MAN Energy Solutions
Future in the making

The Path to Decarbonization

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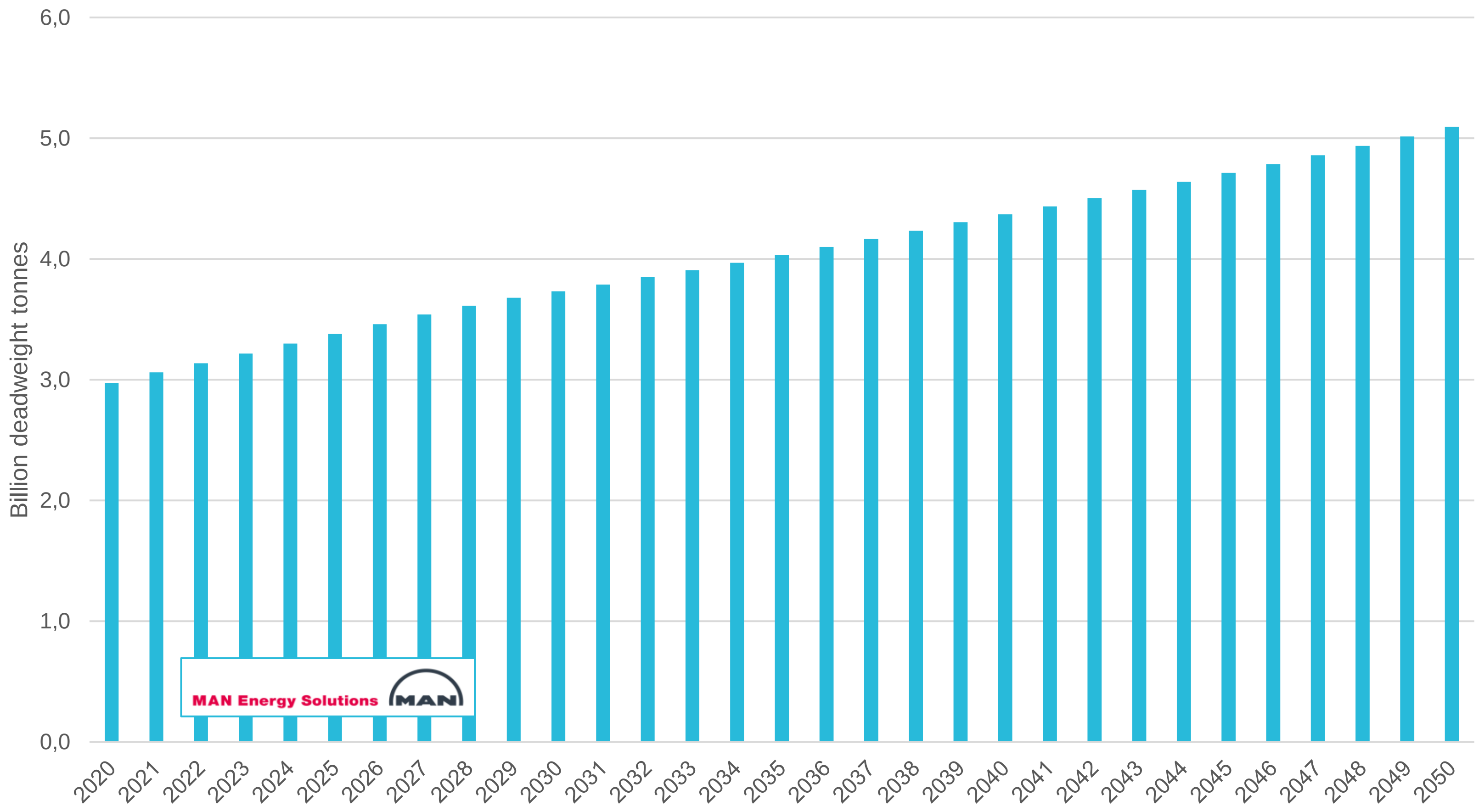
In the following, future ‘unknown’ or clearly theoretical energy efficiency measures and legislation are not taken into account

Neither are very ambitious global legislation as banning fossil fuels nor significant carbon taxes or unlimited ship- and repair yard capacity

