



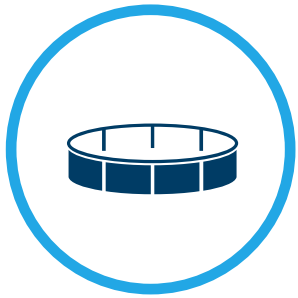
THE GREEN MARITIME FUTURE

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Research manager SINTEF Ocean

Contributions by Gunnar Malm Gamlem, Elizabeth Lindstad, Dag Stenersen

SINTEF Ocean – Research for ocean industries



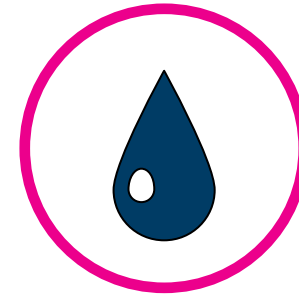
Aquaculture



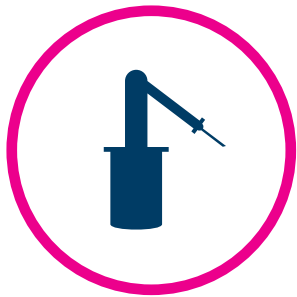
Maritime



Bio marine resources



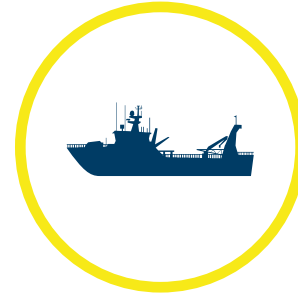
Oil and gas



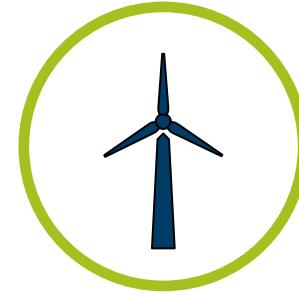
Process industry



Environmental
technology



Fisheries



Offshore wind



SMART MARITIME

Norwegian Centre for improved energy efficiency and reduced harmful emissions



RESEARCH ORGANISATIONS



SINTEF

NTNU



DNV GL



Norges Rederiforbund
Norwegian Shipowners' Association



Kystrederiene

INDUSTRY STAKEHOLDERS



Sjøfartsdirektoratet
Norwegian Maritime Authority

DESIGN, EQUIPMENT, SYSTEMS



SHIP OPERATORS



KONGSBERG



a Fincantieri company



HÖEGH AUTOLINERS



Torvald Klaveness



Rolls-Royce



norwegian electric systems



KRISTIAN GERHARD JEBSEN SKIPSREDERI
PART OF THE KRISTIAN GERHARD JEBSEN GROUP



Wallenius Wilhelmsen Ocean
NTEF

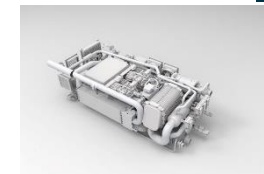
Maritime zero emissions: Research needs

Fleet management and vessel utilization

external conditions,
business models,
human performance

Energy efficiency,
choice of
technology
Energy systems, CCS,
hull, propeller, sail,
foil

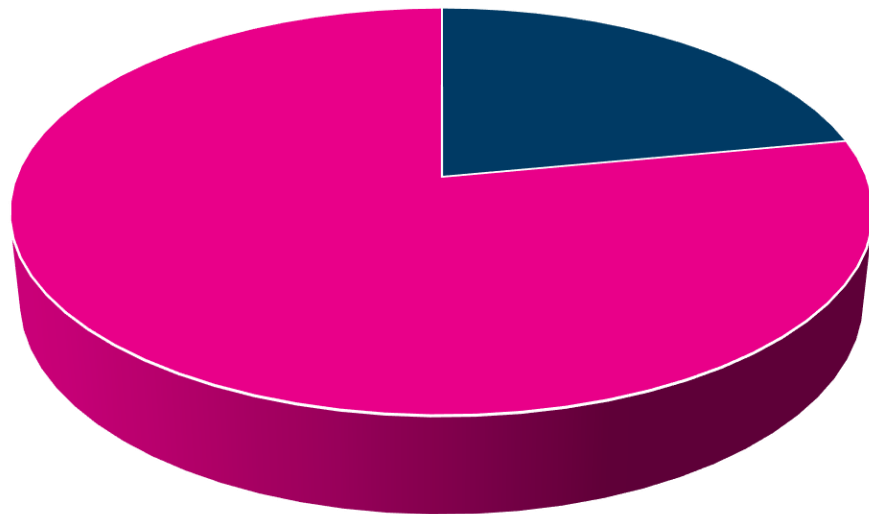
Fuels and energy
carriers
Biogas, biodiesel,
batteries, synthetic
fuels



