FUTURE FUELS IN THE MARITIME INDUSTRY

SMTF – 02 NOV 2022

Who am I? - Tommy Hjälmås BSc.Mar.E.

- 30+ years in maritime industry
- 15 years with gas vessels (Navigator Gas / Dorchester Maritime (Bernard Schulte GmBH)
- JnJ Survey AB 2018 →
- IGF code examinator at Chalmers University, Sweden →
- Consultant for various local and international companies from time to time →

Gymnasium
1985-1987

University
1987-1990

At Sea
1990-1994

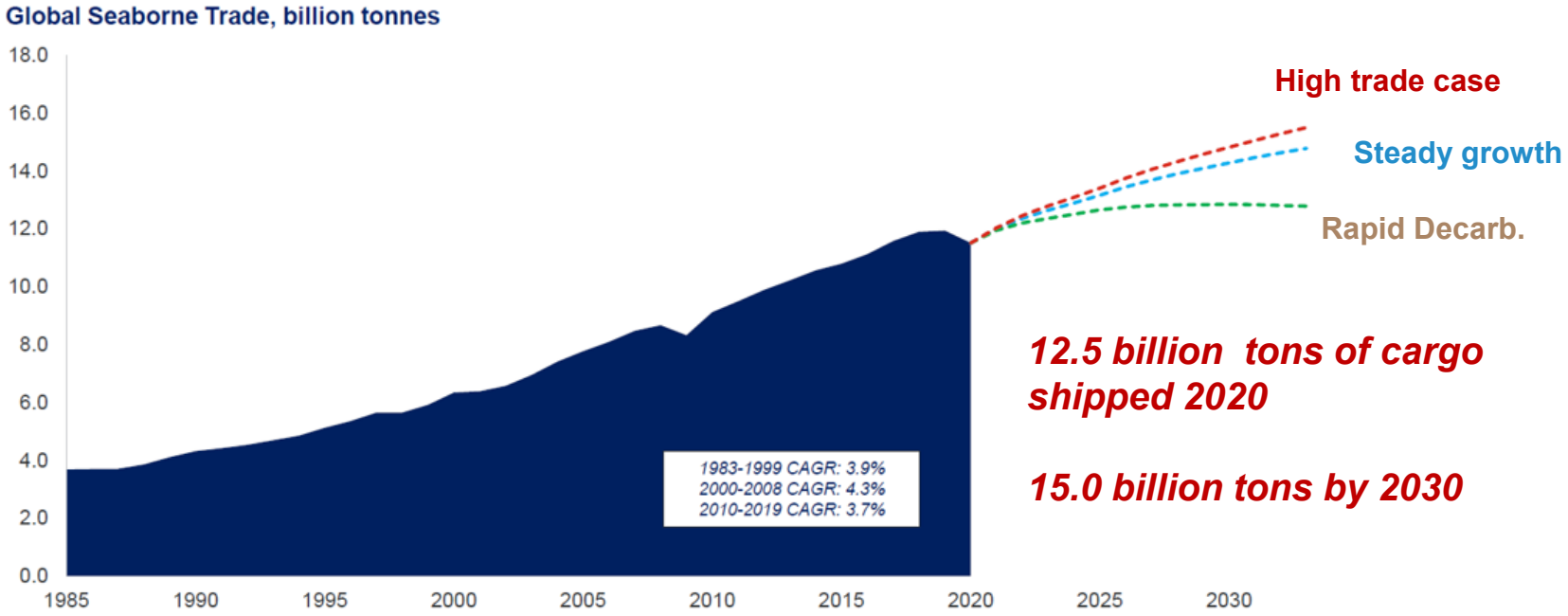
Superintendent
1994-2002

Fleet Manager
2002-2006

Chief Operating Officer
Director – Newbuilds and special projects 2006-2018

Future fuels “and other things…”

World Wide - Trade

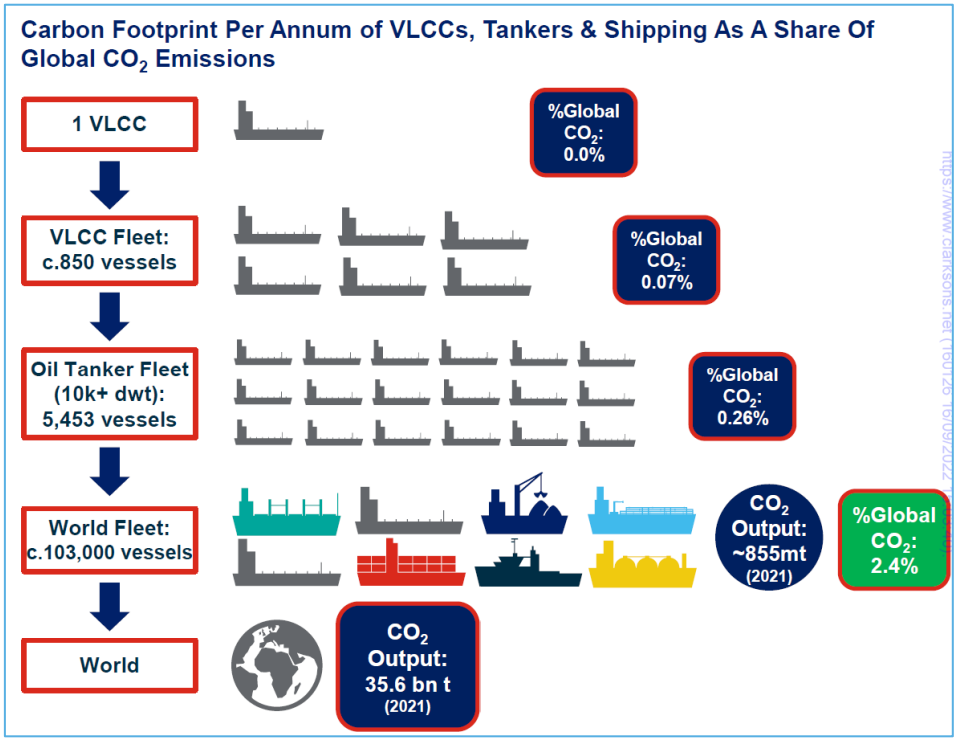


12.5 billion tons of cargo shipped 2020

15.0 billion tons by 2030

Source: Clarkson's Research

Seaborne Trade - Emissions



Ships emissions = **850-900 million** tonnes of CO_2 per year.

700 tonnes CO2 every second, every day around the clock!

