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FUEL TRANSITION STRATEGIES TO ACHIEVE REAL EMISSION REDUCTIONS IN SHIPPING

Anders Valland, Gunnar Malm Gamlem,
Elizabeth Lindstad et.al

SINTEF

« SINTEF Ocean shall be a world-leading research environment within marine technology and biomarine research »

Our role

Contract research

R&D-partner to industry and government

Laboratories and software

Testing, development and verification

Innovation

Develop new technology and knowledge

New ventures

Create new products and spin-offs

Sustainable development

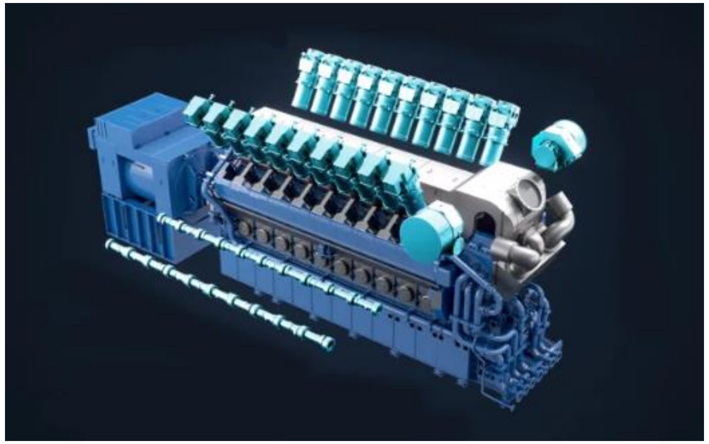
Deliver environmentally friendly solutions

Our social mission

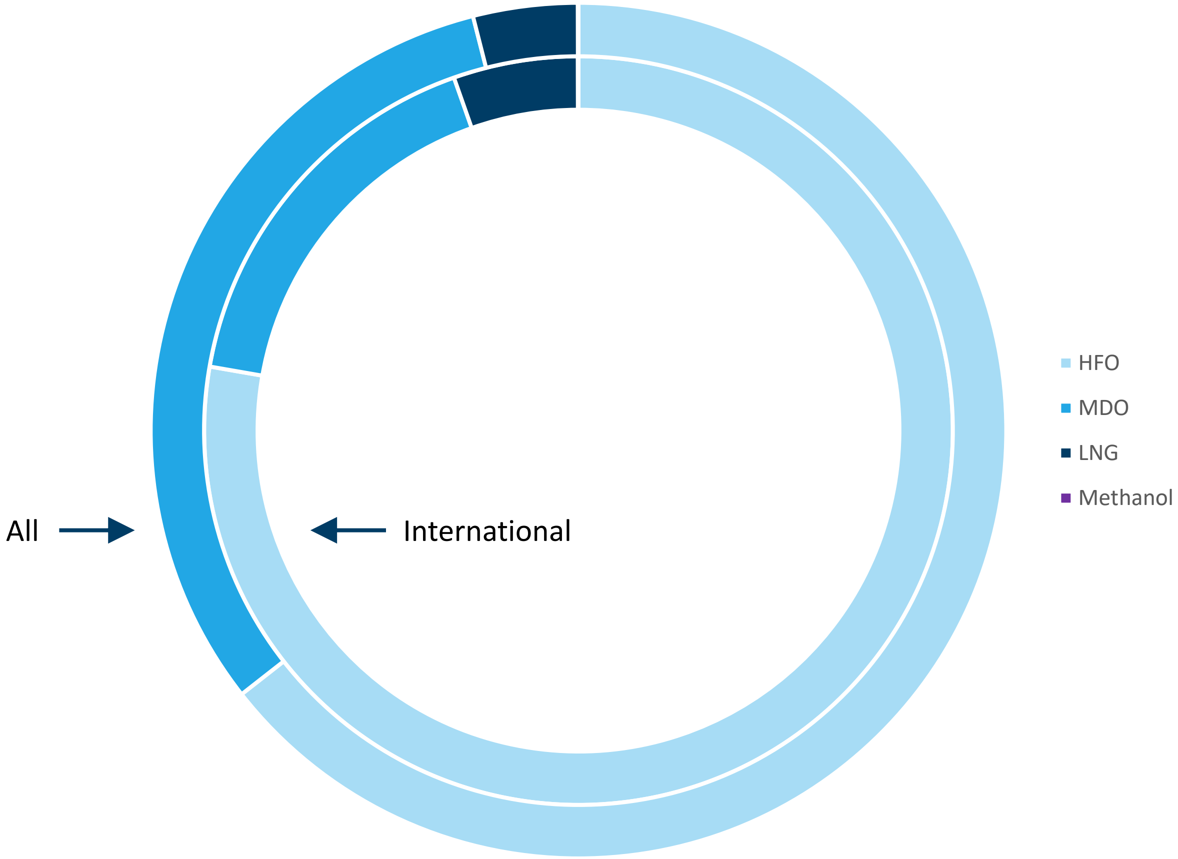
Contribute with knowledge to create debates and shape politics.

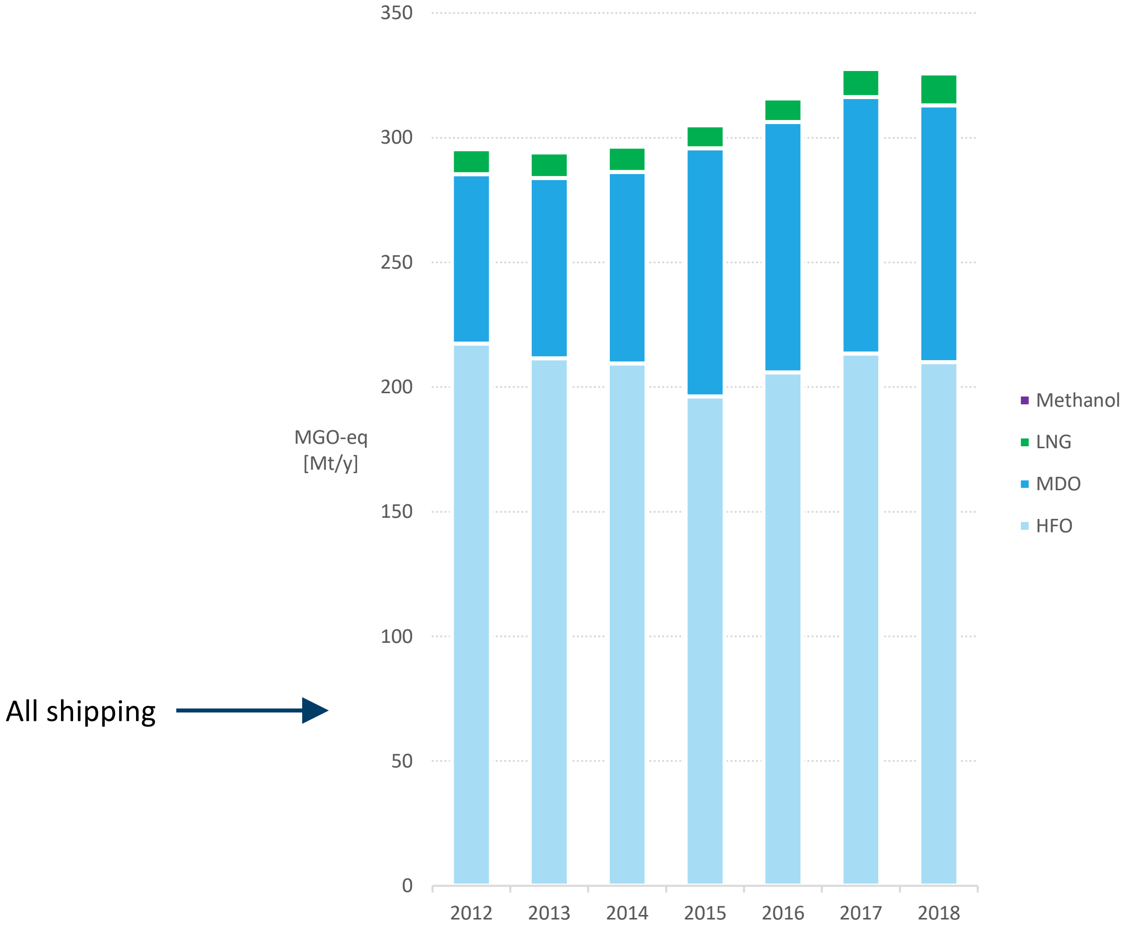
Some projects on alternative fuels

- EU – Fuel-Up –100% biobased resources for sustainable maritime fuels
- ZeroPod - HAV Hydrogen, testing of hydrogen plug'n'play system for smaller vessels
- AMAZE – Bergen Engines, development of multifuel diesel engines



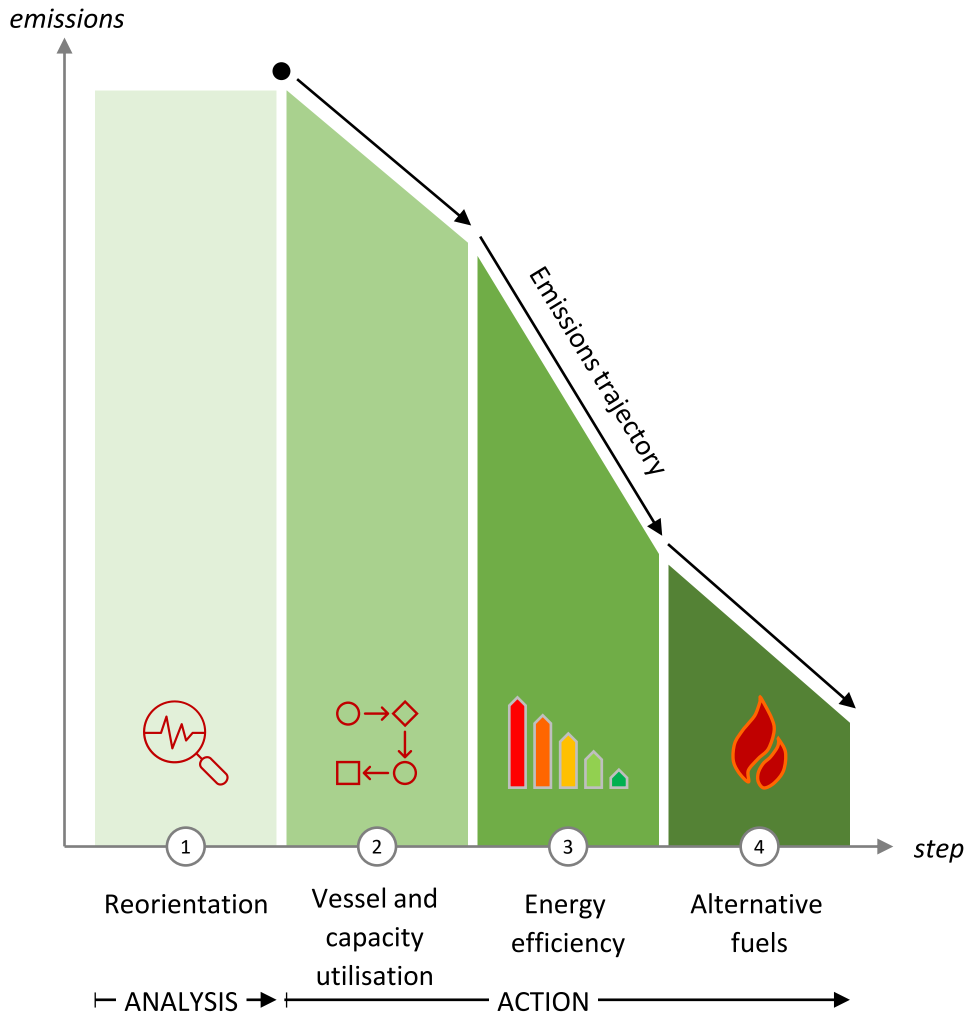
Our primary research domain – Merchant fleet: For 2023 – fuel is 99,89% (!) fossil (IMO figures) with HFO and MDO as dominant. Share of MDO and LNG is growing





