We deliver sustainable energy solutions

8th July 2021 – Monaco Energy Boat Challenge

Energy solutions, analysis of their environmental benefits - a keynote speech reflecting on the solutions available today for the yachting & maritime industry

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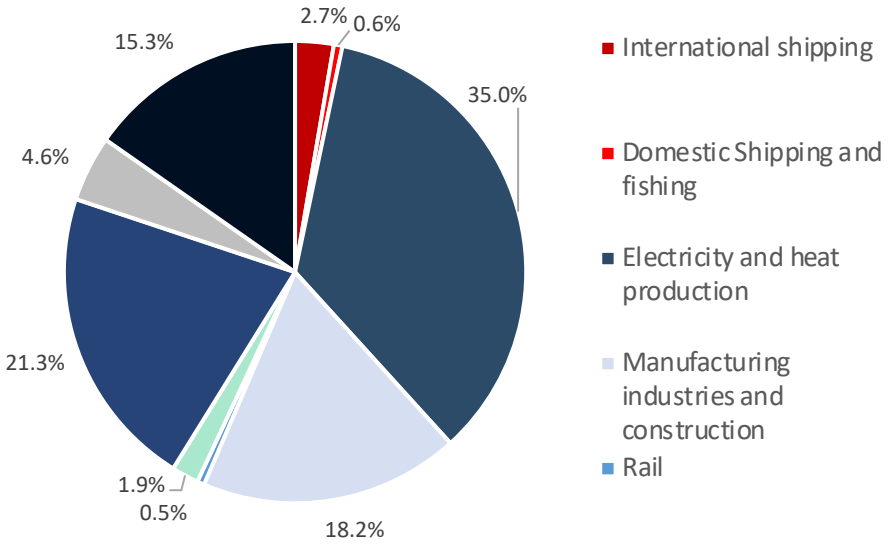
Introduction - Observations

- CO2 emissions produced by maritime sectors account for approximately **3.3%** of global anthropogenic GHG [4]
- **70%** of emissions generated within **400 km** of mainland, especially in close proximity to ports [4]
- IMO imposing limits on the GHG emissions through ship energy efficiency regulations for new constructions (EEDI, EEOI, SEEMP)

CO2 emissions from shipping industry compared with global total emissions



[4] Nuchturee et. al. , 2020

Source: Adapted from [4]

Introduction – what solutions ?

