McKinsey & Company

Decarbonizing Shipping

Challenges and opportunities on reducing carbon footprint in the shipping industry

Marine Money China

November 2020

Agenda

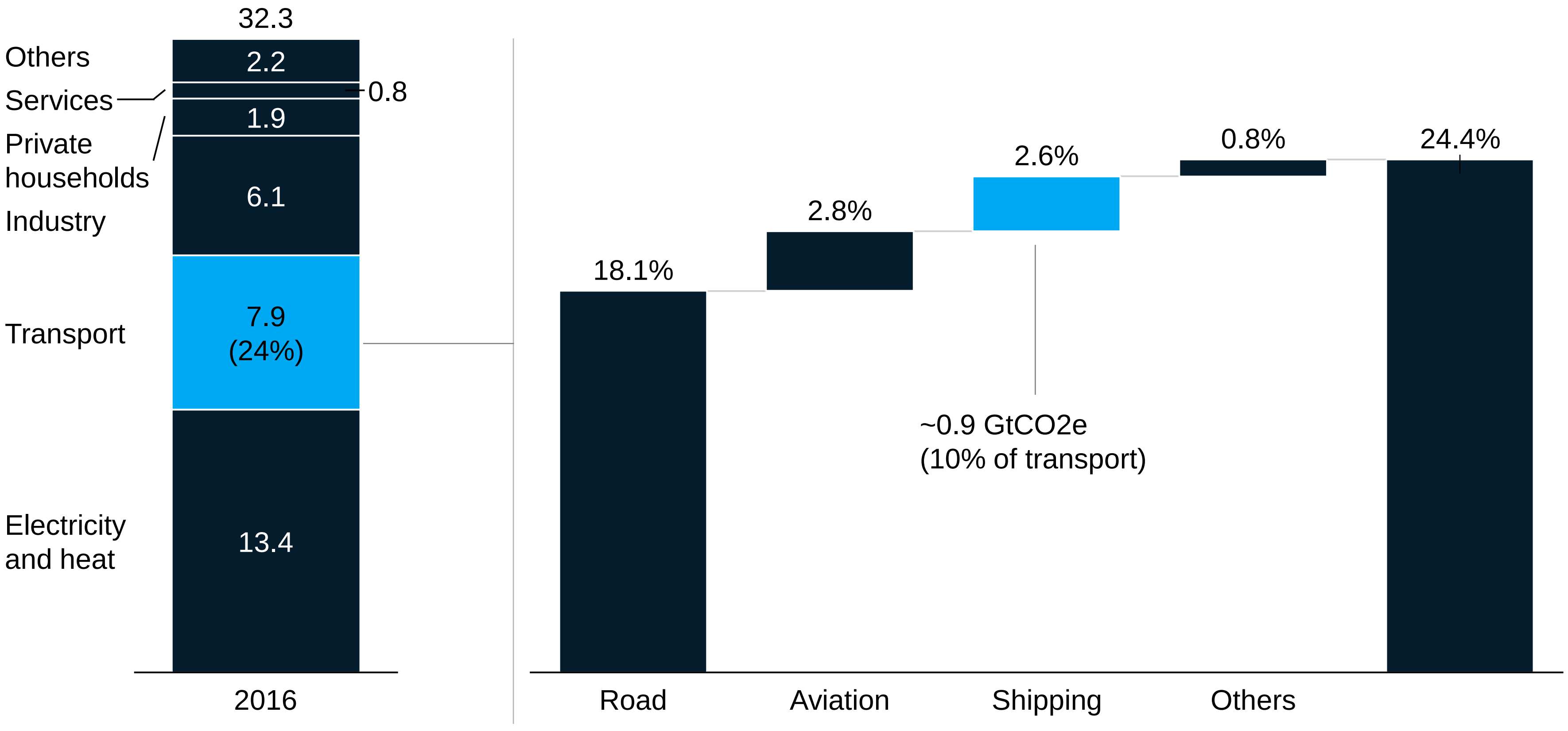
The Challenge

Future fuel pathways

Way forward

Shipping is 3% of global emissions

CO_2 annual emissions, gigatonnes



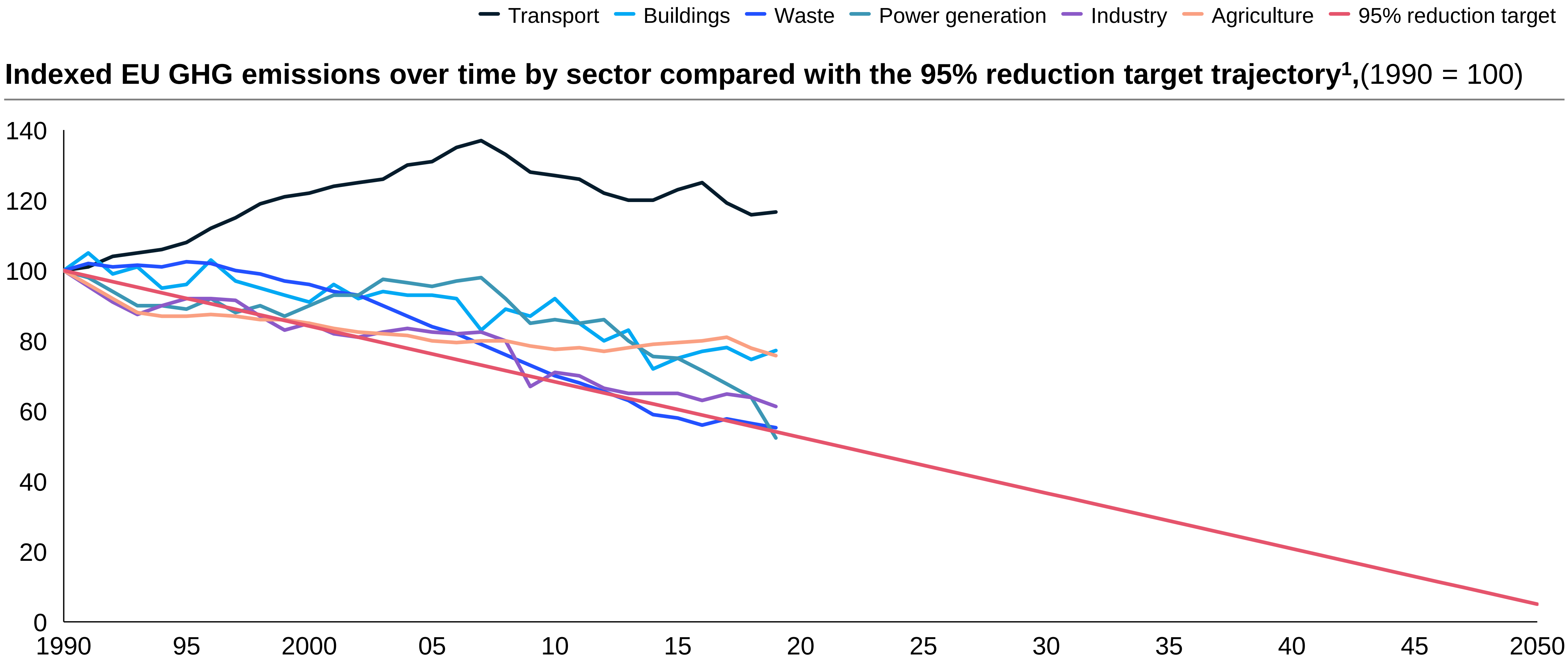
1. Only commercial air transport (passenger and cargo). Excludes general, military and recreational aviation.