Note: Volumes consumed by ships in international and domestic trades plus fishing vessels
Source: IMO 4th GHG-study, page 97-98 (volumes)

Our 4-step model for green shipping



> *As decarbonization will be difficult and ships are very different, we must seek all types of improvements to find the most practical and cost efficient way to (near) zero emissions.*
>
> *Regulations must be technology neutral and goal oriented.*

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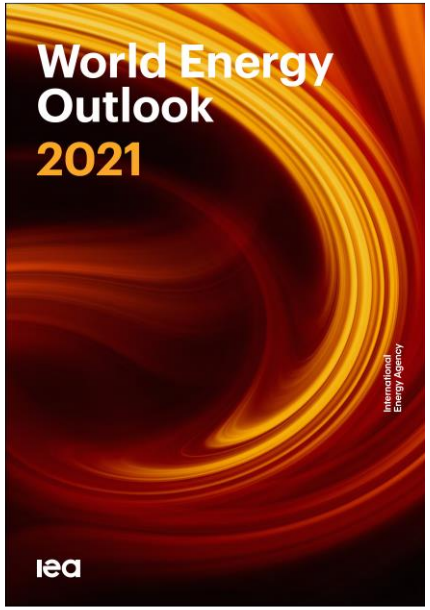
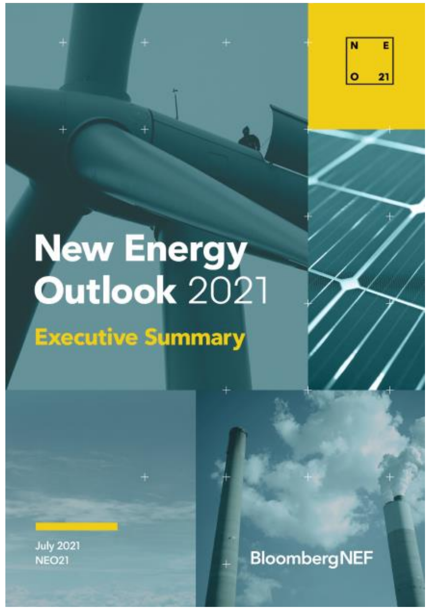
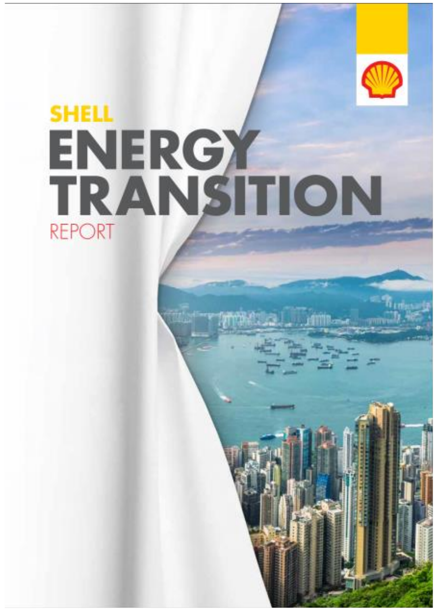
Energy is a limited resource – renewable energy is and will remain scarce – emphasis on energy efficiency!







Energy efficiency delivers more than 40% of the reduction in energy-related GHG over the next 20 years.

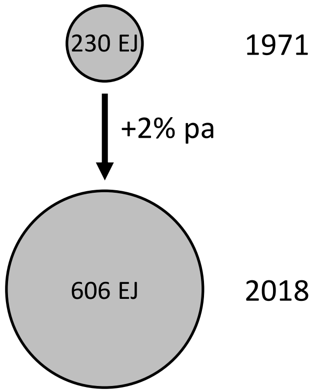
Efficiency improvements make up 2/3 of emissions reductions to 2030 and 45% by 2050.

Renewable energy overtakes fossil fuels as the primary source of energy in the 2050s.

IEA on energy efficiency (www.iea.org/topics/energy-efficiency). Dr Timur Gul, IEA, at Forskningsrådet 24 June 2021.
Bloomberg New Energy Outlook, page 8. (https://about.bnef.com/new-energy-outlook/)
Note: BNEF developed three scenarios, i.e. explorations of what is required to reach certain goals, in this case global warming well below 2°C.

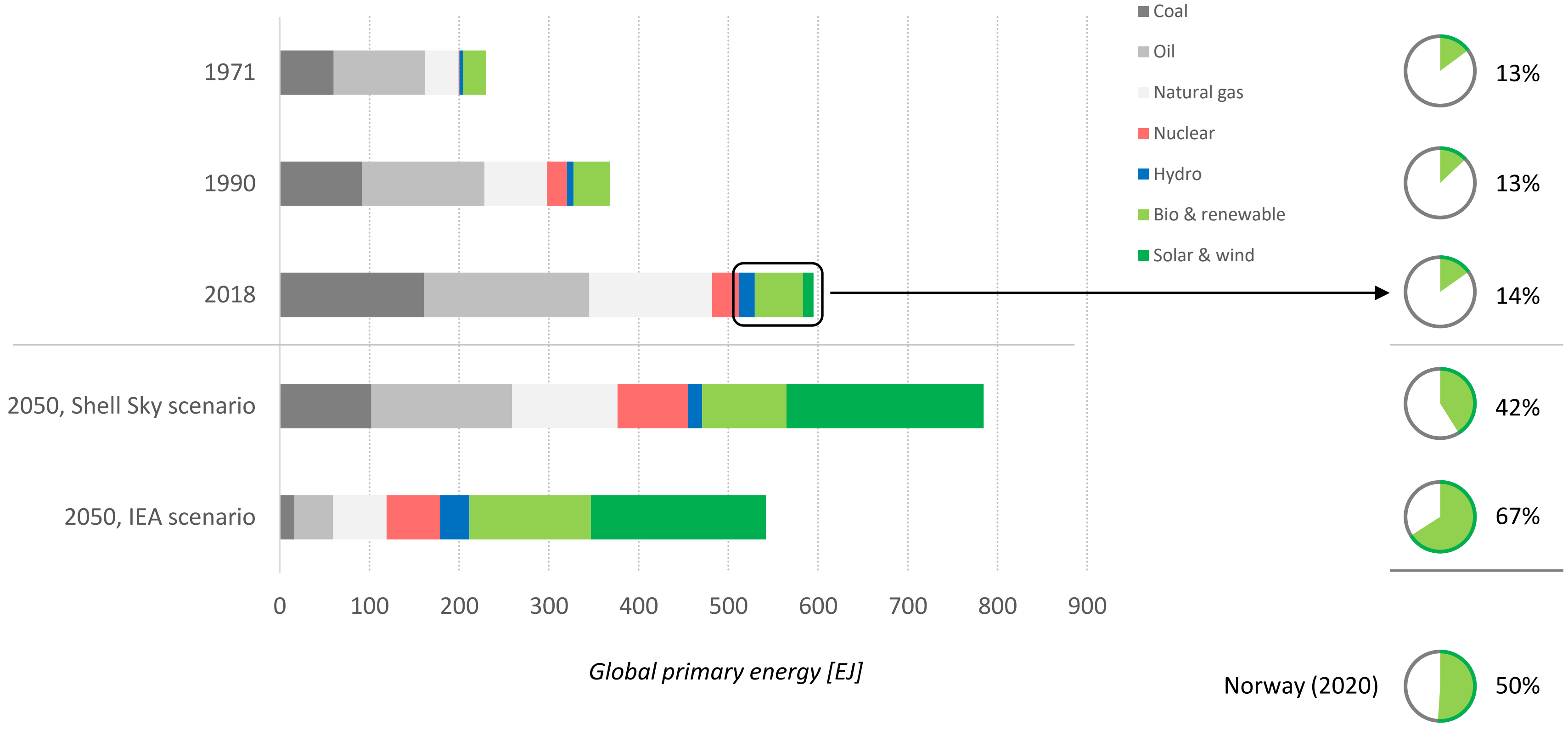
Global energy demand and primary energy mix 1971-2019