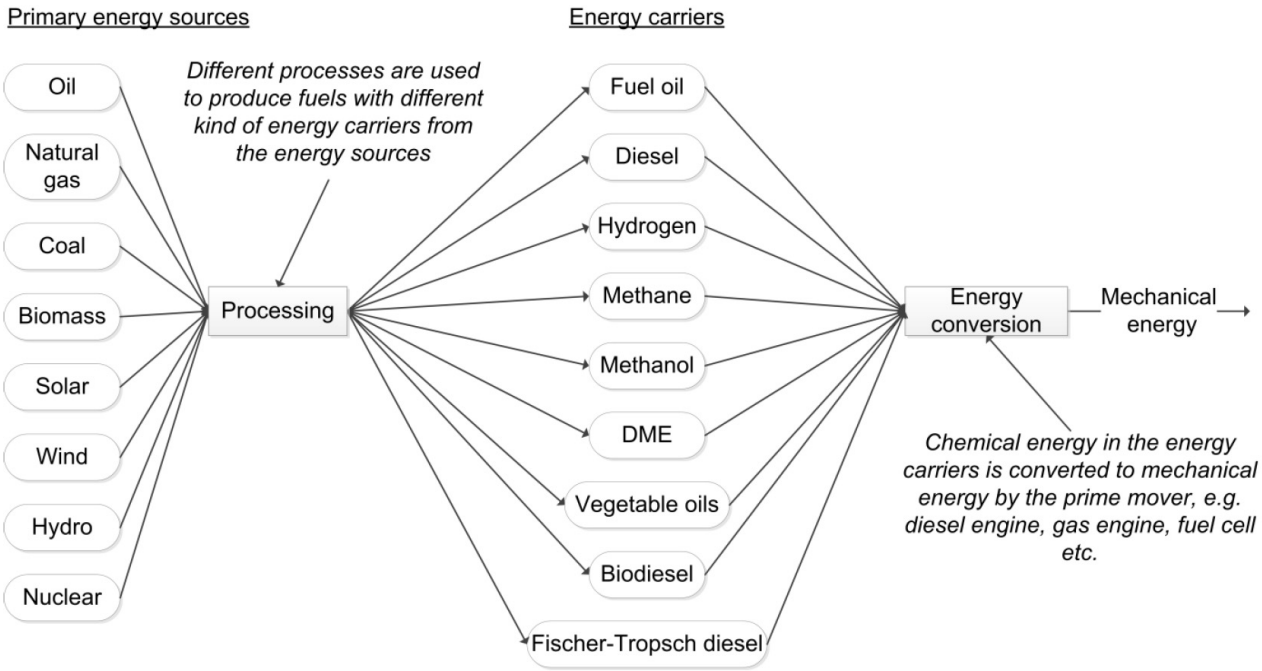


Figure 3-1 A simplified diagram of the chain from energy resources to mechanical energy for marine propulsion.

Source: [5] Brynolf, 2014

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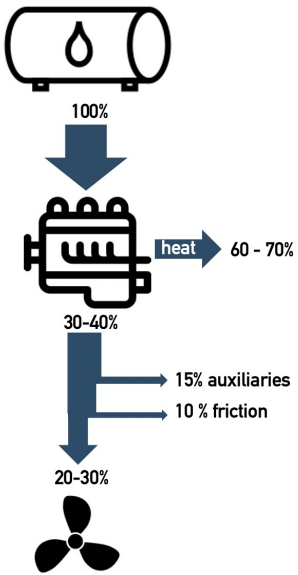
Energy efficiency of propulsion systems - from tank to propeller

ICE engine
(HFO, MGO, GNL, BTL, LBG)

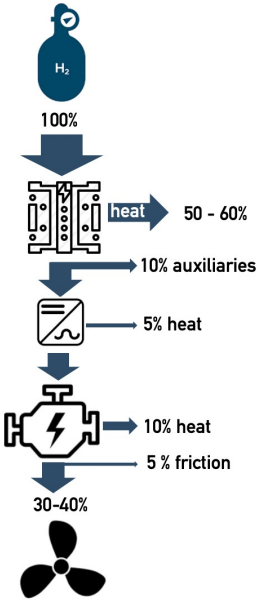
4 kWh final energy



1 kWh useful energy

FC + electric engine (H2)