Source: Clarkson's Research

Rules / Regulations - History

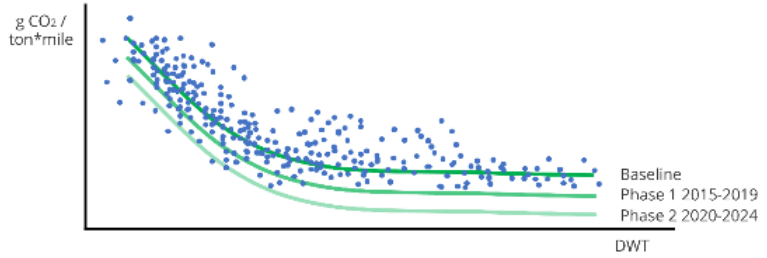
• “Titanic”	1912	**1,517**	life's
• “Torrey Canyon”	1967	**40,000**	tonnes oil
• “Amoco Cadiz”	1978	**220,000**	tonnes oil
• “Herald of Free Enterprise”	1987	**193**	life's
• “Exxon Valdez”	1989	**36,000**	tonnes oil
• “Scandinavian Star”	1990	**159**	life's
• “Estonia”	1994	**852**	life's
• “Sea Empress”	1996	**70,000**	tonnes oil
• “Erika”	1999	**30,000**	tonnes oil
• “Sept 11”	2001	**2,966**	life's
• “Prestige”	2002	**78,000**	tonnes oil
• “Costa Concordia”	2013	**32**	life's

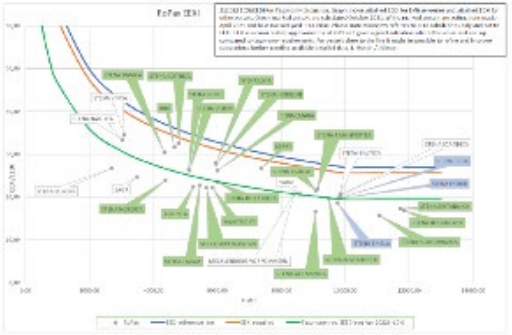
“Titanic” 1912	→	SOLAS The International Convent on Life at Sea 1914
“Torrey Canyon” 1967	→	MARPOL/STWC The International Convention for the Prevention of Pollution from Ships.
“Herald of Free Enterprise” 1987	→	ISM The International Safety Management Code
“11 Sept 2001 gave ISPS”	→	The International Ship & Shore Facility Security Code

EEDI / EEXI

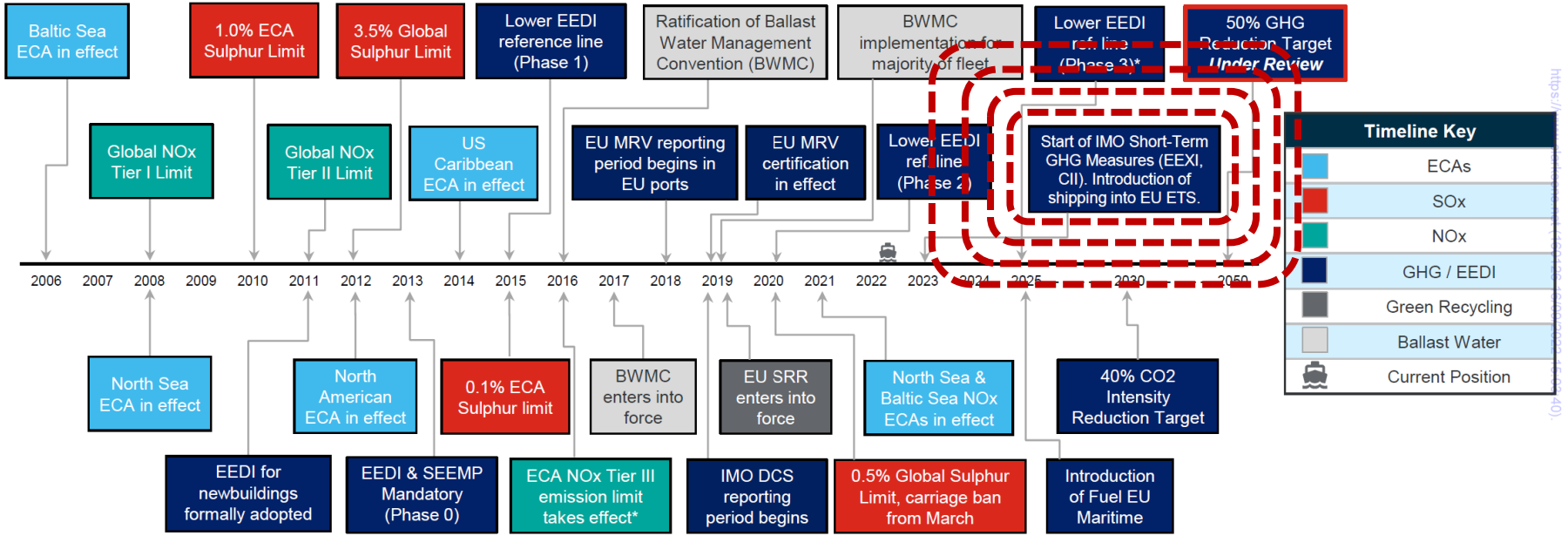
Result table based on 2020 operational figures and unchanged operation over time.

NAME	IMO N°	GT	CO2	distance	cgDIST	2023	2024	2025	2026	2027	2028	2029	2030
[redacted]	NA	37587	35167,014	80502,98	11,5	B	B	B	B	B	B	C	C
[redacted]	NA	42705	38975,559	83834,1	10,9	B	B	B	B	B	B	C	C
[redacted]	NA	43532	57326,977	78577,63	16,8	D	D	D	D	D	D	E	E
[redacted]	NA	22308	29061,279	73879,78	17,6	B	B	C	C	C	C	C	C
[redacted]	NA	64039	67598,375	73873,01	14,3	D	D	D	E	E	E	E	E
[redacted]	NA	29289	24193,009	47773,09	17,3	C	C	C	C	C	D	D	D
[redacted]	NA	41671	41262,866	82172,98	12,1	B	B	C	C	C	C	C	C
[redacted]	NA	41671	42544,021	72147,98	14,2	C	C	C	C	C	D	D	D
[redacted]	NA	24828	26478,514	67472,25	15,8	B	B	B	B	C	C	C	C
[redacted]	NA	26904	39316,707	53636,66	15,6	B	B	C	C	C	C	C	C
[redacted]	NA	51837	39358,119	78407,76	9,7	B	B	B	B	B	B	C	C
[redacted]	NA	13294	22779,63	55834,63	17,9	A	A	A	A	B	B	B	B
[redacted]	NA	64039	60571,8	74014,43	12,8	D	D	D	D	D	D	D	E
[redacted]	NA	27522	42513,454	84143,63	18,4	C	C	C	C	D	D	D	D
[redacted]	NA	29691	37381,39	77928,17	16,2	C	C	C	C	C	C	C	D
[redacted]	NA	27510	14036,592	24772,58	20,6	D	D	D	D	D	D	D	D
[redacted]	NA	27510	43594,446	91139,35	17,4	C	C	C	C	C	C	D	D
[redacted]	NA	19504	21335,421	74589,03	14,7	A	A	A	B	B	B	B	B
[redacted]	NA	24206	30952,619	54188,25	23,6	D	D	D	D	D	D	E	E
[redacted]	NA	58084	48180,056	82066,87	10,1	B	C	C	C	C	C	C	C
[redacted]	NA	39193	55416,708	106825,72	13,2	C	C	C	C	C	C	C	C
[redacted]	NA	30285	46186,042	70438,14	21,6	D	D	D	D	E	E	E	E
[redacted]	NA	30285	46254,302	69207,02	22,1	D	D	D	D	E	E	E	E
[redacted]	NA	33690	32280,364	67174,52	14,3	C	C	C	C	C	C	C	C
[redacted]	NA	33690	33875,115	67158,38	15,0	C	C	C	C	C	C	C	D
[redacted]	NA	14551	13740,899	49374,63	19,1	B	B	B	B	B	B	B	B
[redacted]	NA	39191	52344,88	102116,85	13,1	C	C	C	C	C	C	C	C
[redacted]	NA	13144	23411,448	99224,13	18,0	A	A	A	A	B	B	B	B