Global, annual energy use



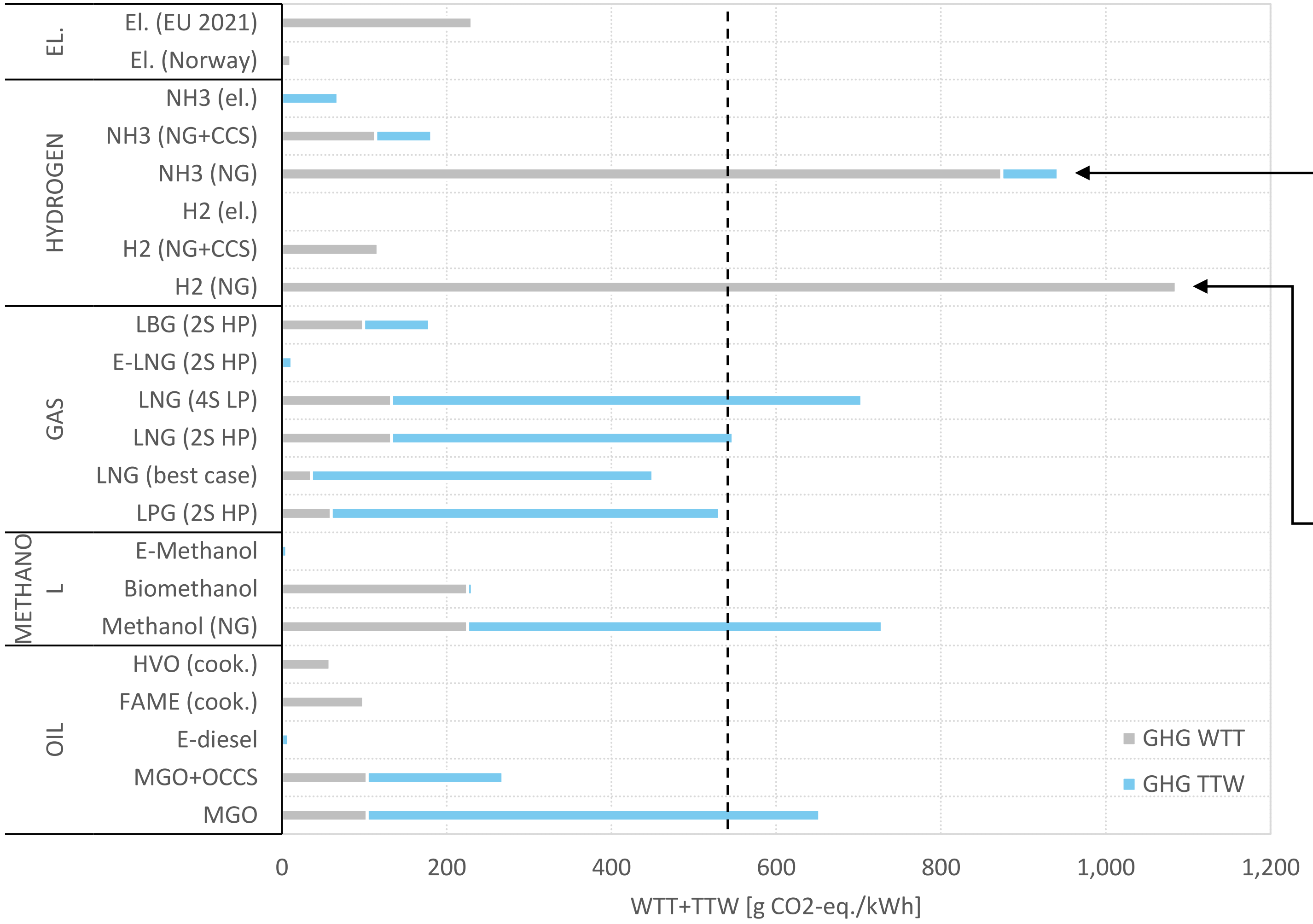
Breakdown of primary energy

Renewables



IEA (https://www.iea.org/data-and-statistics/charts/total-primary-energy-supply-by-fuel-1971-and-2019)
Energi Norge and Thema Consulting (https://fornybarometeret.no/status-for-norsk-omstilling-til-fornybar-energi)

Alt. fuels: Decarbonising existing H_2 and NH_3 first?




DECHEMA

Perspective Europe 2030

Technology options for CO_2- emission reduction of hydrogen feedstock in ammonia production

"This new report proposes a scenario for eliminating as much as 19% of carbon emissions (from EU ammonia production) by 2030..." (Dechema, January 2022)

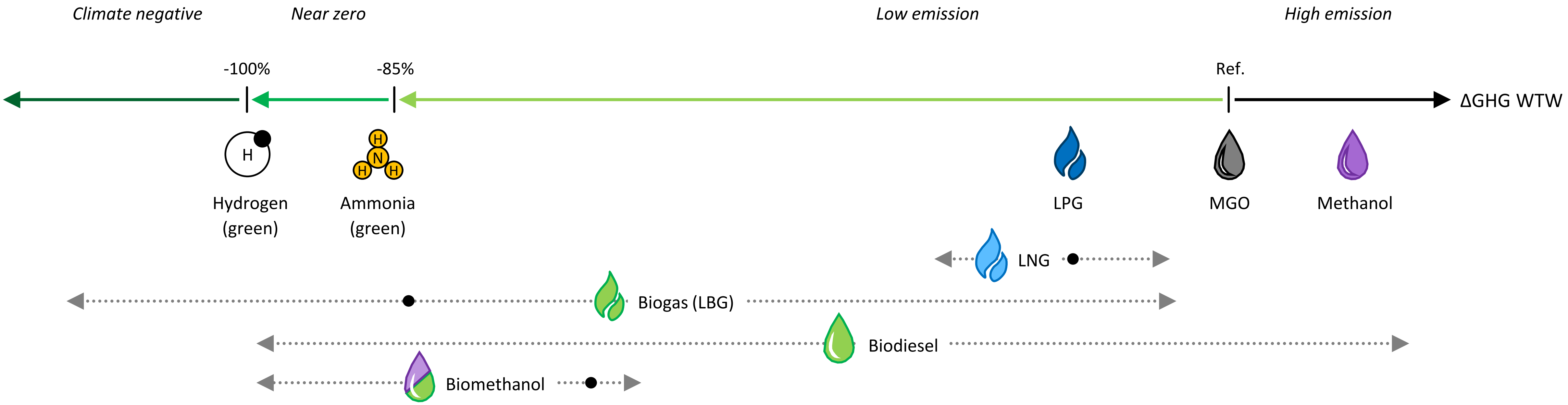

FEEDING LIFE 2030
THE EUROPEAN FERTILIZER INDUSTRY AT THE CROSSROADS BETWEEN NUTRITION AND ENERGY

fertilizers europe

"...perhaps 10% of hydrogen for ammonia production in 2030 would come from renewable resources. (Fertilizers Europe, 2018)

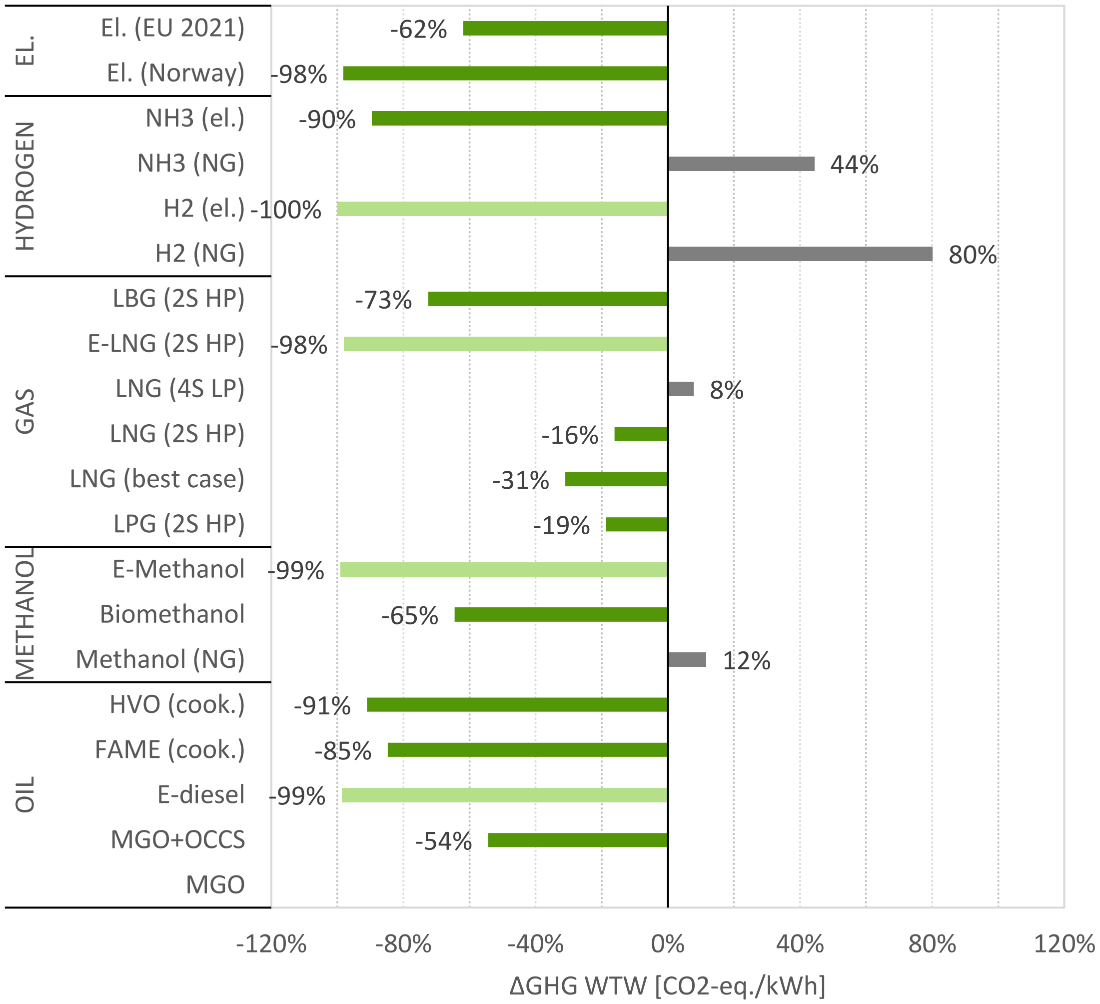
Source: Lindstad et al, LR and UMAS, ABS. Zero emission for synthetic green hydrogen and ammonia and synthetic fuels depend upon renewable electricity. Data for blue H2 and ammonia and MGO+OCCS uncertain,.

