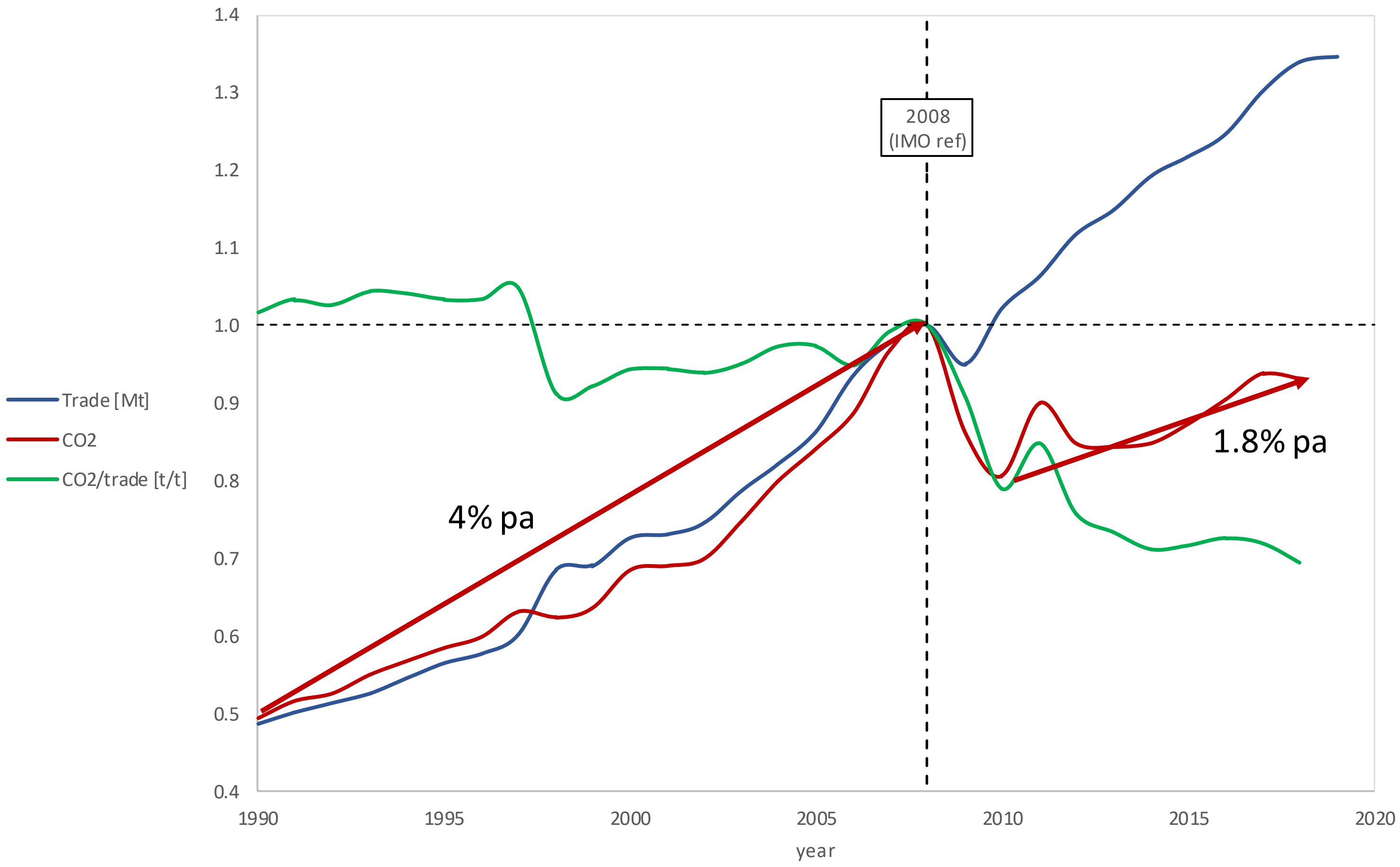
SINTEF

LNG FOR SKIP:
FOR LITE ELLER NØKKELEN TIL NULL (UTSLIPP)?

Gunnar M Gamlem,

Gasskonferansen, Oslo, 19. oktober 2022

Shipping emissions since 1990: Still climbing (at half the pace)



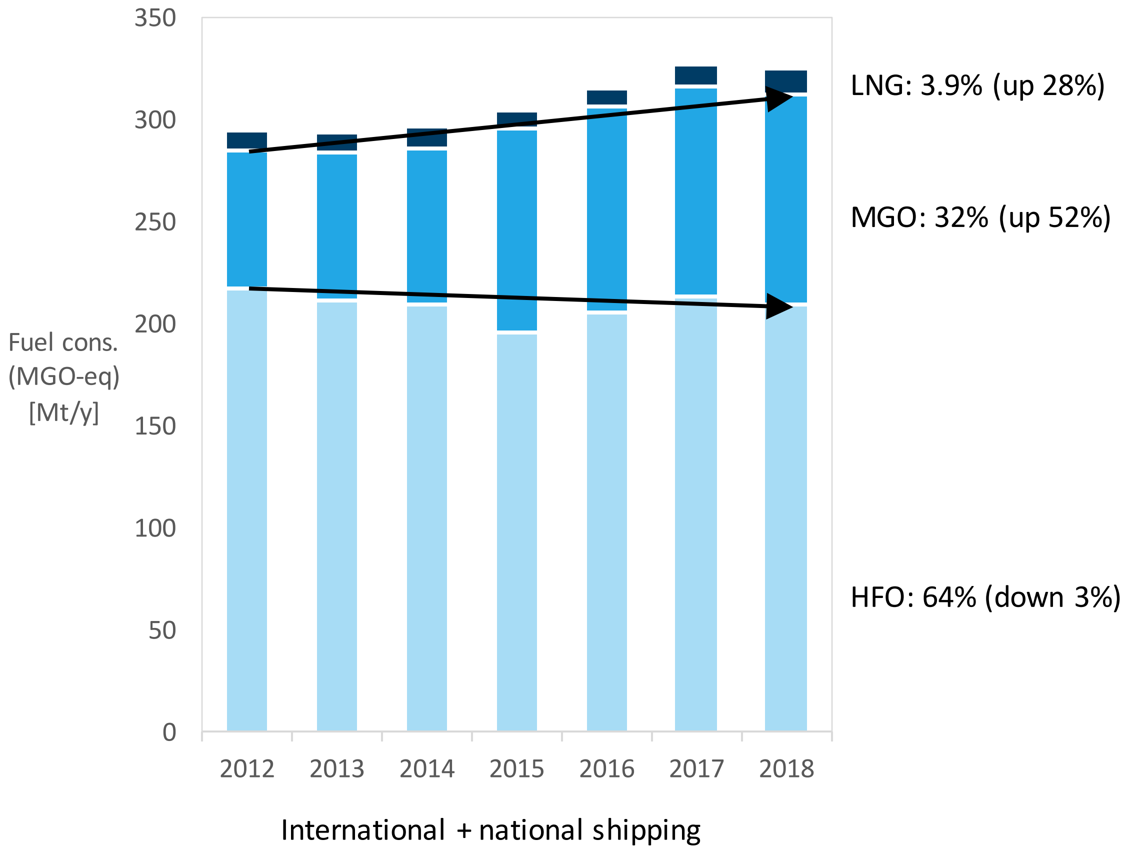
+35% Seaborne trade [t]