New regulations - Environment



Source: Clarkson's Research

Global Warming Potential (GWP)

- ***CO_2**, by definition, has a **GWP of 1** regardless of the time period used, because it is the gas being used as the reference. CO_2 remains in the climate system for a very long time: CO_2 emissions cause increases in atmospheric concentrations of CO_2 that will last thousands of years.*
- ***Methane** (CH_4) is estimated to have a **GWP of 28–36** over 100 years. CH_4 emitted today lasts about a decade on average, which is much less time than CO_2. But CH_4 also absorbs much more energy than CO_2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for some indirect effects, such as the fact that **CH_4 is a precursor to ozone, and ozone is itself a GHG**.*
- *Nitrous Oxide (N_2O) – NOx has a **GWP 265–298** times that of CO_2 for a 100-year timescale. N_2O emitted today remains in the atmosphere for more than 100 years, on average.*
- *Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) are sometimes called **high-GWP gases** because, for a given amount of mass, they trap substantially more heat than CO_2. (The GWPs for these gases can be in the **tens of thousands**.)*

Global warming potential (GWP) values relative to CO_2

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second Assessment Report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous oxide	N_2O	310	298	265
Substances controlled by the Montreal Protocol				
CFC-11	CCl_3F	3,800	4,750	4,660
CFC-12	CCl_2F_2	8,100	10,900	10,200
CFC-13	$CClF_3$		14,400	13,900
CFC-113	CCl_2FCClF_2	4,800	6,130	5,820
CFC-114	$CClF_2CClF_2$		10,000	8,590
CFC-115	$CClF_2CF_3$		7,370	7,670
Halon-1301	$CBrF_3$	5,400	7,140	6,290
Halon-1211	$CBrClF_2$		1,890	1,750
Halon-2402	$CBrF_2CBrF_2$		1,640	1,470
Carbon tetrachloride	CCl_4	1,400	1,400	1,730
Methyl bromide	CH_3Br		5	2
Methyl chloroform	CH_3CCl_3	100	146	160

https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Global / National / Regional

ExxonMobil

Chevron

bp

ConocoPhillips

TOTAL

TRANSPORT STYRELSEN

IMO INTERNATIONAL MARITIME ORGANIZATION

LNG Operating Regulations Including LNG Bunkering

GOTHENBURG ENERGY PORT

21/03/2017

ABS

GUIDE FOR

GAS AND OTHER LOW-FLASHPOINT FUEL READY VESSELS

JULY 2020

LIBERIAN REGISTRY

www.liscr.com

SIGTTO

Lloyd's Register

BUREAU VERITAS

DNV

Made in EU

ABS Quality Evaluations, Inc. Management System Certification

RINA

gard

TRANSPORT STYRELSEN

Styrande dokument

Riktlinje

2018-08-03

Nationella riktlinjer för bunkring av flytande metan i Sverige

2 LNG BUNKER OPERATION REGULATIONS

2.1 GENERAL

All bunkering operations in the Port of Gothenburg harbour area are subject to Port Regulations. In order to perform ship to ship bunkering the following conditions must be met:

- The bunker vessel must have accreditation from Port of Gothenburg (see 2.1.1).
- The receiving vessel must comply with the IGF code.
- The terminal must have a Port of Gothenburg-approved safety management system for allowing bunker operations alongside terminal berths with or without ship operations (see 2.1.3).
- All bunkering operations must be approved by Port of Gothenburg.

2.1.1. Bunker vessel criteria

The bunker vessel shall:

- be built according to IGC code.
- be inspected according to the Green Bunkering concept.
- hold proof or adequate training and certification according to STCW and the standard ISO 20519:2017.

2.1.2 Receiving vessel criteria

The receiving vessel must fully comply with the IGF code and also have a safe procedure, which is carried out according to the approved ISM manual onboard.

The receiving vessel should comply with the standard ISO 20519:2017 or similar.

2.1.3 Terminal criteria

The terminal must have safe bunkering procedures which are carried out according to the approved safety manual.

2.2 APPLICABLE REGULATIONS AND STANDARDS

- National Regulations.
- IMO IGF-code.
- ISO 20519:2017.
- Port Bye-laws.
- General harbour regulations for Port of Gothenburg.
- Operating regulations for Energy Port Gothenburg.

