US California WIF project

In Cooperation with MSC, SCAQMD, Port of Long Beach and Port of Los Angeles

Agenda

1 Introduction

2 WIF system

3 WIF Fuel

4 Sea Trials on board MSC Anzu

5 Test program & Measurements

6 Costs and NOx reduction

7 Future Projects - Dual Fuel Conversion

1. Introduction / How did we get here?

Timeline

2018 May, SCAQMD reached out to MAN with a question

2018 December, Ocean Going Vessels Technology Forum at SCAQMD facility

2019 June, MSC confirmed their participation / MSC Silvia identified as demonstration vessel

2019 November, SCAQMD board approved the WIF project

2020 May, Port of Long Beach and Los Angeles Boards approved

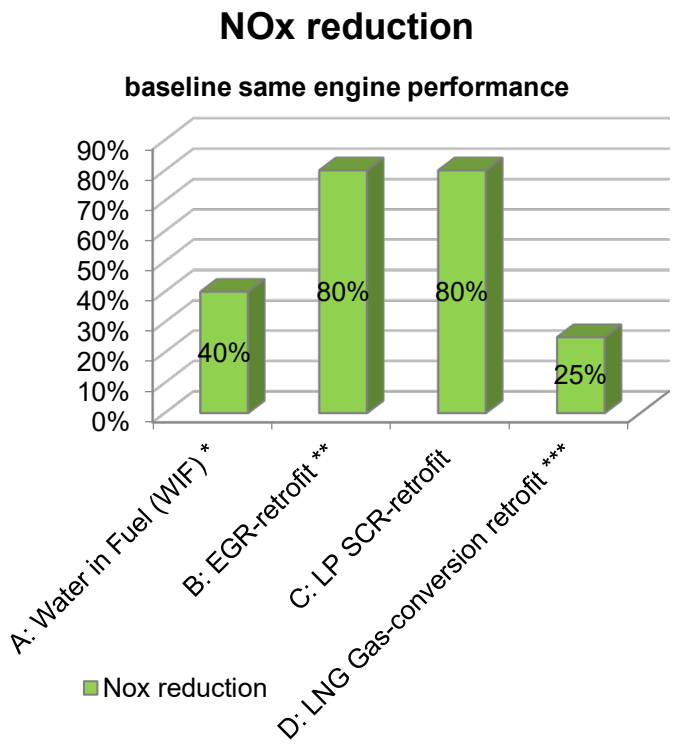
2020 June, Contracts signed - between SCAQMD and MAN
- between MSC and MAN

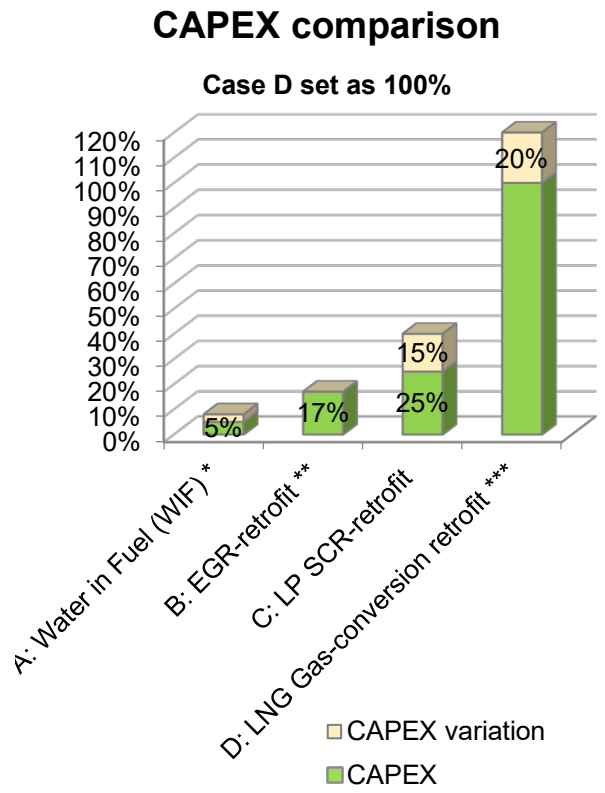
2020 October, MSC Anzu is selected to be the demonstration vessel

