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MARITIME

Alternative fuel in the Arctic

Pame Meeting 4-5 February 2019

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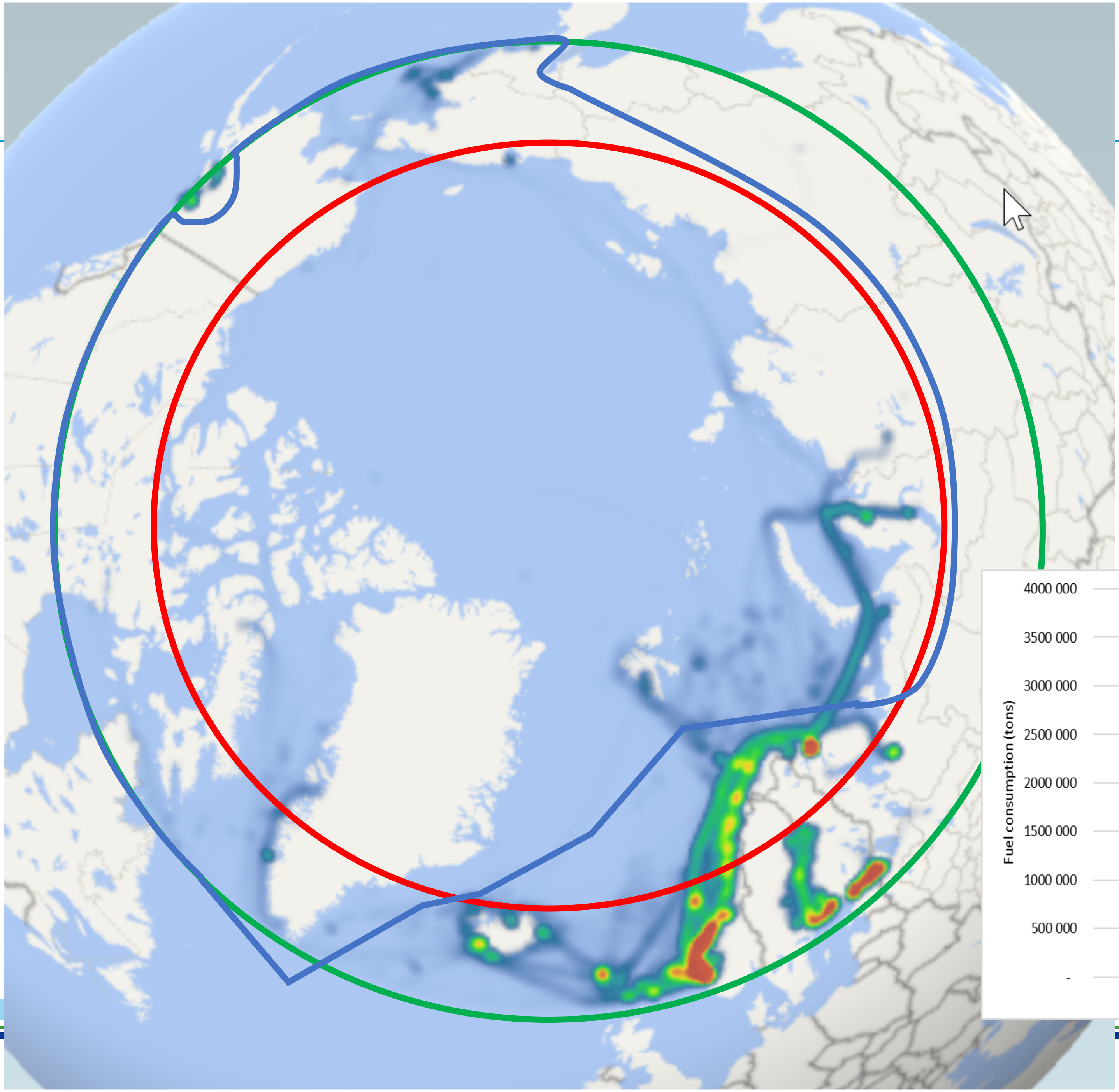
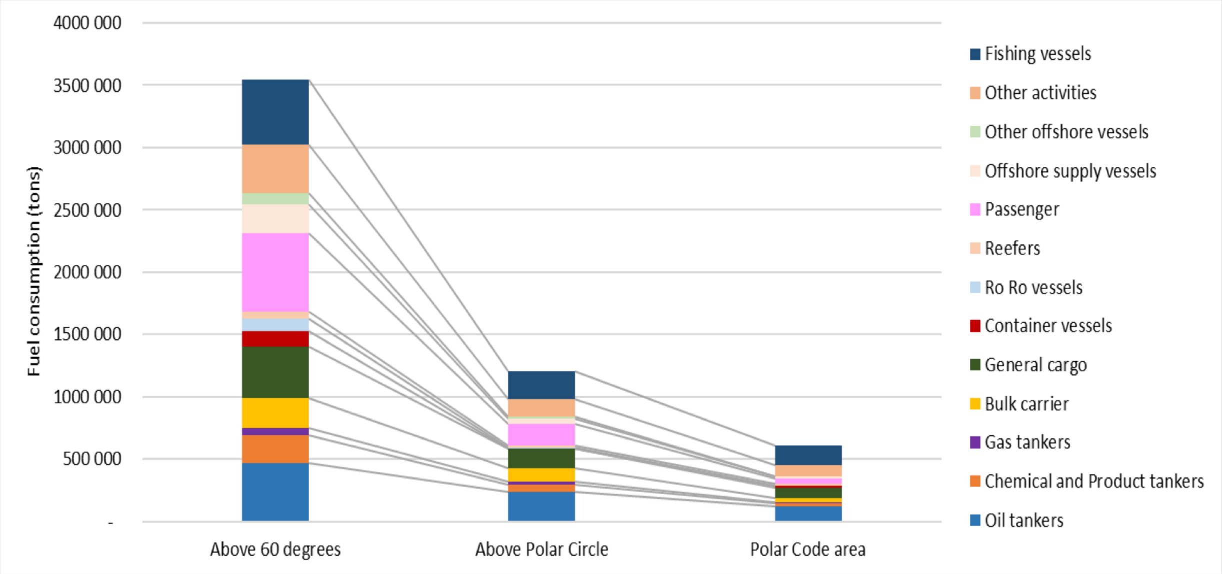
05 February 2019