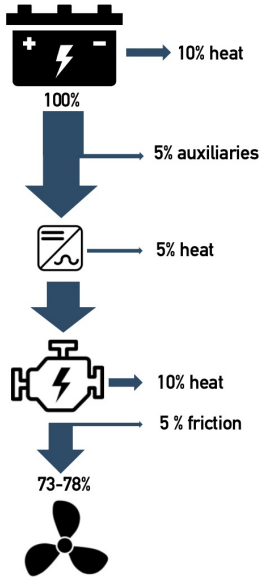
2.74 kWh final energy



1 kWh useful energy

Battery + electric engine

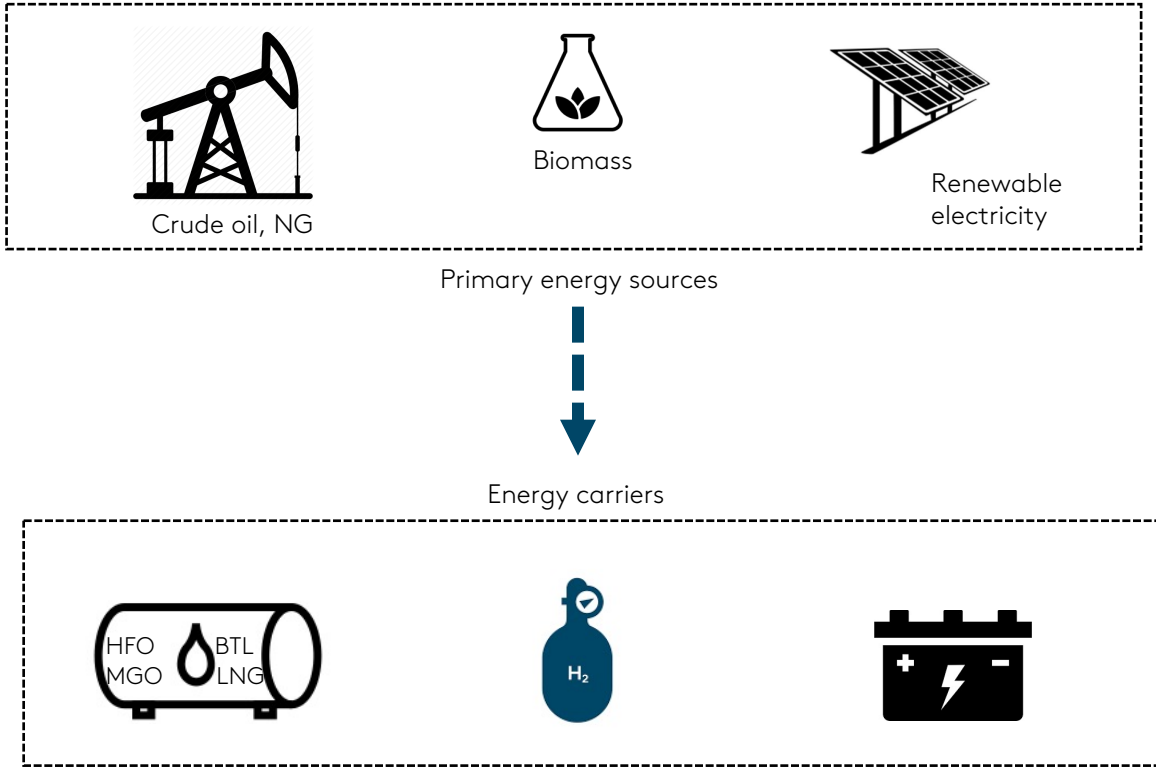
1.3 kWh final energy



1 kWh useful energy

Sources: [4] Nuchturee et. al. , 2020; Internal documentation

Energy efficiency of propulsion systems - from well to tank



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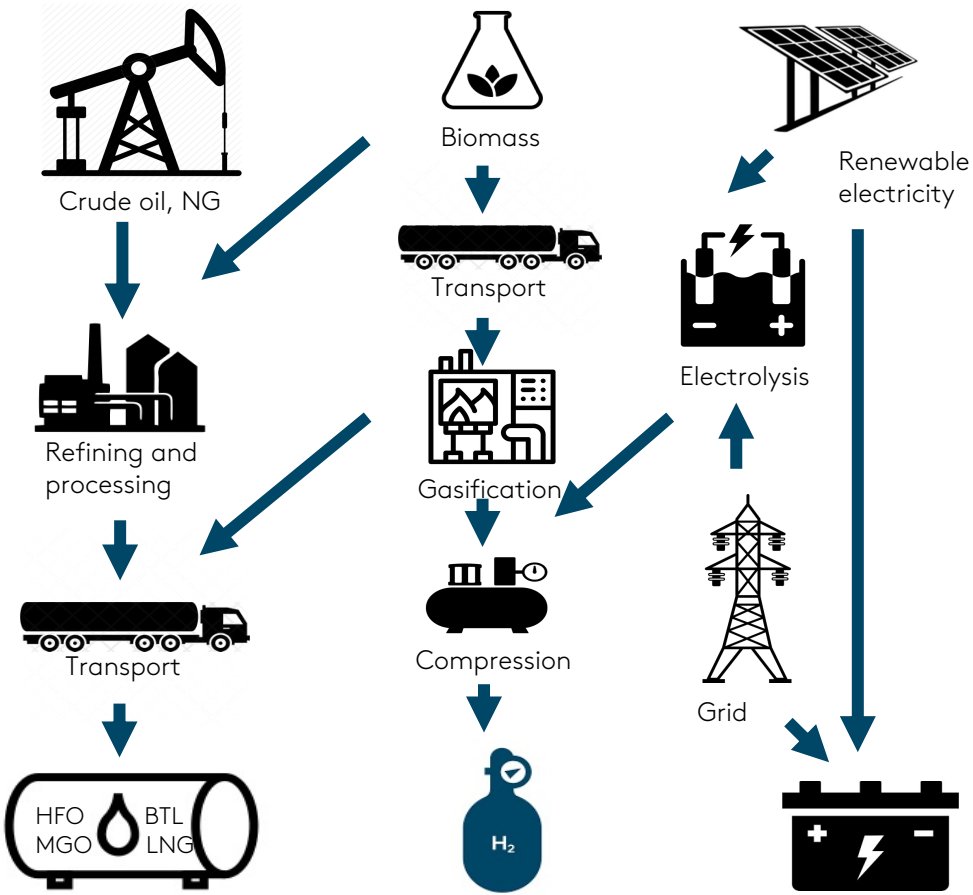