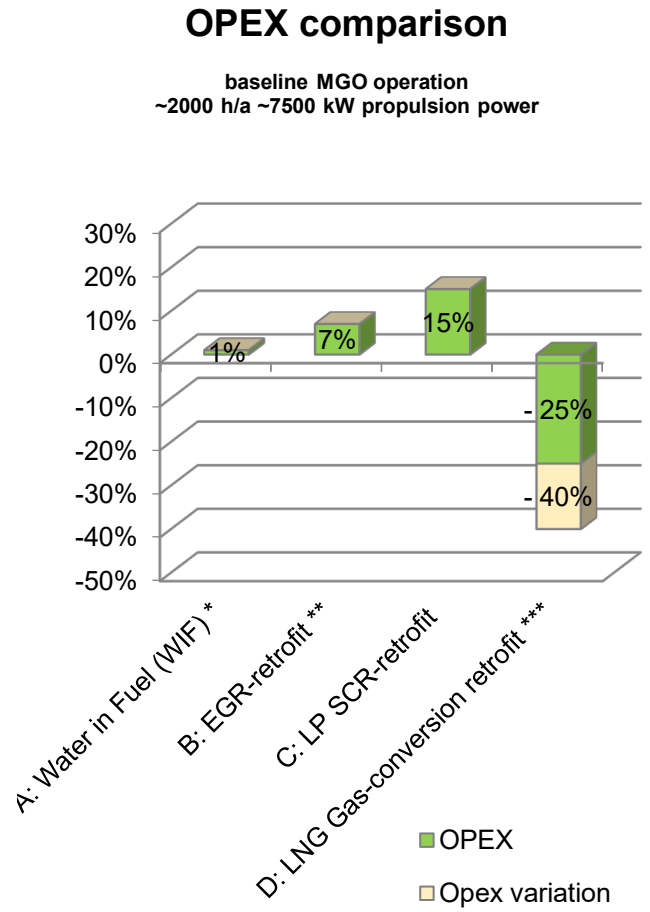
2022 August, Final sea trial and results