Source: IEA 2019, Ship & Bunker news, IMO, ICCT 2015, Platts News

Other sectors are decarbonizing, attention is shifting to transport

Transport is the only sector not on track for EU climate targets

Indexed EU GHG emissions over time by sector compared with the 95% reduction target trajectory[1],(1990 = 100)



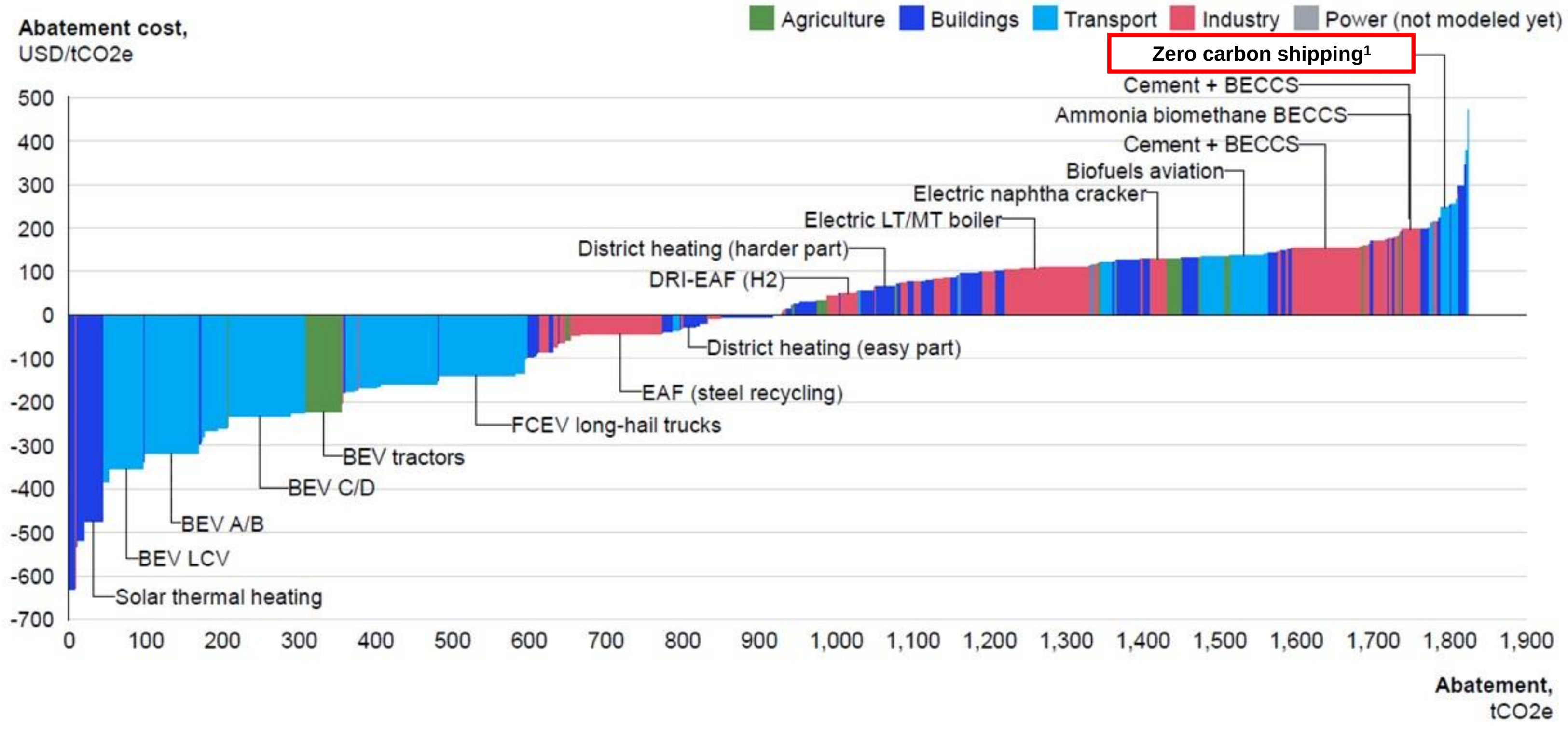
1. 2017-2019 data extrapolated based on German greenhouse gas emission