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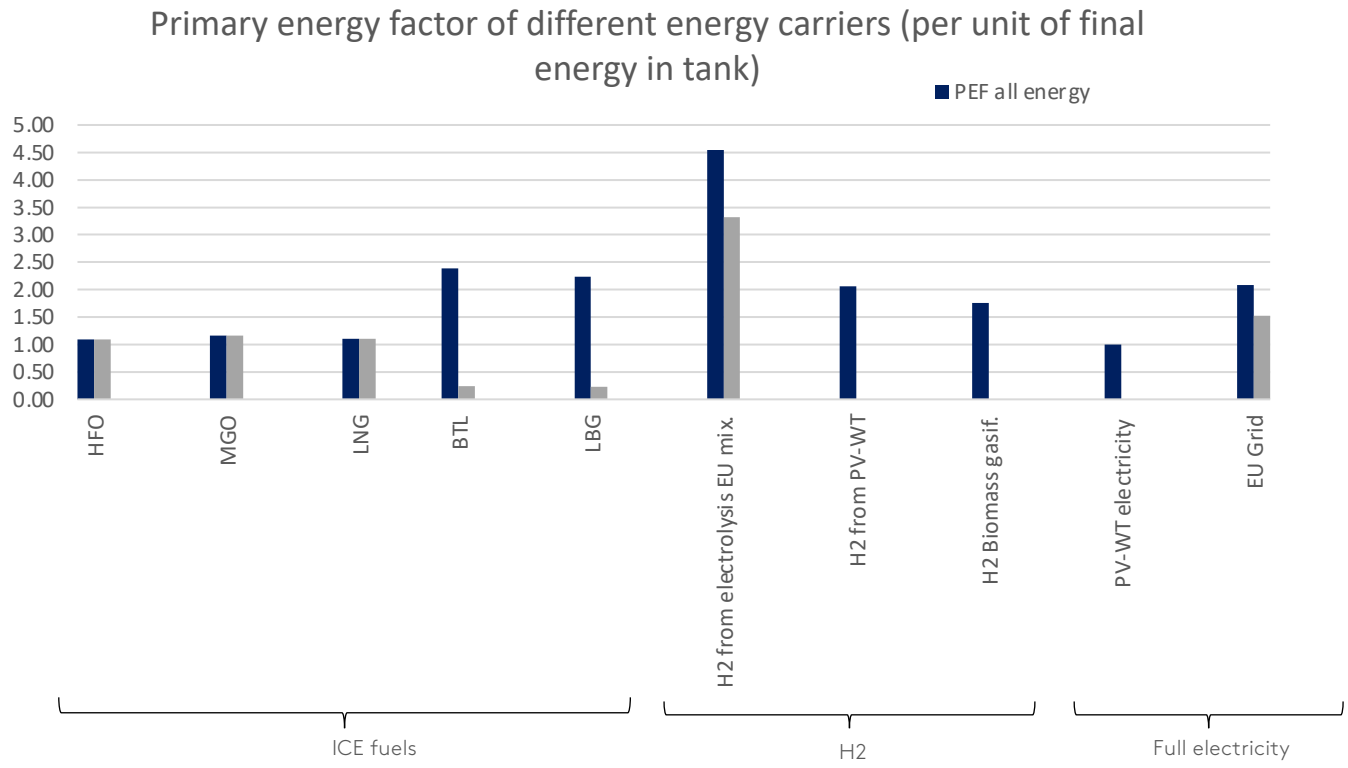
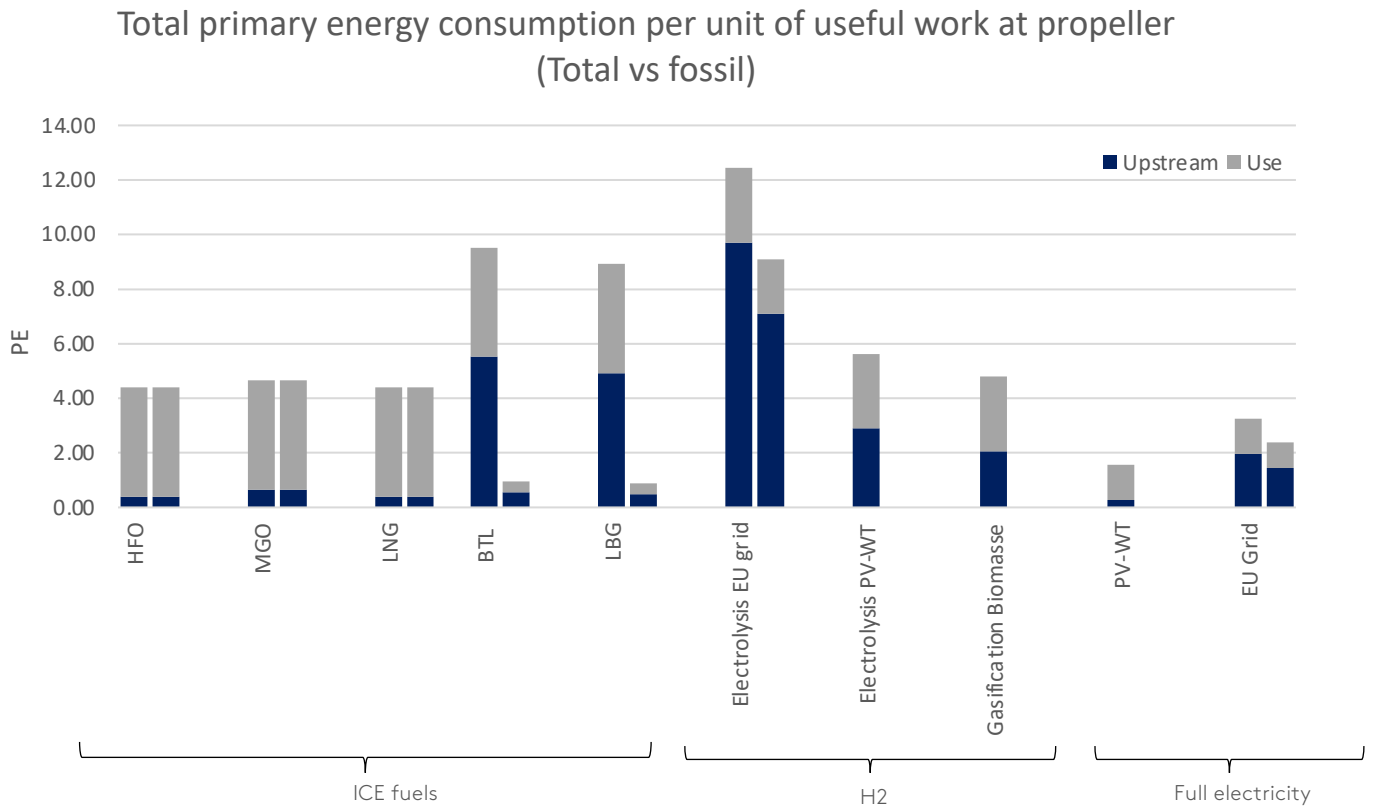