-7% Shipping CO_2

-30% Carbon intensity [EEOI]

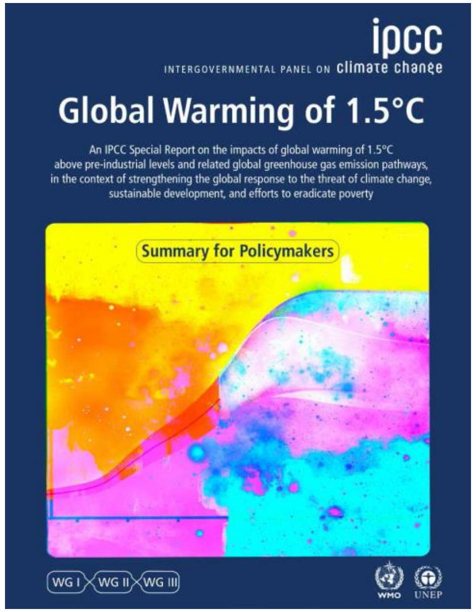
Sources
IMO GHG-studies (3rd and 4th), UNCTAD review of Maritime transport

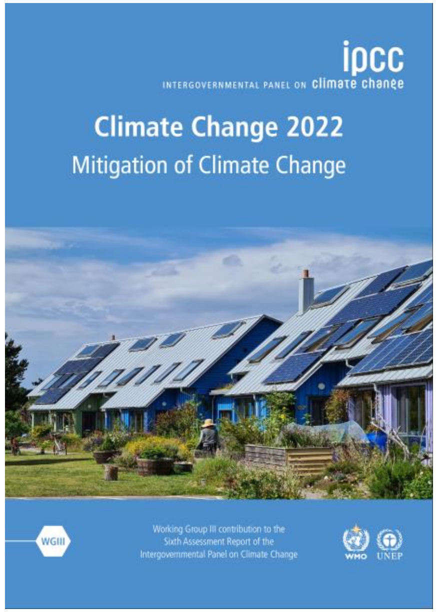
Maritime fuels: Shift towards MGO but no change in carbon intensity



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

Global warming: Urgent vs deep emission cuts?





Comment

Climate tipping points — too risky to bet against

Timothy M. Lenton, Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen & Hans Joachim Schellnhuber

The growing threat of abrupt and irreversible climate changes must compel political and economic action on emissions.

Politicians, economists and even some natural scientists have tended to assume that tipping points[1] in the Earth system – such as the loss of the Amazon rainforest or the West Antarctic ice sheet – are of low probability and little understood. Yet evidence is mounting that these events could be more likely than was thought, have high impacts and are interconnected across different biophysical systems, potentially committing the world to long-term irreversible changes.

Here we summarize evidence on the threat of exceeding tipping points, identify knowledge gaps and suggest how these should be plugged. We explore the effects of such large-scale changes, how quickly they might unfold and whether we still have any control over them.

In our view, the consideration of tipping points helps to define that we are in a climate emergency and strengthens this year's chorus of calls for urgent climate action – from schoolchildren to scientists, cities and countries.

The Intergovernmental Panel on Climate Change (IPCC) introduced the idea of tipping points two decades ago. At that time, these 'large-scale discontinuities' in the climate system were considered likely only if global warming exceeded 5 °C above pre-industrial levels. Information summarized in the two most recent IPCC Special Reports (published in 2018 and in September this year)[2,3] suggests that tipping points could be exceeded even between 1 and 2 °C of warming (see 'Too close for comfort').

If current national pledges to reduce greenhouse-gas emissions are implemented – and that's a big 'if' – they are likely to result in at least 3 °C of global warming. This is despite the goal of the 2015 Paris agreement to limit warming to well below 2 °C. Some economists, assuming that climate tipping points are of very low probability (even if they would be catastrophic), have suggested that 3 °C warming is optimal from a cost–benefit perspective. However, if tipping points are looking more likely, then the 'optimal policy' recommendation of simple cost–benefit climate-economy models[4] aligns with those of the recent IPCC report[2]. In other words, warming must be limited to 1.5 °C. This requires an emergency response.

Ice collapse

We think that several cryosphere tipping points are dangerously close, but mitigating greenhouse-gas emissions could still slow down the inevitable accumulation of impacts and help us to adapt.

Research in the past decade has shown that the Amundsen Sea embayment of West Antarctica might have passed a tipping point[3]: the 'grounding line' where ice, ocean and bedrock meet is retreating irreversibly. A model study shows[5] that when this sector collapses, it could destabilize the rest of the West Antarctic ice sheet like toppling dominoes – leading to about 3 metres of sea-level rise on a timescale of centuries to millennia. Palaeo-evidence shows that such widespread collapse of the West Antarctic ice sheet has occurred repeatedly in the past.