Source: European Federation for Transport and Environment; Adapted from EEA, Approximated EU greenhouse gas inventory 2016; Transport & Environment from Member States' reporting to the UNFCCC (1990-2015 data) and EEA's approximated EU greenhouse gas inventory (2016 data)

Shipping is one of the hardest sectors to decarbonize

2050 EU-27 CO2e abatement cost curve

Preliminary



1. Biofuels only in this abatement curve. Other levers might end up higher or lower depending on technology cost and learning curves and can be added later

Shipping is one of the hardest sectors to decarbonize due to the cost effectiveness of heavy fuel and dispersed refueling

This cost abatement curve is optimized for cheapest cost options but even more expensive fuel abatement options exist such as

- Batteries/ shore power
- Hydrogen (derivative) fuels

It excludes abatements through increased operating efficiency

And yet a broad set of stakeholders are pushing the industry for it (and soon)

Regulation

IMO INTERNATIONAL MARITIME ORGANIZATION

Capital markets

Customers

MÆRSK

H&M

Levi's

Competitive pressure

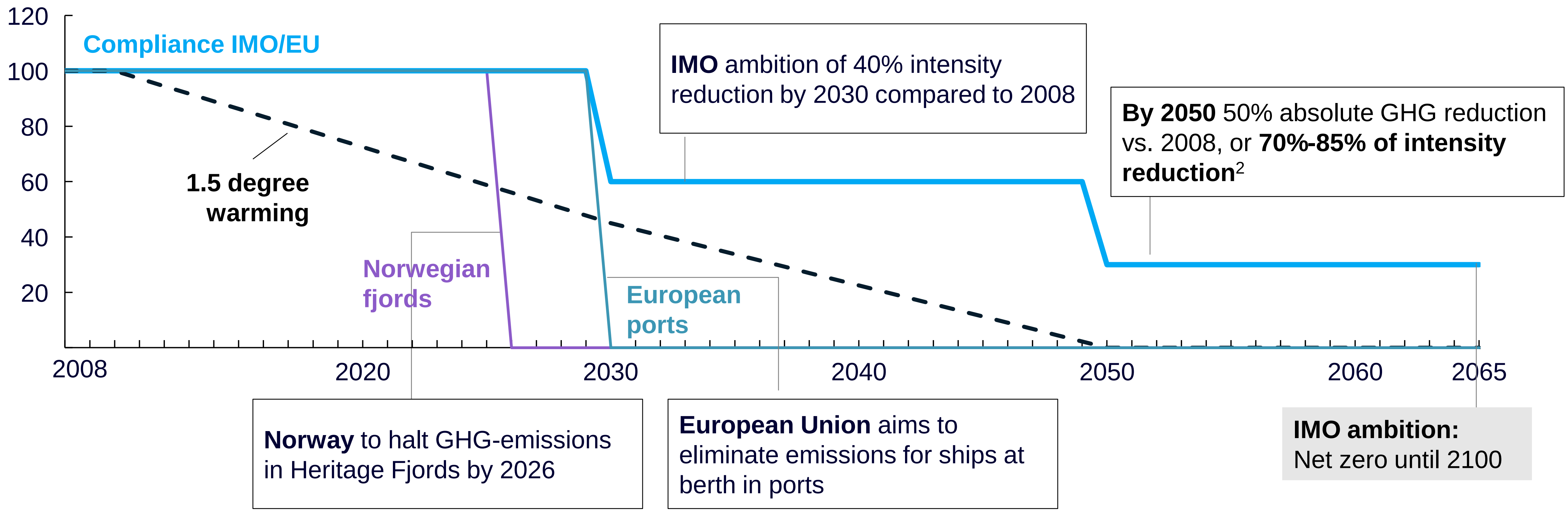
NORLED

Stena Line

HURTIGRUTEN