Sources: [5] Brynolf, 2014, [9] Esser et. al., 2016

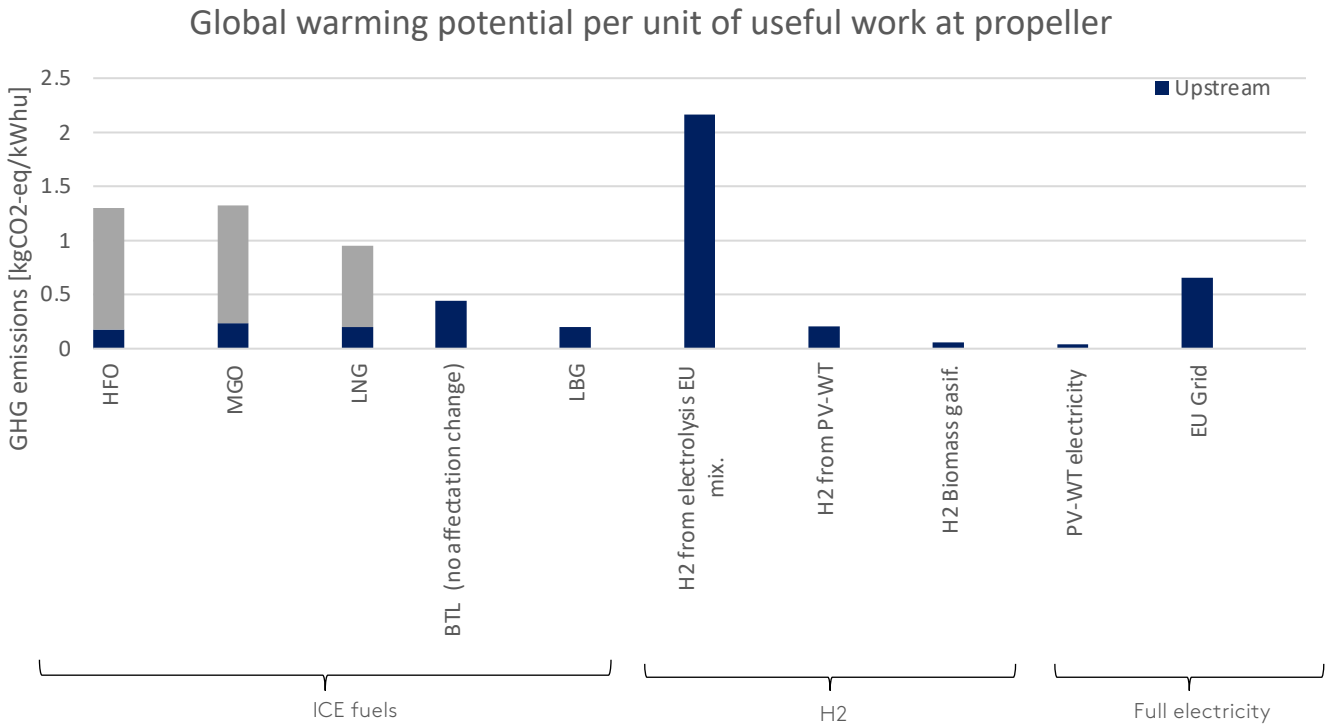
Overall energy efficiency - from well to propeller