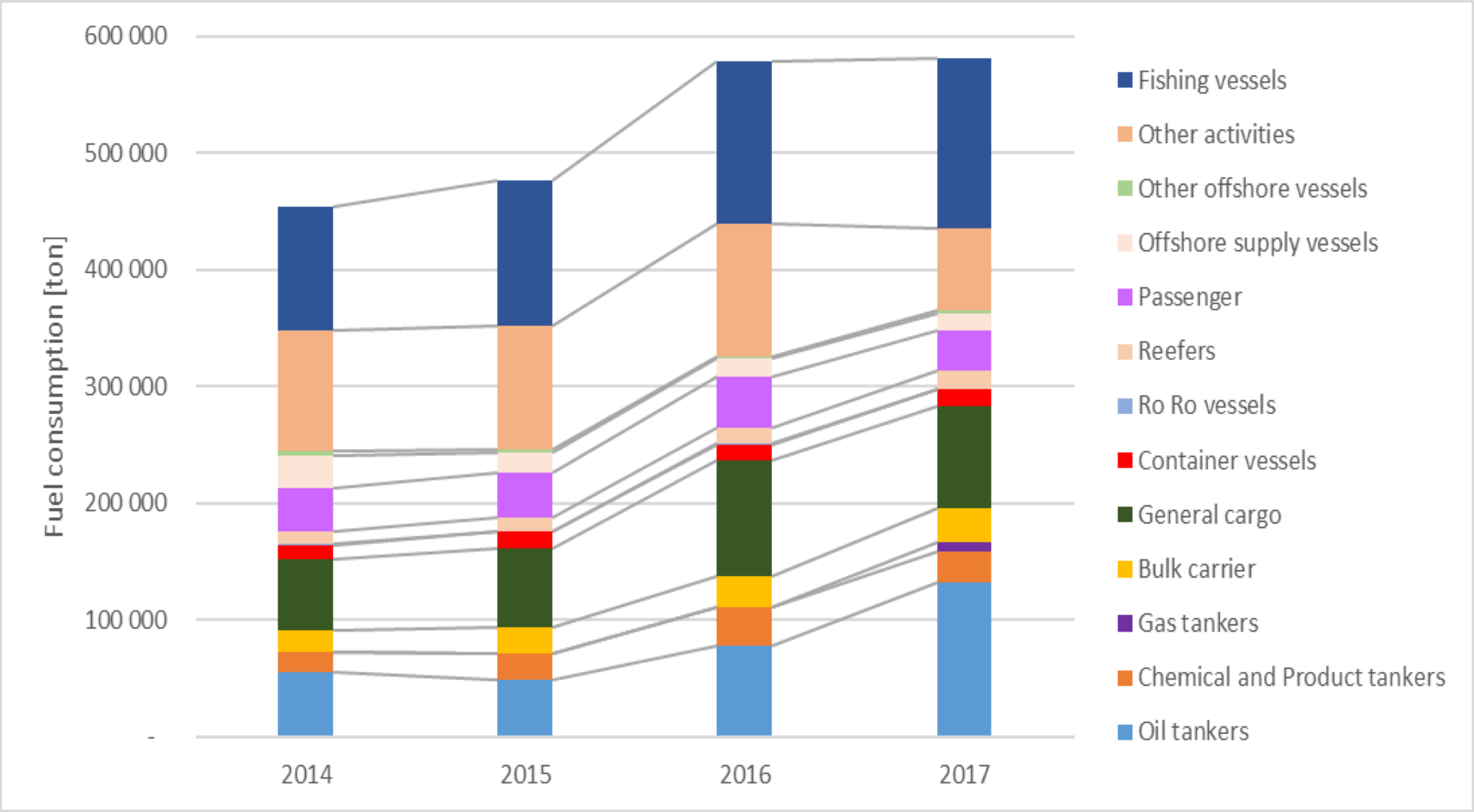
North of 60 degrees

North of the Polar Circle

The IMO Polar Code Area



Fuel consumption in the Arctic – 2014 - 2017



Which are the main consumers in the Arctic - 2017

Ship type	<1000 GT	1000 - 4999 GT	5000 – 9999 GT	10000-24999 GT	25000-49999 GT	50000-99999 GT	≥100000 GT	Totals
Oil tankers		1 %	1 %	3 %	16 %	2 %	1 %	23 %
Chemical and Product tankers	0 %	1 %	1 %	2 %	1 %			5 %
Gas tankers							1 %	1 %
Bulk carrier		0 %		1 %	4 %	0 %	0 %	5 %
General cargo	0 %	1 %	4 %	7 %	2 %			15 %
Container vessels			1 %	1 %				2 %
Ro Ro vessels	0 %			0 %				0 %
Reefers	0 %	1 %	1 %	0 %				3 %
Passenger	0 %	1 %	1 %	1 %	1 %	1 %	0 %	6 %
Offshore supply vessels	0 %	2 %	1 %					3 %
Other offshore vessels	0 %	0 %	0 %					0 %
Other activities	2 %	3 %	4 %	3 %	0 %			12 %
Fishing vessels	5 %	19 %	1 %					25 %
Total	7 %	29 %	15 %	19 %	24 %	3 %	2 %	**100%**