The challenge ahead: 70%-85% intensity improvement needed to halve absolute emissions[1]

Current main regulatory announcements/targets, emissions permitted vs. 2008 baseline



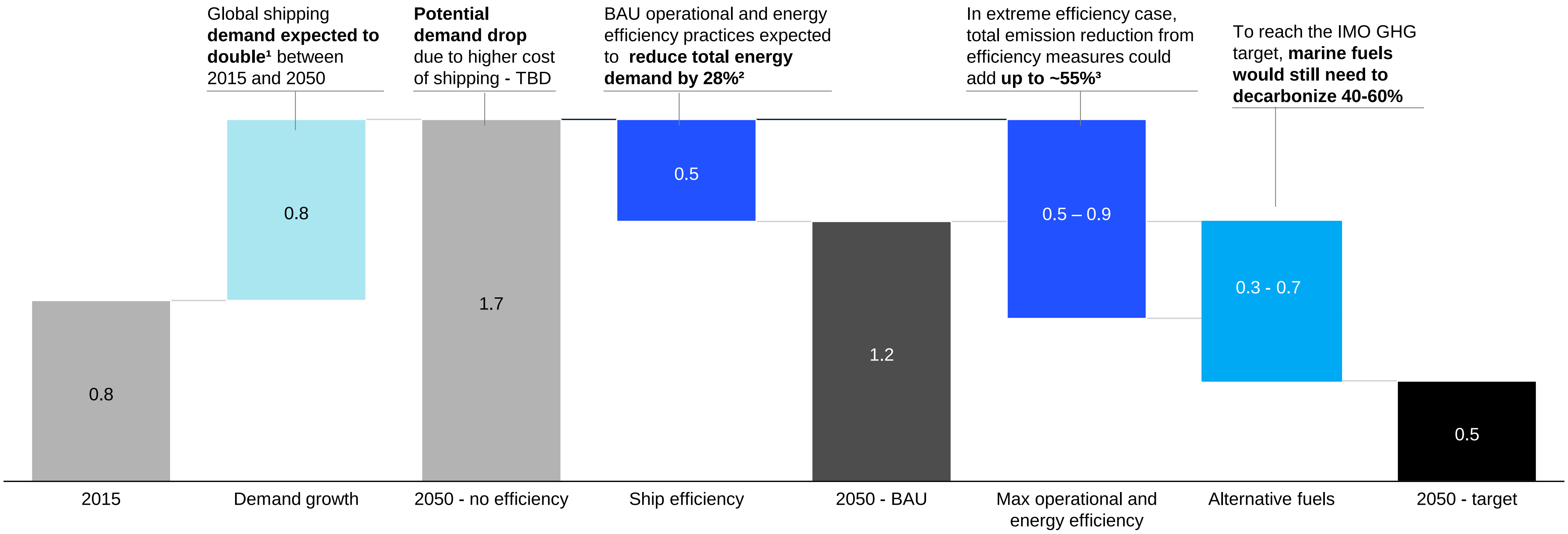
1. IPCC calculation with 45% reduction target in 2030 (vs. 2010) and net zero in 2050; Graph assuming 2010 base year equals 2008; 2 Based on a 50% absolute GHG industry reduction scenario, which translates into 70 – 85% of reduction in CO_2 intensity

Source: Norwegian Parliament, IMO, EU, press search, expert interviews; IPCC

The answer will have to be a mix of energy efficiency and new fuels

High-level analysis

International shipping GHG emissions, $GtCO_2e$



1 McKinsey Energy Insights
2 BAU efficiency gain based on McKinsey Global Energy Perspectives Model, in line with DNV GL estimations of 20-30%
3 Applying maximum efficiency gain based on DNV GL and ETC estimations of 50-60%
4 Global GHG emissions if demand in 2050 would be met with fleet and ship efficiency of 2015

Source: IMO, ICCT, DNV GL, McKinsey Global Energy Perspectives

Initial focus will be on efficiency but alternative fuels will be required to meet 2030 and especially 2050 target

Low → High Relative scale (1 = Low … 5 = High)