This is based on the most likely scenario we expect from where we stand today

Great challenge to decarbonize a sector with 60% growth over the next 30 years



Projections are based on MAN ES assessment and OECD, Real GDP long-term forecast, predating war in Ukraine: https://data.oecd.org/gdp/real-gdp-long-term-forecast.htm#indicator-chart

- Economic growth and world trade are important drivers to lift developing countries out of poverty
- New geopolitical uncertainties can alter the outlook but the future trend is upwards
- Mix of transported goods are changing but seaborne bulk transportation will increase globally
- Total propulsion power requirements will also increase but the question is: At what pace and technology?
- Internal combustion engines sheer energy efficiency makes them very difficult to replace in deep sea shipping

Method

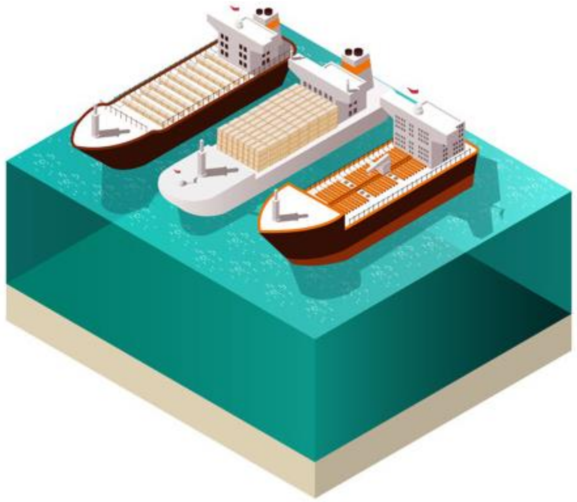
Two-Stroke Fleet

Forecast fleet size in DWT → Two-stroke fleet size in kW → Yearly energy consumption → Yearly fuel demand → CO_2 emissions

Four-Stroke Fleet

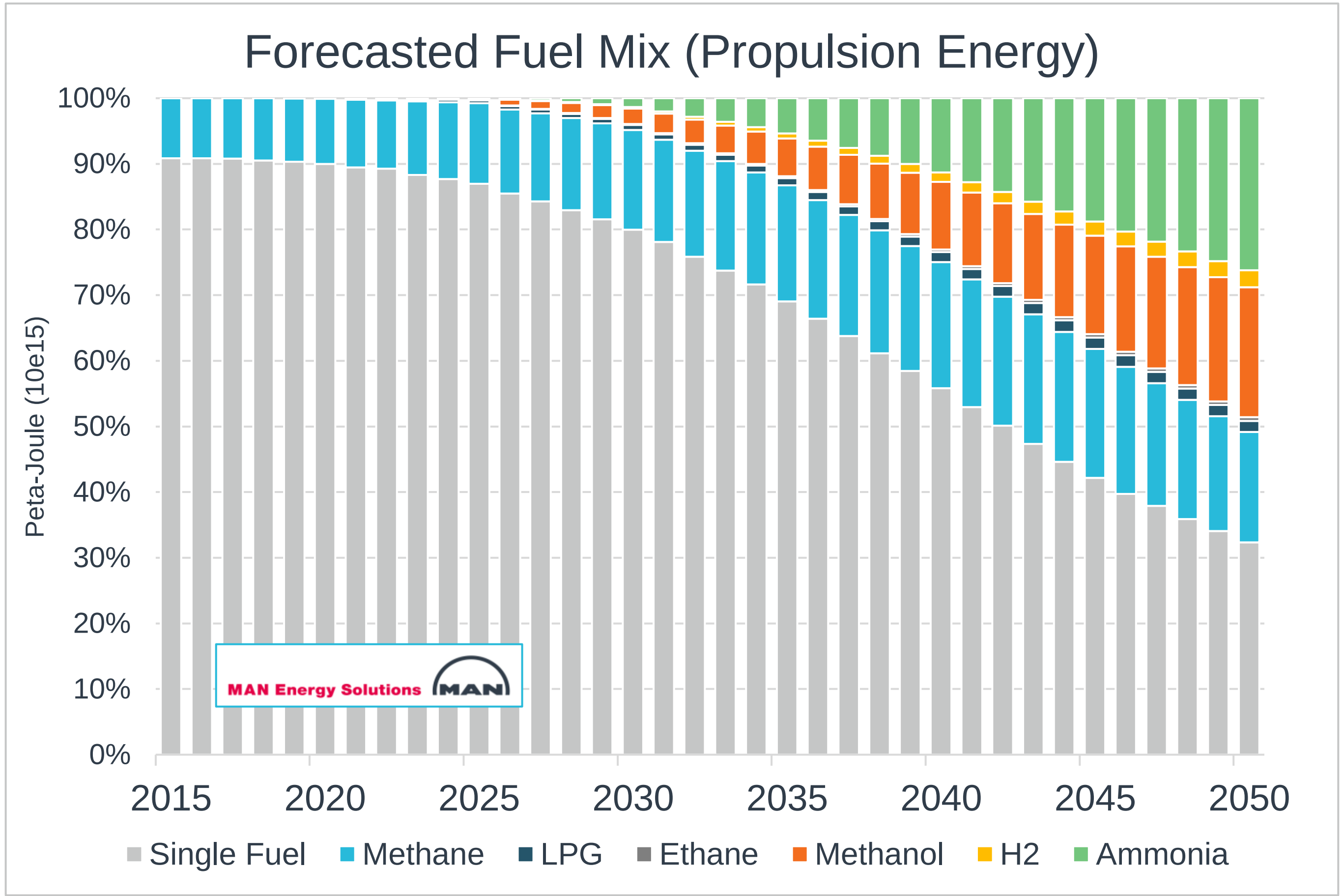
Count number of engines in each ship type and size → Use Table O.7 in Fourth IMO GHG Study 2020 to calculate share of CO2 emission → Forecast CO2 emission based on Clarkson figures and MAN ES forecast