Sources: [1] Bengtsson et. al, 2011, [5] Brynolf, 2014, [8] Baldi et. al., 2013, [9] Esser et. al., 2016

GHG emissions from well to propeller

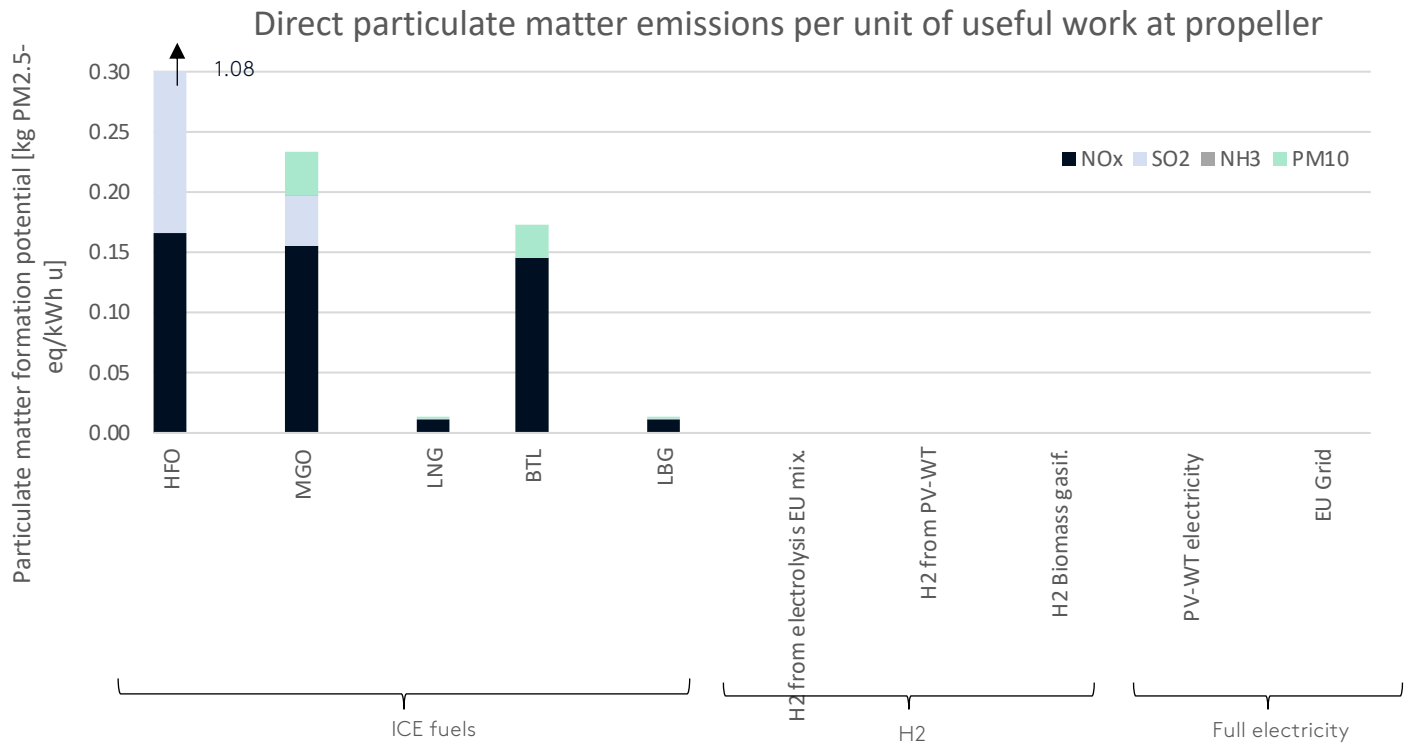
- Eq. CO_2 emissions includes weighted impact of CO_2, CH_4, N_2O over 100 years