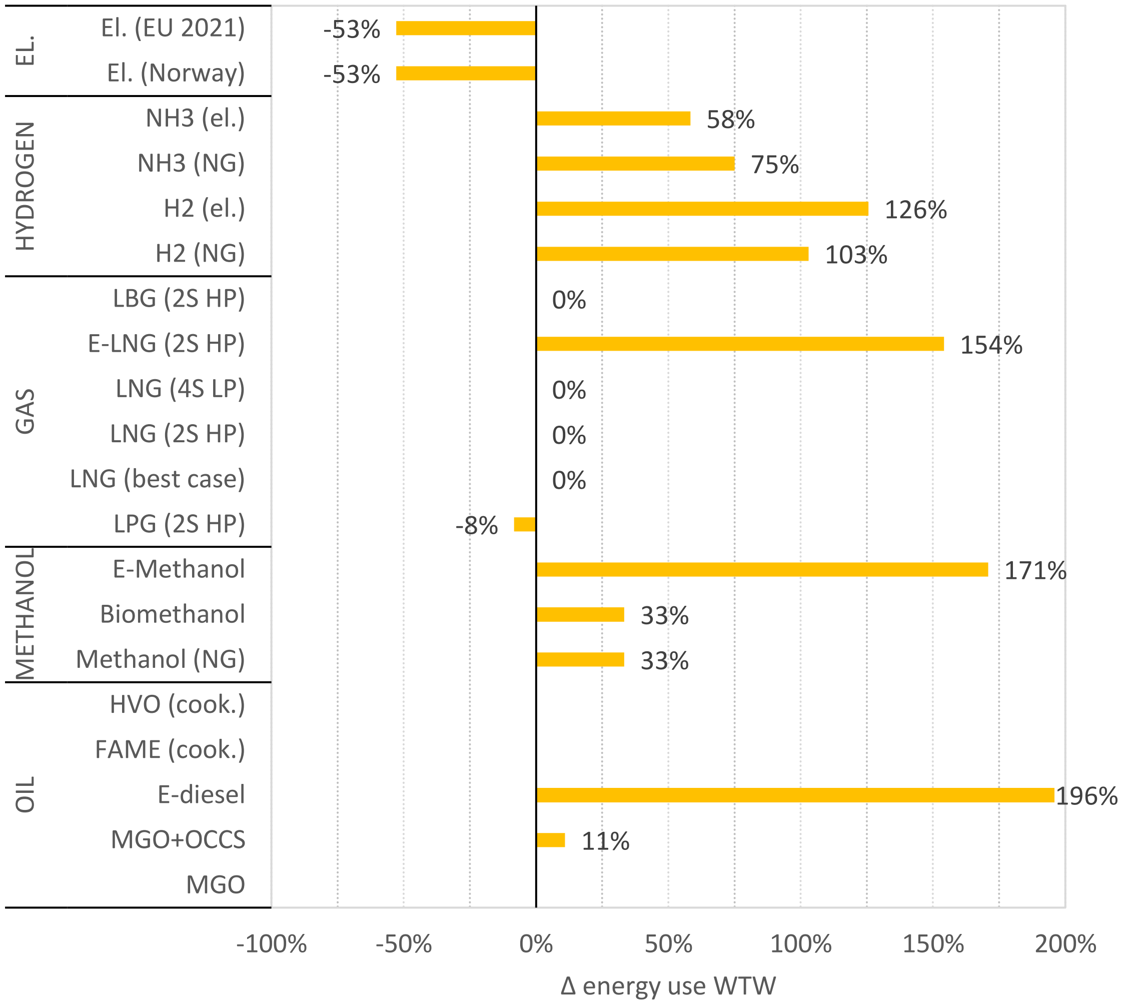
Alternative fuels overview



Note on terminology near zero: Author's understanding/proposal for. No consensus on the term.
GHG factors for well to wake emissions (scope 1+2+3) based on Lindstad et al, EU RED II, SINTEF Ocean estimates, IRENA Innovation Outlook: Renewable methanol.

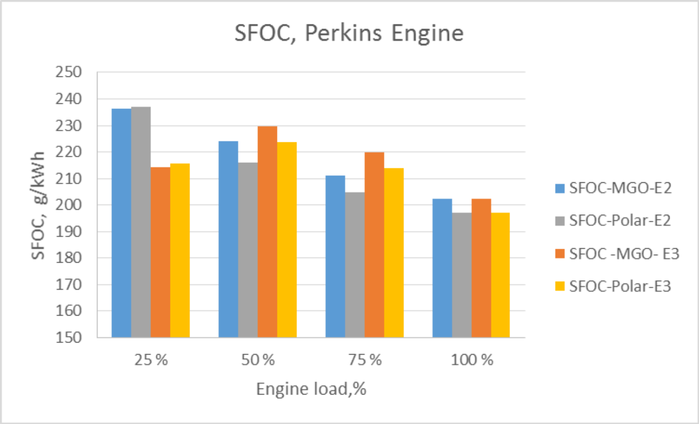
GHG and energy: Grey / green / dark green fuels

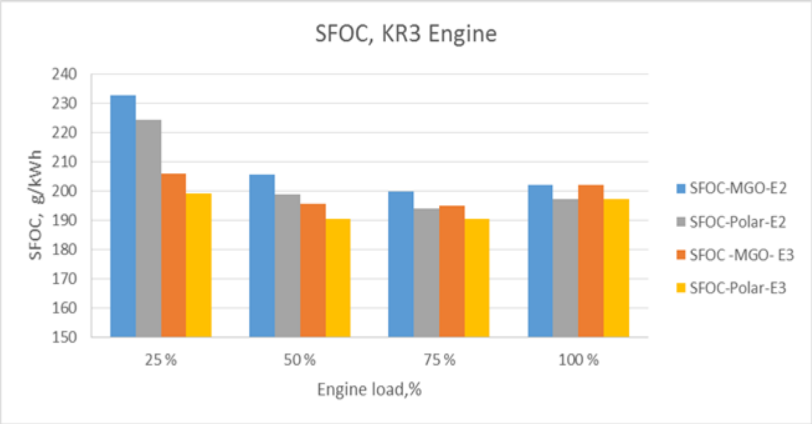




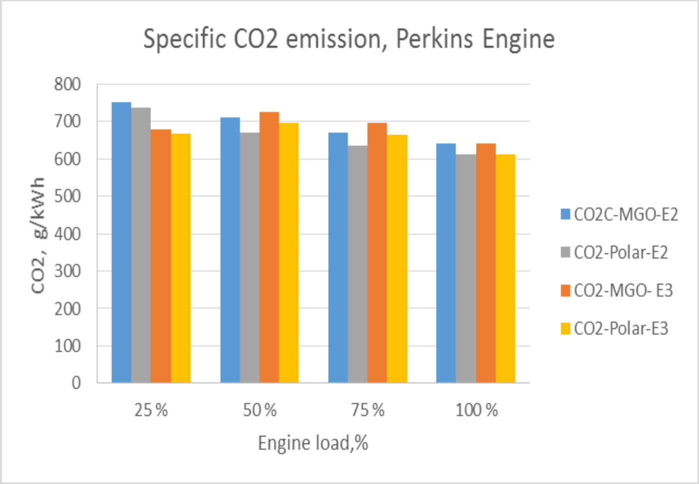
Source: Lindstad et al, LR and UMAS, ABS.
Energy use for HVO and FAME is pending.

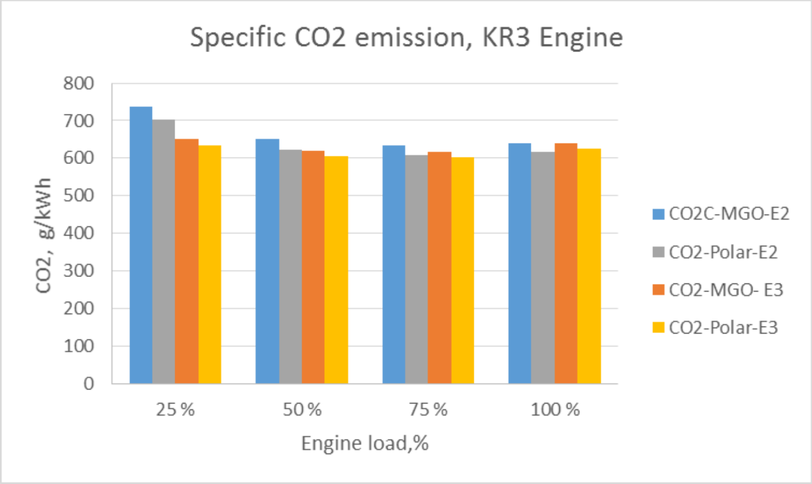
Comparison of MGO with biodiesel – typical results


SFOC, Perkins Engine

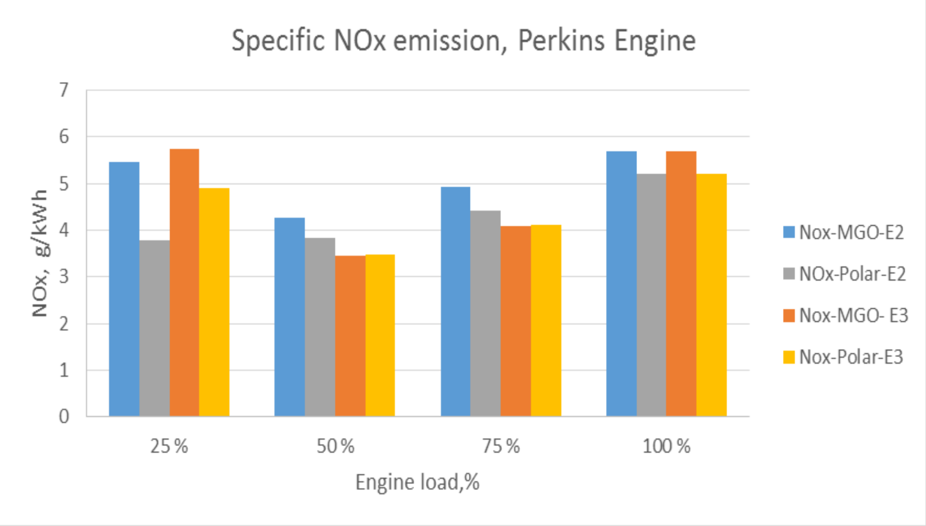

SFOC, KR3 Engine

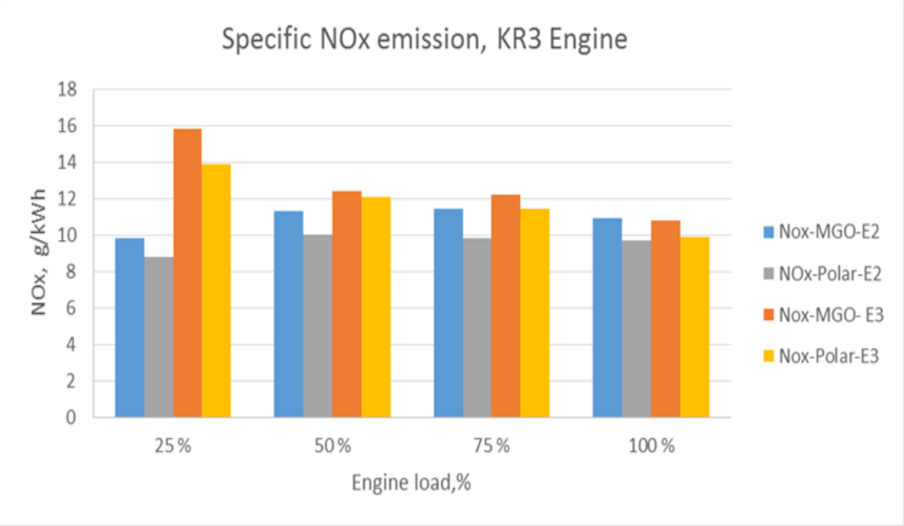
Note:
Perkins – 300 kW, 1500 rpm
KR3 – 450 kW, 720 rpm