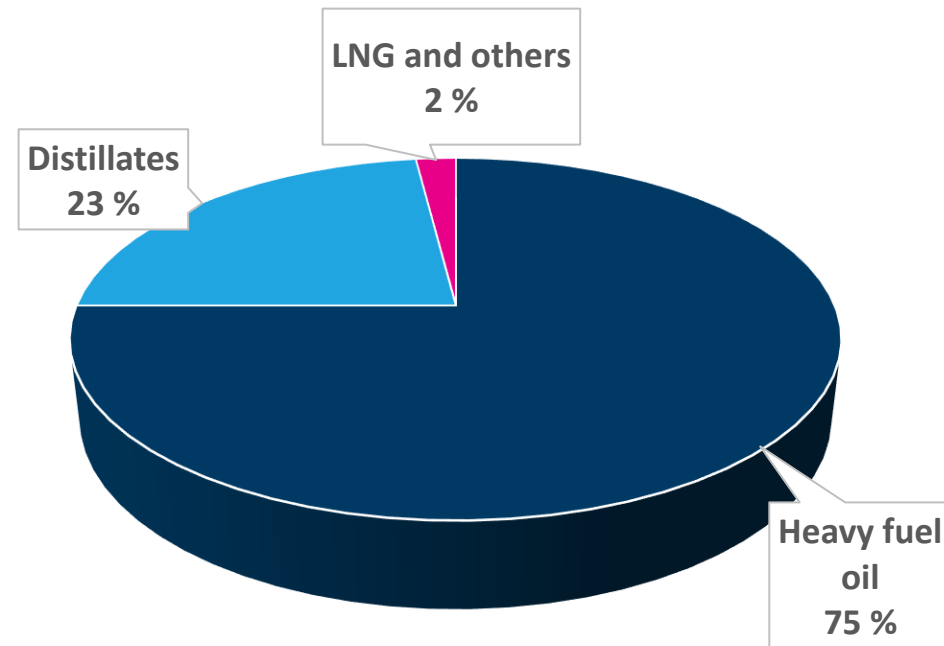
Vessel sizes and consumption

250 - 300 million tons of oil equivalents per year

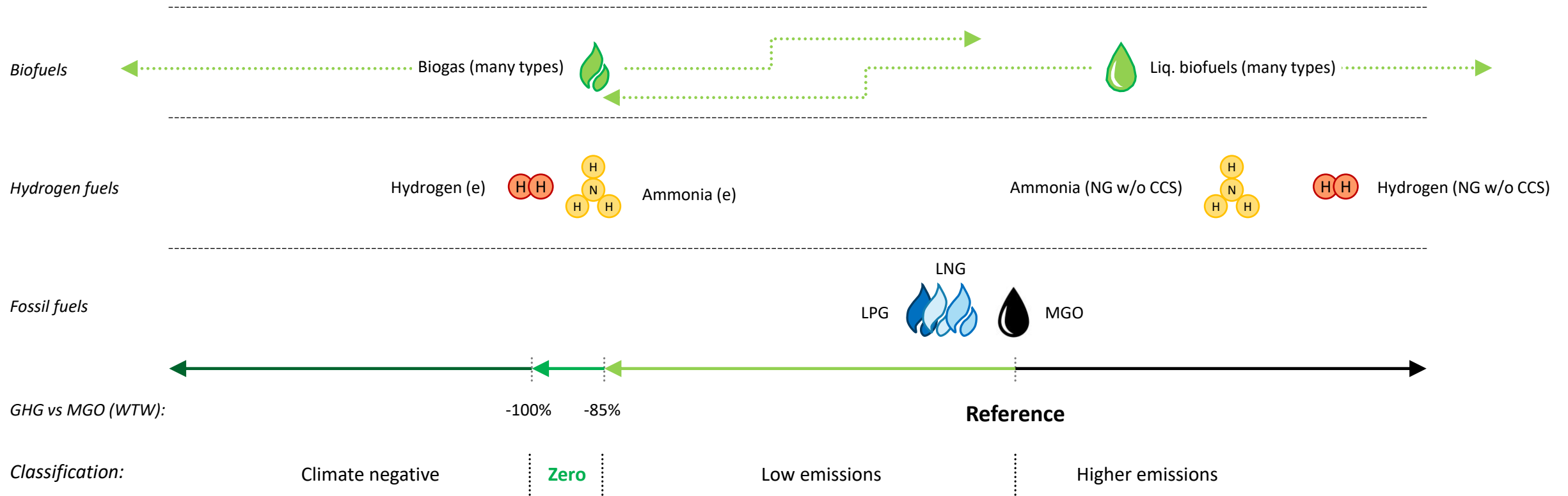
% vessels vs. fuel use



■ Small (22%) ■ Large (78%)



Classification of low and zero emissions



Hydrogen, ammonia and biogas can be produced in different ways, with very different footprint WTT.
 LNG can be combusted in Diesel and Otto engines with different levels of methane slip.
 Different opinions exist, no clear definition or consensus on the classification.

Synthetic E-fuels

- Synthetic electro-fuels or E-fuels are gaseous or liquid fuels from hydrogen and captured carbon using renewable electricity
- They have high energy efficiency and are compatible with and blends easily: for example MGO & E-diesel or LNG & E-LNG
- No need for new infrastructure or bunkering facilities in contrast to Hydrogen and Ammonia
- Can be used on existing vessels
- No need for additional crew training