The latest data show that part of the East Antarctic ice sheet – the Wilkes Basin – might be similarly unstable[3]. Modelling work suggests that it could add another 3–4 m to sea level on timescales beyond a century.

The Greenland ice sheet is melting at an accelerating rate[3]. It could add a further 7 m to sea level over thousands of years if it passes a particular threshold. Beyond that, as the elevation of the ice sheet lowers, it melts further, exposing the surface to ever-warmer air. Models suggest that the Greenland ice sheet could be doomed at 1.5 °C of warming[3], which could happen as soon as 2030.

Thus, we might already have committed future generations to living with sea-level rises of around 10 m over thousands of years[3]. But that timescale is still under our control. The rate of melting depends on the magnitude of warming above the tipping point. At 1.5 °C, it could take 10,000 years to unfold[3]; above 2 °C it could take less than 1,000 years[6].

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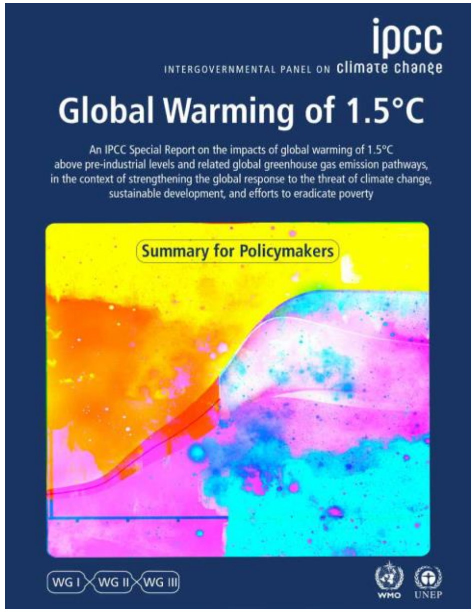
GHG:
45% reduction from 2010 to 2030 necessary to limit global warming to 1.5°C.

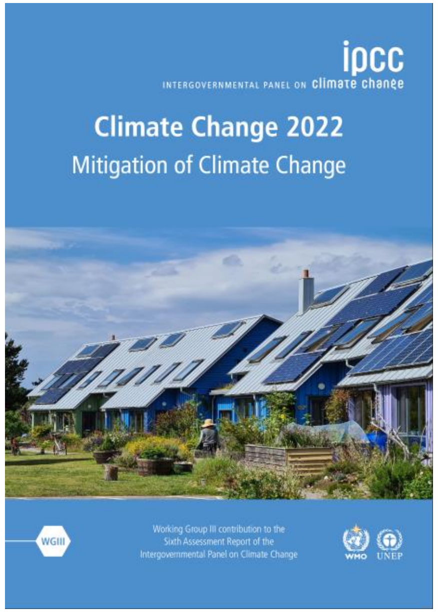
GHG:
GHG emissions must peak before 2025 to limit global warming to 1.5°C with no or limited overshoot.

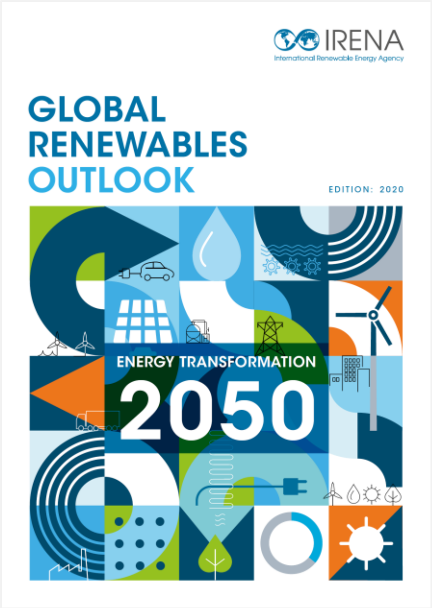
GLOBAL WARMING:
Tipping points can be exceeded even between 1 and 2°C warming.

Sources:
IPCC SRR1.5 (2018), AR6 (2022), Lenton and Rockstrom (2022)

More than global warming on the table







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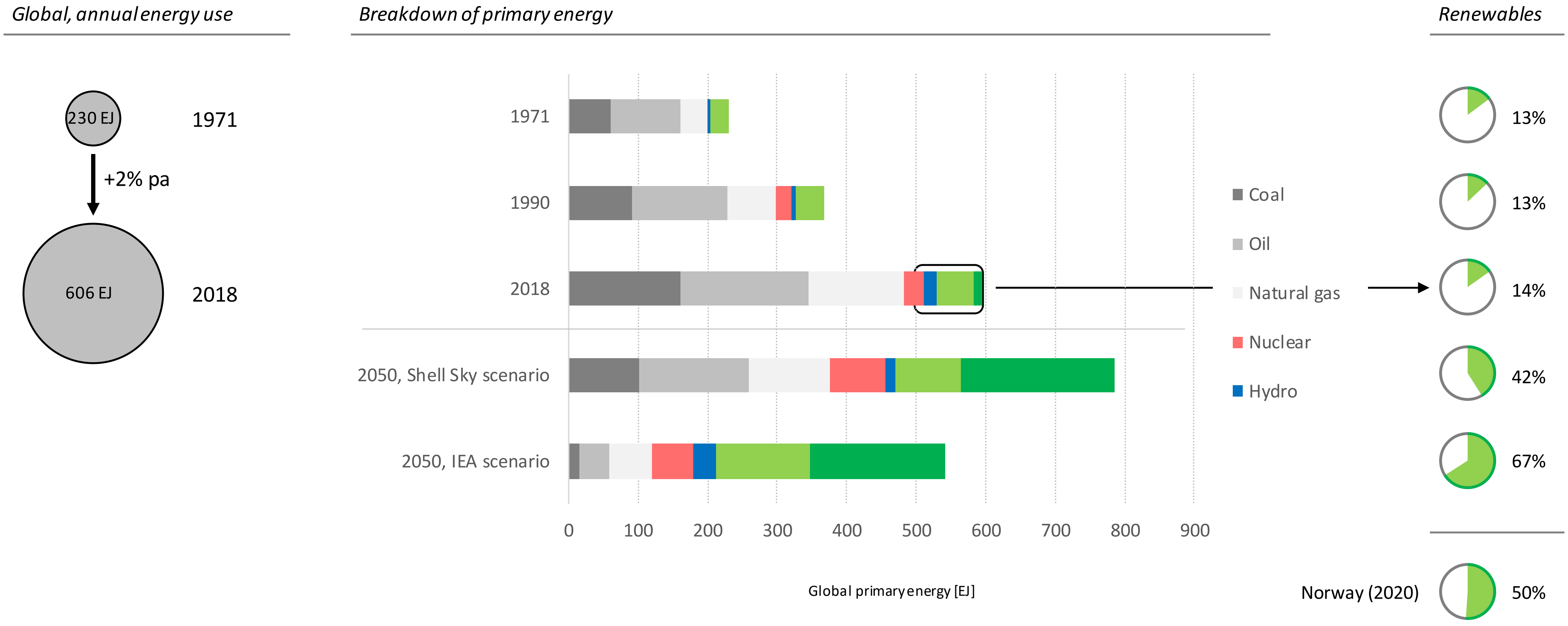
CLEAN AIR:
97.3% live in areas where air pollution exceed the WHO threshold (PM2.5 > 5 µg/m^3) and PM shortens the average life expectancy by 2.2 years worldwide,