Specific CO2 emission, Perkins Engine


Specific CO2 emission, KR3 Engine

Comparison of MGO with biodiesel – typical results


Specific NOx emission, Perkins Engine


Specific NOx emission, KR3 Engine

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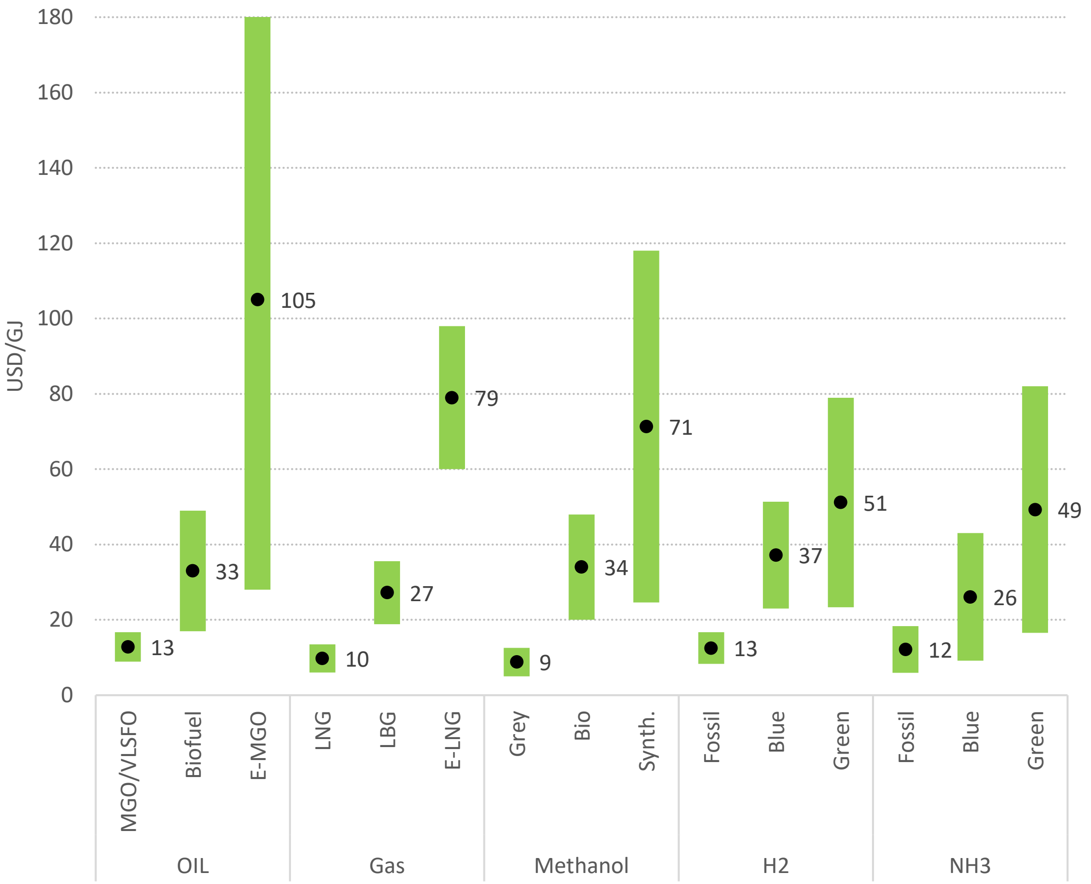
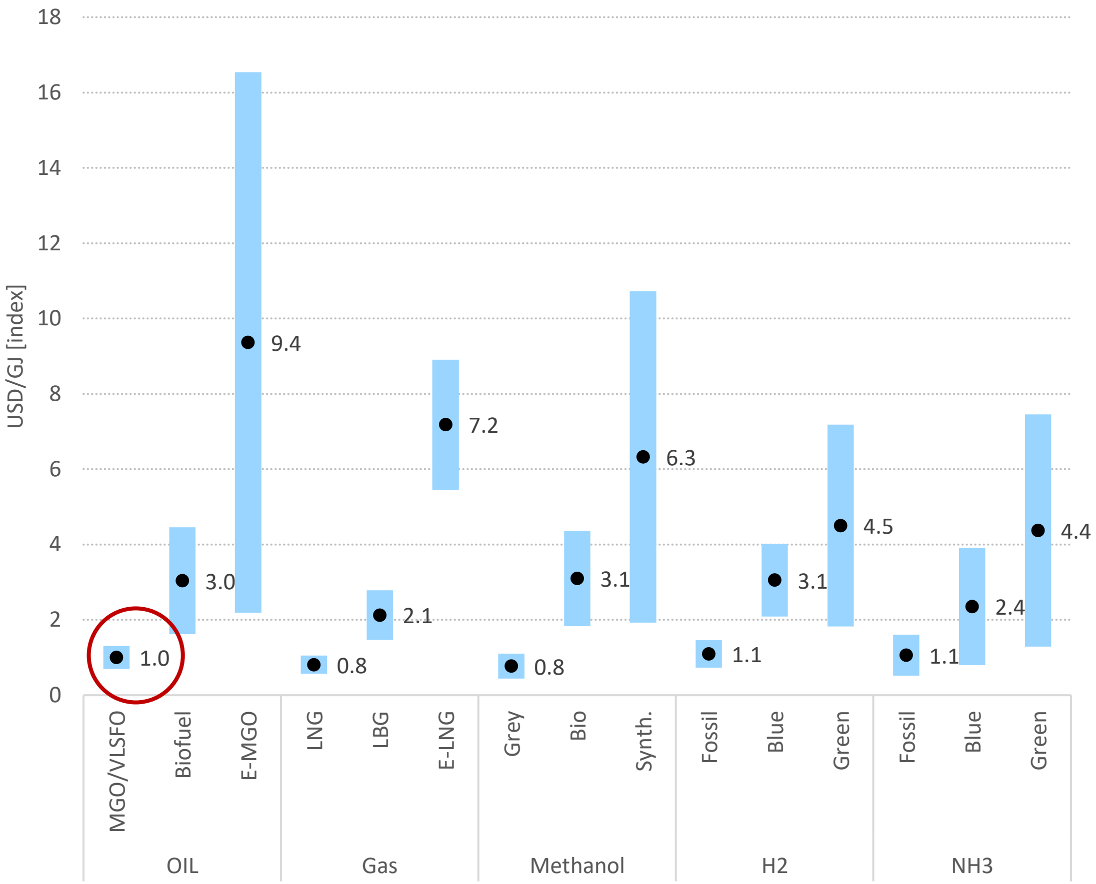
Fuel prices (multiple of MGO-price)



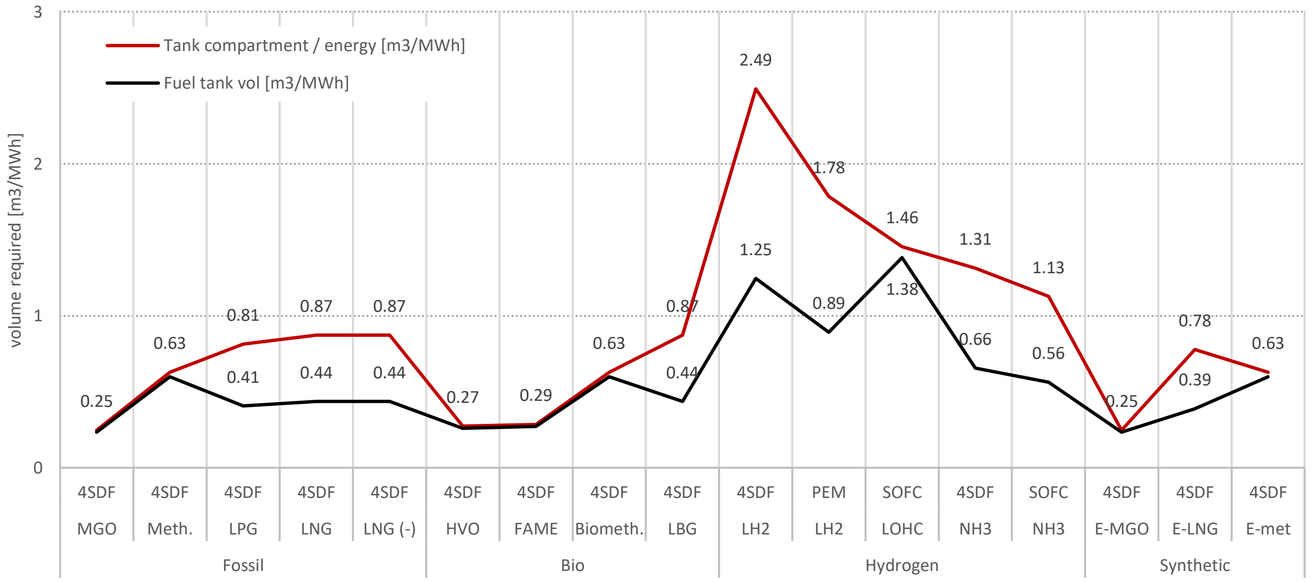


Note: Prices of alt. fuels are indexed against the reference price for MGO from the same source to give a multiple.
Sources: DNV ETO 2022, Mærsk McKinney Møller centre for zero carbon shipping, LR/UMAS (2020) techno economic evaluation of zero carbon fuels, IRENA Innovation outlook.

Fuel systems

- Many alternative fuels contain less energy per volume.