LNG BUNKER CHECKLIST

PORT OF ENERGY IN GOTHENBURG - SHIP TO SHIP

BUREAU VERITAS

Gas Fuelled Ships

January 2020

Rule Note

NR529 DT R03 E

Marine & Offshore

8 Cours du Triangle – CS 50101

92937 Paris La Défense Cedex – France

Tel: + 33 (0)1 55 24 70 00

https://marine-offshore.bureauveritas.com/bv-rules

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BIMCO

IACS

INTERTANKO

International Chamber of Shipping

SJÖFARTSVERKET

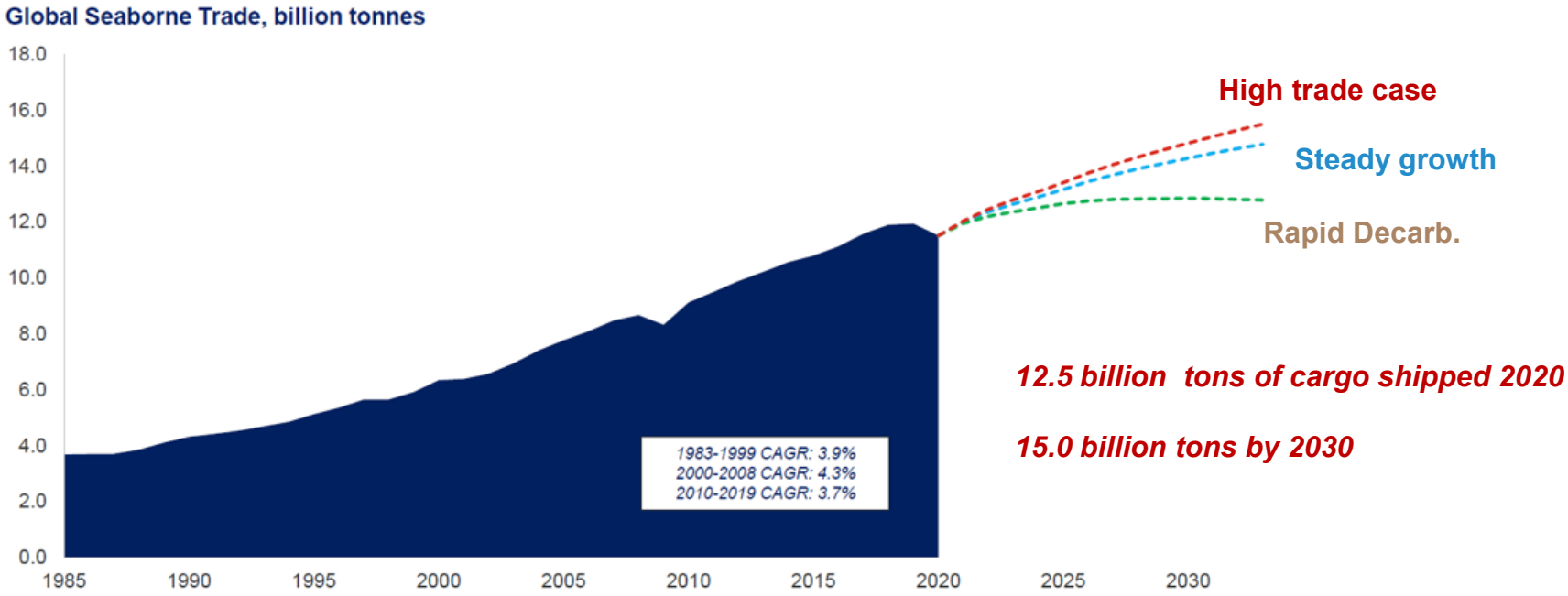
UNITED STATES COAST GUARD

U.S. DEPARTMENT OF HOMELAND SECURITY

OCIMF Oil Companies International Marine Forum

Future fuels – World fleet

World wide seaborne trade



12.5 billion tons of cargo shipped 2020

15.0 billion tons by 2030

World Wide - Fleet

Total Fleet	Numbers, end:					m. GT, end:					Forecast	
	2018	2019	2020	2021	Aug*	2018	2019	2020	2021	Aug*	2022	2023
TOTAL CARGO FLEET	60,832	61,784	62,572	63,382	64,045	1,237.7	1,290.2	1,330.1	1,374.0	1,402.4	1,414.1	1,442.9
% change	*1.1%*	*1.6%*	*1.3%*	*1.3%*	*1.0%*	*3.1%*	*4.2%*	*3.1%*	*3.3%*	*2.1%*	**2.9%**	**2.0%**
GLOBAL TOTAL FLEET	98,523	100,191	101,463	102,944	103,883	1,347.5	1,401.3	1,441.2	1,487.4	1,517.0	1,530.9	1,563.1
% change	*1.3%*	*1.7%*	*1.3%*	*1.5%*	*0.9%*	*3.0%*	*4.0%*	*2.8%*	*3.2%*	*2.0%*	**2.9%**	**2.1%**

In 2021, global newbuild contracting reached its highest tonnage levels since 2013, supported by all time high containership orders.

Source: Clarkson's Research

Ships in the world - ALL!

82,480 >100 GT and LOA >30 m (103,925) - In Service.
3,980 >100 GT and LOA >30 m (4,545) - On Order

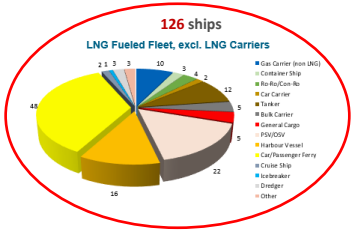
4,214 Chemical Carriers (incl. 168 on order where 19 are LNG fuelled + 4 MEOH.)
1,709 LPG carriers (includes 156 on order where 99 are LPG fuelled)
838 Car carriers (incl. 82 on order, 82 alt. fuelled (LNG))
550 Cruise ships (incl. 74 on order, 27 alt. fuelled (LNG) + 8 other)

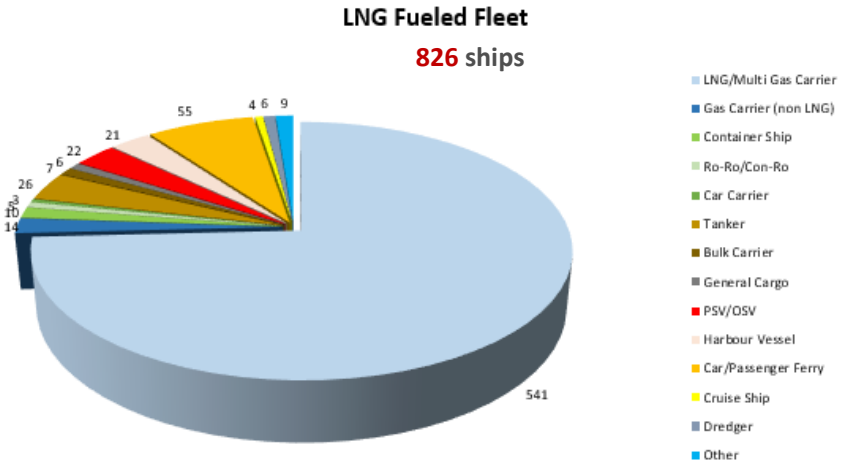
Orders for alternative fuel capable units this year reached 341 ships of 27.1m GT as of start September, representing 59% of GT ordered. This includes 272 units set to be LNG capable and 15 methanol capable units ordered in 2022 so far (following orders for 19 units in 2021).

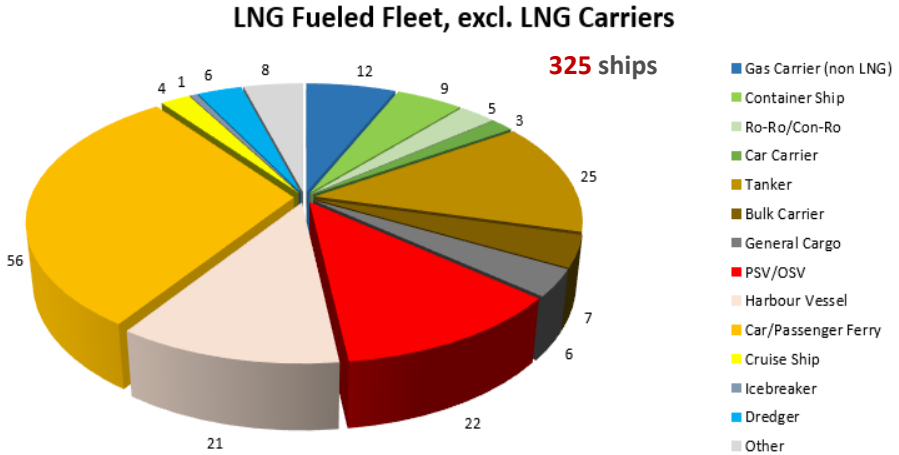
Orderbook - *Alternative Fuelled ships (Excl LNG cargo vessels)!*

Fuel Type	In Service	Total Orderbook
LNG (CH4)	~~317~~ / 325	~~493~~ / 501
ALTERN. FUEL (TOT)	**142**	**159**
METHANOL (CH3-OH)	19	42
LPG (C3/C4)	61	99
ETHANE (C2H6)	18	12
Ammonia (NH3)	0	0 (1)
Hydrogen (H2)	0	3-9