ENERGY:
Improvements in energy efficiency must triple.
So far, growth in renewables is cancelled by growth in energy demand.

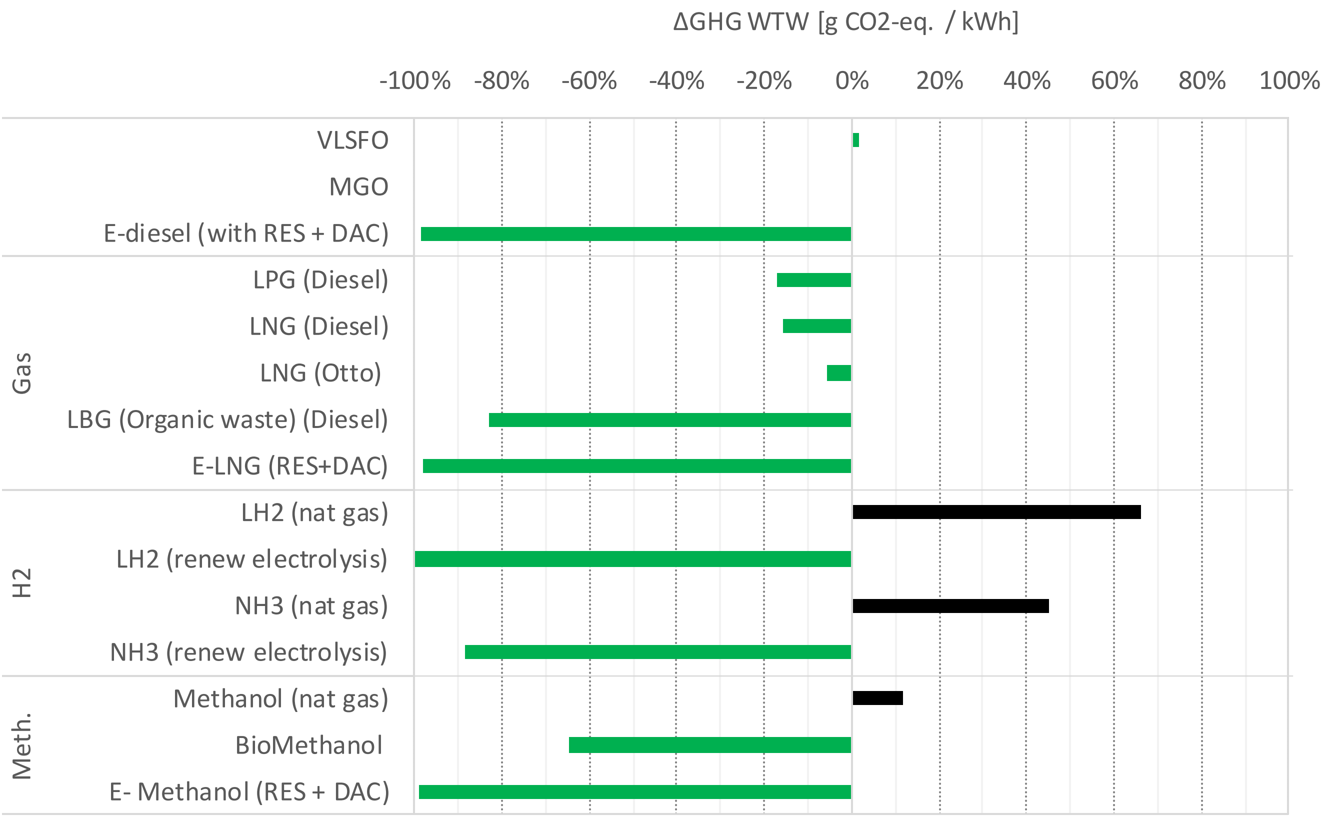
Sources:
IPCC SRR1.5 (2018), AR6 (2022), Lenton and Rockstrom (2022)