Source: [2] ADEME,2021; [16] Mehmeti, 2018; [17] Cetinkaya, 2012; [19] Salkuyeh, 2018

Particulate matter emissions - from tank to propeller

- Eq. 2.5μm particulate matter emissions have both impact on health and on climate change



Sources: [1] Bengtsson et. al, 2011, [5] Brynolf, 2014, [8] Baldi et. al., 2013

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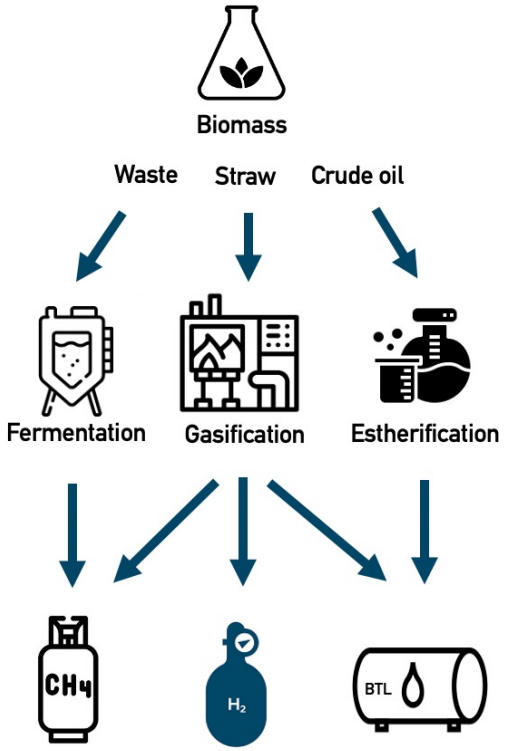
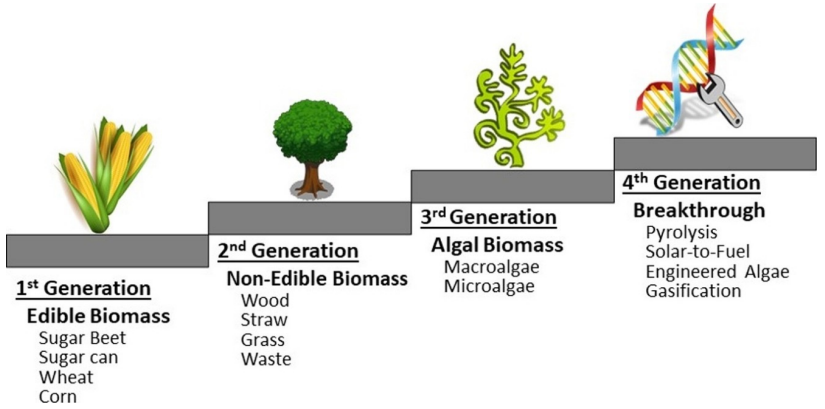
Biomass derived fuel : what perspectives and barriers?



