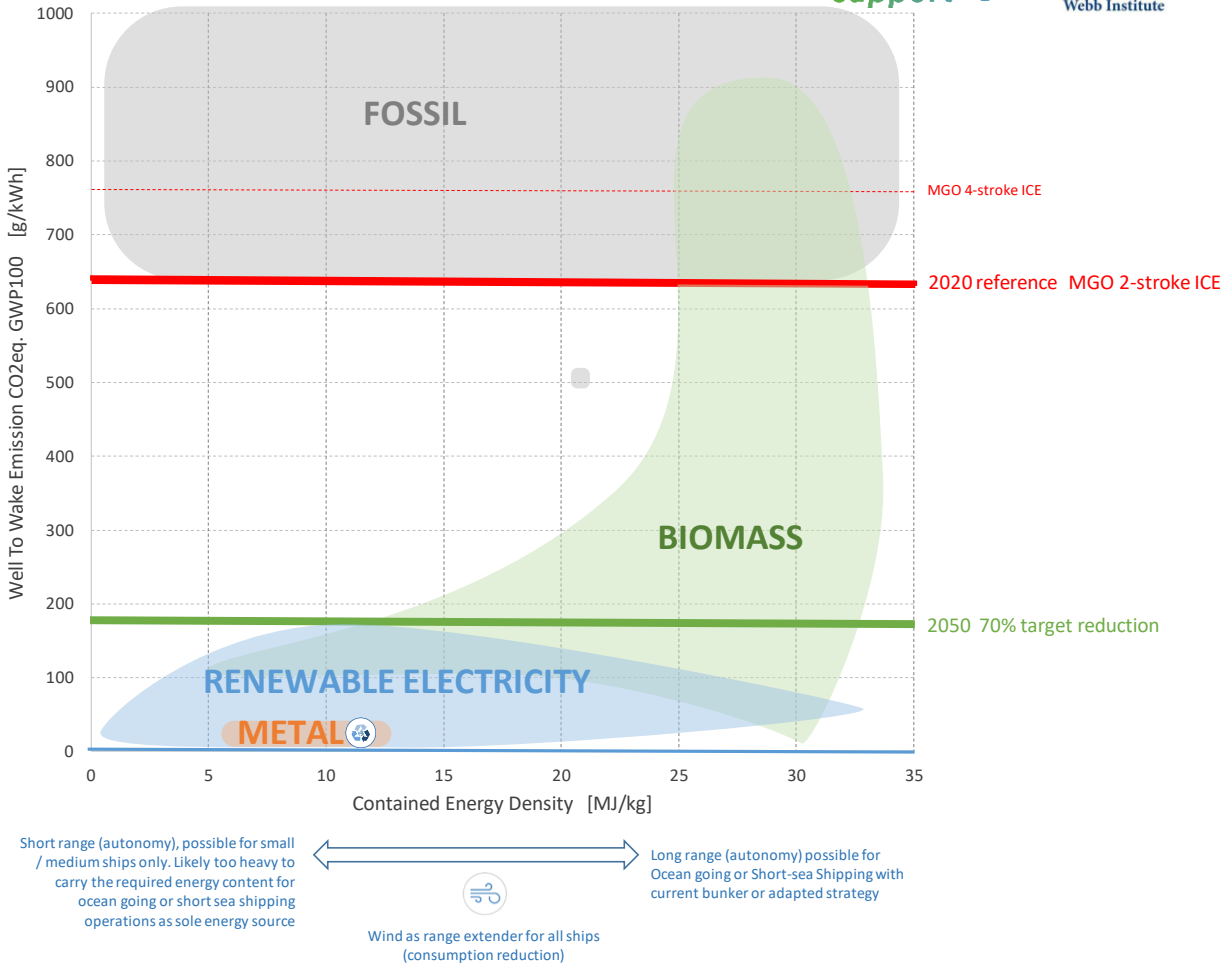
ENERGY CARRIER PRODUCTION PATHWAYS & CONVERSION SYSTEMS