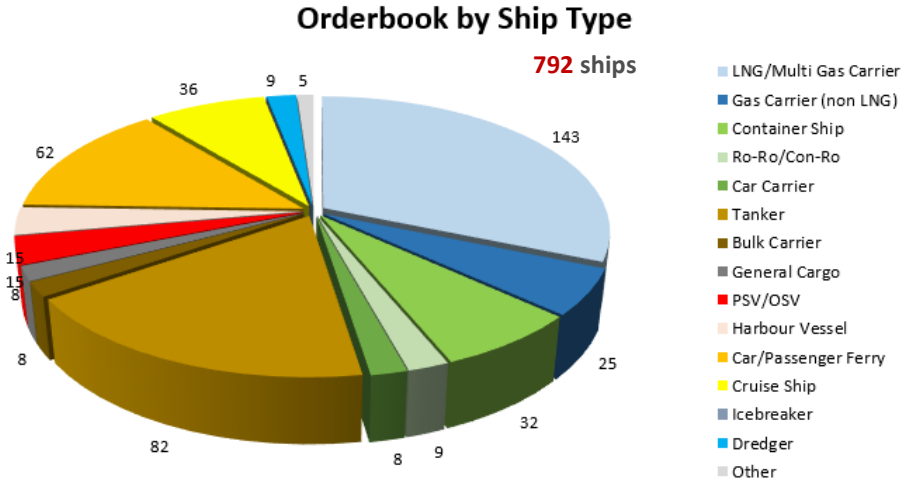
LNG as fuel – Fleet, In Service

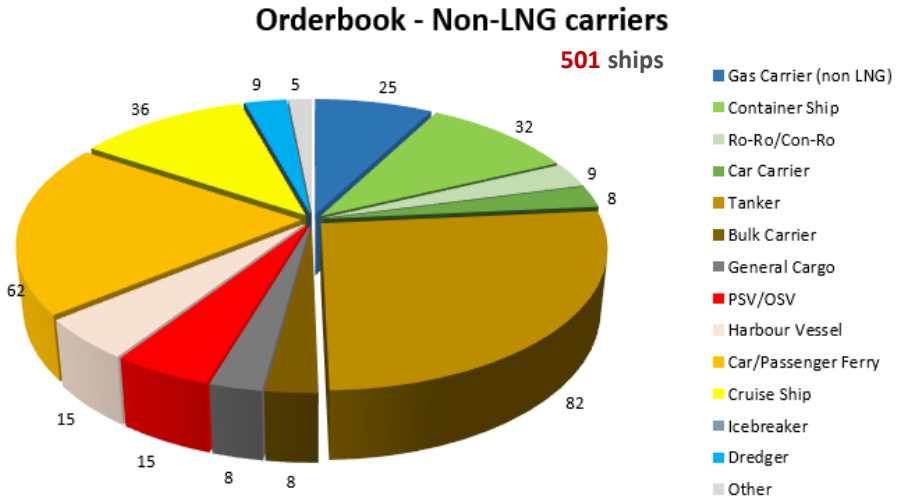






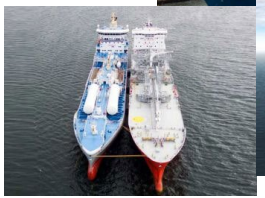
LNG as fuel – Fleet, On Order





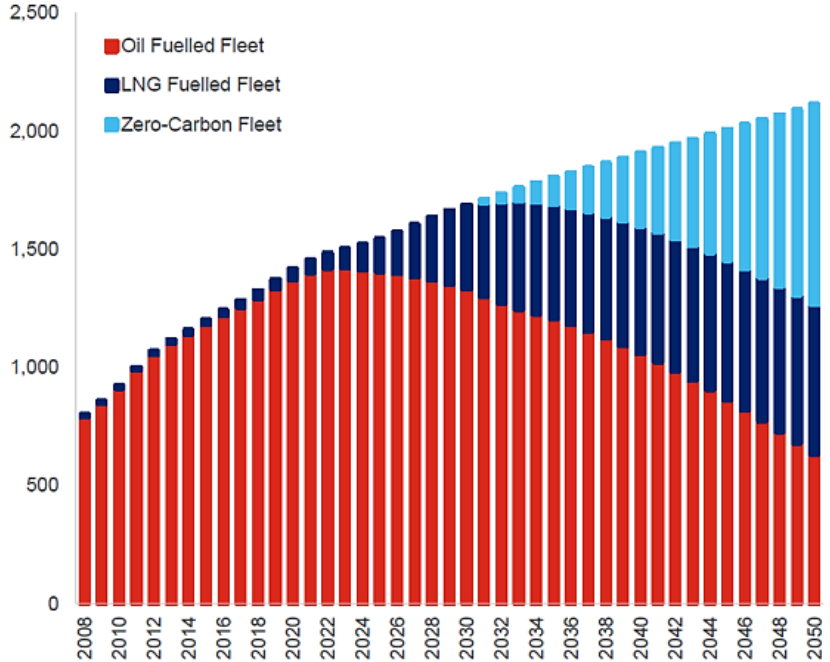
LNG bunker Ships

- Seagas (170 m3) - AGA
- Coralius: (5,800 m3) – A.V / Sirius AB
- Engie Zeebrugge (5,100 m3) – Nippon / NYK
- Kairos (7,500 m3) – BS / LGE
- Cardissa (6,500 m3) – Shell
- NB x **27** (4,000 – 28,000 m3)