Levers		Actions (not exhaustive)	Economics	GHG reduction	Key advantages	Challenges
Operational efficiency		Waiting time reduction	5	1 (group: 3)	Positive NPV given fuel savings & virtually no CAPEX Mature, proven technology at hand Actions have cumulative effect	Need for coordination between ship operators and ports Finite abatement potential Direct dependency on fuel cost (given fuel saving is main incentive)
		Speed reduction	5	2		
		Voyage optimization	5	1		
		Capacity utilization	5	1		
Ship efficiency		Waste heat recovery systems	3	1 (group: 3)	EEDI regulation mandates already a certain saving target With higher fuel price some could be 'back in the money' Actions have cumulative effect	Split incentive between owner (making design decision) and operator (bearing the fuel cost) Finite abatement potential (efficiency limit) Diminishing returns with longer payback periods
		Auxiliary system efficiency	4	1		
		Hull design/coating/lightweight materials	3	1		
		Size increase	4	1		
Alternative fuels	Direct fuels	Cleaner carbon fuels (LNG/LPG/Methanol)	4	2	Relatively high abatement potential	Low price competitiveness (especially high abatement potential fuels) and no clarity on future outlook High investment in supply chain infrastructure Limited compatibility between technologies, creating path dependency
		Biofuels and synthetic fuels (gas/diesel)	3	4		
		Synthetic carbon-fuels (gas/diesel)	2	4		
	Fuel cell	Hydrogen fuels (hydrogen, ammonia, etc.)	3	4		
	Supplementary power source	Electric – shore power	5	4		
		Electric – batteries	3	5		
		Wind/solar assistance	4	5		
Offsets	Carbon credits (MBM)	Including shipping emissions in carbon trading scheme (e.g. ETS)	5	3	Relatively high indirect abatement potential Lower on the abatement cost curve	Short term catalyst, rather than LT solution Difficult to implement locally due to shipping global nature Negative public perception
	Carbon sinks (NBS)	Natural based solutions (e.g. reforestation)	5	5		
	Other	On-board carbon capture	2	3		

Source: McKinsey analysis and Global Energy Perspective, desk research, expert interviews

Summarizing, the transition will depend on the industry’s ability to overcome a set of key challenges

Create a level playing field	How to ensure that early adopters are rewarded for their investments and how to prevent laggards unrightfully receiving economic surplus
Future fuel economics	Immature state of real green sustainable fuels creates a wide range of future value of these fuels, making it hard to decide now
Technical viability not understood	Many of the alternative fuels have not been tested under marine conditions and skepticism around their viability will inhibit adoption
Winner takes all scenario	No clear ‘winner’ amongst the alternative fuel options means that stakeholders are unwilling to invest in one standard, which may become outmoded in the coming years
Long life of assets and long investment cycles	The average ship life is >25 years, implying a high level of risk from retrofitting or substitution and split incentives between owners and operators to drive changes
Bunker supply chain infrastructure	Given global nature of shipping, a global network of supply infrastructure of future fuels is needed. This could result hen and egg situation.

In practice these challenges could be shifted by some form of intervention that either:

- **Reduces the cost of change** (e.g., through innovation or incentive); or
- **Forces adoption** (e.g., through customer pull or regulation)

Agenda

The Challenge

Future fuel pathways

Way forward

The starting point today: LNG and batteries are the most common alternative fuels being used