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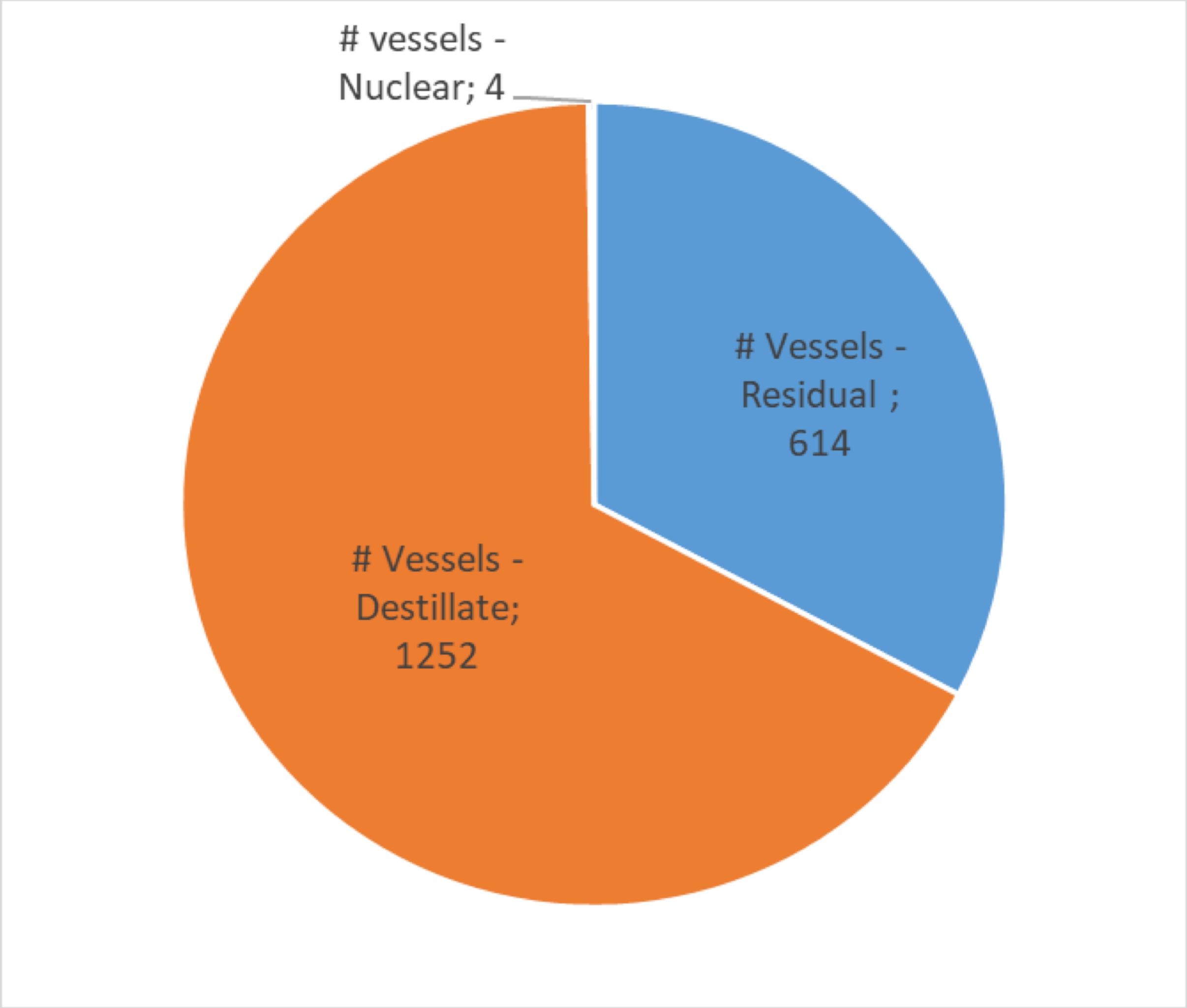
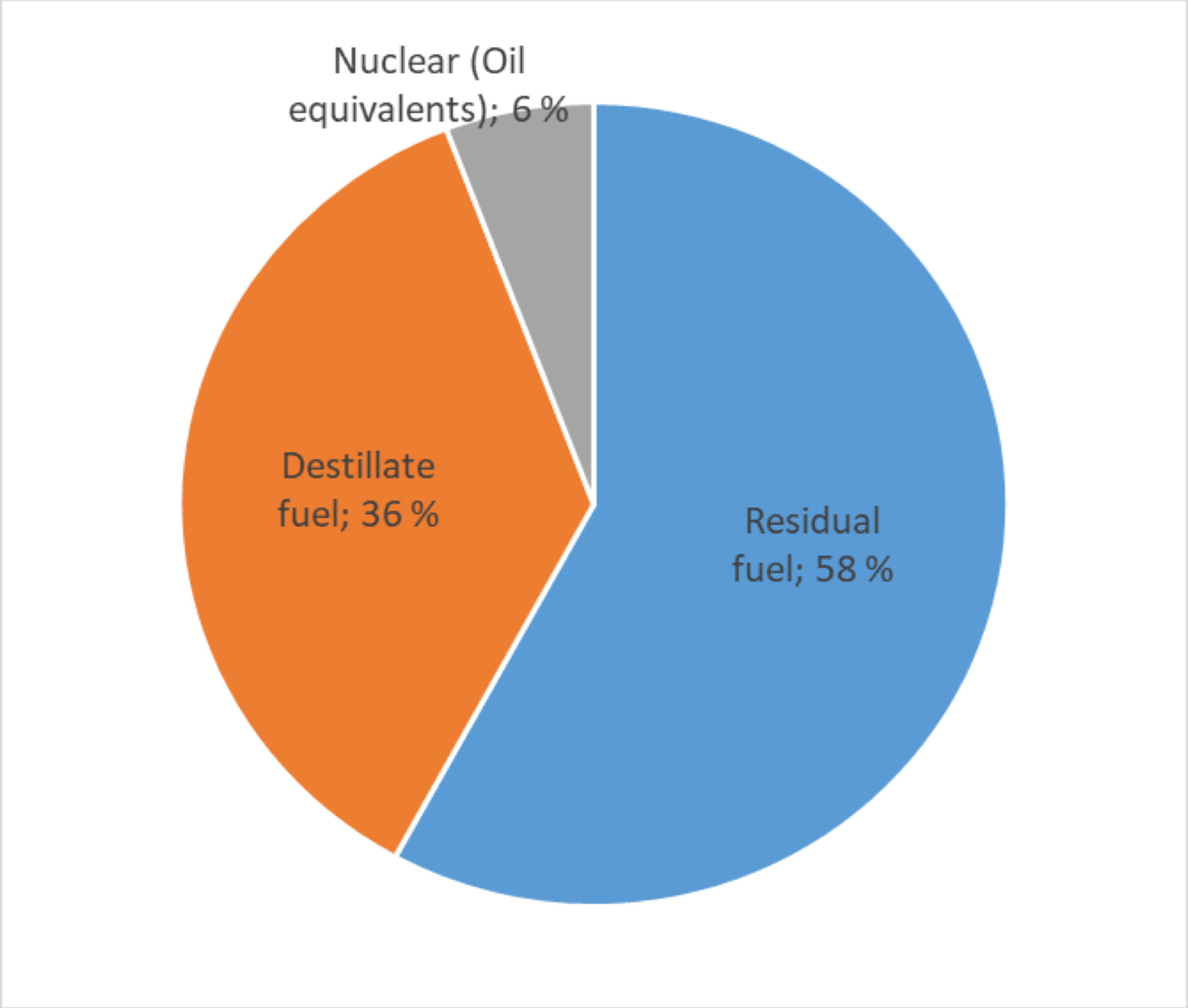
Fuel consumption – Distillates versus Residual





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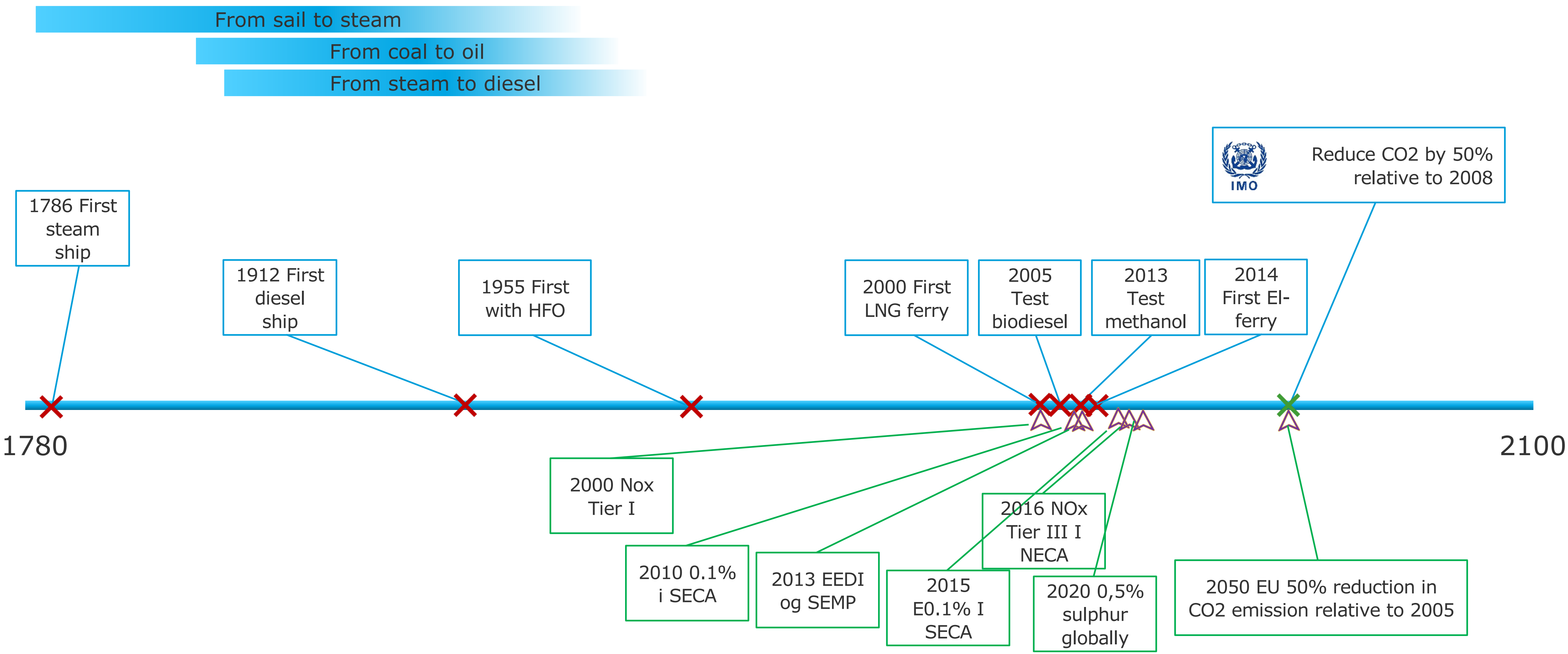
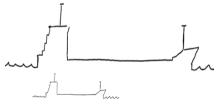
Shipping time line