- Drop-in fuels that use same/similar fuel systems are desireable



Reality bites: Hydrogen

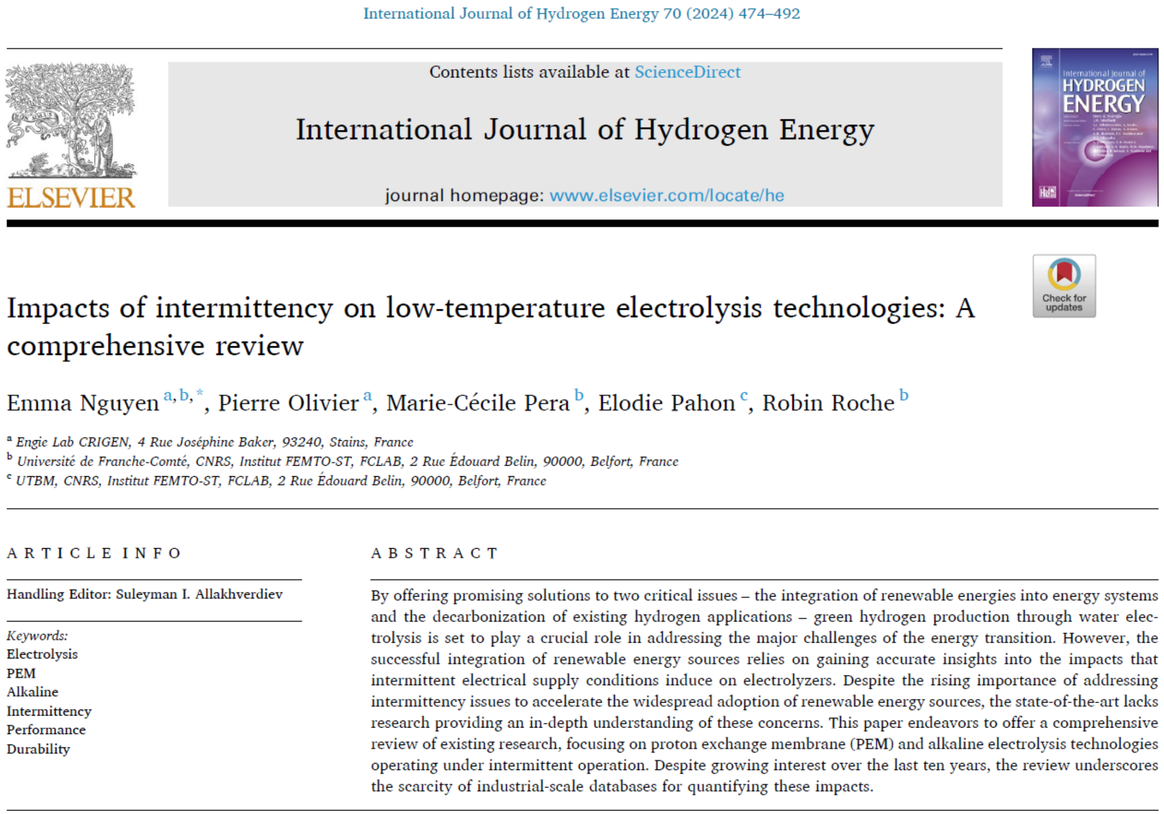
Hydrogen levelized cost of production @ 60 bar: 12-14 Euro/kg

Intermittent production lowers efficiencies, increases O&M cost

TNO innovation for life

Evaluation of the levelised cost of hydrogen based on proposed electrolyser projects in the Netherlands

Renewable Hydrogen Cost Element Evaluation Tool (RHyCEET)



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Impacts of intermittency on low-temperature electrolysis technologies: A comprehensive review

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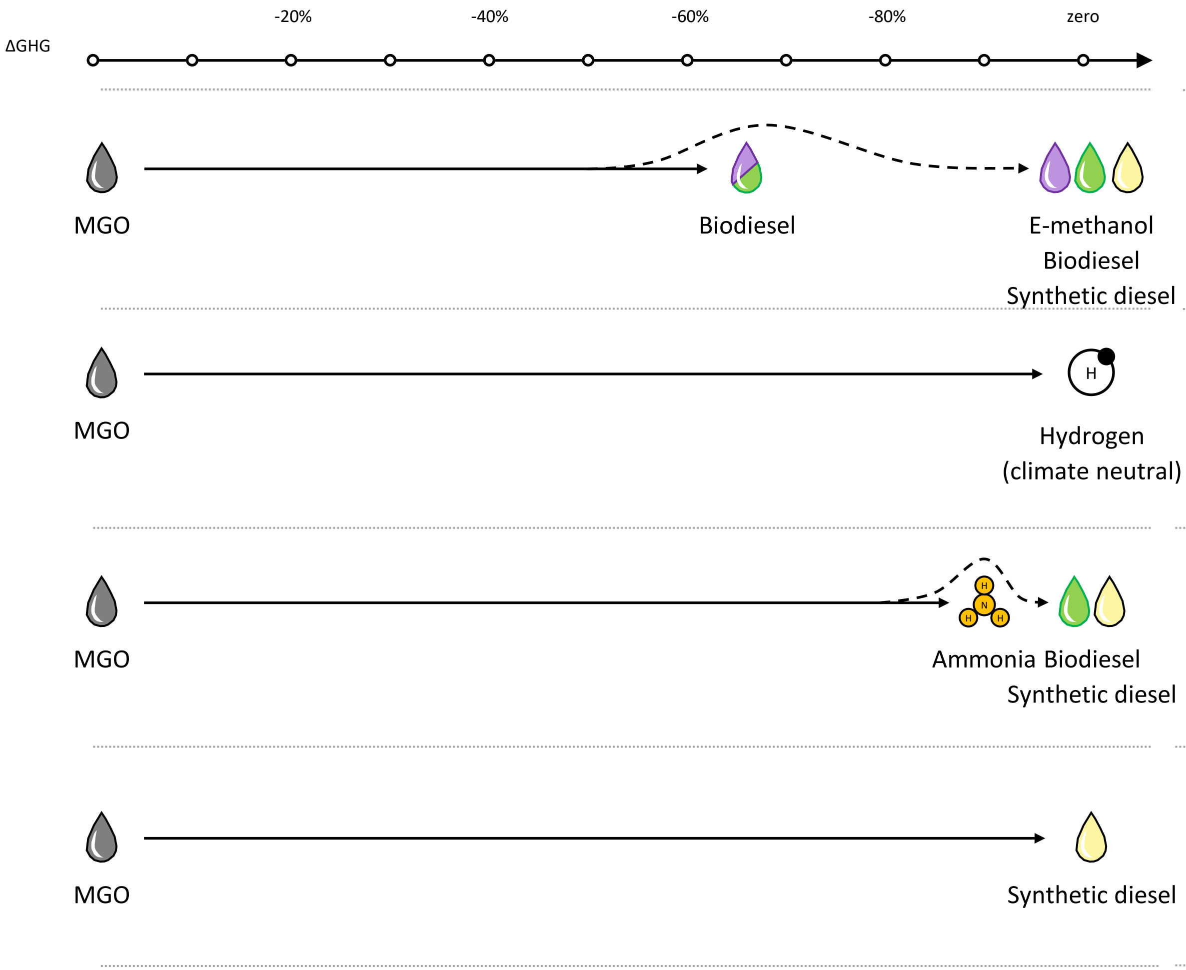
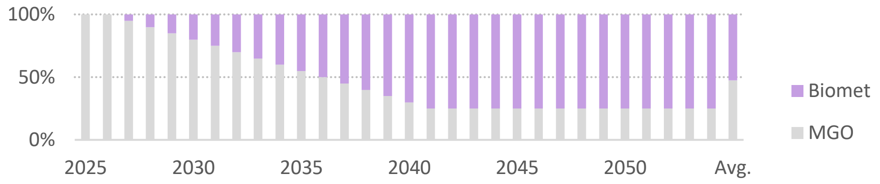
ABSTRACT

By offering promising solutions to two critical issues – the integration of renewable energies into energy systems and the decarbonization of existing hydrogen applications – green hydrogen production through water electrolysis is set to play a crucial role in addressing the major challenges of the energy transition. However, the successful integration of renewable energy sources relies on gaining accurate insights into the impacts that intermittent electrical supply conditions induce on electrolyzers. Despite the rising importance of addressing intermittency issues to accelerate the widespread adoption of renewable energy sources, the state-of-the-art lacks research providing an in-depth understanding of these concerns. This paper endeavors to offer a comprehensive review of existing research, focusing on proton exchange membrane (PEM) and alkaline electrolysis technologies operating under intermittent operation. Despite growing interest over the last ten years, the review underscores the scarcity of industrial-scale databases for quantifying these impacts.

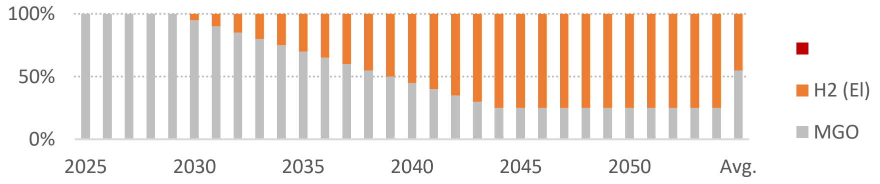
Fuel transition strategies building on MGO