NOx reduction technologies for 2 stroke engines

Comparison of Reduction Potentials vs. Investment Cost vs. Operational cost







* up to 50%SMCR

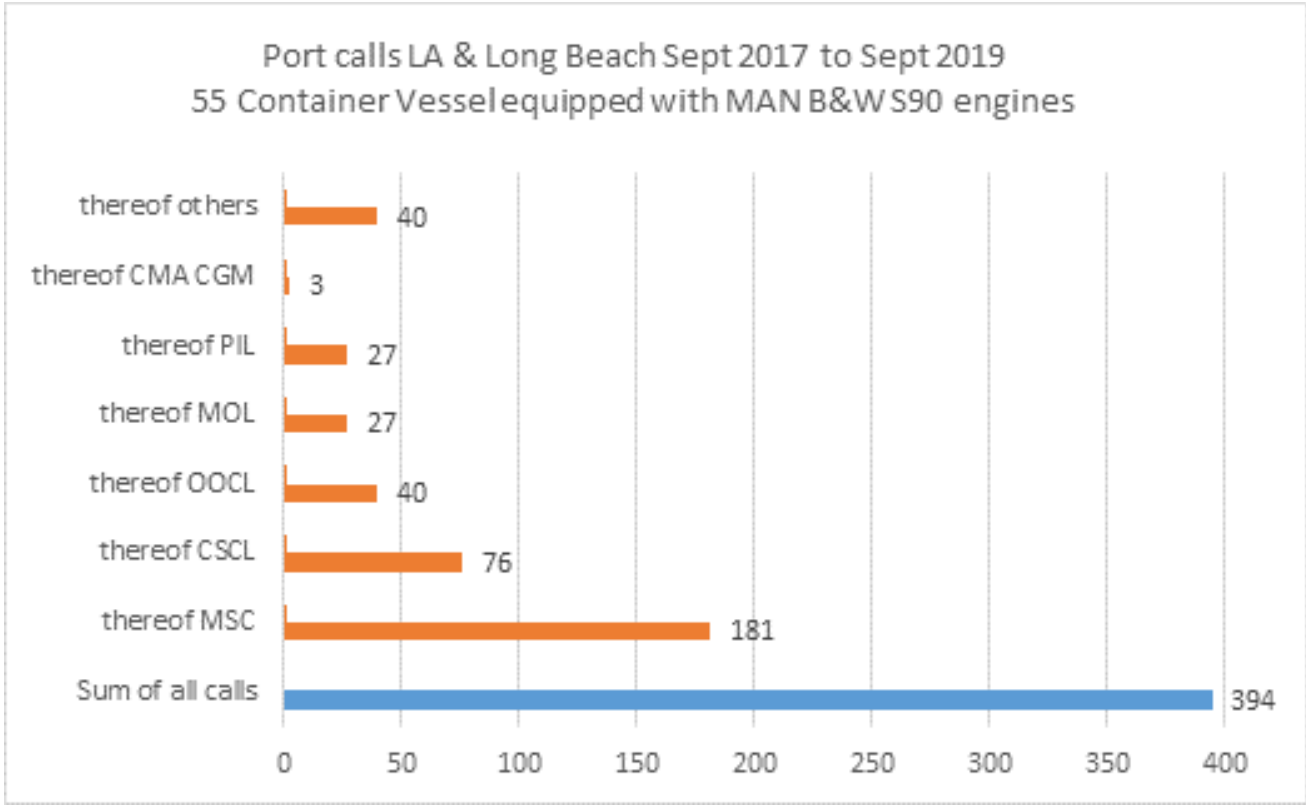
** if ME-engine is prepared for EGR

*** ME engine types Tier II

Ship type selection

How to achieve the most reduction

- Bigger ships producing the highest amount of emissions in quantity
- Tackling containership segment
- Which vessels have visited the Los Angeles and Long Beach ports the most in a given time period?
- Which engines are the best candidates for highest amount of reduction?



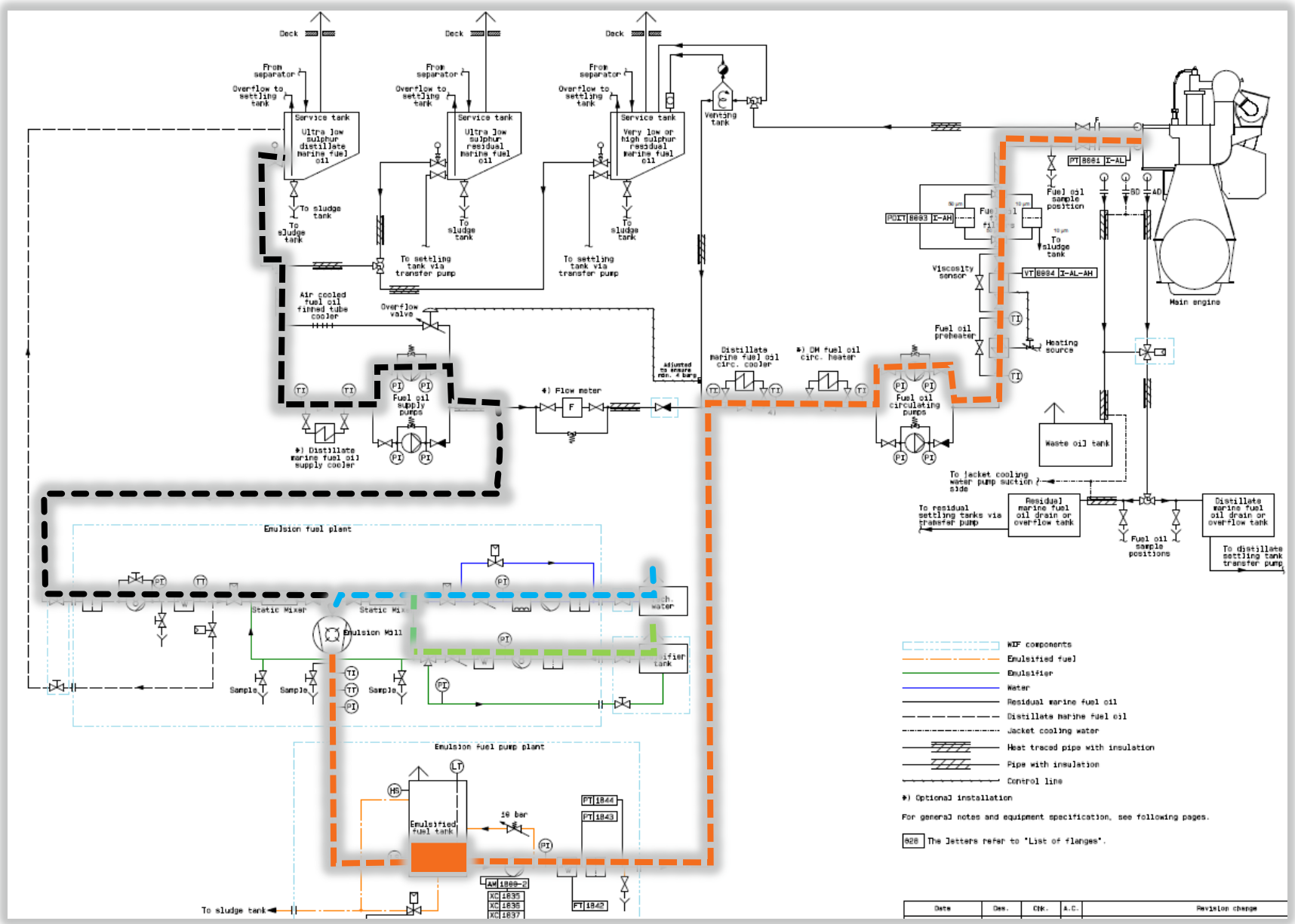
2. Water in Fuel System

Design stage

What's unique about this Water in Fuel System?