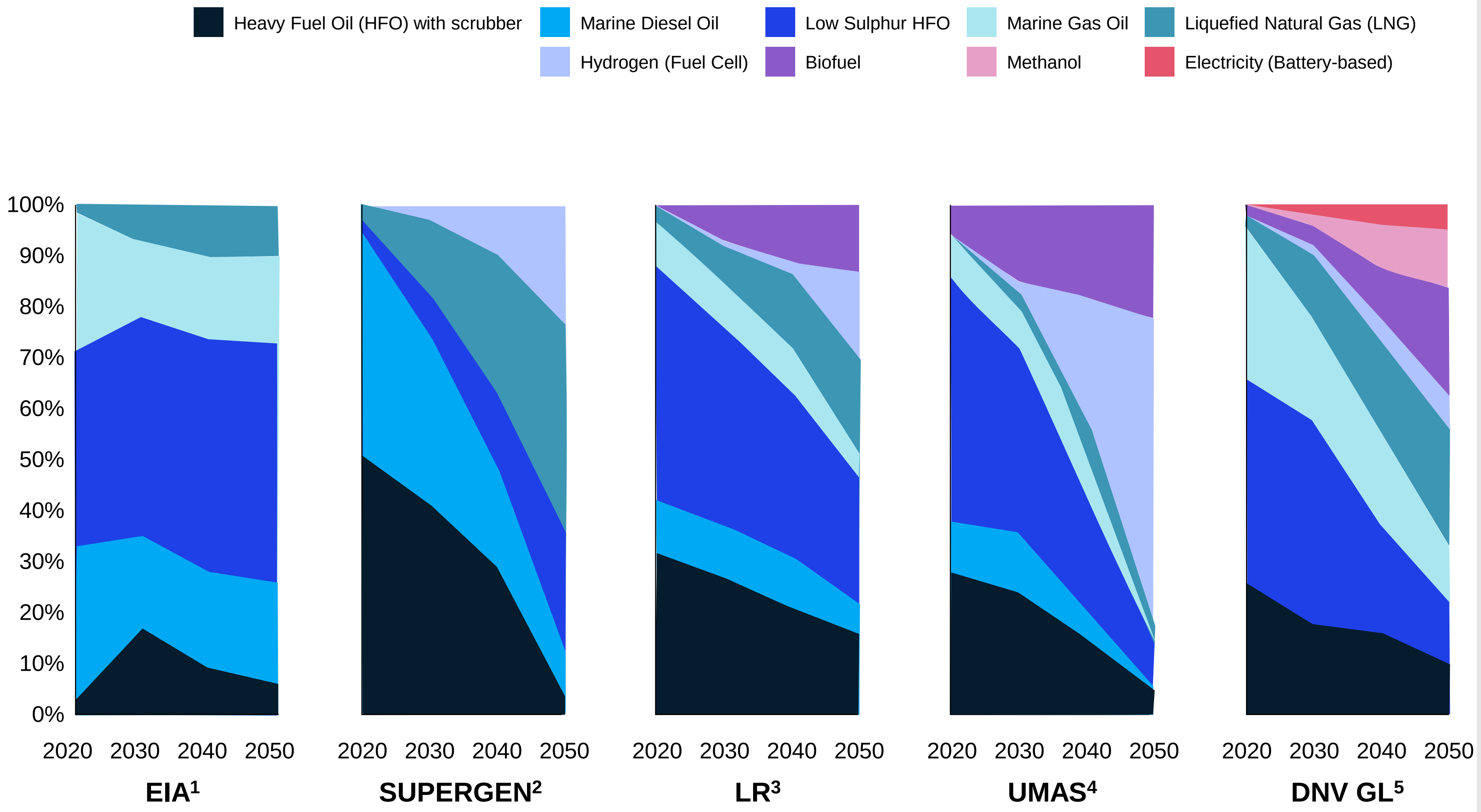
Number of ships with alternative fuels as of Jan. 2020 (not including sustainable biofuels)

	LNG	Battery	Methanol	Hydrogen	Ammonia
Number of vessels *(out of ~65k ships in the global fleet)*	~385	~375	~15	~2	~1
Merchant fleet (cargo ships)	49%	5% Teekay, Stenersen	94% Methanol tankers (NYK, Marinvest)	-	-
Passenger	31% Most major cruise operators, + ferries (Fjord1, Norled) and ropax (Fjordline, Viking Line)	54% Hurtigruten, Havila, AIDA	6% Stena	100% Norled ferries Pilots: Havila, Aida, …	-
Offshore and fishing	20% OSV (Eidesvik, Solstad, DOF, Simon Møkster)	41% Eidesvik, Harvey Gulf, Atlantic offshore, Seacor Marine, Havila	-	-	100% Equinor / Eidesvik

Source: DNV alternative fuels database

The jury is very much out on what the future fuel mix will be

Five projections of marine fuels form 2020 to 2050



1. U.S. Energy information administration, 2019, The effects of changes to marine fuel Sulphur limits in 2020 on energy markets
2. The Hydrogen and Fuel Cells (H2FC) SUPERGEN Hub, 2019, Scenarios and drivers for Hydrogen as fuel in international shipping; average of three scenarios
3. Lloyd Register, 2019, Zero-emission vessels; transition pathways
4. University Maritime Advisory Services, 2016, CO2 emissions from international shipping; possible reduction targets and their associated pathways
5. Det Norske Veritas and Germanischer Lloyd, 2018, Maritime forecast to 2050

Source: Jiahui Liu and Dr. Okan Duru

Diverging forecasts are driven by considerable **uncertainty regarding the technical and economic characteristics** of different fuels

Of the future potential fuels, ammonia is one of the few fuels to address all emissions