Global energy demand and primary energy mix 1971-2019



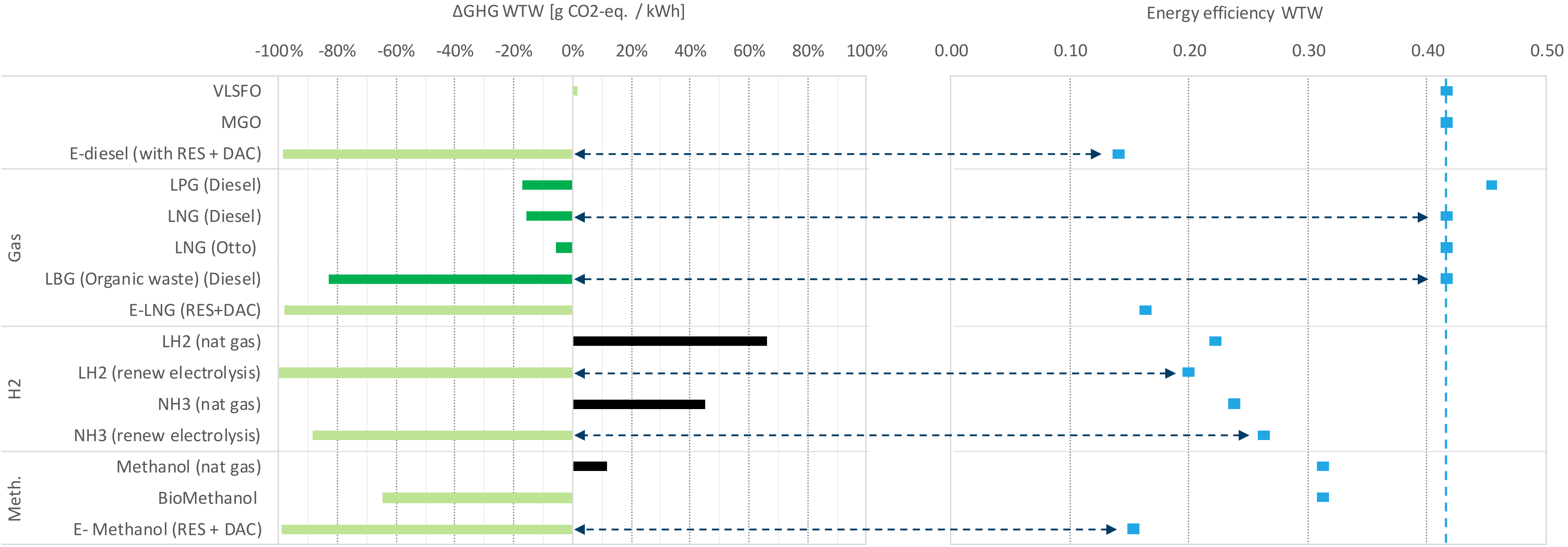
IEA (https://www.iea.org/data-and-statistics/charts/total-primary-energy-supply-by-fuel-1971-and-2019)
Energi Norge and Thema Consulting (https://fornybarometeret.no/status-for-norsk-omstilling-til-fornybar-energi)

Alt. fuels: GHG (WTW) vs MGO



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.
Biofuels can be produced from very different raw materials and have very different footprints.
Other sustainability criteria apply.

Alt. fuels: GHG and energy efficiency (WTW) vs MGO



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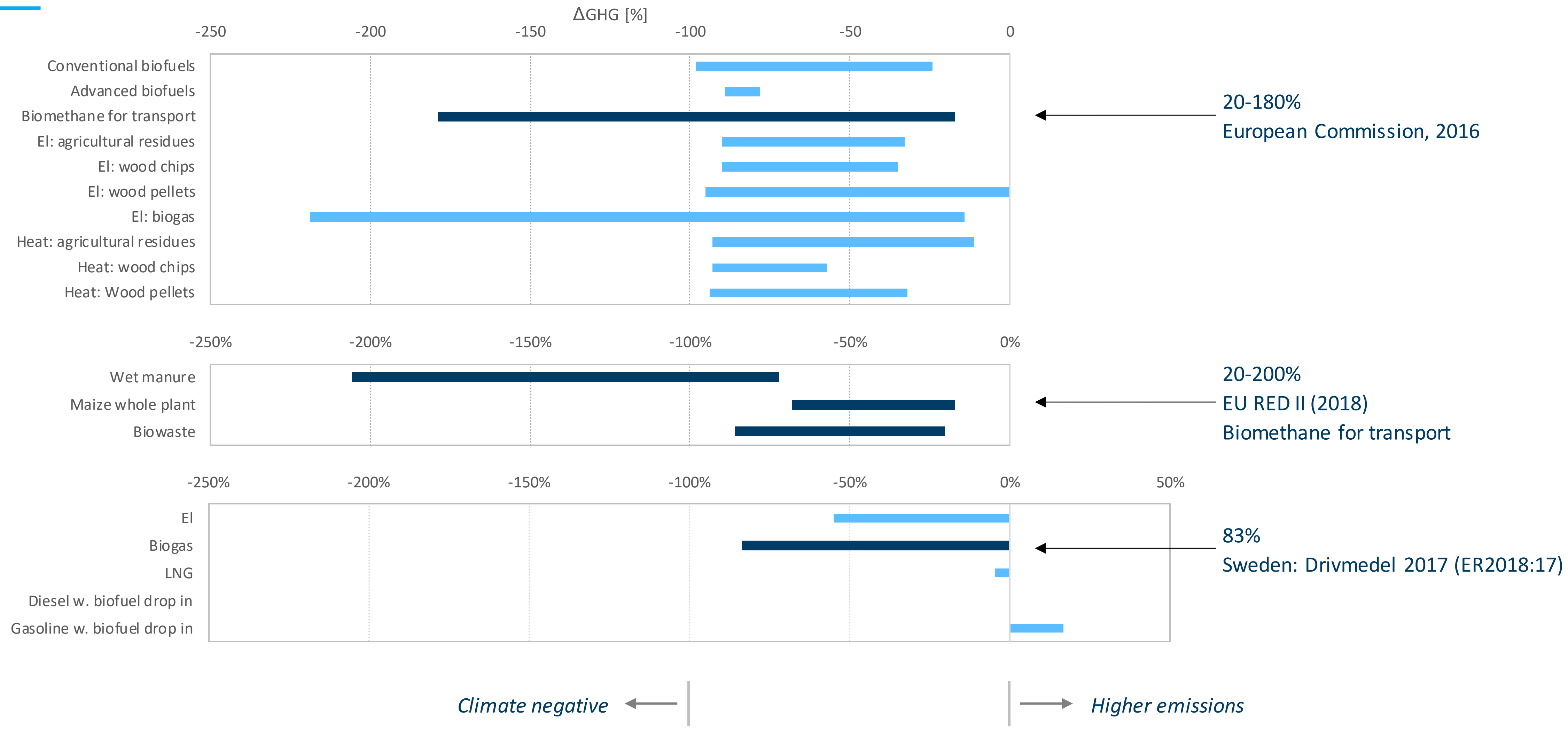
Biogas: The GHG-saving varies and depends!