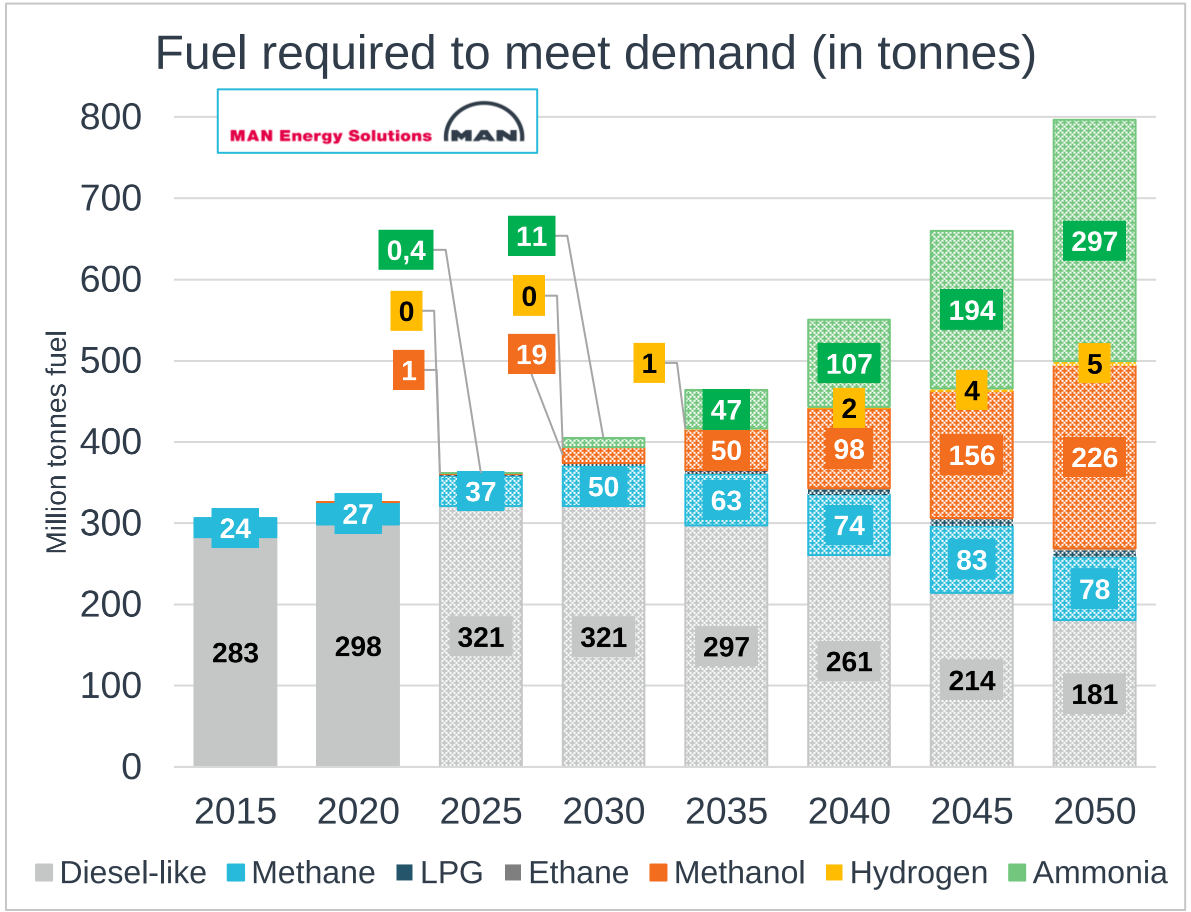
Auxiliary is calculated as a percentage of two-stroke main engine depending on ship type.
Assumed auxiliary fuel type follows main engine