High | Medium | Low

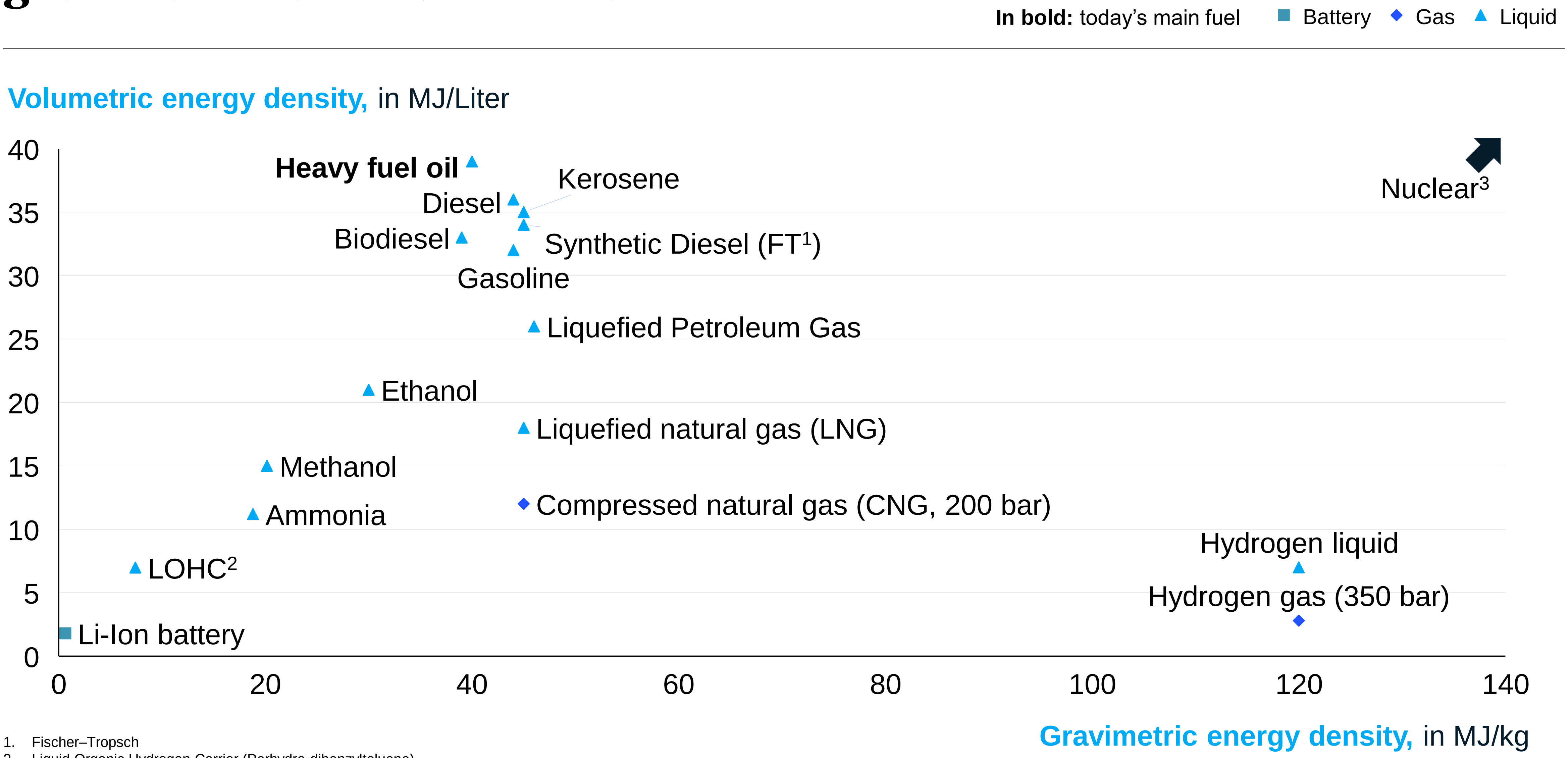
Current Fuels | Future fuels

	Lifecycle Emissions *ton / TJ* GHG	SOx[1]	NOx[2]	PM	TRL *(1-9)*	TCO[3] *(HFO = 1)*	Remarks
HFO	80				8	1.0	MARPOL 2020 allows ships to only use HFO with sulfur content of > 0.5% if a scrubber is installed
MGO	80				9	1.2	MGO main fuel in waters with stricter SOx regulation (i.e. ECAs in EU/NA)
LNG	70				8	1.0	LNG is 20-30% lower on CO2 emissions compared to HFO, but methane slip in engine and supply could offset most of these reductions
Biodiesel (2nd Gen)	60				7	2.0	Usable in existing vessels and infrastructure without big adaptations Competition for limited availability of 2nd Gen. biodiesel could increases prices Fuel quality and sustainability standards still pending
Methanol (2nd Gen Bio/ Syn)	25 / 0				6	2.5	Dozen ships already operable with methanol, retrofitting relatively small procedure Methanol can only be net-zero carbon if CO2-source is DAC[4] or from certain bio sources, which are expensive
Ammonia (green)	0				5	1.5	Engine and fuel supply system still in prototype phase Fuel quality and safety standards need to be developed further SCR can reduce NOx emissions
Hydrogen (green)	0				3	2.0	Large volumes required for storage make hydrogen unlikely option for long-haul shipping

1. sulphur limitations in ECAs
2. NOx emissions are commonly reduced using Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) solutions for both FO and MGO
3. Full lifecycle TCO of Large Container entering the fleet in 2035 assuming no Carbon price
4. CO2 source is from direct air capture (DAC)

Source: Techno-economic assessment of zero-carbon fuels, Lloyd's Register (2020)

Gravimetric and volumetric energy density of selected liquid and gaseous fuels and batteries



1. Fischer–Tropsch
2. Liquid Organic Hydrogen Carrier (Perhydro-dibenzyltoluene)
3. Nuclear fission of Uranium-235, for example – has a gravimetric energy density of ~3,900,000 MJ/kg

Source: German Federal Environmental Agency; DNV-GL; Andreas Jess, Peter Wasserscheid "Chemical Technology: From Principles to Products" (2019).