&

WTW EMISSIONS

Global results per type of resource



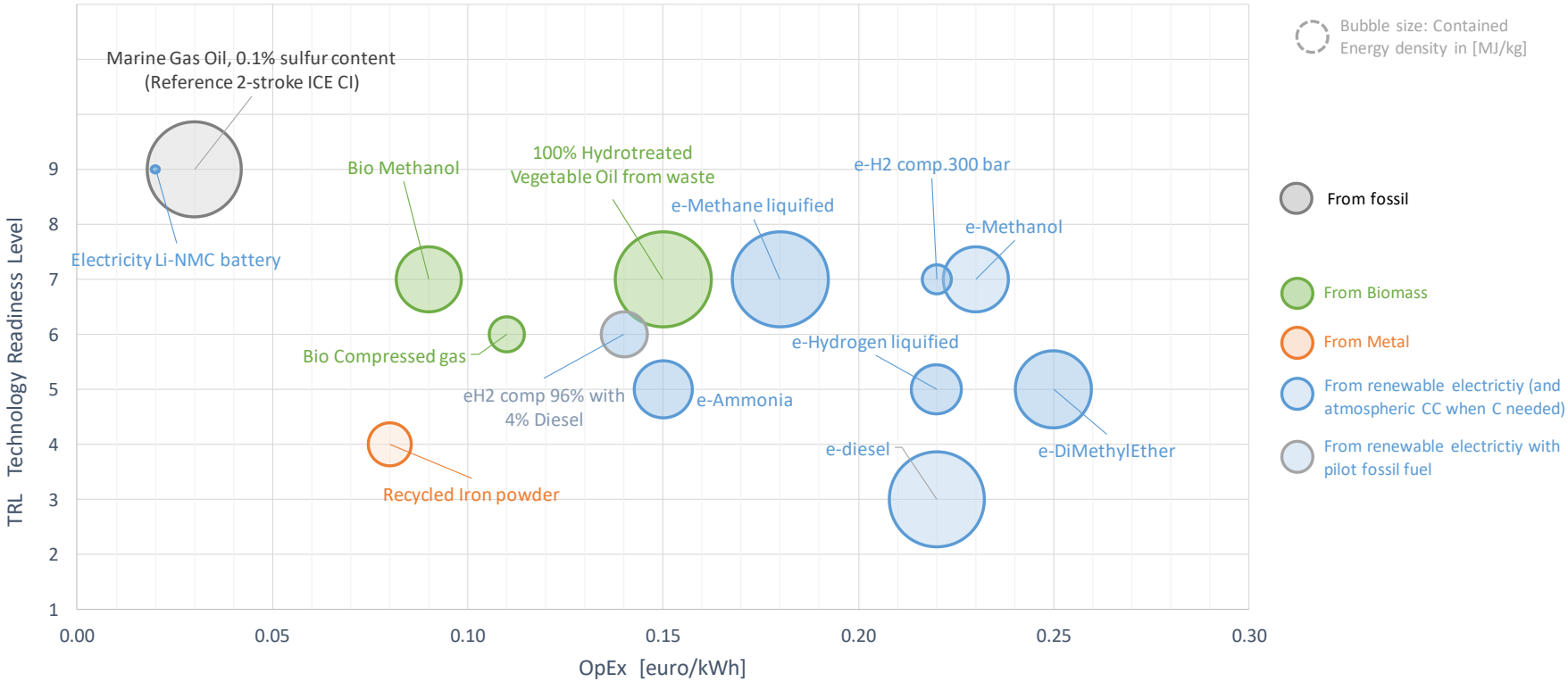


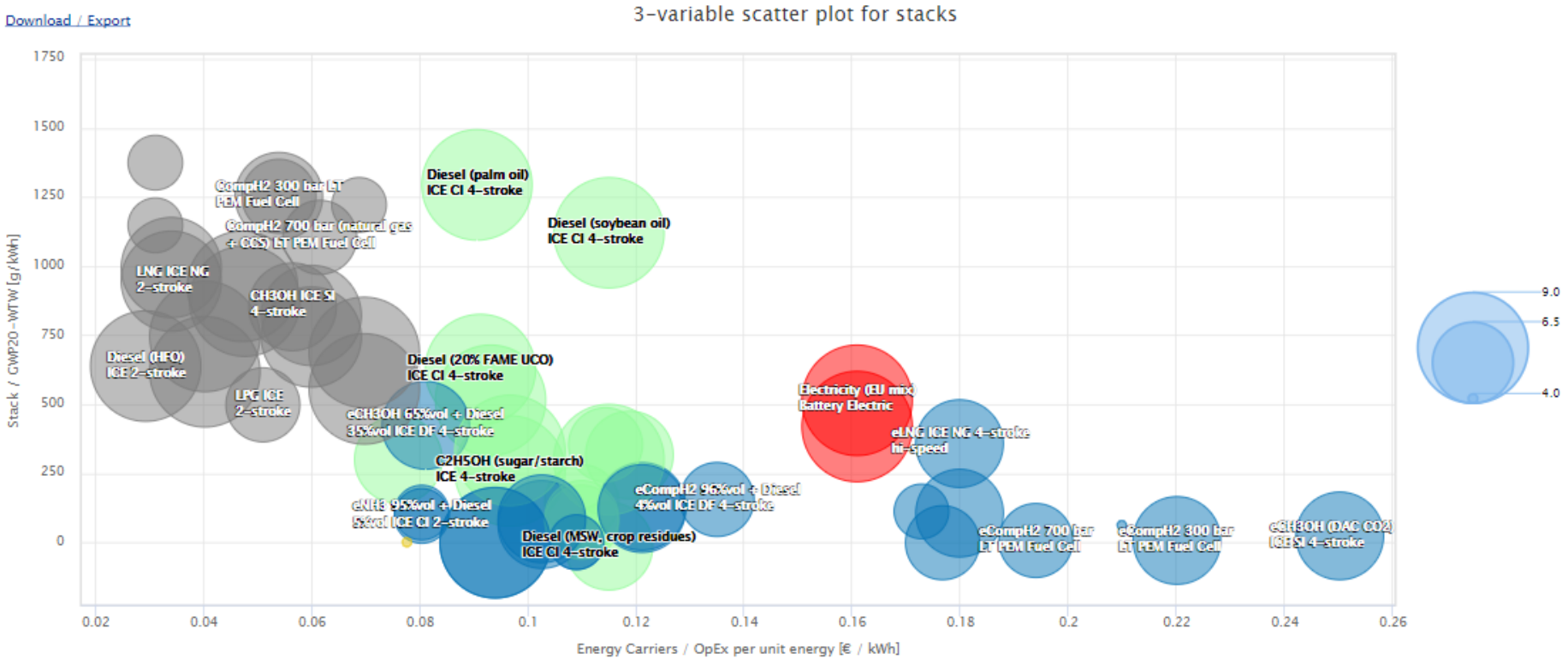
ENERGY CARRIER:

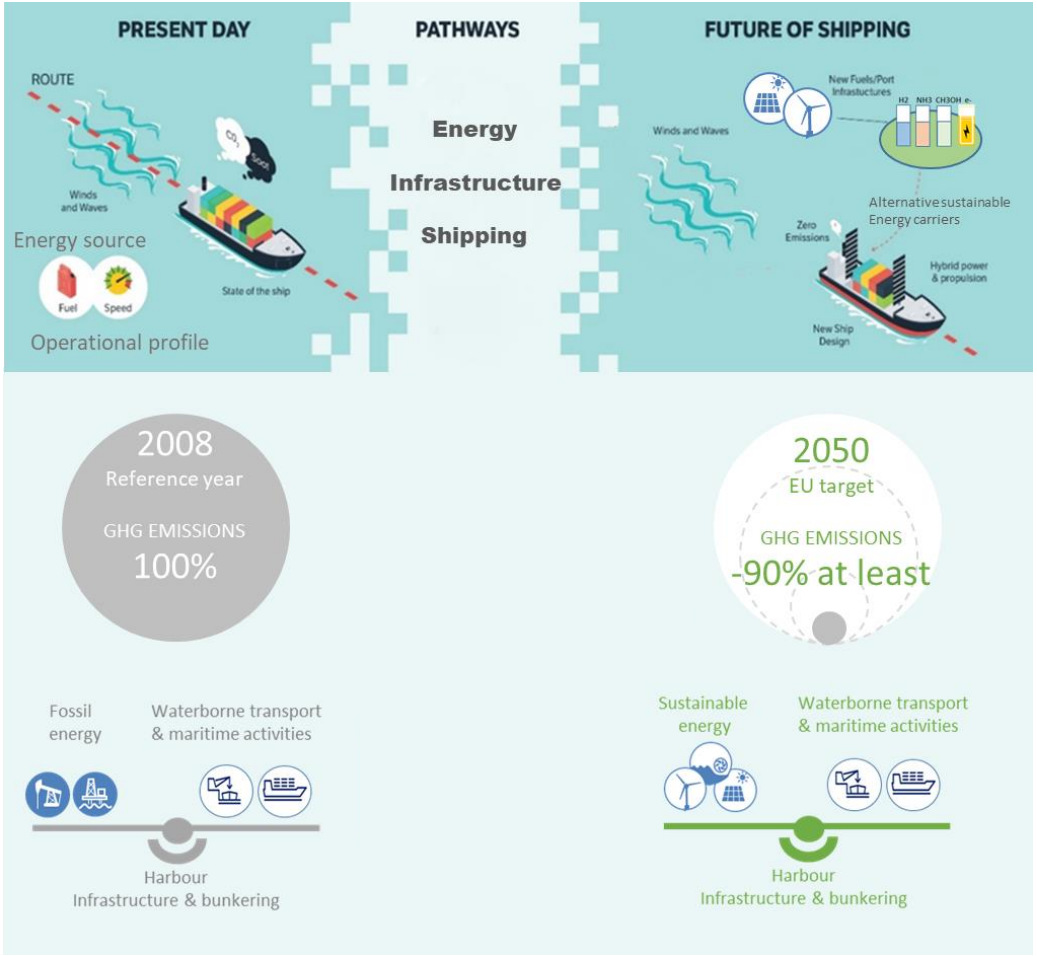
ENERGY DENSITY
&
TRL + COST (OpEx)

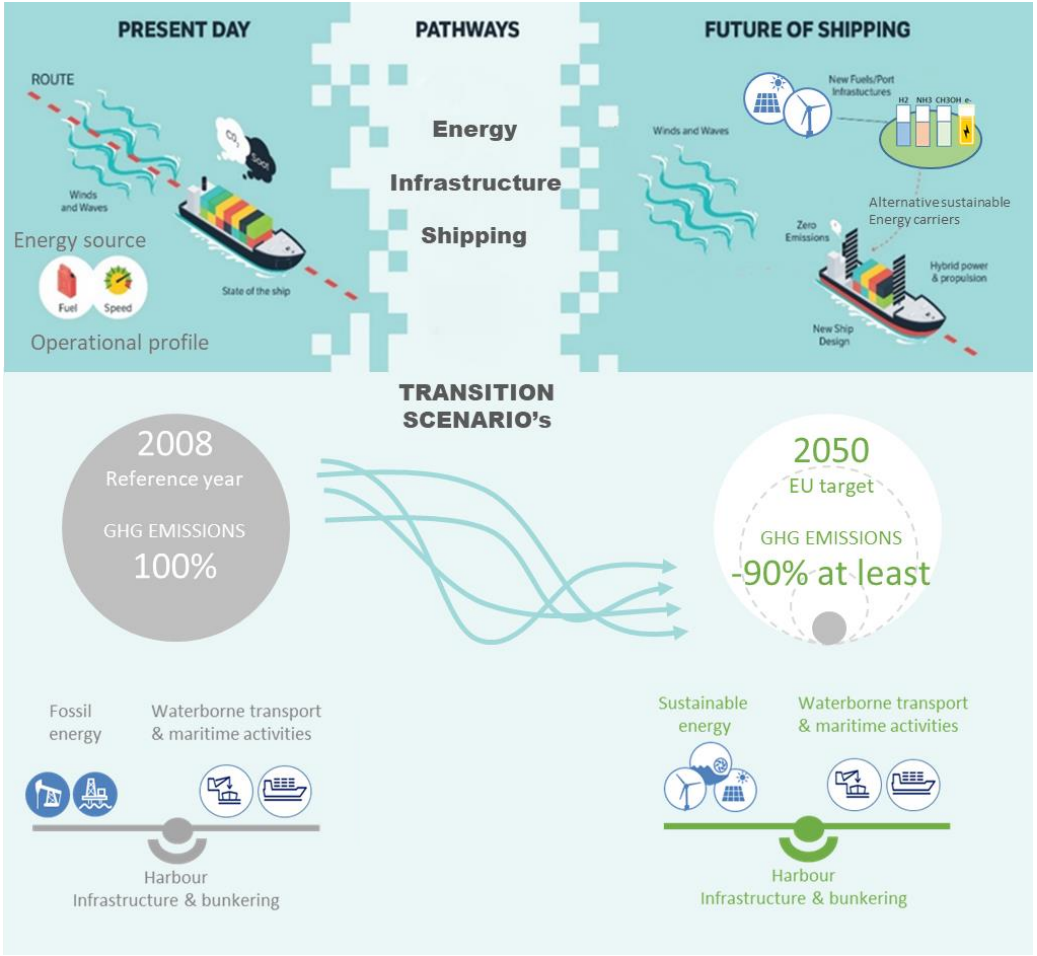
Properties of alternative sustainable powering solutions compared to Diesel MGO in 2-stroke ICE