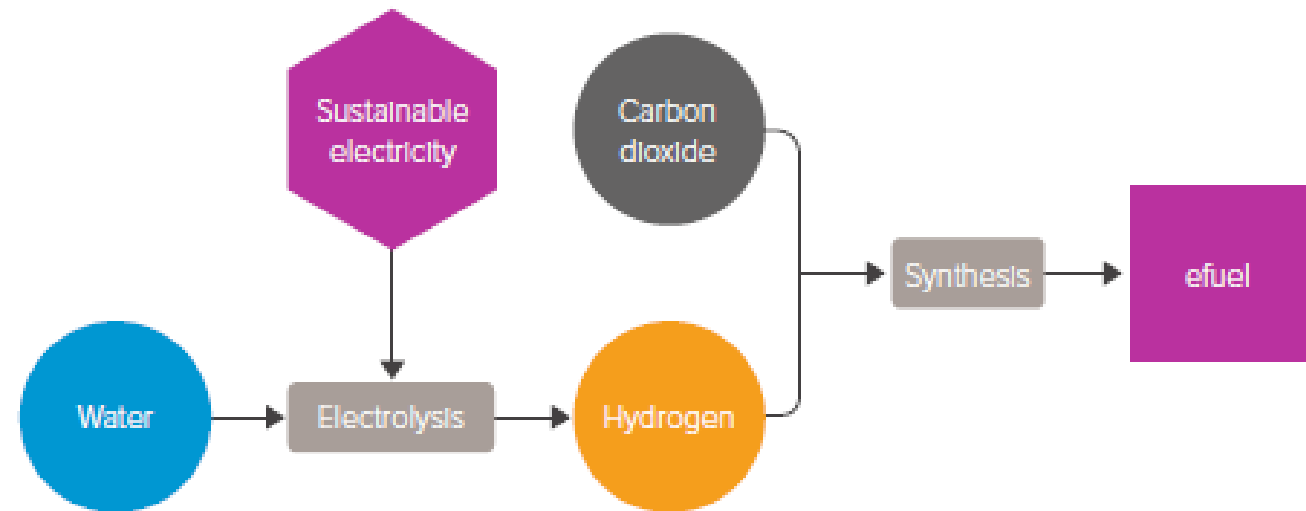
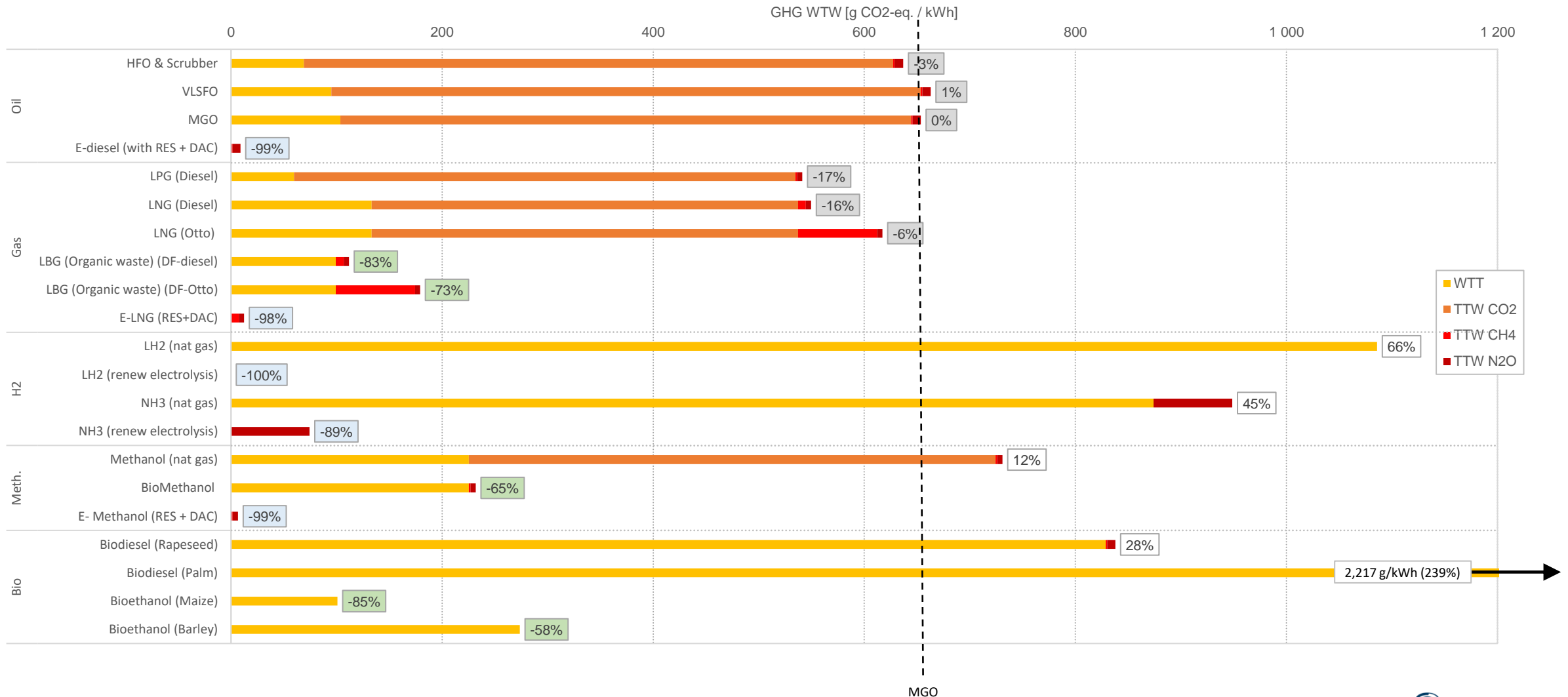