Name	Type	Status	Contract Date	Built Date	Capacity (cu m)	Dwt	LOA (m)	Builder	Owner	Operator
N/B EK Heavy Industries	LNG Bunkering Vessel	On Order	01-Feb-2020	01-Jan-2022	500	300		EK Heavy Industries	S Korea Fisheries	
N/B Hyundai Mipo Ulsan 8298	LNG Bunkering Vessel	On Order	18-Nov-2019	01-Jan-2022	18,000	15,000	166.00	Hyundai Mipo	Korea Line	Shell Western LNG
N/B Hudong Zhonghua Shanghai H1870A	LNG Bunkering Vessel	On Order	03-Dec-2019	01-Nov-2021	18,600	15,000	135.00	Hudong Zhonghua	Mitsui OSK Lines	Total
N/B Nantong CIMC SOE	LNG Carrier	On Order	12-Apr-2019	01-Aug-2021	7,500	7,000	116.00	CIMC SOE	Avenir LNG	
N/B Nantong CIMC SOE	LNG Carrier	On Order	12-Apr-2019	01-May-2021	7,500	7,000	116.00	CIMC SOE	Avenir LNG	
N/B CIMC SOE Nantong S1044	LNG Carrier	On Order	31-Jan-2019	01-Mar-2021	20,000	12,000	159.70	CIMC SOE	Avenir LNG	
N/B Sembcorp Boulevard Singapore J420004	LNG Bunkering Vessel	On Order	25-Feb-2019	01-Feb-2021	12,000	10,000	112.00	Sembcorp Boulevard	Mitsui OSK Lines	Pavilion Gas
Ecobunker Tokyo Bay	LNG & Oil Bunkering Vessel	On Order	26-Feb-2019	01-Jan-2021	2,500	5,000	95.57	JMU Isogo Works	Ecobunker Shipping	
N/B CIMC SOE Nantong S1043	LNG Carrier	On Order	31-Jan-2019	01-Jan-2021	20,000	12,000	159.70	CIMC SOE	Avenir LNG	
N/B Damen Yichang Yichang 559014	LNG Bunkering Vessel	On Order	02-Oct-2018	01-Jan-2021	6,000	3,300	99.80	Damen Yichang	Infortar	Eesti Gaas
N/B Keppel Nantong Nantong H414	LNG Bunkering Vessel	On Order	26-Dec-2018	01-Dec-2020	5,800	5,000		Keppel Nantong	Shturman Koshelev	Gazpromneft Marine
N/B Dalian Shipbuilding Dalian G8500-1	LNG Bunkering Vessel	On Order	18-Oct-2018	01-Oct-2020	8,500	7,500	119.30	Dalian Shipbuilding	Xinao Energy	
FueLNG Bellina	LNG Bunkering Vessel	On Order	05-Jun-2018	01-Oct-2020	7,500	6,500		Keppel Nantong	FueLNG	FueLNG
N/B Keppel Nantong Nantong H401/H056	LNG Carrier	On Order	24-May-2017	01-Oct-2020	7,500	7,000		Keppel Nantong	Avenir LNG	Hygo Energy
Kaguya	LNG Bunkering Vessel	On Order	06-Jul-2018	01-Sep-2020	3,500	2,500	81.70	Kawasaki HI Sakaide	Central LNG Shipping	
Avenir Advantage	LNG Carrier	On Order	24-May-2017	01-Sep-2020	7,500	7,000		Keppel Nantong	Avenir LNG	Petronas
Gas Agility	LNG Bunkering Vessel	In Service	06-Feb-2018	01-Apr-2020	18,600	9,457	135.50	SCS Shipbuilding	Mitsui OSK Lines	Total
SM Jeju LNG2	LNG Carrier	In Service	05-May-2017	01-Jan-2020	7,654	5,752	96.96	Samsung HI	Korea Line	KOGAS
CNTIC VPower Global	LNG Carrier	In Service	05-Apr-2013	01-Jan-2020	28,689	15,996	176.80	COSCO HI (Dalian)	CNTIC VPower	CNTIC VPower
SM Jeju LNG1	LNG Carrier	In Service	05-May-2017	01-Sep-2019	7,654	5,857	96.96	Samsung HI	Korea Line	KOGAS
Kairos	LNG Bunkering Vessel	In Service	30-Nov-2016	01-Oct-2018	7,500	4,376	117.00	Hyundai Mipo	Schulte Group	Nauticor
Coral Energice	LNG Carrier	In Service	26-Jun-2015	01-Jan-2018	18,000	9,125	163.86	Neptun Werft	Anthony Veder	Anthony Veder
Coralius	LNG Bunkering Vessel	In Service	14-Jan-2015	01-Aug-2017	5,737	3,163	99.60	Royal Bodewes SY	Anthony Veder	Sirius Shipping
Cardissa	LNG Bunkering Vessel	In Service	04-Dec-2014	01-Jun-2017	6,469	5,320	119.94	STX SB (Jinhae)	Shell Western LNG	Shell Western LNG
Engie Zeebrugge	LNG Bunkering Vessel	In Service	30-Jun-2014	01-Feb-2017	5,100	3,121	107.60	HHIC (Yeongdo)	Nippon Yusen Kaisha	Nippon Yusen Kaisha
Hua Xiang 8	LNG Carrier	Dedicated Storage	01-Mar-2014	01-Dec-2016	14,000	9,094	125.80	Fengshun Ship Hvy	Zhejiang Huaxiang	
Coral Energy	LNG Carrier	In Service	25-Jan-2011	01-Dec-2012	15,600	12,268	155.64	Neptun Werft	Anthony Veder	Anthony Veder
Pioneer Knutsen	LNG Carrier	In Service	03-May-2002	01-Feb-2004	1,100	817	69.00	Veka SY Lemmer	Knutsen OAS Shipping	Knutsen OAS Shipping

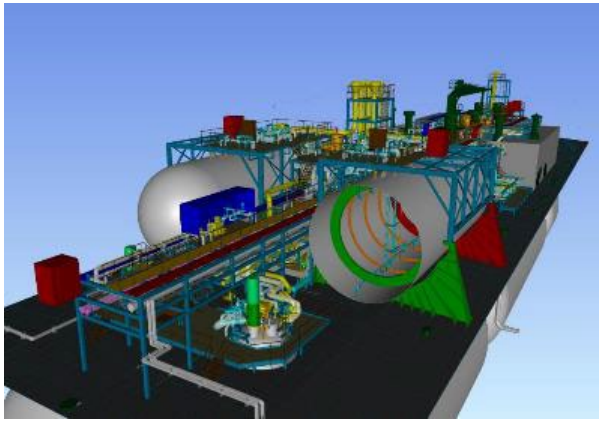
What fuels are they going to use?

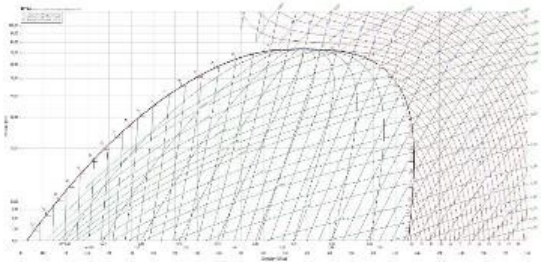


NH3, CCS, ME-OH etc.

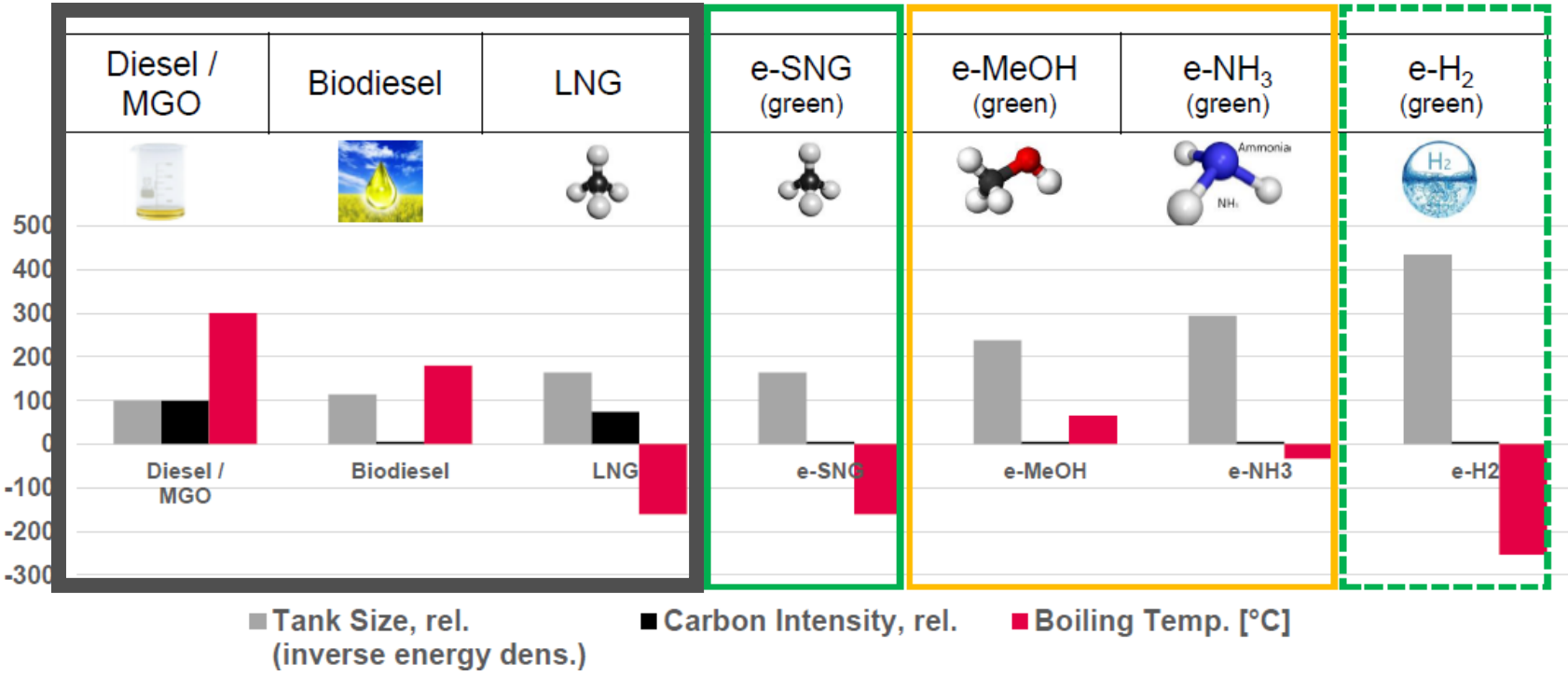
LNG

Fossil fuels





What options are there?