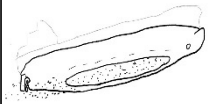
Possible strategies for reduces GHG emission from shipping



LOGISTICS & DIGITALIZATION

- Speed reduction
- Vessel utilization
- Vessel size
- Alternative routes

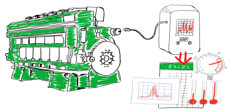
>20%



HYDRODYNAMICS

- Hull coating
- Hull form optimization
- Air lubrication
- Cleaning

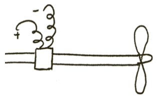
10-15%



MACHINERY

- Machinery improvements
- Waste heat
- Engine de-rating
- Battery hybridization

5-20%

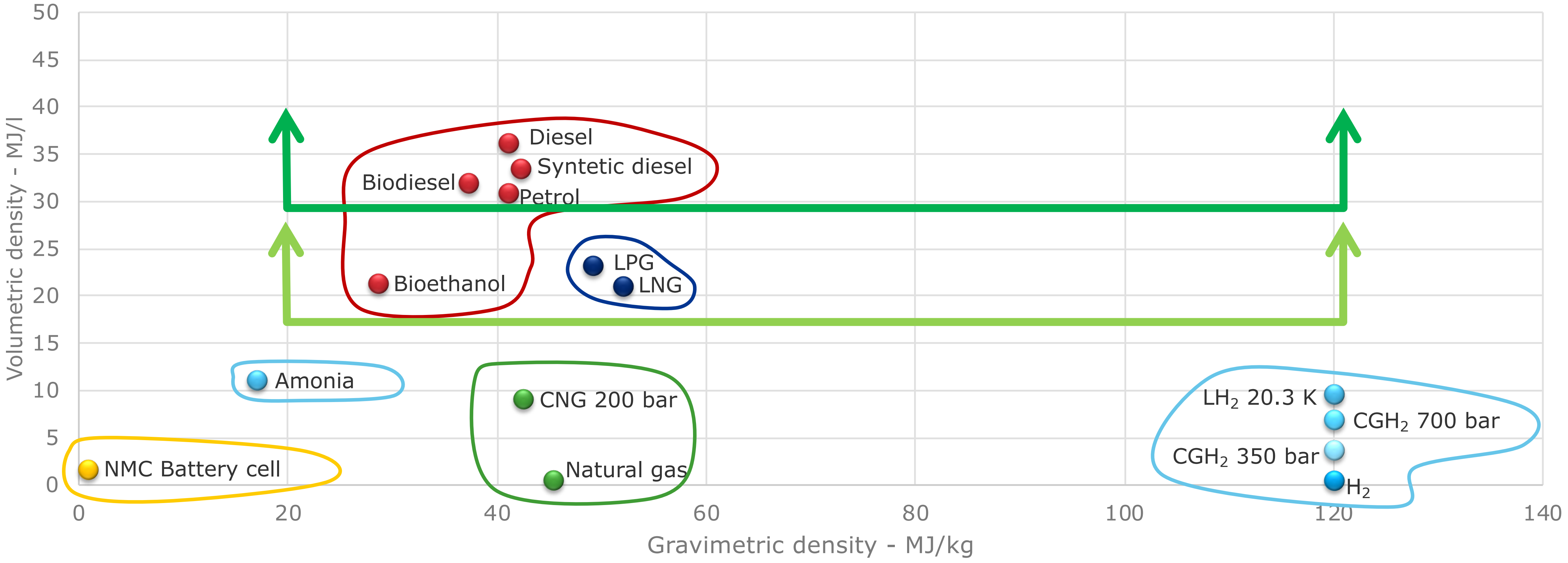


FUELS AND ENERGY SOURCES

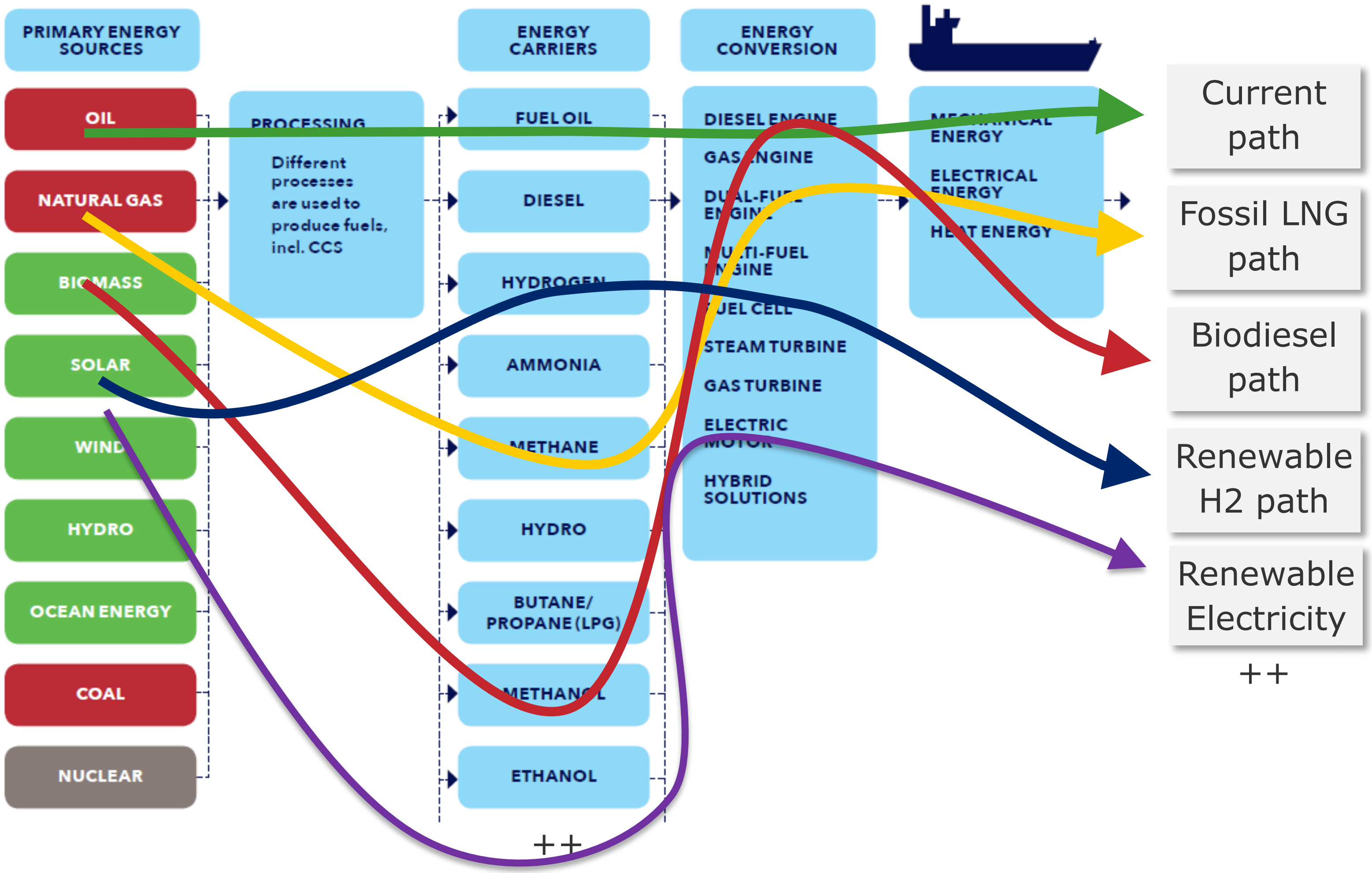
- LNG/LPG
- Electrification
- Biofuel
- Synthetic/hydrogen etc.