[11] Hartman,2008



Source: [6] Alalwan,2019

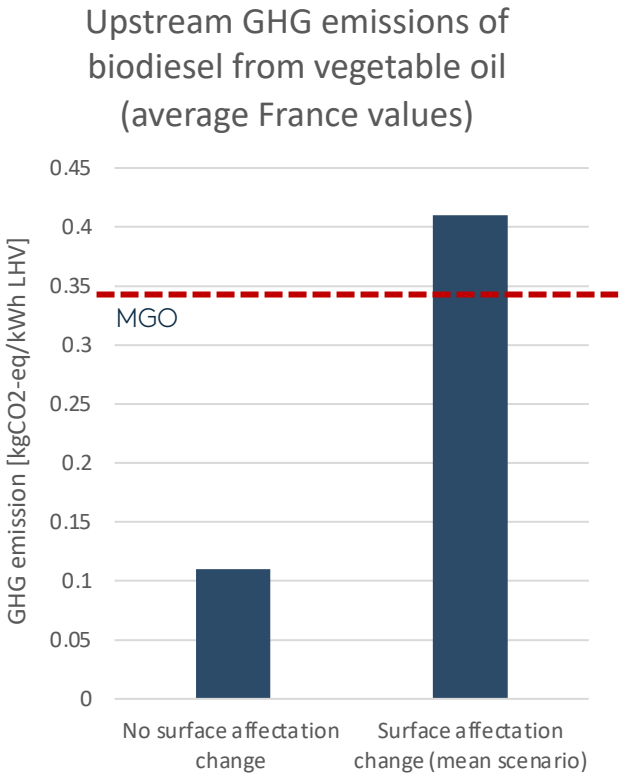
- First generation biomass (vegetable oils): **competition with the food industry, degradation of arable land** due to high production yields

- Production from algae represents a **large-scale production potential** (better biomass yield) : 1kWh of fuel requires 10 times more surface area if produced from palm oil than from algae fermentation [11]

Biomass derived fuel : example of biodiesel

- Change of surface affectation : major environmental problems linked to the exploitation of palm oil in Indonesia (**deforestation, loss of biodiversity, pollution by pesticides, etc.**). Palm oil is the **most widely used** (20% of world consumption of this oil in 2018, the main factor in deforestation due to this fruit [10])

- **Production cost of $0.07/kWh to 0.1 $/kWh** (for a European rapeseed oil chain) The price of the raw material accounts for the majority of the total production cost. **The high production cost is the main obstacle to the development of the sector** [12].



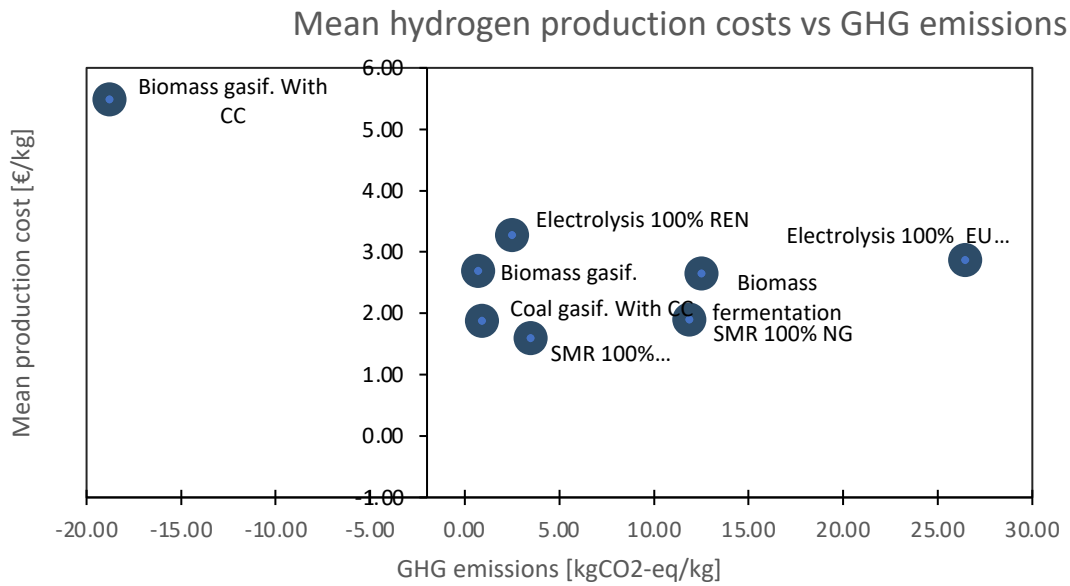
Source: [2] ADEME,2021

[10] Wikipedia, 2021, [12] Gebremariam, 2018

Hybrid electrical propulsion system - Hydrogen + battery

- Hydrogen – battery hybridization helps **reducing the mass** of the system while **maximizing its efficiency**

Storage type	Eq. Electrical capacity [kWhe]	Mass [kg]	Volume [m3]
Battery LiFePo	1	11.0	0.009
H2 Cylinder 350bar	1	1.1	0.023



- Announced distribution costs for 2030 in Europe: **1.2 - 2 €/kg** (0.04 - 0.07 €/kWh)

Source: [13]-[20]

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- The balances do not take into account the life cycle of the propulsion technologies and the real total emissions are therefore higher than announced

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Time to shift