Fuel Mix Projection

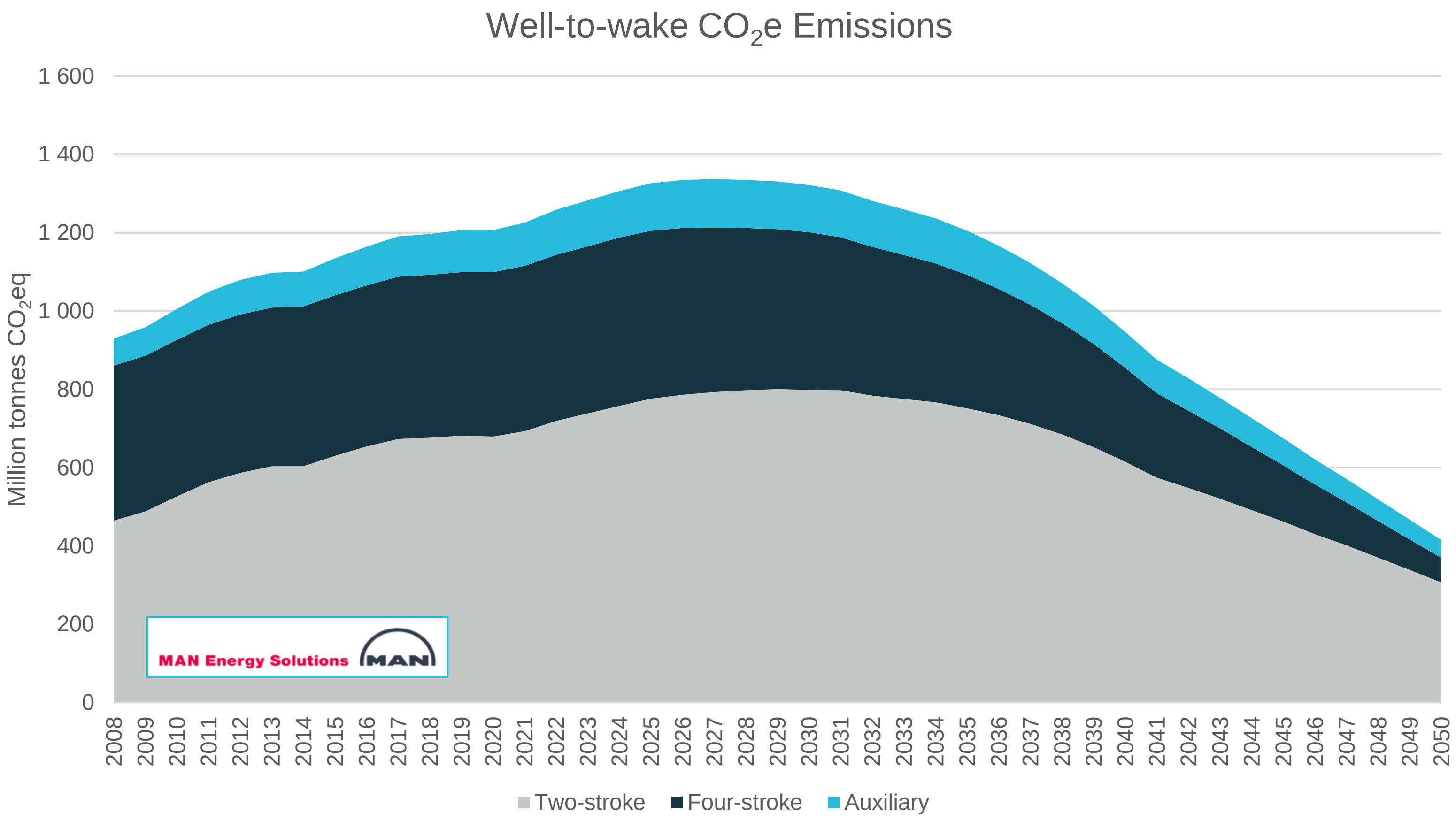
Significant increase in production capacity required both in volume and in technology
– HFO was chosen for a reason....