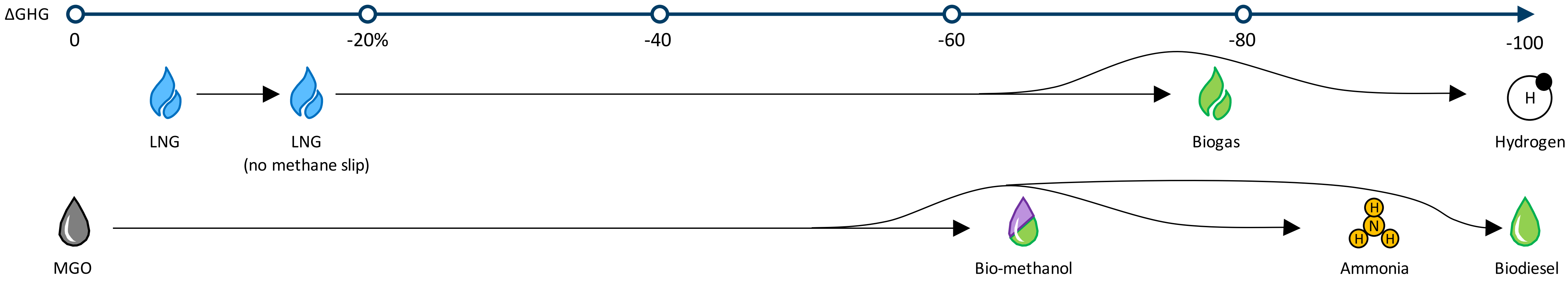


Sources.

EU RED II, 2018 (s. 97), IEA, Technology roadmap Delivering sustainable bioenergy, 2017 (tabell 7, s. 51), Svensk energimyndighet: Drivmedel 2017, (tabell 11, s. 33)

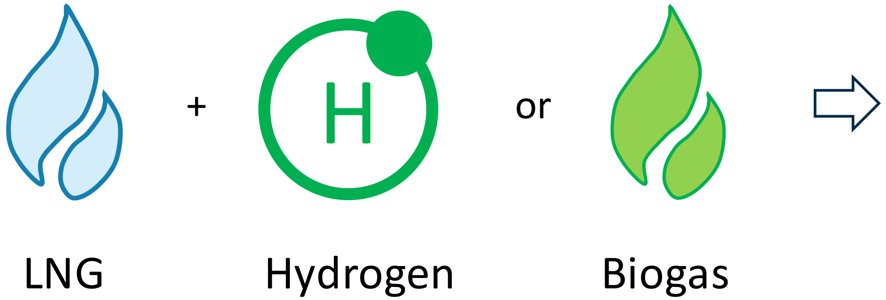
SINTEF

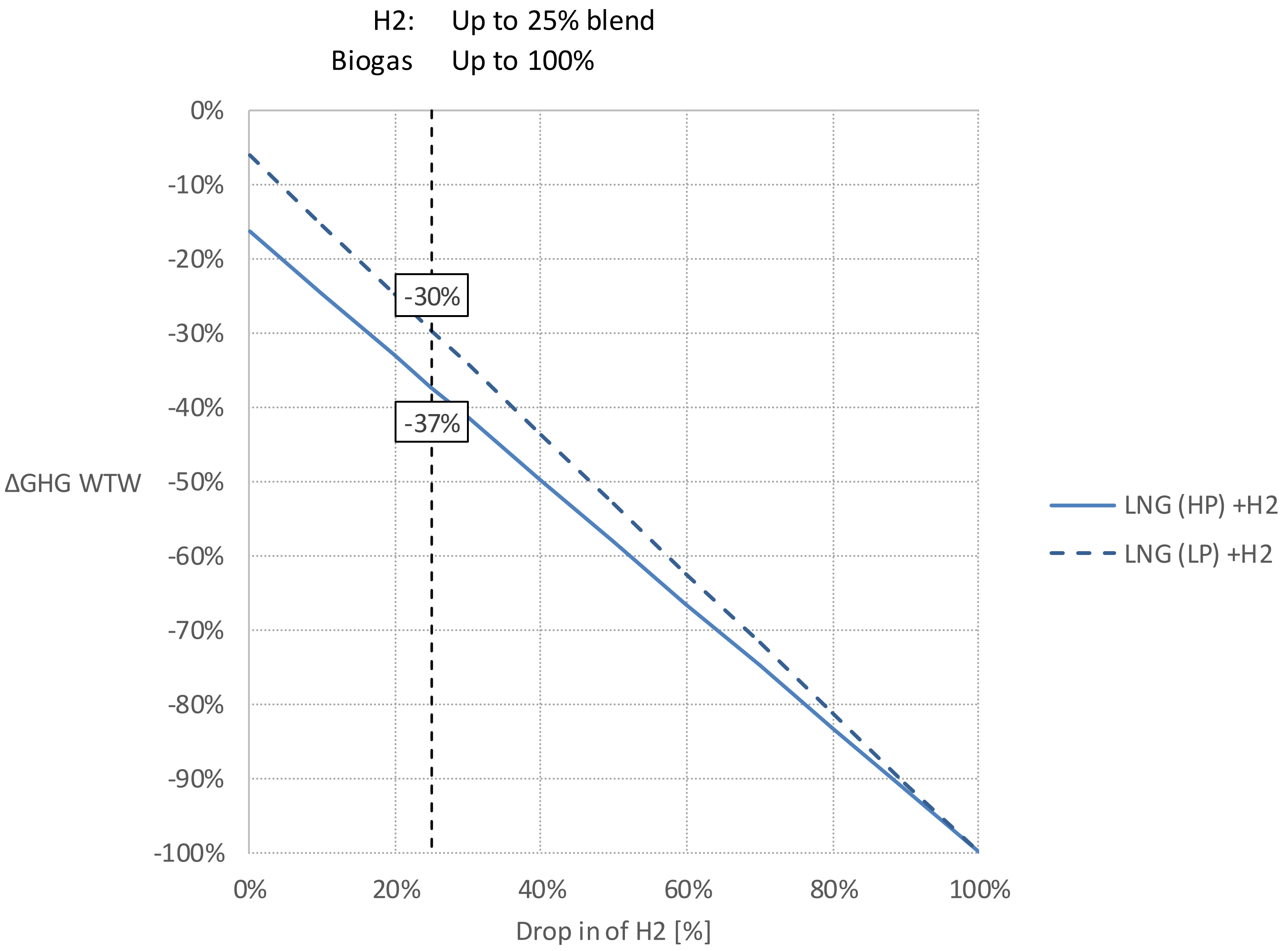
Two distinct pathways: Gaseous fuels (top) and liquid fuels (bottom)