Selection of carriers combined with power distribution systems, meeting 2050 targets (at least 70% reduction of CO2 eq. GWP100 in [g/kWh])




Download / Export
3-variable scatter plot for stacks
Stack / GWP20-WTW [g/kWh]
Energy Carriers / OpEx per unit energy [€ / kWh]
1750
1500
1250
1000
750
500
250
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
CompH2 300 bar LT PEM Fuel Cell
CompH2 700 bar (natural gas + CCS) LT PEM Fuel Cell
LNG ICE NG 2-stroke
CH3OH ICE SI 4-stroke
Diesel (HFO) ICE 2-stroke
LPG ICE 2-stroke
Diesel (palm oil) ICE CI 4-stroke
Diesel (soybean oil) ICE CI 4-stroke
Diesel (20% FAME UCO) ICE CI 4-stroke
eCH3OH 65%vol + Diesel 35%vol ICE DF 4-stroke
C2H5OH (sugar/starch) ICE 4-stroke
eNH3 95%vol + Diesel 5%vol ICE CI 2-stroke
Diesel (MSW, crop residues) ICE CI 4-stroke
eCompH2 96%vol + Diesel 4%vol ICE DF 4-stroke
Electricity (EU mix) Battery Electric
eLNG ICE NG 4-stroke hr-speed
eCompH2 700 bar LT PEM Fuel Cell
eCompH2 300 bar LT PEM Fuel Cell
eCH3OH (DAC CO2) ICE SI 4-stroke
9.0
6.5
4.0


PRESENT DAY
PATHWAYS
FUTURE OF SHIPPING
ROUTE
Winds and Waves
Energy source
Fuel
Speed
State of the ship
Operational profile
Energy
Infrastructure
Shipping
New Fuels/Port Infrastuctures
H2 NH3 CH3OH e-
Winds and Waves
Alternative sustainable Energy carriers
Zero Emissions
Hybrid power & propulsion
New Ship Design
2008
Reference year
GHG EMISSIONS
100%
2050
EU target
GHG EMISSIONS
-90% at least
Fossil energy
Waterborne transport & maritime activities
Harbour
Infrastructure & bunkering
Sustainable energy
Waterborne transport & maritime activities
Harbour
Infrastructure & bunkering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Waterborne transport & maritime activities
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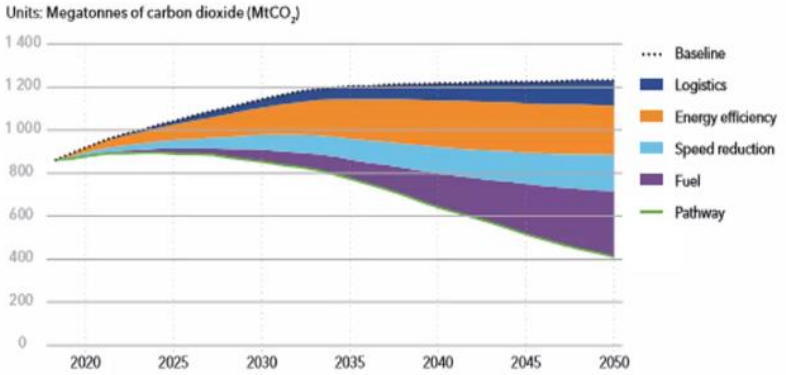
Infrastructure & bunkering
Sustainable energy
Waterborne transport & maritime activities
Harbour
Infrastructure & bunkering