Only newbuilding included in graph; a more or less gradual transition to green fuels is built into each fuel which then contains both a fossil and net-zero share
*Mass of the fuel types: Energy content of fuels varies due to differences in gravimetric heating value

As the fleet grows 60%, we expect well-to-wake emissions to increase by approx. 10% over the next decade, then decrease as new fuels enters on a larger scale



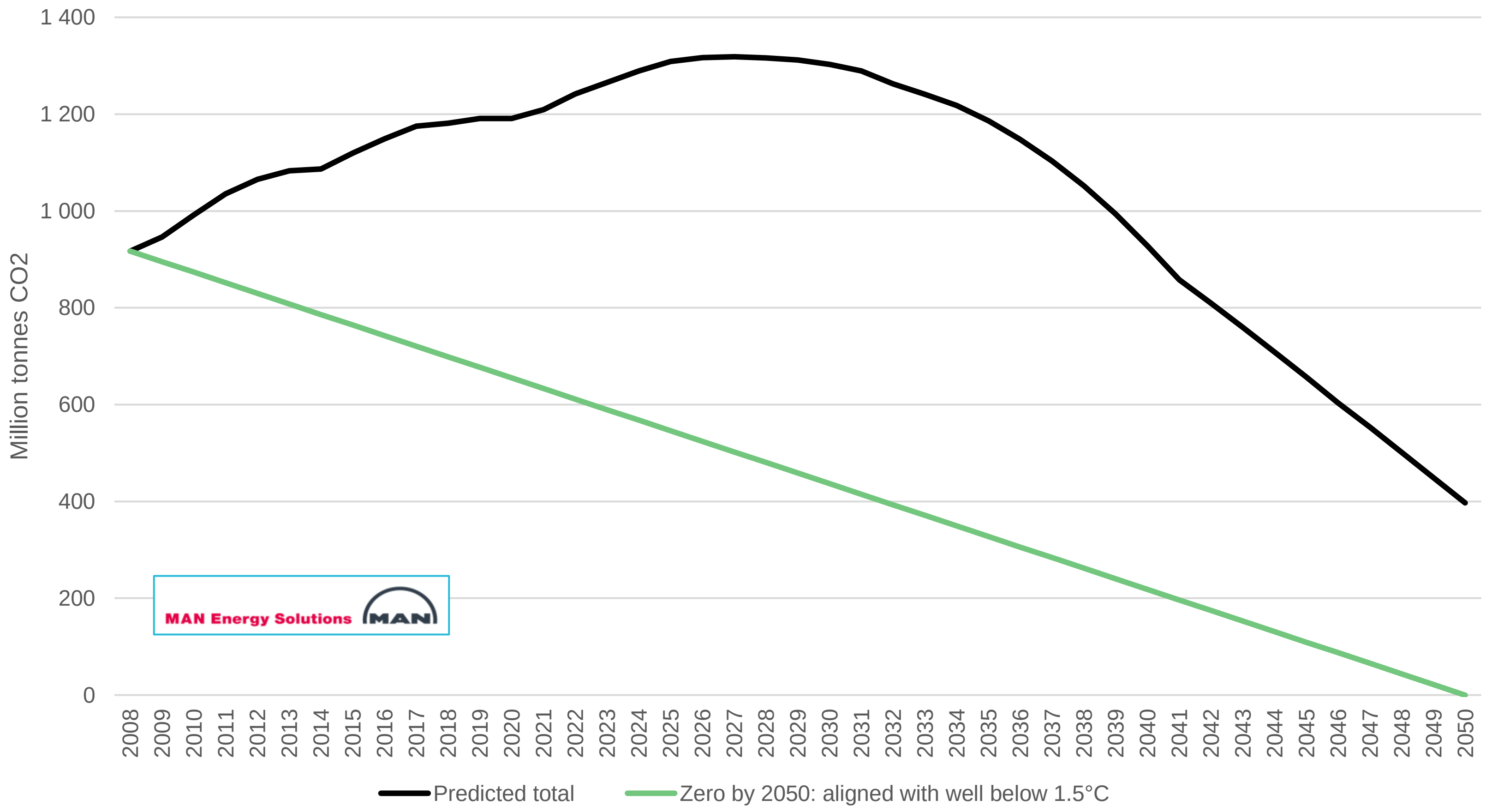
Emission factors from ISWG-GHG 11/2/3: factors are preliminary and no decision has been taken in IMO on default values of WtT and TtW CO2e emissions.
CO2 equivalents, e.g. from methane and nitrous oxide, not included