Emission (CO2) / power (kWh)

Fuel	Liquid density	Specific carbon content	Specific Energy content		Specific CO_2 emission (amount of fuel basis)			Specific CO_2 emission (amount of energy basis)		
	kg/l	kg_C/kg_{fuel}	kWh/kg_{fuel}	Btu/lb_{fuel}	Kg_{CO2}/kg_{fuel}	Kg_{CO2}/gal_{fuel}	lb_{CO2}/gal_{fuel}	kg_{CO2}/kWh	kg_{CO2}/GJ	$lb_{CO2}/mill\ Btu$
Methane (natural gas)		0.75	15.4	23900	2.75			0.18	50	115
Propane	0.510	0.82	13.8	21300	2.99	5.78	12.7	0.22	60	140
Butane	0.564	0.83	13.6	21100	3.03	6.47	14.3	0.22	62	144
LPG (wt of C3=C4)	0.537	0.82	13.7	21200	3.01	6.12	13.5	0.22	61	142
Gasoline	0.737	0.90	12.9	19900	3.30	9.20	20.3	0.26	71	165.3
Kerosene (Jet)	0.821	0.82	12.0	18500	3.00	9.33	20.6	0.25	70	162.5
Diesel	0.846	0.86	12.7	19605	3.15	10.1	22.3	0.25	69	160.8
Heavy fuel oil (No.6/Bunker C)	0.980	0.85	11.6	18000	3.11	11.6	25.5	0.27	75	173.3
Petroleum coke		0.89	9.4	14500	3.26	14.7	32.4	0.35	97	225.1
Coal:										227.3
Anthracite		0.92	9.0	14000	3.37			0.37	104	229.5
Bituminous		0.65	8.4	13000	2.38			0.28	79	231.7
Subbituminous		0.4	6.8	10500	1.47			0.22	60	233.9
Lignite		0.3	3.9	6000	1.10			0.28	79	236.1
Coke		0.77	7.2	11200	2.82			0.39	108	251.5
Peat (dry)[1)]		0.52	4.7	7300	1.91			0.40	112	260.7
Ethanol fuel (E100)[2)]	0.789	0.52	8.3	12800	1.91	5.71	12.6	0.23	64	149.6
Methanol fuel (M100)[2)]	0.791	0.37	5.5	8500	1.37	4.11	9.1	0.25	70	162.2
Biodiesel (B100)[2)]	0.880	0.78	11.3	17400	2.85	9.48	20.9	0.25	70	162.8
Wood [1) 2)]		0.50	4.5	7000	1.83			0.41	113	263.1
Bio energy [2)]								0 [2)]		