	All sizes Dual fuel	Yes: 2/4S	Yes: 2/4S	2/4S in 2025	Fuel cells 4S in 2025
	Methane slip	Raw materials Direct Air Capture	Sustainability Raw materials	Renew. el or CCS. N_2O, NO_x	Renew. el or CCS. Pressure & temp.

GHG-effect of blending in H2 or biogas





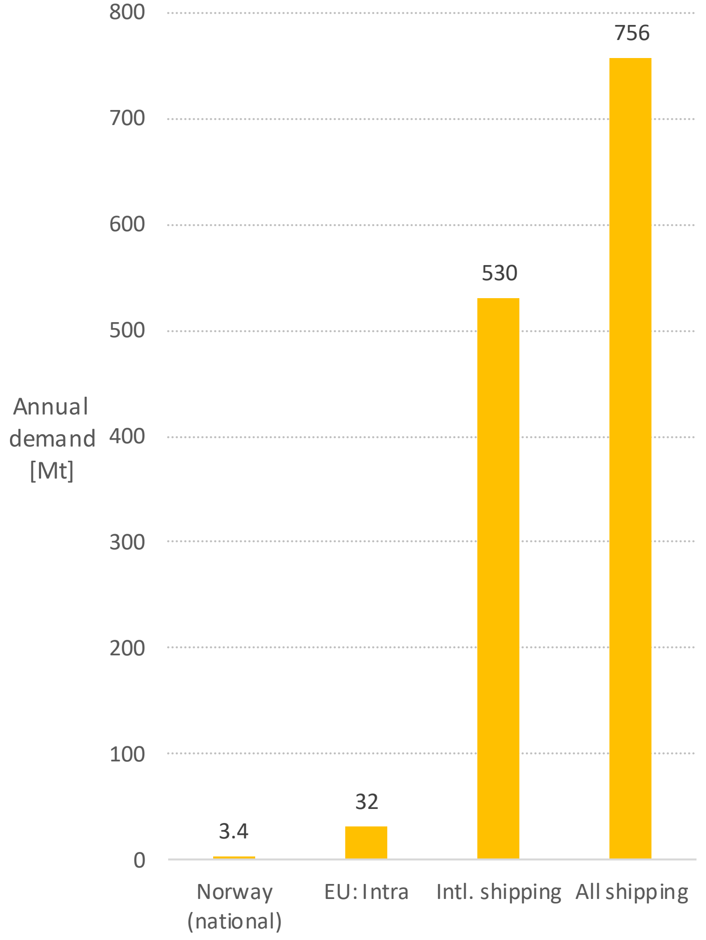
Wärtsilä engines ok with up to 25% hydrogen blend. WTW emission factors from Lindstad et al.
Can be reduced further (-10%) once methane slip is eliminated.

Supply side: The map for LNG supply looks a bit like the oil bunkering map

Supply network for LNG (incl. bunker barges)

SOURCES:
IMO 4th GHG-study, page 97-98. Maritime Fairtrade (↗), DNV AFI

Shipping's need for ammonia vs plans




12 Nyheter

Industri

Vil skape stor aktør på grønn hydrogen – trenger statsstøtte

Prosjektet er ikke konkurranse-dyktig i dag, men kan gi Norge viktig plass i hydrogenøko-nomien, sier Yaras konsernsjef.

Yara, 2026: 0.5 mill. t/y
20,000 t for shipping
Green ammonia (electrolysis)


14 Nyheter

Energi

Bykser på børs – gründers aksjer verd 60 mill. mer

Horisont Energi og partnerne får nesten en halv milliard kroner til ammoniakkprosjekt i Finnmark. Nå kan det hende de ikke trenger med offentlig støtte, sier gründeren bak selskapet.

Horisont Energi, 1 mill. t/y (planned
Blue ammonia (Natural gas + CCS)