- Shipping sector can be decarbonized although considered hard to abate
- Current and expected future decarbonization technologies curb the development of CO_2 emissions

Assumptions:

- *Engine technologies follow the fuel mix*
- *MAN ES assessment of share of renewable fuels by fuel type*
- *Less power installed, higher load (EEDI-driven)*
- *No efficiency improvements included*

Well-to-wake CO_2 emissions and the Paris Agreement: It may be possible to reach Net zero by 2050, but the intermediate overshoot is problematic

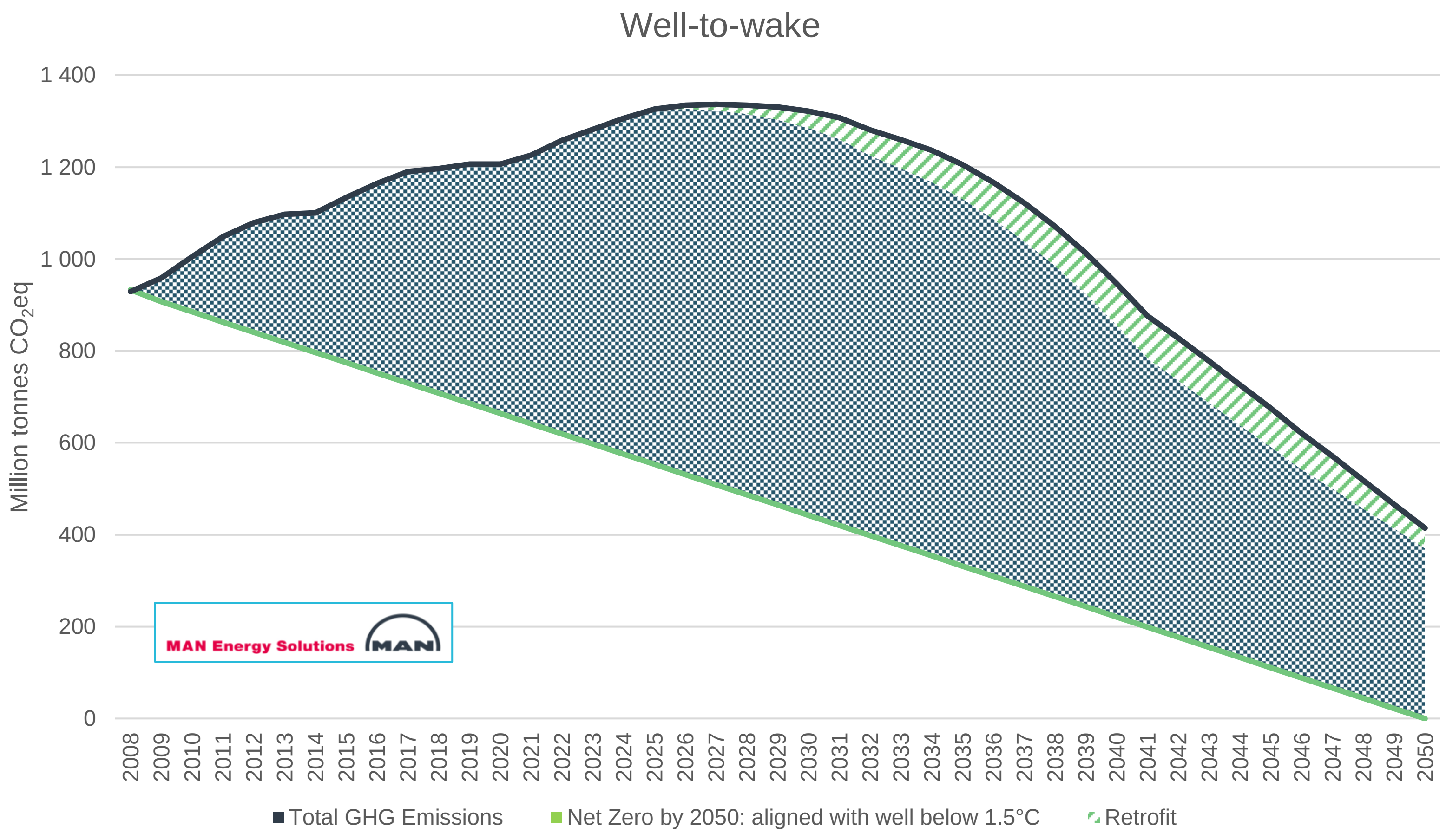


Net zero by 2050: IPCC Sixth Assessment Report (AR6), pathways limiting global warming to 1.5°C with no or limited overshoot

- Net zero by 2050 represents a pathway that limits global warming to 1.5°C with no or limited overshoot
- Deviation is expected to only increase over the next decade
- Shipping is annually making large withdrawals on the carbon budget – so large they probably cannot be caught up
- Cumulated overshoot of the carbon budget is foreseen to reach 25 gigatonnes by 2050

Retrofit potential ~ 6% of overshoot reduction

Capacity and competences are limited for large impact on emissions



- Vessel candidates for retrofit, yard capacity and -competences are limiting factors to volume
- Retrofit is focused on LNG initially but Methanol and Ammonia will dominate on the longer run
- Further analysis of retrofit potential and energy efficiency is required, but abatement of overshoot is hard to overcome with current outlook

Net zero by 2050: IPCC Sixth Assessment Report (AR6), pathways limiting global warming to 1.5°C with no or limited overshoot

In conclusion

Net-zero fuels are not the complete answer to net-zero shipping