0-100%

Volumetric and gravimetric density of fuels



Paths to low/zero-emission – no "silver bullet"



Key elements

Energy source:
- Fossil, renewable, nuclear?

Prosessering:
- Carbon capture

What energy carrier?:
- Liquid, gas, hydrocarbons?

Energy converter?:
- Internal combustion, fuel cell, electromotor?

Inspired by Brynolf S. (2014), 'Environmental assessment of present and future marine fuels'

Source: Maritime Forecast to 2050, DNV GL 2018

Ranking the fuel/converter options

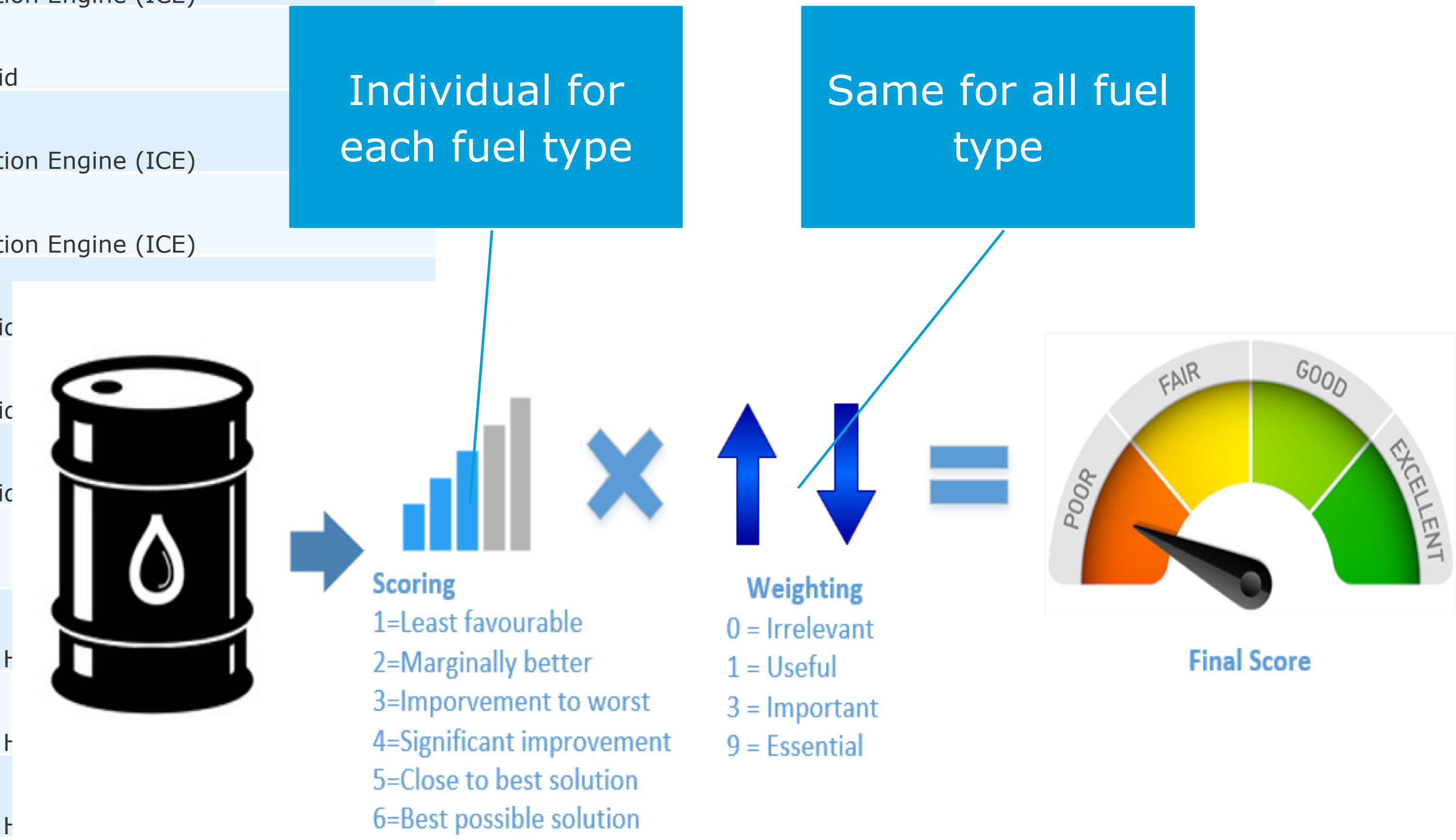
Environmental

Economic

Scalability

Fuel alternatives and ranking methodology

	Fuel type	Converter technology
1	HFO	Internal Combustion Engine (ICE)
2	MGO	ICE/Battery hybrid
3	Low Sulphur Hybrid	Internal Combustion Engine (ICE)
4	Low Sulphur Hybrid (Arctic optimized)	Internal Combustion Engine (ICE)
5	Bio Diesel(HVO)	ICE/Battery hybri
6	Bio-gas	ICE/Battery hybri
7	LNG	ICE/Battery hybri
8	Full electric	Battery Electric.
9	Methanol	Fuel Cell/Battery H
10	Hydrogen	Fuel Cell/Battery H
11	Ammonia	Fuel Cell/Battery H



Environmental weighting factors

Environment	WF-Short Sea	WF-Deep Sea	
Emission to air			
GHG emission	3	3	Arctic traffic is of limited in magnitude and impact
Short-lived climate pollutants	9	9	Disproportionally high GHG effect in the Arctic
NOx emission	9	9	Not health – Arctic haze and ozone
SOx	1	1	Mainly health related
PM emission	9	9	Not health – GHG effect
Emission to sea			
Toxicity effects of water soluble components	9	9	Critical in Arctic waters
Environmental damage potential	9	9	Critical in Arctic waters
Response effectiveness	9	9	Critical in Arctic waters

Economic weighting factors

Ship economy		WF-Short Sea	WF-Deep Sea	
Investment cost for the ship (additional cost)		3	3	From a policy maker perspective, economy is considered to be important, but not critical
Compliance cost - cost of modification		3	3	
Fuel cost		3	3	
Operational cost for the ship (crew, maintenance etc)		3	3	