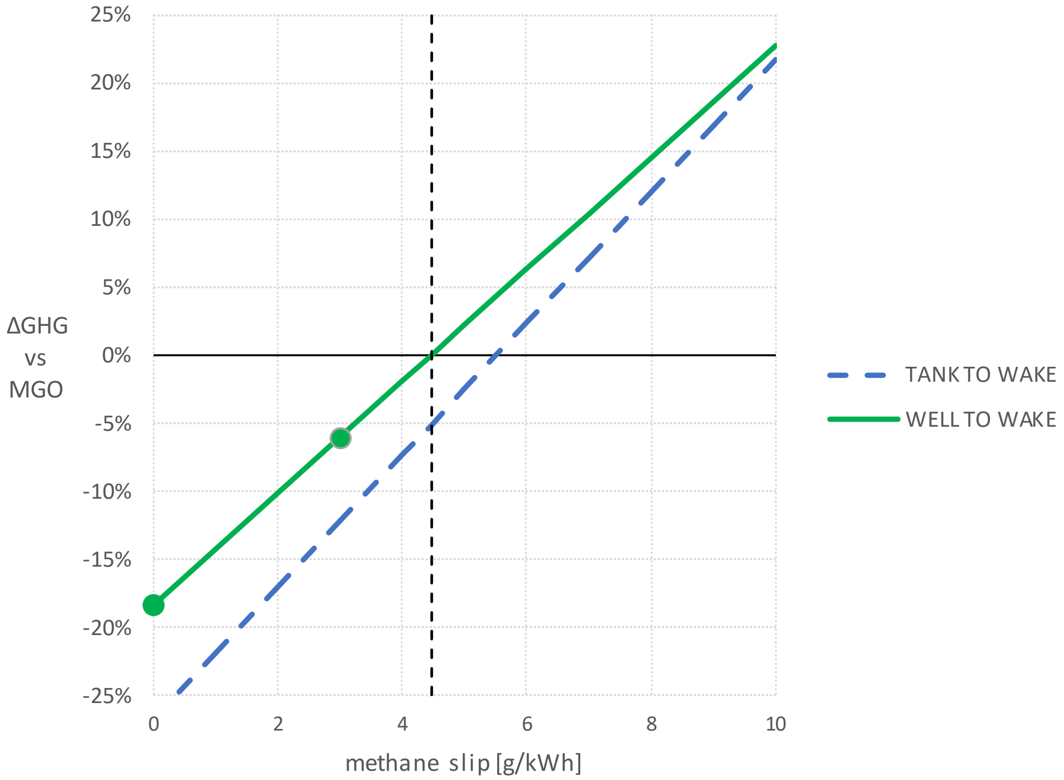
Based on current energy consumption. Conversion based on heating value (LCV) and assuming same engine thermal efficiency for all fuels.
Source: DN 8 Dec 2020, DN 18 Dec 2021.

Alternative fuels overview

	Fossil fuels	Natural gas	Biofuels	Hydrogen fuels	Synthetic fuels
Examples	HFO Residual fuel blends MGO Methanol	LNG LPG Ethane	Liquid biofuels (many variants) Biogas (many variants) Bio-methanol	Hydrogen (LH2, PH2, LOHC) Ammonia	E-diesel E-LNG E-Methanol Dimethylether (DME)
GHG	High	6-17% below MGO	20-200% below MGO	45-65% above MGO to zero	Depending on the production
Prerequisites for climate neutrality	Carbon capture onboard	No methane slip Carbon capture onboard	Sustainable biomass No methane slip	Climate neutral electricity CCS (Carbon capture & storage)	Climate neutral electricity Direct air capture (DAC)
Pitfalls	High capture rate?	High capture rate?	Sustainability? Indirect land use change? Alternative use as crops? Disruption of food chain?	N_2O from ammonia?	Climate neutral electricity Direct air capture (DAC)
Major advantage	No/little disruption Synergies with other CCS-projects	No/little disruption Synergies with other CCS-projects	Climate negative at best Wastes as raw material Small scale local production	Ammonia: Energy dense Hydrogen: Emission free	No/little change onboard
Use/supply	HFO: 64% / MGO 32%	LNG 4% / LPG: Minor	Piloting	Grey variants only	N/A

Source:
Smart Maritime sea map to green shipping (SINTEF/NTNU, Gamlem 2022)

Methane slip; the Achilles heel of natural gas



Engine manufacturers take on the methane slip challenge

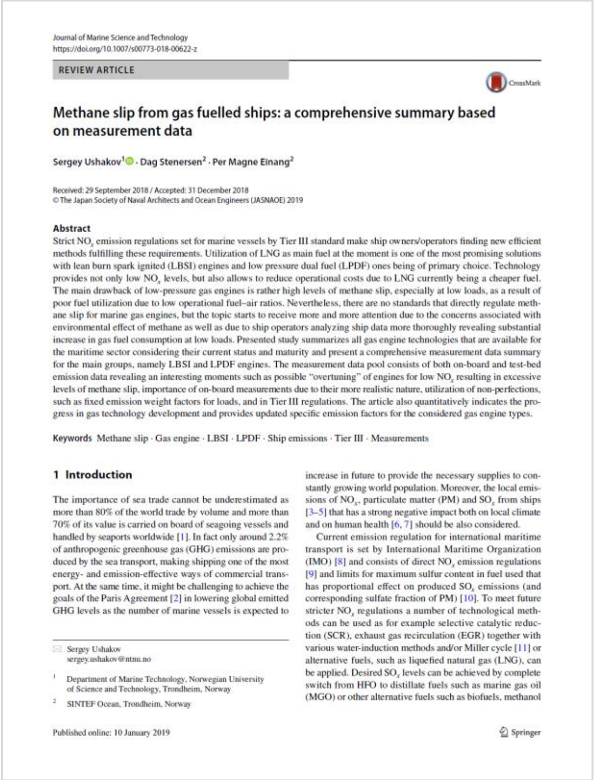
Combating methane slip proves to be an important turning point in reducing GHG emissions in the mass changeover to LNG combustion

MAN's 51/60DF engine, the largest in its dual-fuel range

Disputing the findings

22

October 2020



Journal of Marine Science and Technology
https://doi.org/10.1007/s00773-018-00622-z

REVIEW ARTICLE

Methane slip from gas fuelled ships: a comprehensive summary based on measurement data

Sergey Ushakov[1] · Dag Stenersen[2] · Per Magne Einang[2]

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© The Japan Society of Naval Architects and Ocean Engineers (JASNAOE) 2019

Abstract

Keywords Methane slip · Gas engine · LBSI · LPDF · Ship emissions · Tier III · Measurements

1 Introduction

Published online: 10 January 2019

Springer

Note:
Author's calculations, The Naval Arthictect Oct 2020, Ushakov et al (2018)

Key conclusions

- LNG offers small GHG-reductions now (6-16% WTW, up to 25% TTW)
- LNG can be combined with biogas tomorrow (and reduce GHG up 100% and beyond)
- LNG can be combined with hydrogen soon (to give 30-40% and above)
- LNG and biogas are more energy efficient WTW (than hydrogen, ammonia, bio-methanol and synthetic fuels)
- LNG (and biogas and hydrogen) gives clean air; no SO_X, no particles and (with the right machinery) no NO_X

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Teknologi for et bedre samfunn