- Fuel infrastructure investment requirements alone calls for more ambitious legislative pressure on emissions to increase new fuel technology uptake on a general scale
- Necessary propulsion technology uptake impossible in practice with current market prospects of capacity and competences
- Crew training and -availability is also challenging

Further analysis of potential energy efficiency are required

- Digitalization e.g:
  - Route planning
  - Propulsion system optimization in service
- Hybrid solutions e.g. Air lubrication, Power take out, Batteries, Rotors
- Shore side logistics
- ...

And the forbidden question: What is the cost/benefit of complete Paris-agreement-net-zero shipping vs. more ambitious shore side abatement investments as compensation for some of the overshoot?

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Strictly confidential

Thank you very much!

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Supplementary data

MAN ES assessment of share of renewable fuels by fuel type

Share of green fuels	2030	2040	2050
Conventional	10%	50%	100%
LNG	10%	50%	100%
LPG	10%	50%	100%
Ethane	20%	20%	20%
Methanol	90%	95%	100%
Hydrogen	90%	95%	100%
Ammonia	90%	95%	100%

CO2 emission factors in gCO2eq/MJ

Feedstock	Fuel type	Well-to-tank	Tank-to-wake	Well-to-wake
Fossil	HFO	13,5	78,1	91,6
Fossil	LNG (large Diesel)	18,5	57,7	76,2
Fossil	LPG	7,8	65,5	73,3
Liquid biofuels	Bio-diesel (waste mix)	-26,1	77,5	51,4
e-fuels	e-Methane (large Diesel)	-52,1	57,7	5,6
e-fuels	e-Methanol	-67,1	71,6	4,5
e-fuels	e-Hydrogen	3,6	0,0	3,6
e-fuels	e-Ammonia	0,0	0,0	0,0

Calculation of Auxiliary Power

Ship type	Auxiliary % of main engine CO2e emission
Tanker	16%
VLCC	15%
Bulk	12%
General cargo	17%
Container	13%
LNGC	17%
LPGC	15%
All others	43%

e-LPG and e-Ethane are here assumed to have the same WtT emission factor as SNG/e-LNG/e-Methane