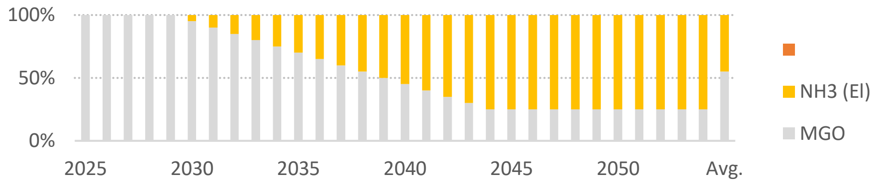
Lifetime GHG reduction



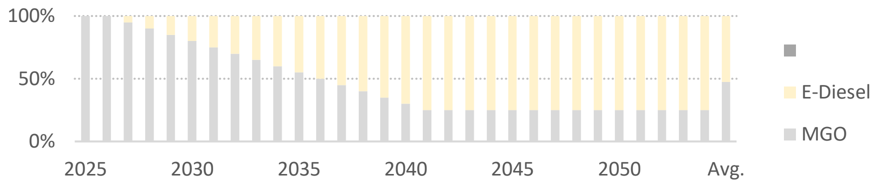
35%



45%



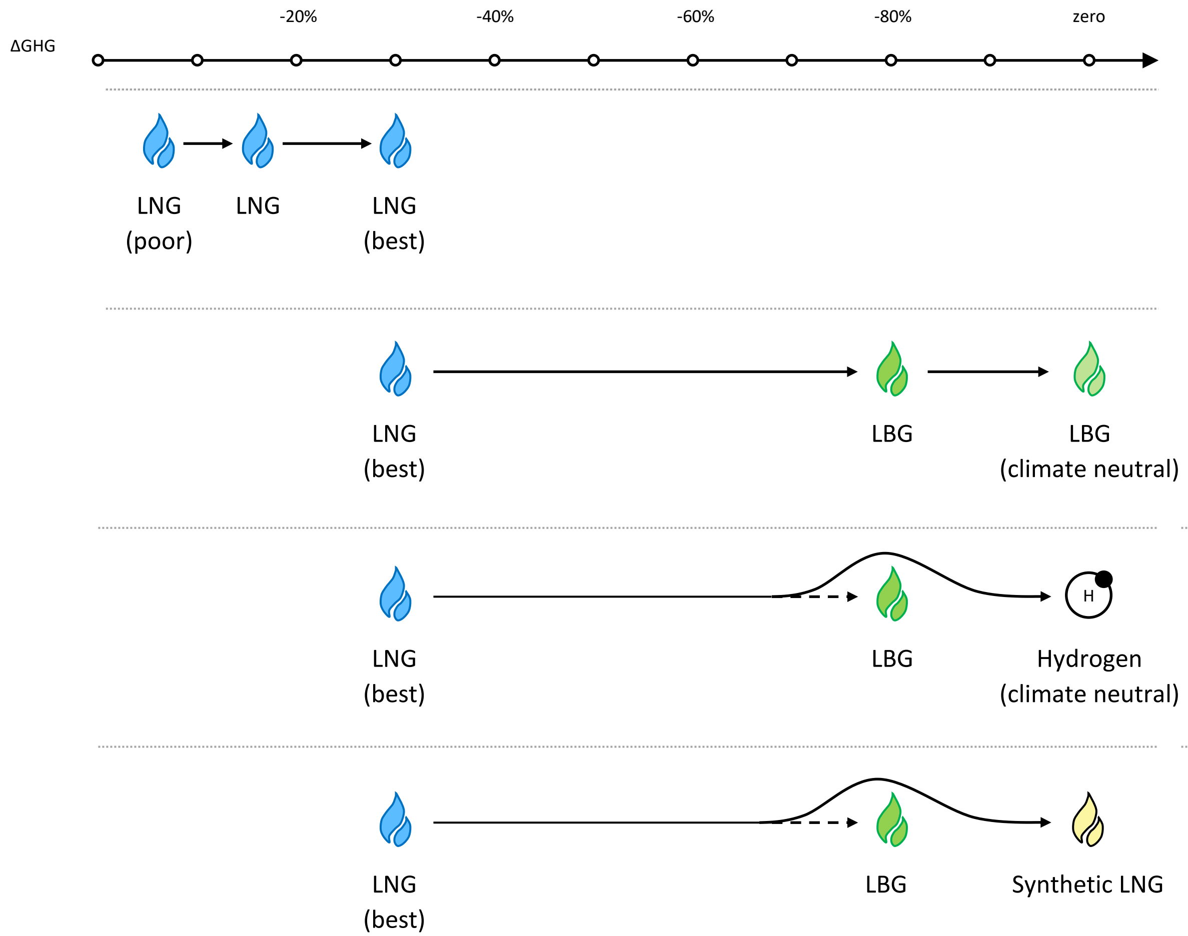
40%



50%

Note: Accumulated emissions depend on the emission factors, implementation schedule, max blending ratio.
Assumptions: Biogas and biomethanol becomes available first (2026), then synthetic fuels (2027) , then hydrogen and ammonia (from 2030).

Fuel transition strategies building on LNG


ΔGHG

-20%

-40%

-60%

-80%

zero

LNG (poor)

LNG

LNG (best)

LNG (best)

LBG

LBG (climate neutral)

LNG (best)

LBG

Hydrogen (climate neutral)

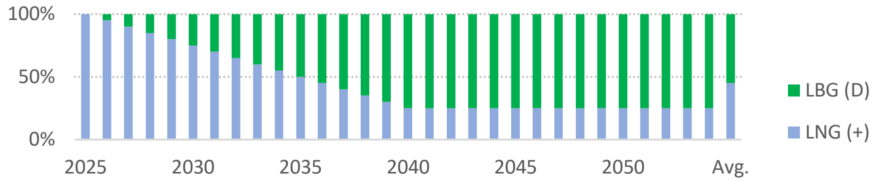
LNG (best)

LBG

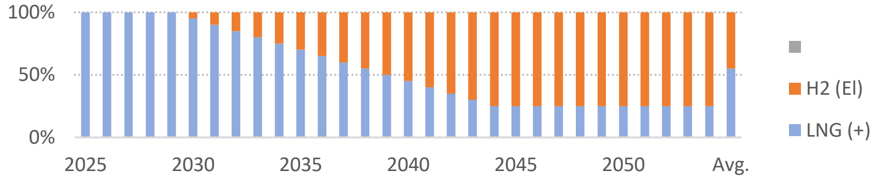
Synthetic LNG

Lifetime GHG reduction

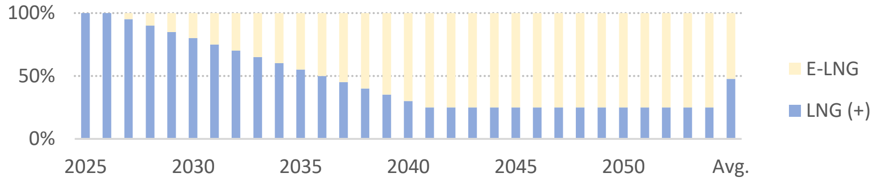
15-30%



50-60%



55-65%



60-65%

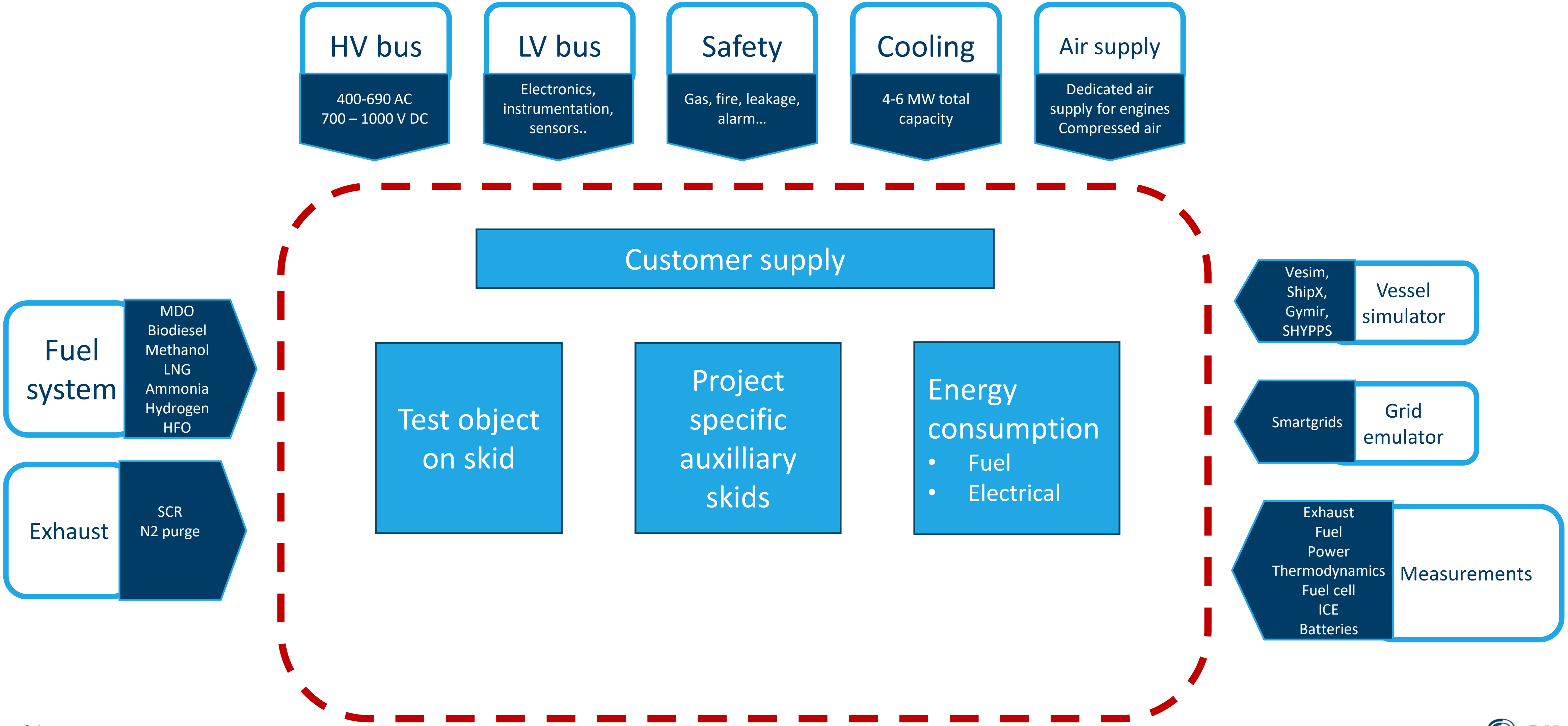
Note: Accumulated emissions depend on the emission factors, implementation schedule, max blending ratio.
Assumptions: Biogas and biomethanol becomes available first (2026), then synthetic fuels (2027) , then hydrogen and ammonia (from 2030).
LNG best case: WTT 5 g Co2-eq./MJ, engine thermal efficiency 0.50, methane slip 0.25 g/kWh