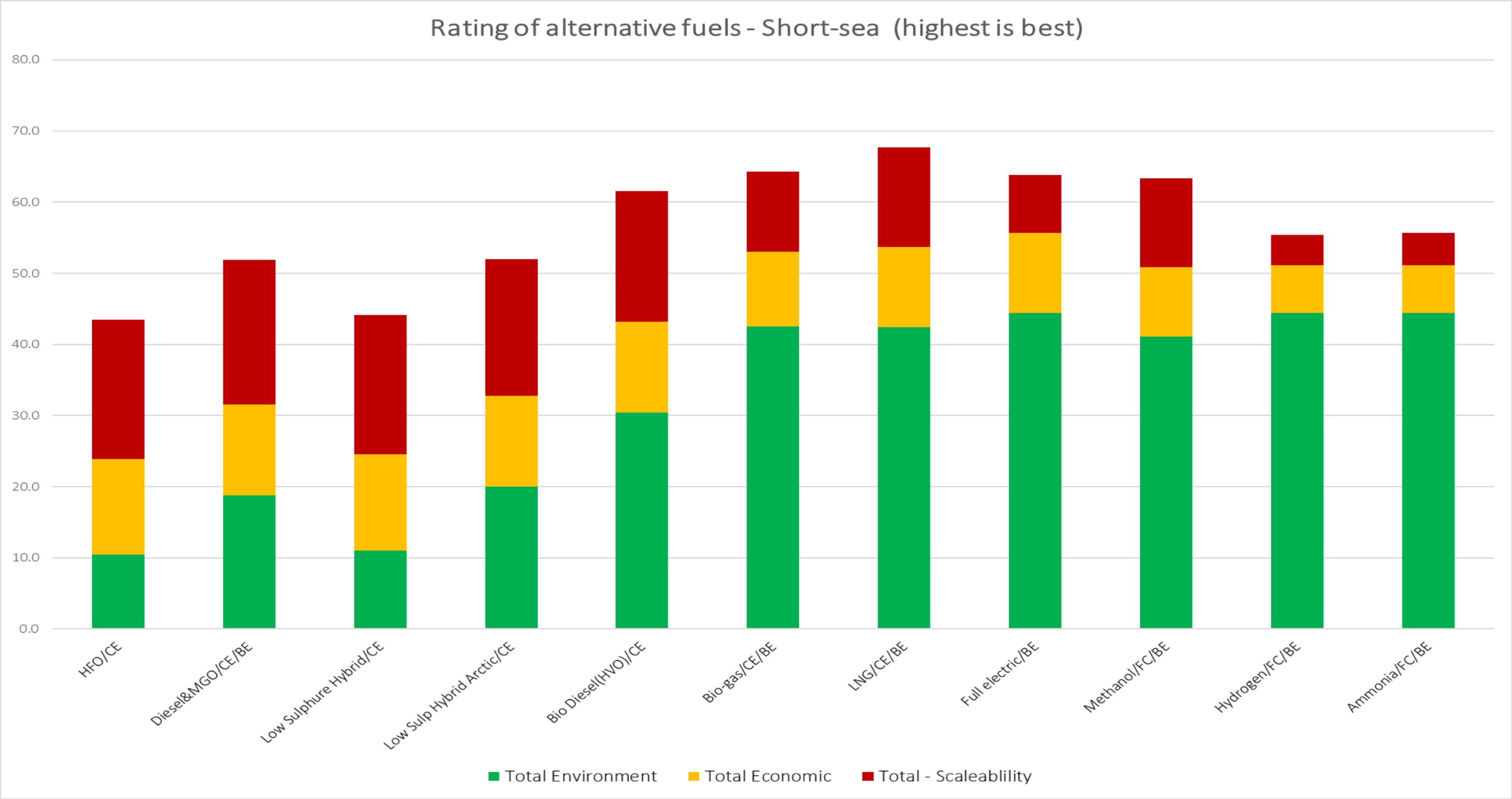
Scalability weighting factors

Scalability	WF-Short Sea	WF-Deep Sea	
Technical – Scalability			
Safety	9	9	limited infrastructure and severe climate
Technical maturity	3	3	Important, but introducing alternative technologies will require risk taking.
Energy efficiency - including converter	3	3	Important, but not critical
System complexity and maintainability	3	3	New technologies will intrinsically lead to an acceptance of a higher degree of complexity
Applicability – Scalability			
Adaptability - existing ships	3	3	Important – but may require newbuilds anyway
Power and energy limits	3	9	Less critical for short-sea than for deep-sea
Compatibility to existing infrastructure	1	9	Less critical for short-sea than for deep-sea

Scalability weighting factors

Availibility – Scalability			WF-Short Sea	WF-Deep Sea	
	Global availability of fuel		1	9	Not critical for Short-sea shipping – but for deep-sea it is
	Available infrastructure		1	9	Less critical for short-sea than for deep-sea – Local investment in infrastructure may be accepted
	Reliable and sustainable supply of fuel		3	9	Less critical for short-sea than for deep-sea – Local investment in infrastructure may be accepted

Overall ranking – Short sea



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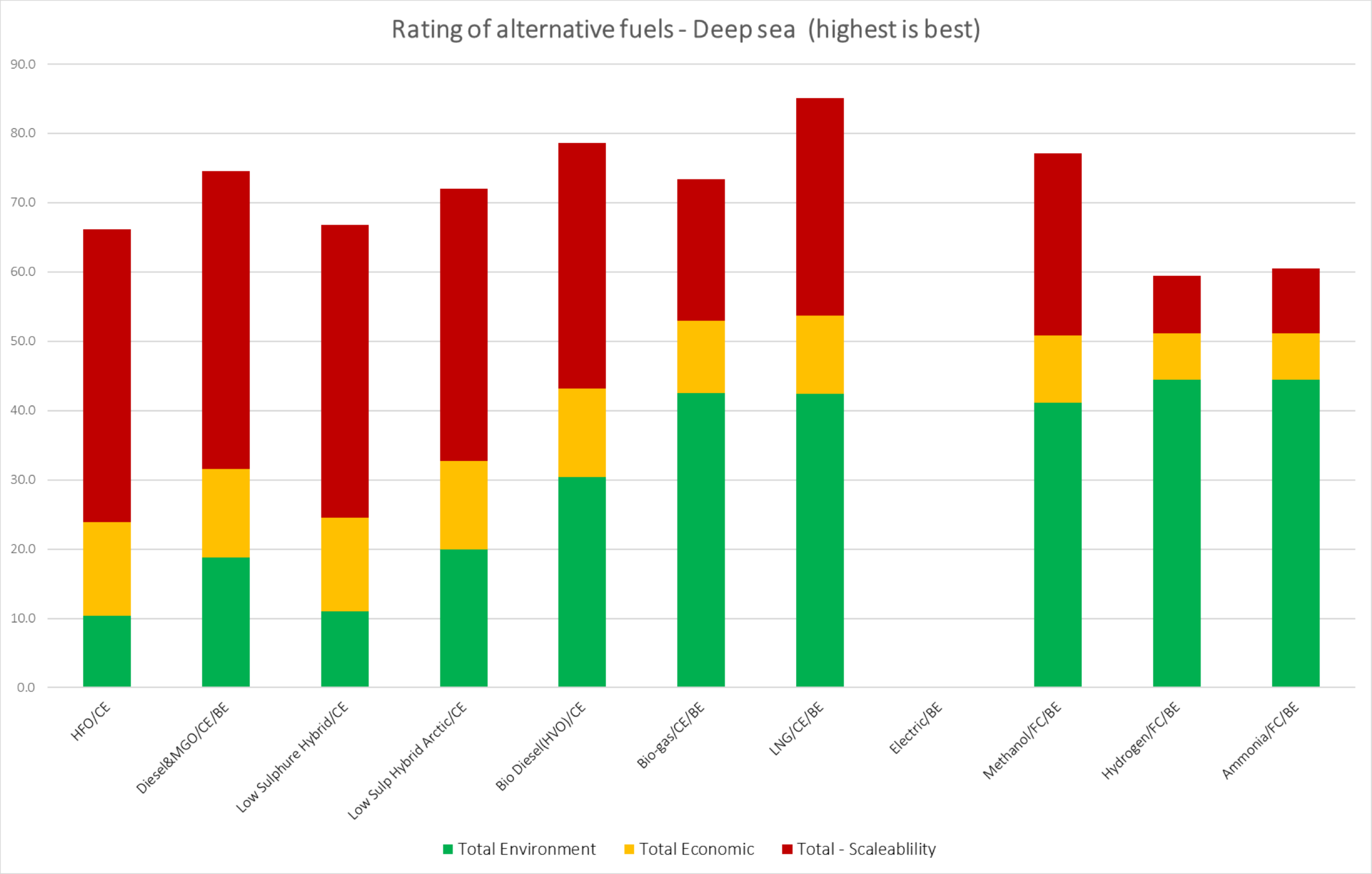
Overall ranking – Short sea