Figure Source: The Royal Society (2019)

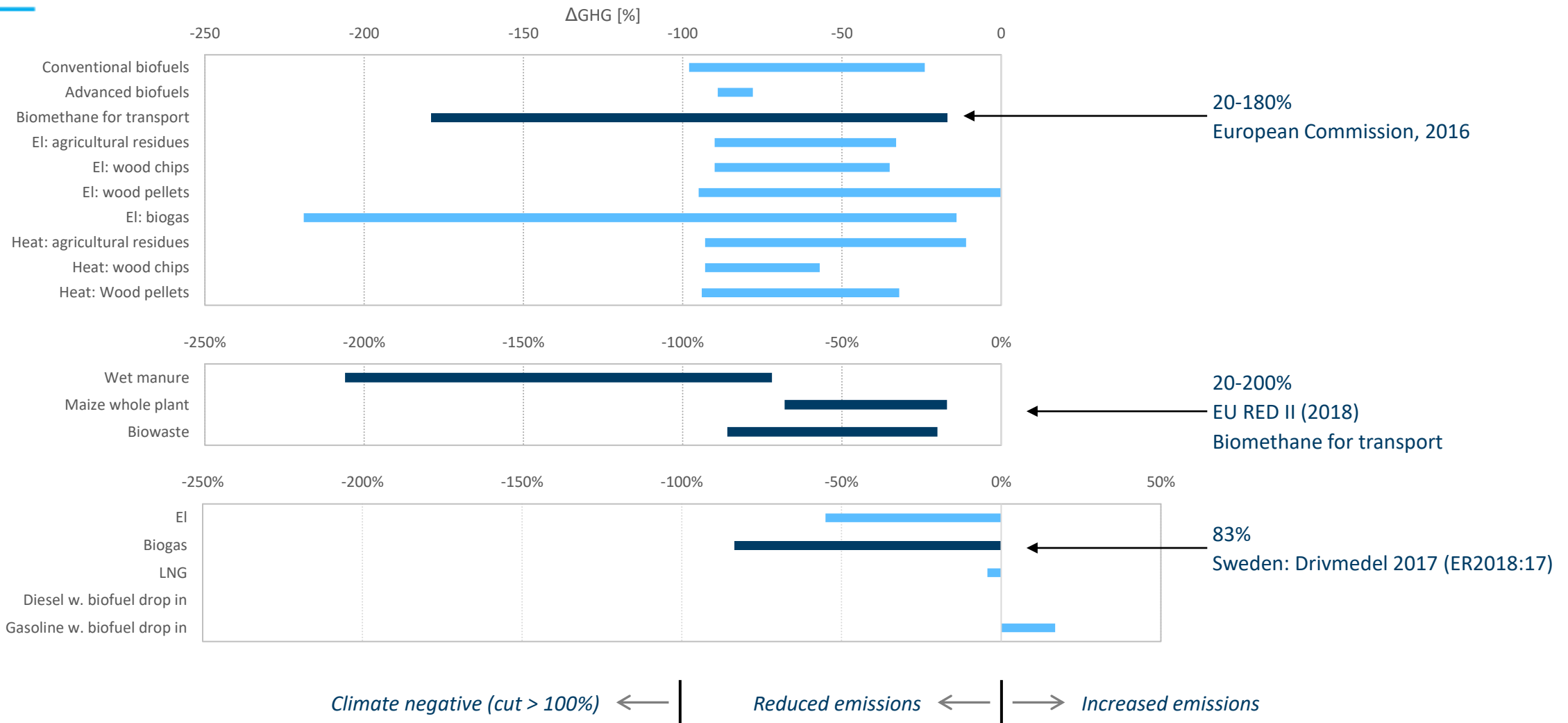
Emissions well to wake (WTW = WTT+TTW)