MARITIME ENERGY SYSTEMS LABORATORY SINTEF OCEAN

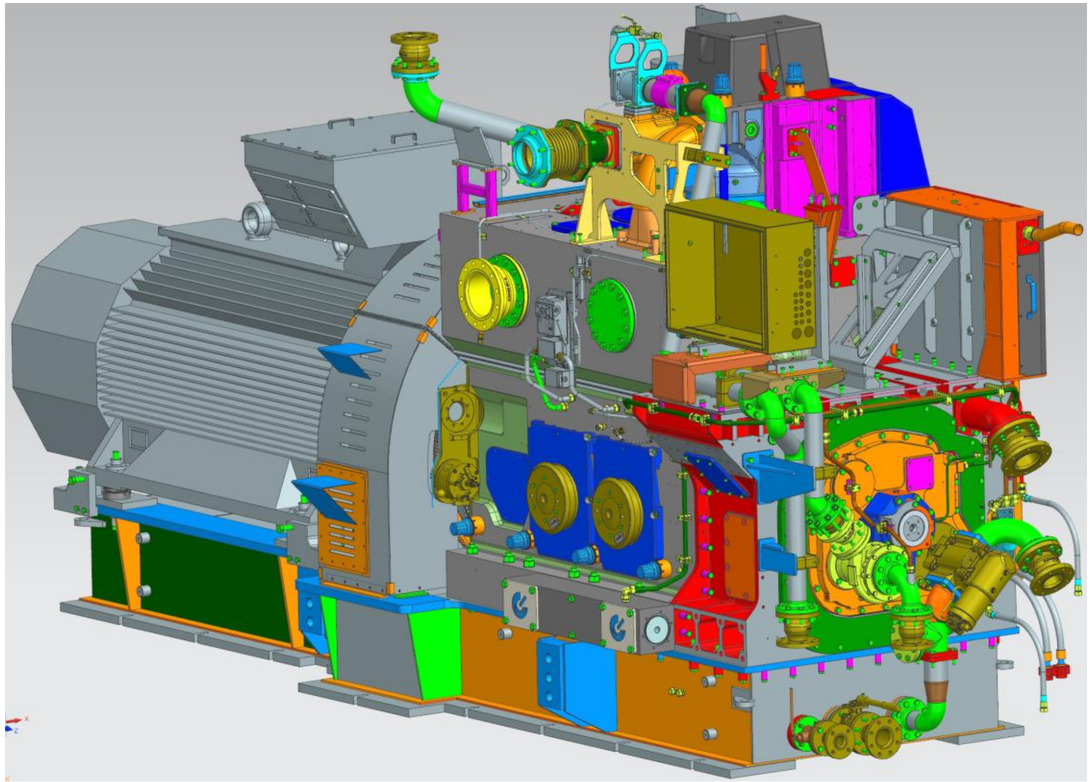
February 2024

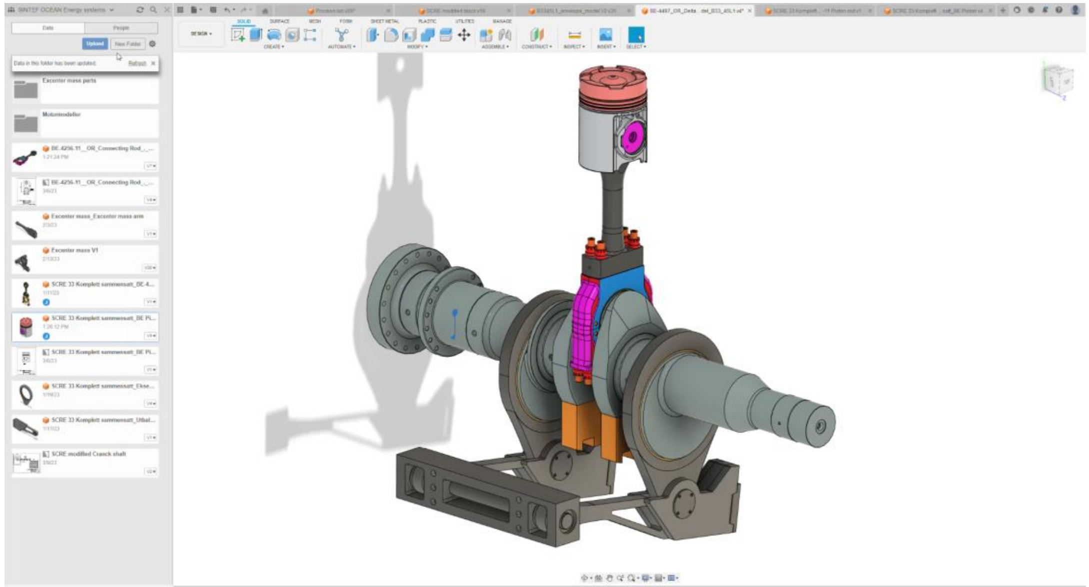

SINTEF
NTNU

New maritime energy systems laboratory

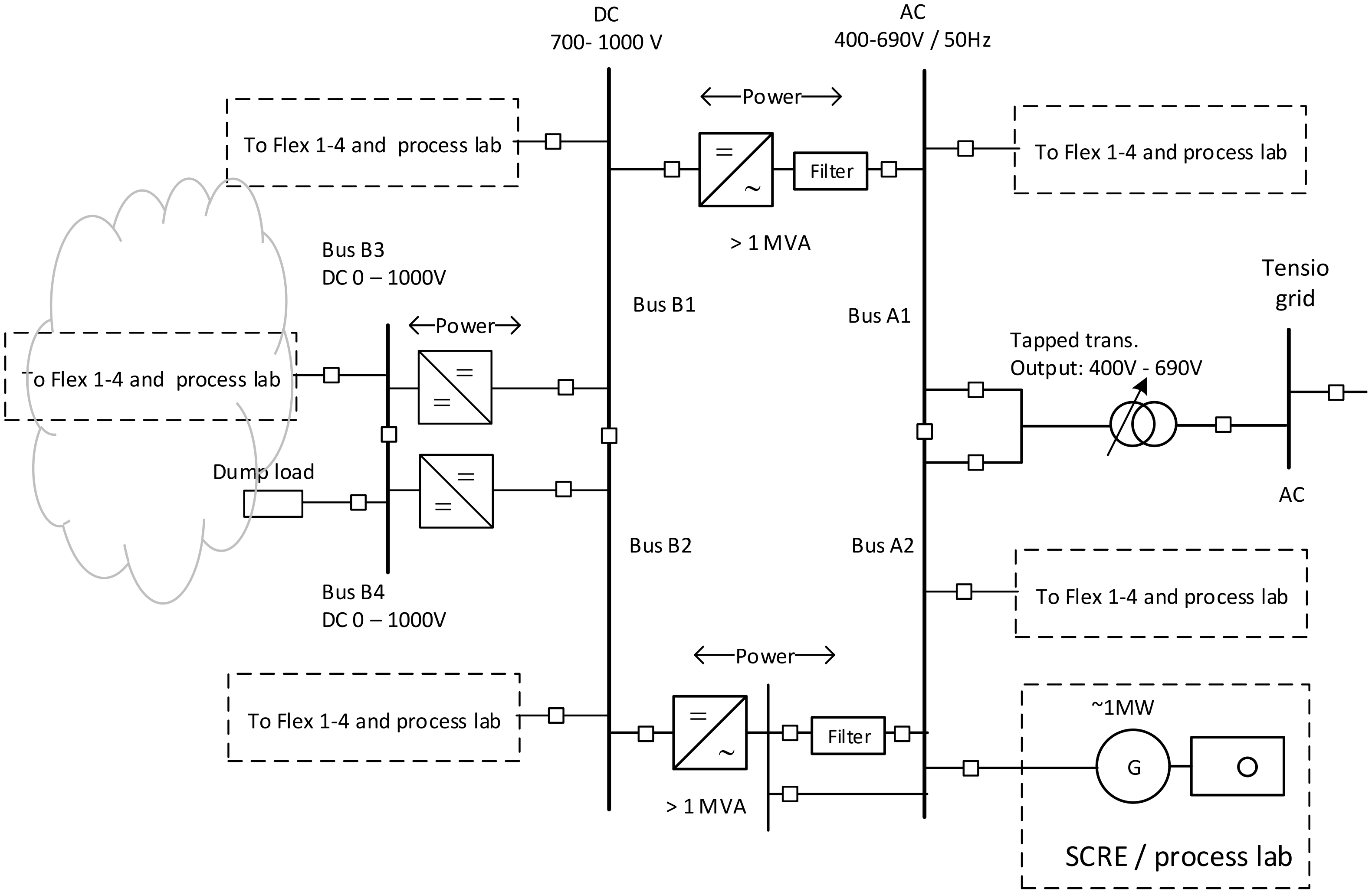


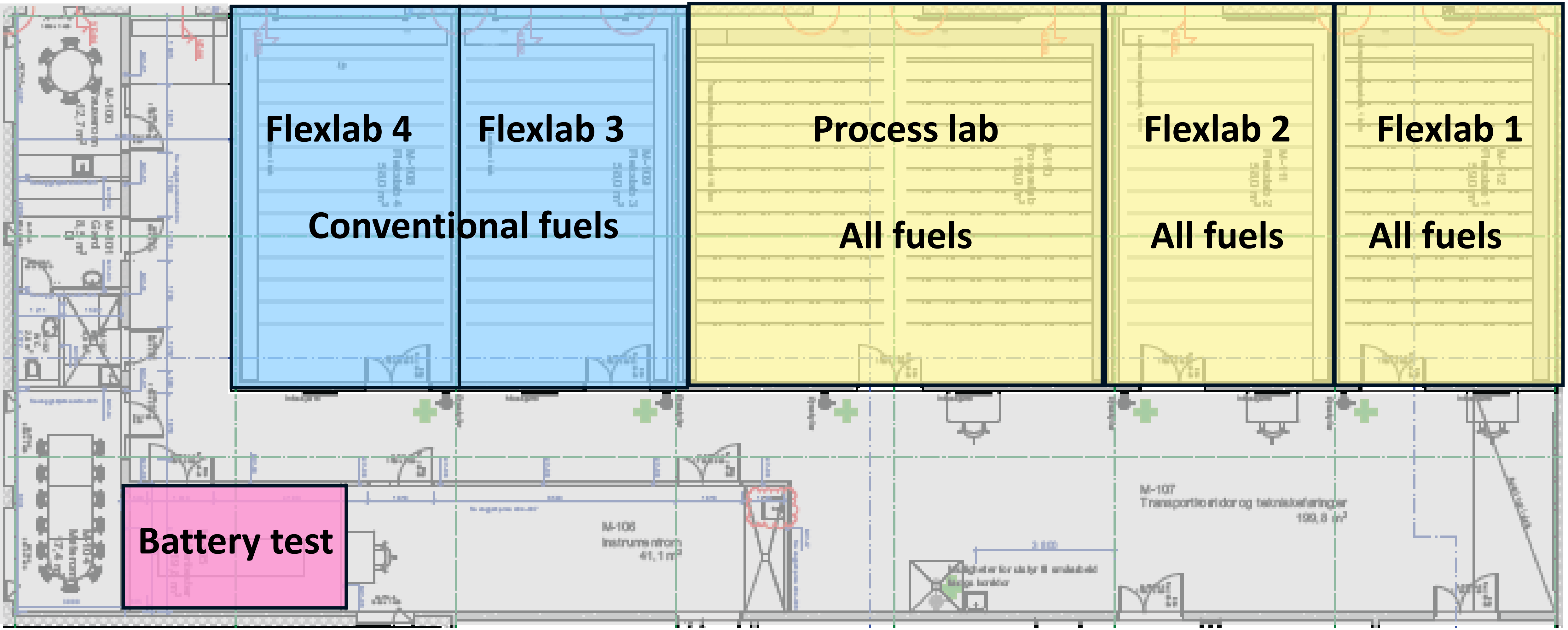
Single Cylinder Research Engine





Principal layout of power electronics





Flexlab 4

Flexlab 3

Conventional fuels

Process lab

All fuels

Flexlab 2

All fuels

Flexlab 1

All fuels

Battery test

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Teknologi for et bedre samfunn