Energy source/carrier	Environmental			Economic		Scalability				Sum total
	Air	Bunker	Total Environment	Ship	Total Economic	Technical	Applicability	Availibility	Total - Scaleablility	
HFO/CE	5.8	15	10.4	13.5	13.5	30.75	14.0	14.0	19.6	43.5
Diesel&MGO/CE/BE	13.6	24	18.8	12.75	12.8	33	14.0	14.0	20.3	51.9
Low Sulphure Hybrid/CE	10	12	11.0	13.5	13.5	30.75	14.0	14.0	19.6	44.1
Low Sulp Hybrid Arctic/CE	10	30	20.0	12.75	12.8	30.75	14.0	13.0	19.3	52.0
Bio Diesel(HVO)/CE	21.8	39	30.4	12.75	12.8	31.5	14.0	9.7	18.4	61.5
Bio-gas/CE/BE	31	54	42.5	10.5	10.5	23.25	8.3	2.3	11.3	64.3
LNG/CE/BE	30.8	54	42.4	11.25	11.3	23.25	8.3	10.7	14.1	67.7
Full electric/BE	34.8	54	44.4	11.25	11.3	17.25	4.3	3.0	8.2	63.8
Methanol/FC/BE	34.2	48	41.1	9.75	9.8	21.75	7.7	8.0	12.5	63.3
Hydrogen/FC/BE	34.8	54	44.4	6.75	6.8	6	3.3	3.3	4.2	55.4
Ammonia/FC/BE	34.8	54	44.4	6.75	6.8	6	4.3	3.3	4.6	55.7

Overall ranking – Deep sea



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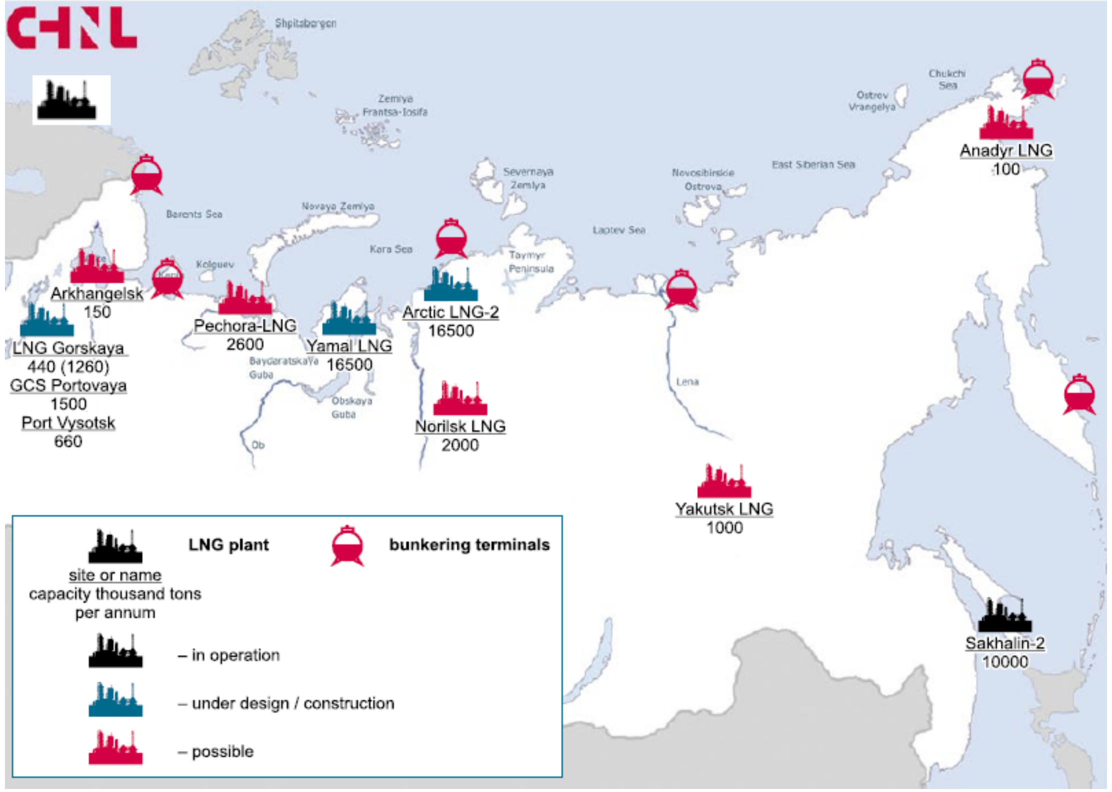
Overall ranking – Deep sea

Energy source/carrier	Environmental			Economic		Scalability				Sum total
	Air	Bunker	Total Environment	Ship	Total Economic	Technical	Applicability	Availibility	Total - Scaleablility	
HFO/CE	5.8	15	10.4	13.5	13.5	30.75	42.0	54.0	42.3	66.2
Diesel&MGO/CE/BE	13.6	24	18.8	12.75	12.8	33	42.0	54.0	43.0	74.6
Low Sulphure Hybrid/CE	10	12	11.0	13.5	13.5	30.75	42.0	54.0	42.3	66.8
Low Sulp Hybrid Arctic/CE	10	30	20.0	12.75	12.8	30.75	42.0	45.0	39.3	72.0
Bio Diesel(HVO)/CE	21.8	39	30.4	12.75	12.8	31.5	42.0	33.0	35.5	78.7
Bio-gas/CE/BE	31	54	42.5	10.5	10.5	23.25	29.0	9.0	20.4	73.4
LNG/CE/BE	30.8	54	42.4	11.25	11.3	23.25	29.0	42.0	31.4	85.1
Electric/BE	0	0	0.0	0	0.0	0	0.0	0.0	0.0	0.0
Methanol/FC/BE	34.2	48	41.1	9.75	9.8	21.75	27.0	30.0	26.3	77.1
Hydrogen/FC/BE	34.8	54	44.4	6.75	6.8	6	7.0	12.0	8.3	59.5
Ammonia/FC/BE	34.8	54	44.4	6.75	6.8	6	10.0	12.0	9.3	60.5

Barriers to introducing LNG in the Arctic

Main category	Sub category	Barrier level	Comments
Technical	Safety and reliability Technical maturity Infrastructure and availability	Low	Mature technology Lack of infrastructure for LNG, charging
Economic	Commercial implications Economic and finical challenges Taxes and incentives	High	High investment cost Suitable for new buildings Lack of marked demand
Regulatory	Rules by authorities Class rules Incentives and incentives	Low	Established by IMO Established major classifications society Lack of incentives and drivers
Cultural/non-technical	Organizational challenges Complexity in applications	Significant	Organizational challenges Operational and competence intensive