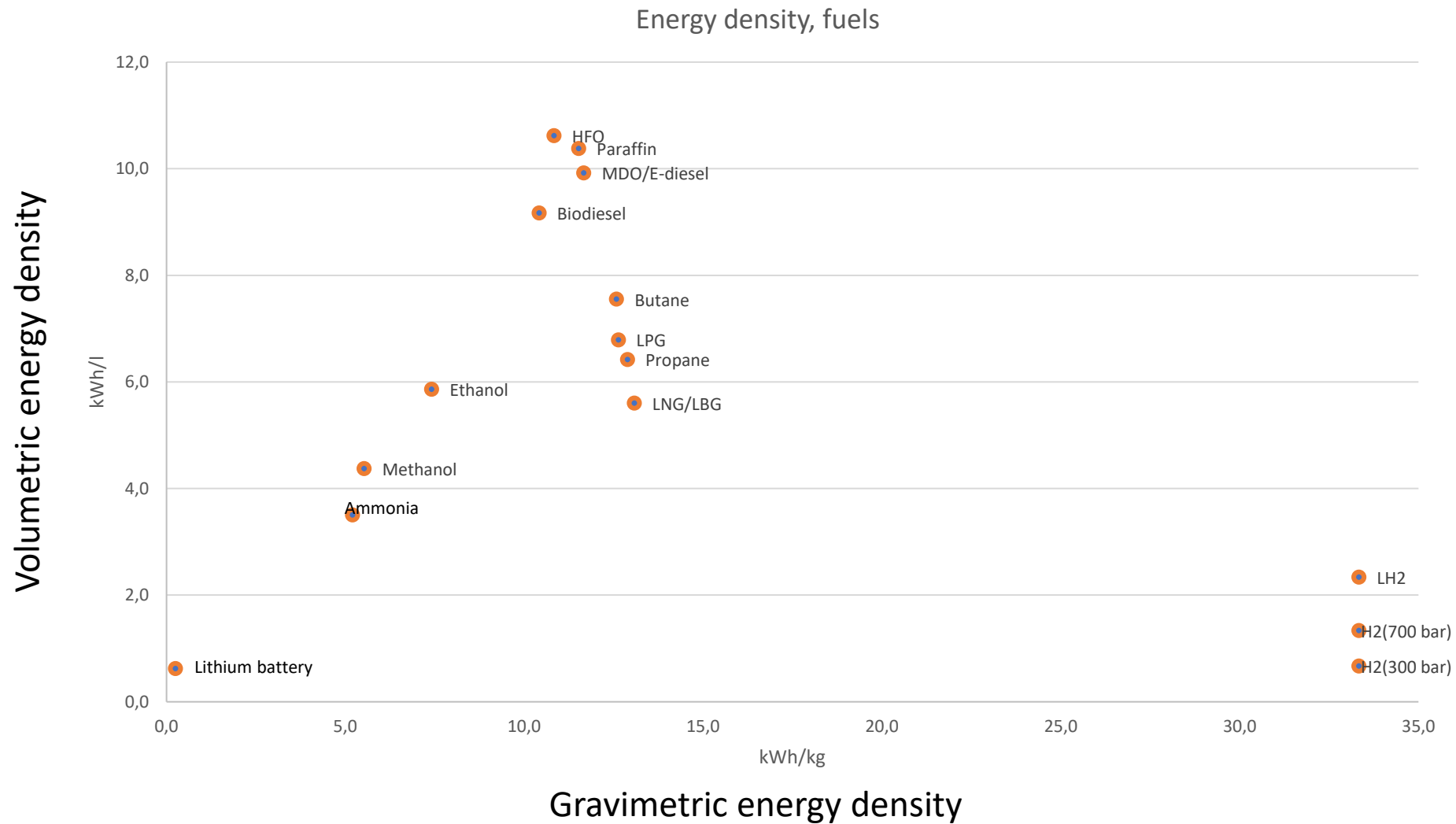
Source: Elizabeth Lindstad et al.

While we know that the type of engine (Diesel or Otto) affect the GHG from LNG, we do not know exactly how the type of engine or fuel cell will impact the emissions with H₂ and NH₃. Blue colour indicate fuels which depend on renewable electricity to deliver the GHG reductions indicated. Green colour indicate biofuels. Grey indicate fossil fuels.

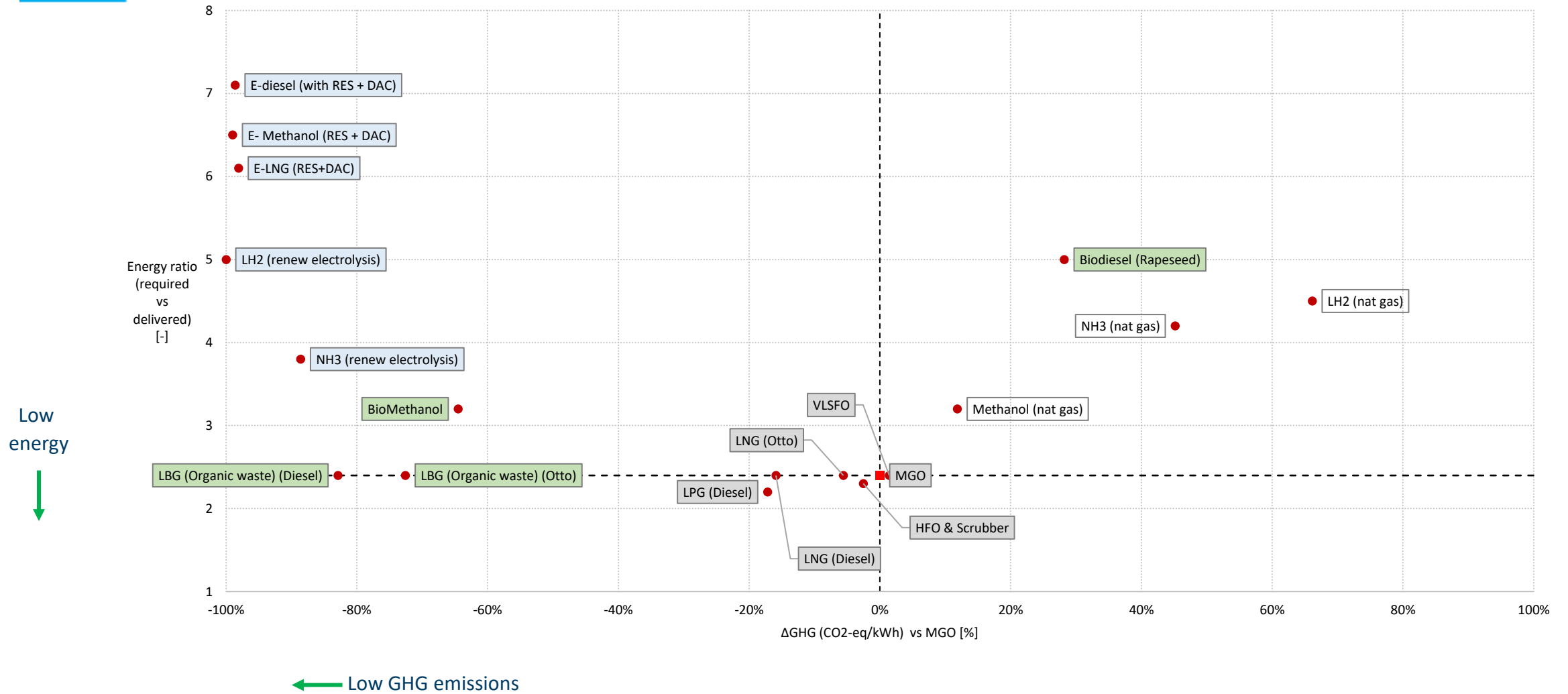
Biogas: The GHG-saving varies and depends!