Ways to reduce maritime emissions

Meeting the climate targets would require significant progress on two aspects:

- Improvement of energy efficiency (covering logistics, design, technical improvements and operations) – ***i.e. using less fuel***
- Greater use of renewable and low carbon fuels – *i.e.* ***using cleaner fuels***



DNV-GL (2019) | Maritime Forecast to 2050

European Commission | Mobility and Transport

Take aways

(part 1 – context energy transition)

- There are many technical solutions to power ships with ultra low emission level, from wheel to wake. It is the choice which is currently difficult.
- Scalability of the supply of sustainable alternative energy carrier is an issue for the coming decades (we need more renewable electricity, probably incl. nuclear…).
- Energy supply logistics and bunkering, as well as role of harbor, will be key in the energy transition (large impact upcoming).
- Energy carriers and power conversion systems providing zero emission solutions will not allow to keep the current autonomy and range of ships. Additional power source and energy use reduction are going to be key in new designs (because of scarcity of sustainable energy and lower energy density of alternative energy carriers)

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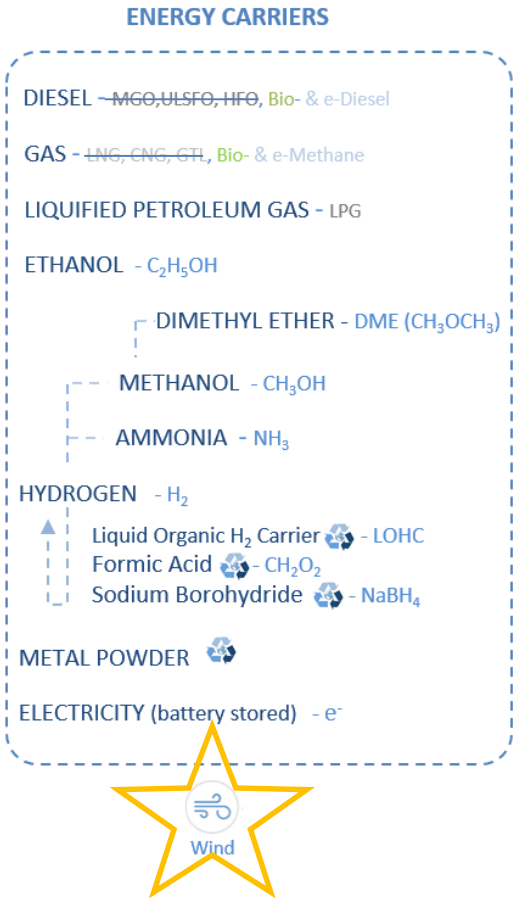
and here the wind begins to blow …



Engine/propeller as prime mover & wind assistance

wind: 5 to 15% total power supply

Possible refit on existing ships, no hull or appendages modifications

Hybrid engine / wind propulsion

Wind: 15 to 40% of total power supply

Requirements for additional appendages (drift/leeway)

Main wind propulsion & engine assistance

Wind: up to 100% of total power supply

Dedicated hull form & appendages


IWSA
International Windship Association
Decade of
Wind Propulsion
Home
Upcoming Activities
Decade of
Wind Propulsion
2021-2030
K LINE
airseas
MAGNUSS
Scandlines

Natural propulsion for Transport & Shipping: potential and expectations in the present context

Thank you for your attention!