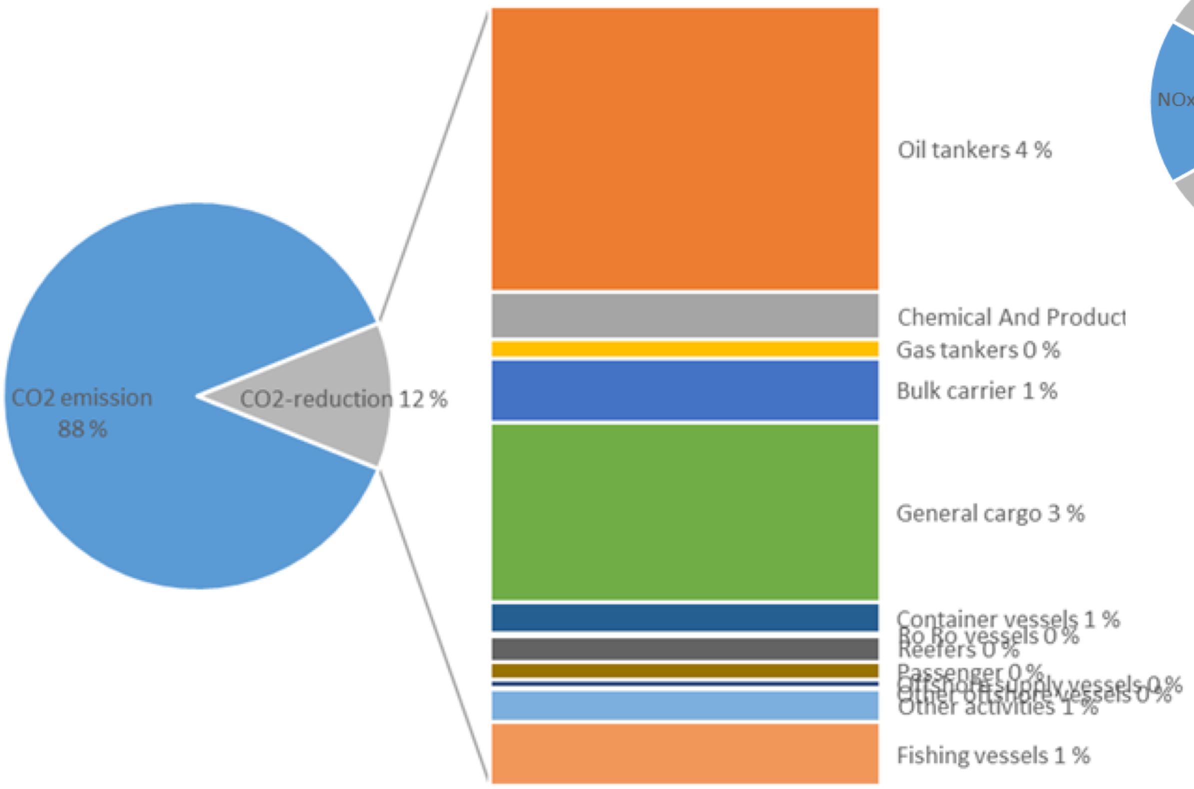


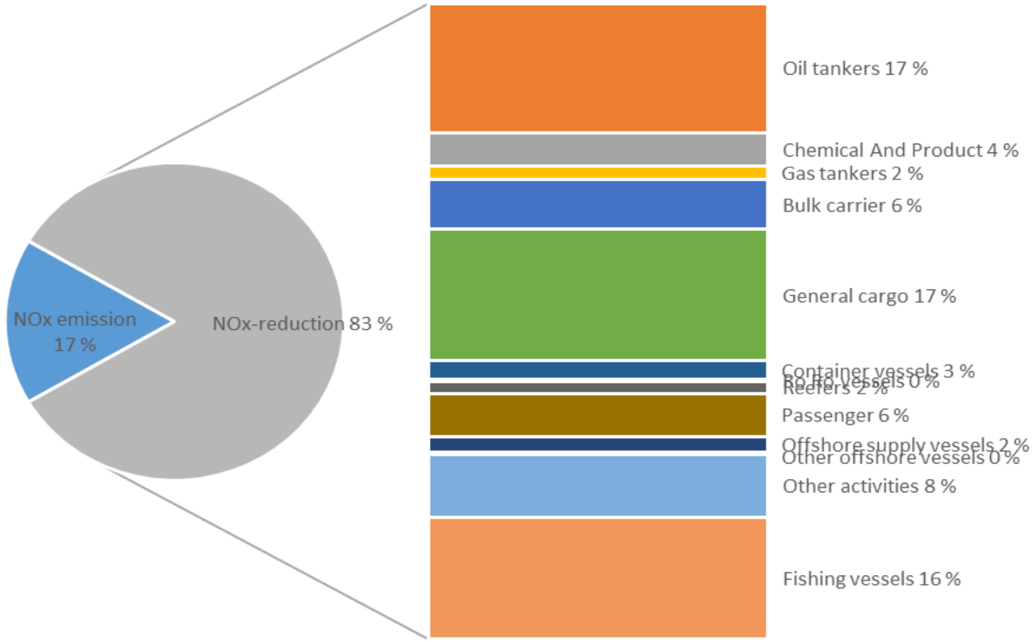
WWF, 2017

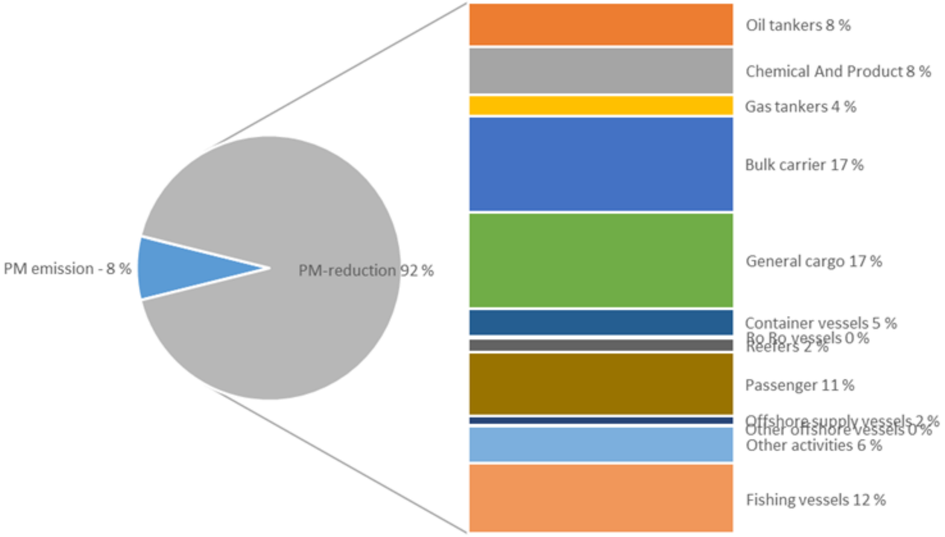
	Number of unique vessels - 2017 – Distillate/Residual							
	< 999	1000 - 4999	5000 – 9999	10000-24999	25000-49999	50000-99999	> 100000	Grand Total
Oil tankers		43	7	10	23	21	4	108
Chemical and Product	1	27	12	16	10			66
Gas tankers					1		5	6
Bulk carrier		4		34	71	2	2	113
General cargo	8	65	76	45	15			209
Container vessels			7	4				11
Ro Ro vessels	7			1				8
Reefers	2	51	38	7				98
Passenger	19	19	9	15	19	17	3	101
Offshore supply vessels	6	25	8					39
Other offshore vessels	5	4	4	1		1		15
Other activities	182	85	33	26	3			329
Fishing vessels	415	335	15					765
Sum Total	645	658	209	159	142	41	14	1868

	LNG engine alternative	Reduction CO2	Reduction NOx	Reduction PM	Reduction SOx
(green)	Not compatible with LNG	0%	0%	0%	100%
(blue)	4-stroke – low-pressure LNG engine	5%	90%	98%	100%
(orange)	2-stroke – high-pressure LNG engine	20%	90%*	98%	100%

Emission reduction potential - LNG







	Emissions - 2017– baseline	Emissions – LNG	Reduction (ton emission)	Reduction (%)
GHG-emissions	1 845 000	1 620 400	224 700	12 %
NOx-emissions	32 500	4 900	27 600	85 %
PM-Emissions	1 900	100	1 800	95 %
SOx-Emissions	32 500	500	32 000	98 %

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