THE FUEL MENU – ENERGY DENSITY



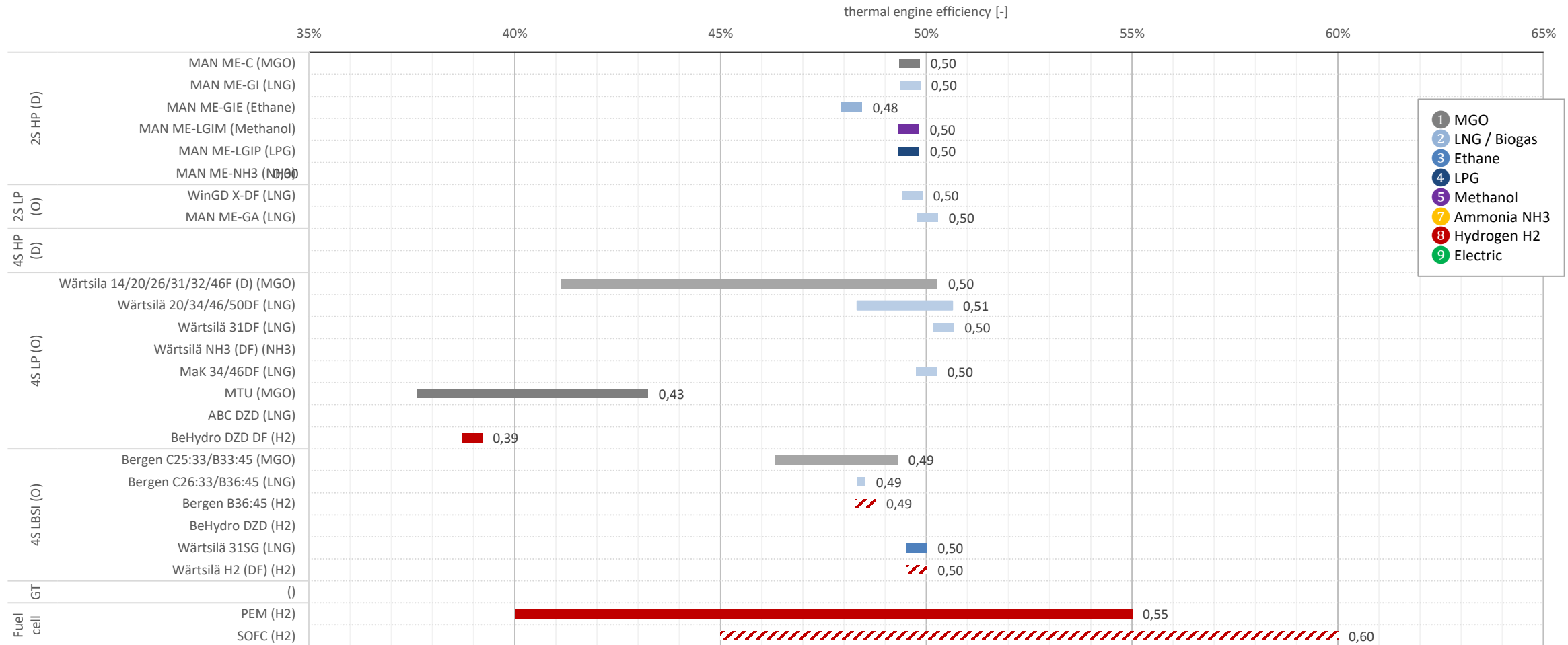
Emissions and energy use well to wake



Source: Elizabeth Lindstad et al

Blue colour indicate fuels which depend on renewable electricity to deliver the GHG reductions indicated. Green colour indicate biofuels. Grey indicate fossil fuels.