Many different alternative fuels are currently being trialled

Zero emissions technologies applications and selected examples

Not exhaustive

Applications	(Net) zero emissions (propulsion) technologies				
	Batteries	H2 fuel cells	e-Ammonia	e-Methanol	SynFuel
Tankers			Lloyd's Register	methanex the power of agility	
Bulk ships					
Gas carriers			MAN Energy Solutions		
Container ships		HYON, nel, PowerCell, Hexagon Composites	Mærsk	Mærsk, Marinvest	Wessels Marine
RoRo & Ferries	ABB, Leclanché	HYON, nel, PowerCell, Hexagon, Ferguson Marine		Stena Line	
Cruise ships	Hurtigruten	AIDA, GE, PowerCell, Freudenberg Innovating Together, Nedstack, Havyard		Abeking & Rasmussen	
Offshore	equinor	Ulstein, Nedstack	equinor, Eidesvik		
Tugs	X Shore	Tokyokisen, OSDIMT, e5 Project, Ballard, ABB, Nedstack		Nissan	
Recreational vessels		Energy Observer, liten			

Source: Press search, Companies websites, McKinsey analysis

And the decision goes beyond economics

Trip range (return to port vs. globally deployed)

Secure fuel supply in port vs. limitations of tank size for long-range vessels

Frequency of port calls

Container ships with frequent port calls vs. tankers and bulk carriers

Safety of passengers

Ammonia fuel is not optimal for passenger ships due to toxicity

Ability to burn cargo as fuel

LNG and LPG tankers

Space availability for extra fuel tanks

Tankers, offshore support vessels, car carriers/RoRo ships have extra space vs. container and bulk ships that do not

Shipping is not a heterogeneous industry, so different pathways emerging for different shipping segments

Zero emissions technologies applications and selected examples

Possible ★
Likely ★★
Highly likely ★★★

Preliminary

Lower emissions (propulsion) technologies

Vessel segment	Batteries	H_2 / fuel cells	e-Ammonia	e-Methanol	Biofuel	LNG
Tankers			★	★★		★
Bulk ships			★★	★		★
Gas carriers			★★			★★
Container ships	☆[1]	☆[1]	★★★		★	★
RoRo & Ferries	★★	★	✕	★	★	
Cruise ships	★	★	✕		★★	★★
Offshore	★	★★★	★			
Tugs	★★	★★★				
Recreational vessels	★★★	★	✕			

1. Auxiliary power

Source: McKinsey analysis

Agenda

The Challenge

Future fuel pathways

Way forward

A full industry shift requires multiple enablers

Enabler		How it works	Example initiatives
1 Customer/ demand pull		Consumers push shipping customers to decarbonize supply chain	• Cooperation on biofuel pilots (e.g. IKEA & CMA CGM, Maersk & H&M) • Rightship vetting system • Clean-Cargo working group benchmarking
2 Investor mobilization		Investors prioritize financing of “green” assets	• Poseidon Principles • Partnership for Carbon Accounting Financials – i.e. banks measuring carbon footprint of their lending portfolios (e.g., ABN AMRO, Citi, Morgan Stanley)
3 Policy and regulation	**Norms**	National governments set binding emission targets	• IMO setting global targets • EU willing to go above and beyond when IMO fails to achieve consensus • Norway implementing zero emission zones in heritage fjords
	Economic incentives	Governments incentives (e.g., tax exemptions, stimulus funds) to support initiatives	• Carve out budgets for dedicated incentive schemes (e.g., tax exemptions for the commercialization of alternative fuels, subsidies for the development of abatement technologies, guaranteed fuel prices)
4 Industry leadership	**Self-regulation**	Individual players set targets above regulated levels for first-mover advantage or consortia to create industry standards	• Consortiums committing to joint targets (including level 3 emissions, to level the playing field along the value chain),and penalty mechanisms (e.g., non-collaboration policies, higher price tags) for non-abiding players
	Collabo-ration	Players can also pool resources in order to jointly reach targets (e.g., through joint ventures)	• Push the development of a chosen fuel pathway, co-investing in technology • Develop shared infrastructure (e.g., cooperative ownership of bunkering facilities for the chosen fuel) • Engaging other actors in the ecosystem (e.g., regulators, end customers)
5 Technological advancements		Increase the efficiency of environmentally-neutral technologies, making them commercially competitive	• Industry players, policy makers and academia pooling resources into accelerating the R&D of a chosen fuel / pathway (e.g., LPG and Ammonia)