1 tonne of MDO = 3.11 tonnes of CO2

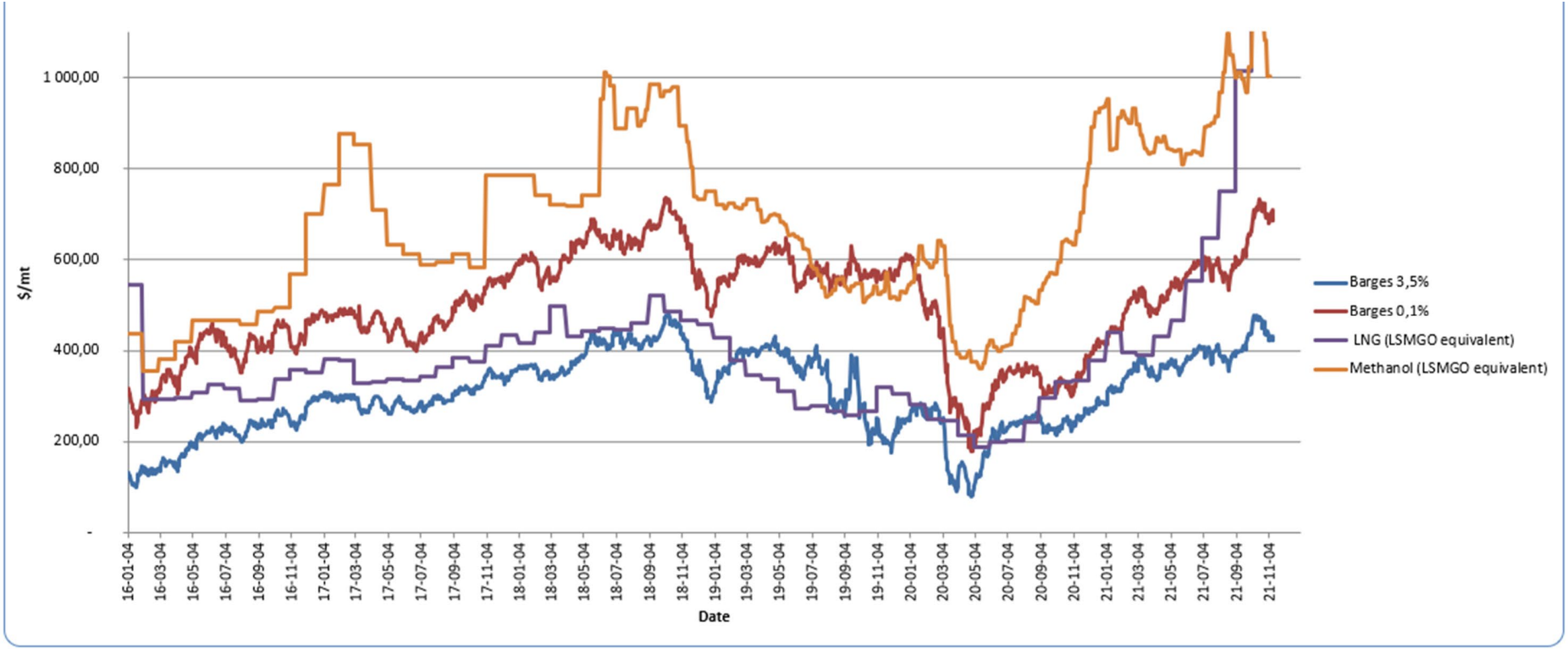
1 tonne of LNG = 2.75 tonnes of CO2

(3.15 – 2,75) / 3.11 = 12,7 % reduction of CO2 emissions

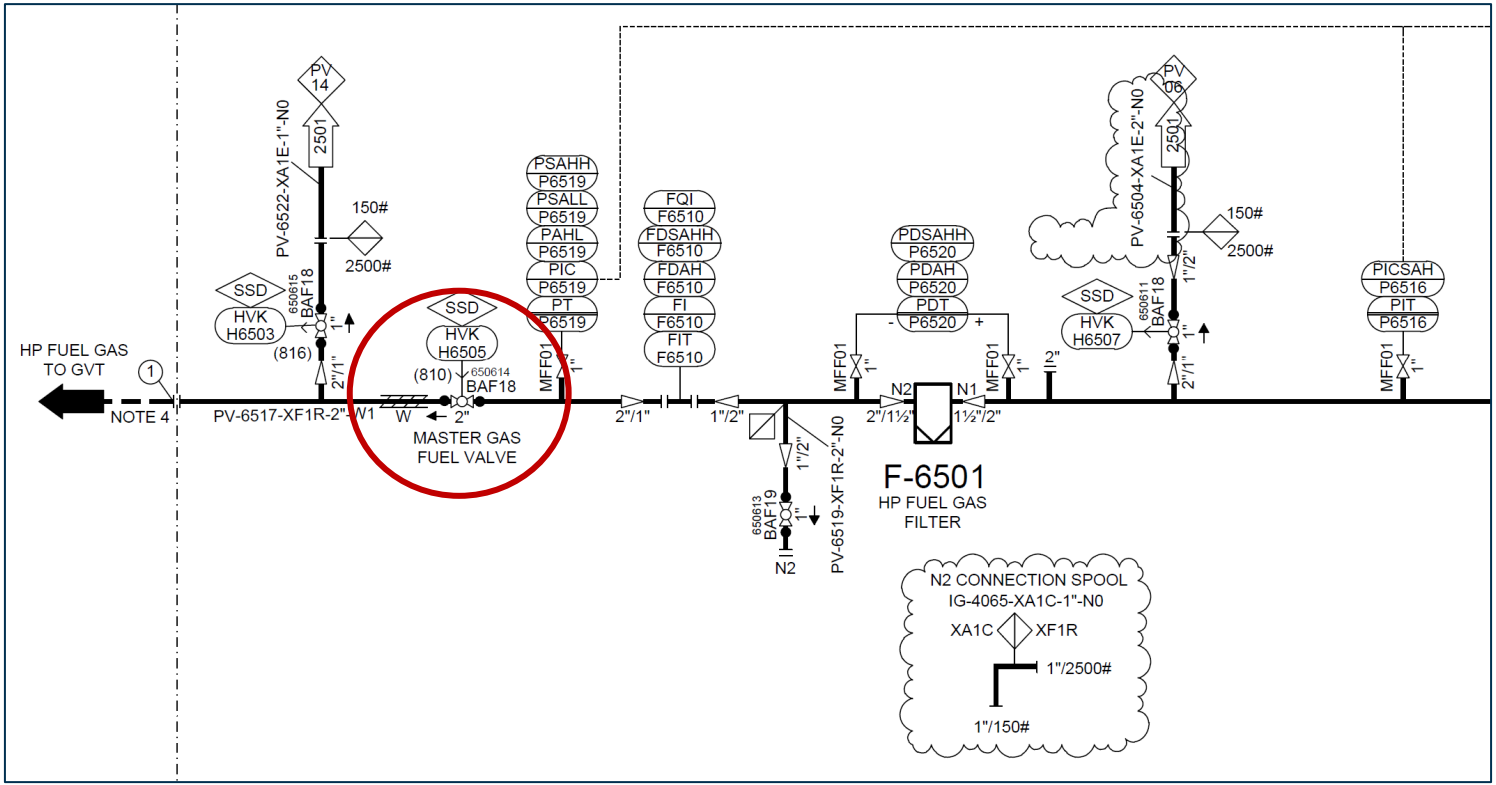
+ LNG has 20 % more energy per kg

So the NET reduction of CO2 emissions should be 25-30 % or ??

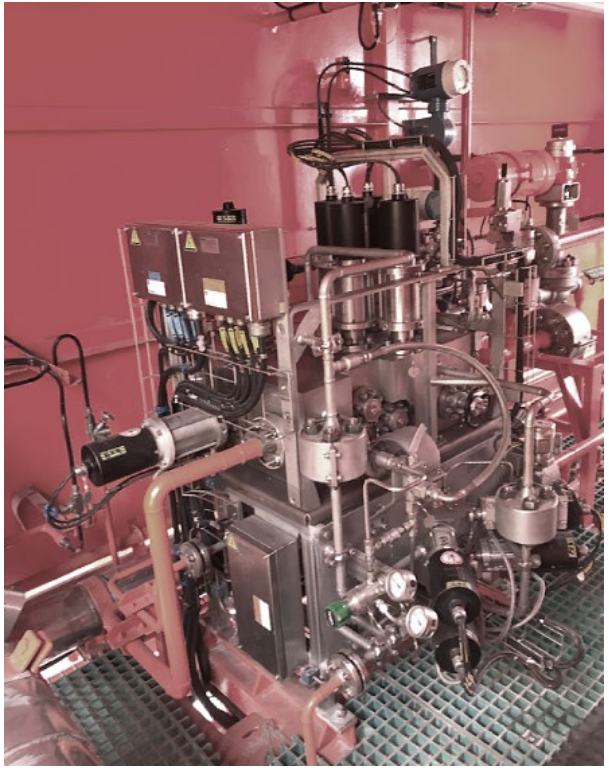
Bunker prices 2016 - 2022

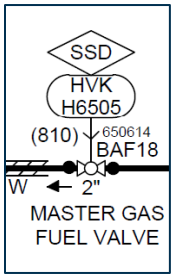


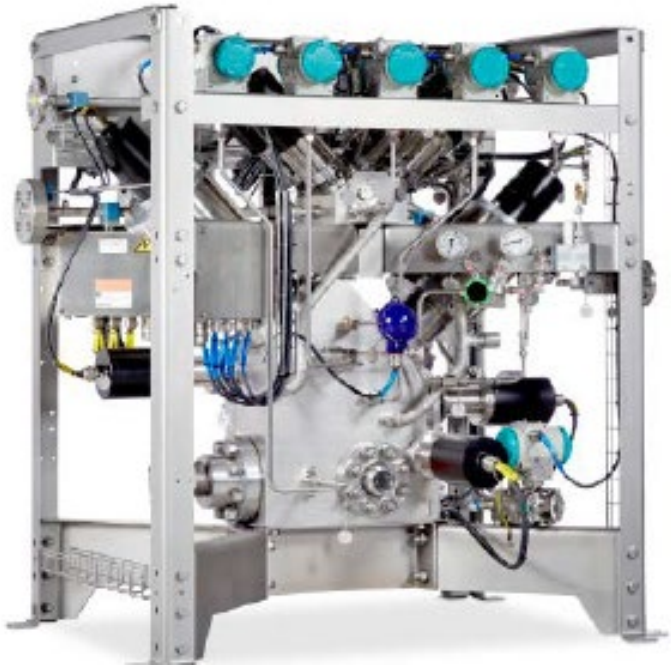
Master Gas Valve - LNG



Master Gas Valve – This is it!







Digitalisation – What is coming?

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