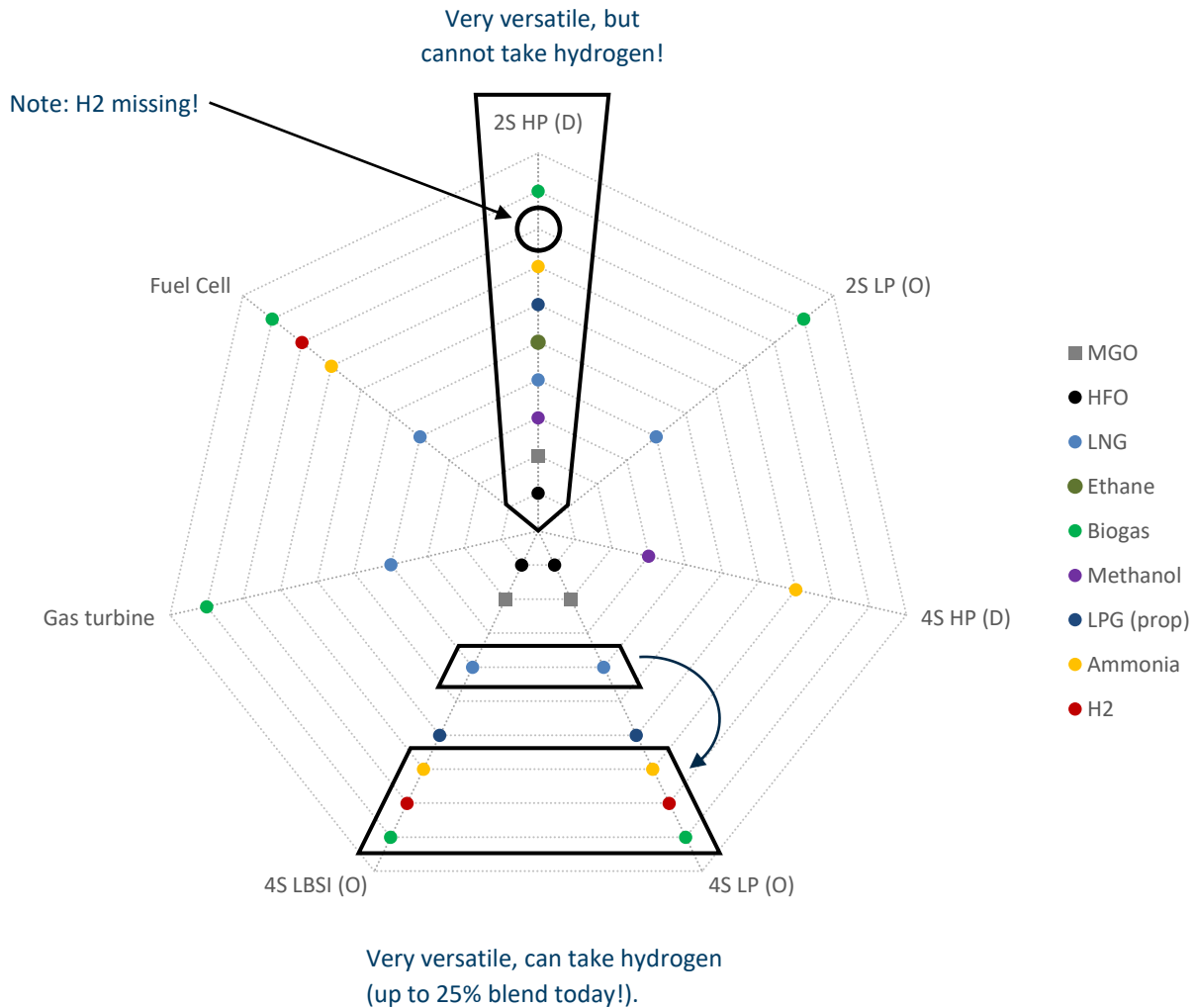
Various existing engines and fuel cells



Based on news, articles and direct dialogue with MAN, Wärtsilä and Bergen Engines (May 2021).

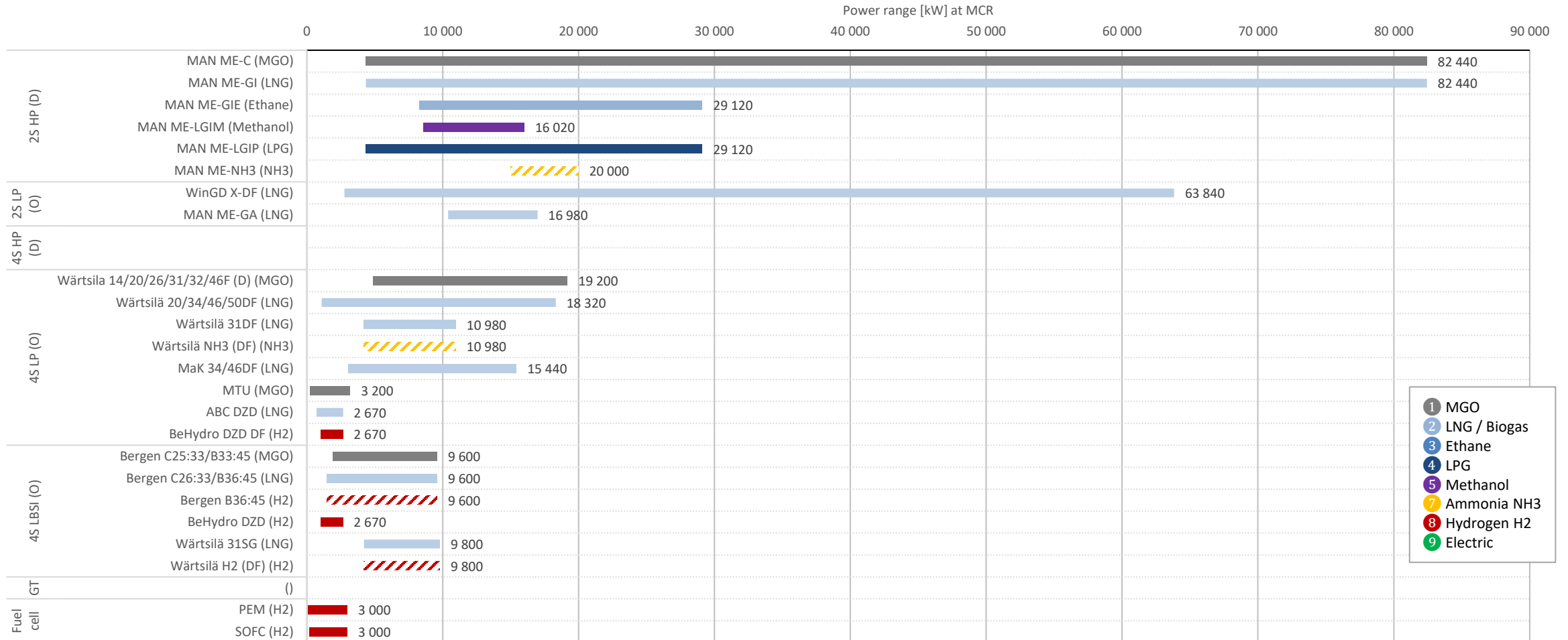
Efficiency for new engines assumed based on parent engine in lack of makers' guidance, i.e. all reservations must be taken on the above for engines under development!

Machinery and fuel combinations



	Stroke	Pressure	Principle	Maker (examples, major)
2S HP (D)	2	High	Diesel	MAN, WinGD, Kobe Diesel
2S LP (O)	2	Low	Otto	WinGD, MAN
4S HP (D)	4	High	Diesel	-
4S LP (O)	4	Low	Otto	Wärtsilä, MaK +++
4S LBSI (O)	4	Low	Lean burn, spark ignited	Bergen ++
Gas turbine				
Fuel cell			PEM or SOFC	Ballard, PowerCell

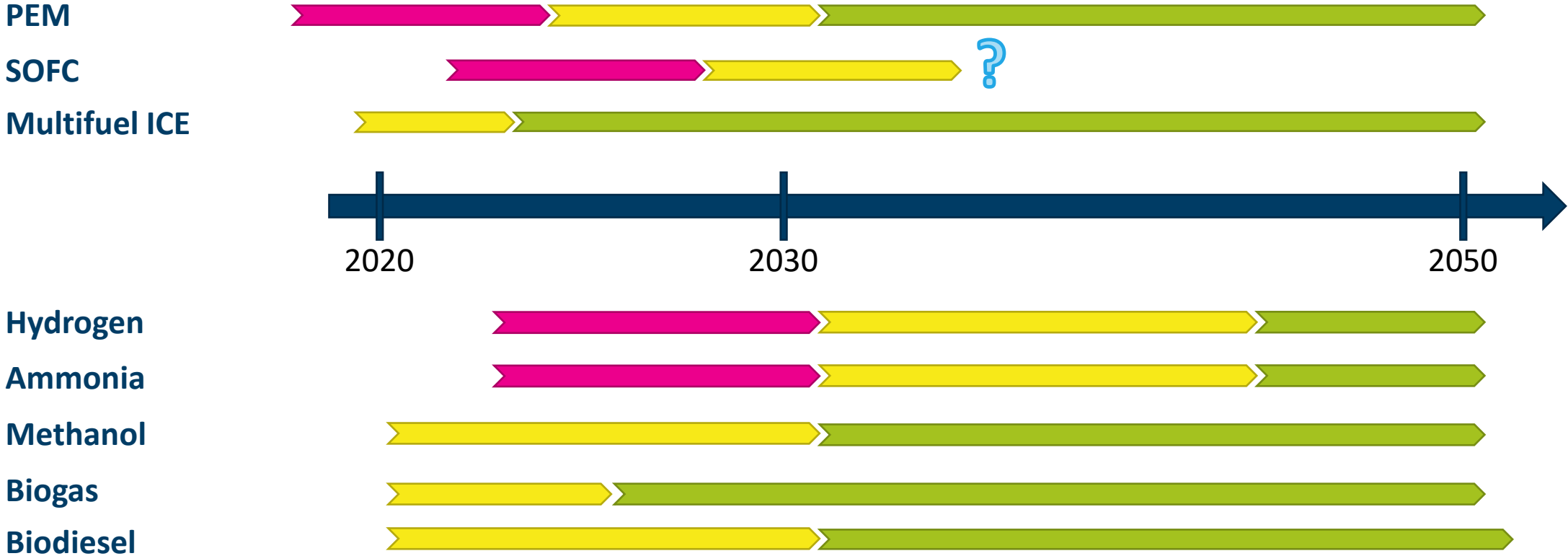
Existing DF and machinery for new fuels under development



Based on news, articles and direct dialogue with MAN, Wärtsilä and Bergen Engines (May 2021).

Power range for new engines assumed based on parent engine in lack of makers' guidance, i.e. all reservations must be taken on the above for engines under development!

The dilemma



The dilemma



PEM
Hydrogen



SOFC
Ammonia



Multifuel ICE
Ammonia
Methanol
Biogas
Biodiesel





Teknologi for et bedre samfunn