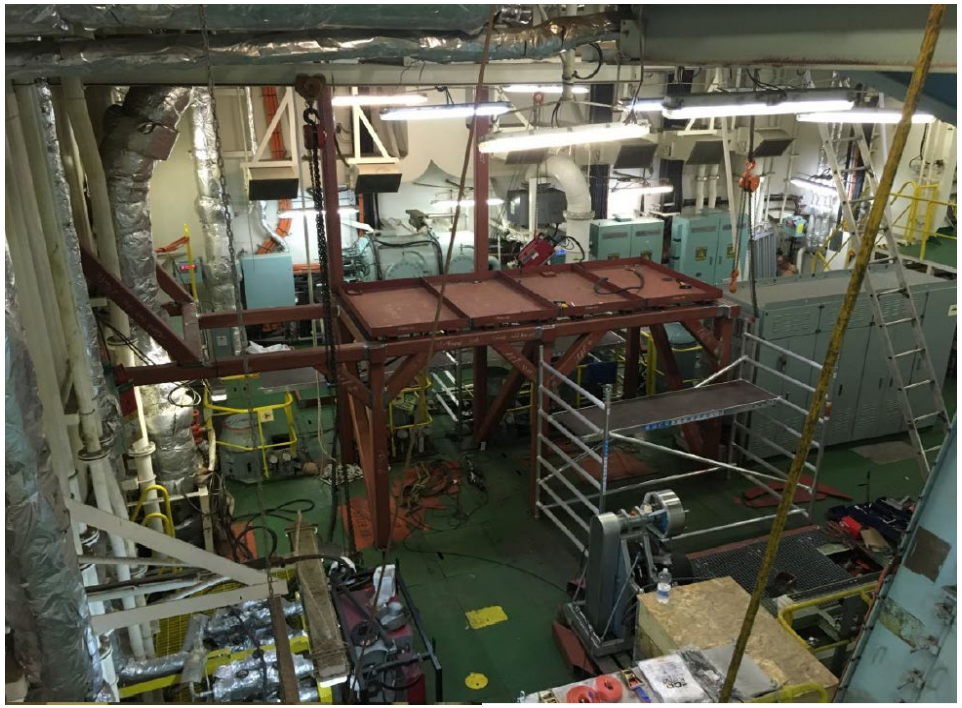
- Previous experience with similar systems
- Reliability
- New emulsification technology, bitumen technology, new materials
- New chemicals
- New partners that MAN has found through other R&D projects
- Designing the WIF unit

How it works?


Deck
From separator
Overflow to settling tank
Service tank
Ultra low sulphur distillate marine fuel oil
Ultra low sulphur residual marine fuel oil
Very low or high sulphur residual marine fuel oil
To sludge tank
To settling tank via transfer pump
Venting tank
Air cooled fuel oil finned tube cooler
Overflow valve
Fuel oil supply pumps
Distillate marine fuel oil supply cooler
Flow meter
Distillate marine fuel oil circ. cooler
DM fuel oil circ. heater
Fuel oil circulating pumps
Fuel oil preheater
Heating source
Viscosity sensor
Fuel oil sample position
Main engine
Waste oil tank
To jacket cooling water pump suction side
To residual settling tanks via transfer pump
Residual marine fuel oil drain or overflow tank
Distillate marine fuel oil drain or overflow tank
Fuel oil sample positions
To distillate settling tank transfer pump
Emulsion fuel plant
Static Mixer
Emulsion Mill
Sample
Emulsifier tank
Emulsion fuel pump plant
Emulsified fuel tank
10 bar
To sludge tank
WIF components
Emulsified fuel
Emulsifier
Water
Residual marine fuel oil
Distillate marine fuel oil
Jacket cooling water
Heat traced pipe with insulation
Pipe with insulation
Control line
Optional installation
For general notes and equipment specification, see following pages.
The letters refer to "List of flanges".
Date
Des.
CHK.
A.C.
Revision change

Installation

- Team of 4
- Sailed with the ship for 4 weeks
- No dry docking, no down time for the ship, installation during service
- Finalizing the installation in Port of Long Beach in December 2021

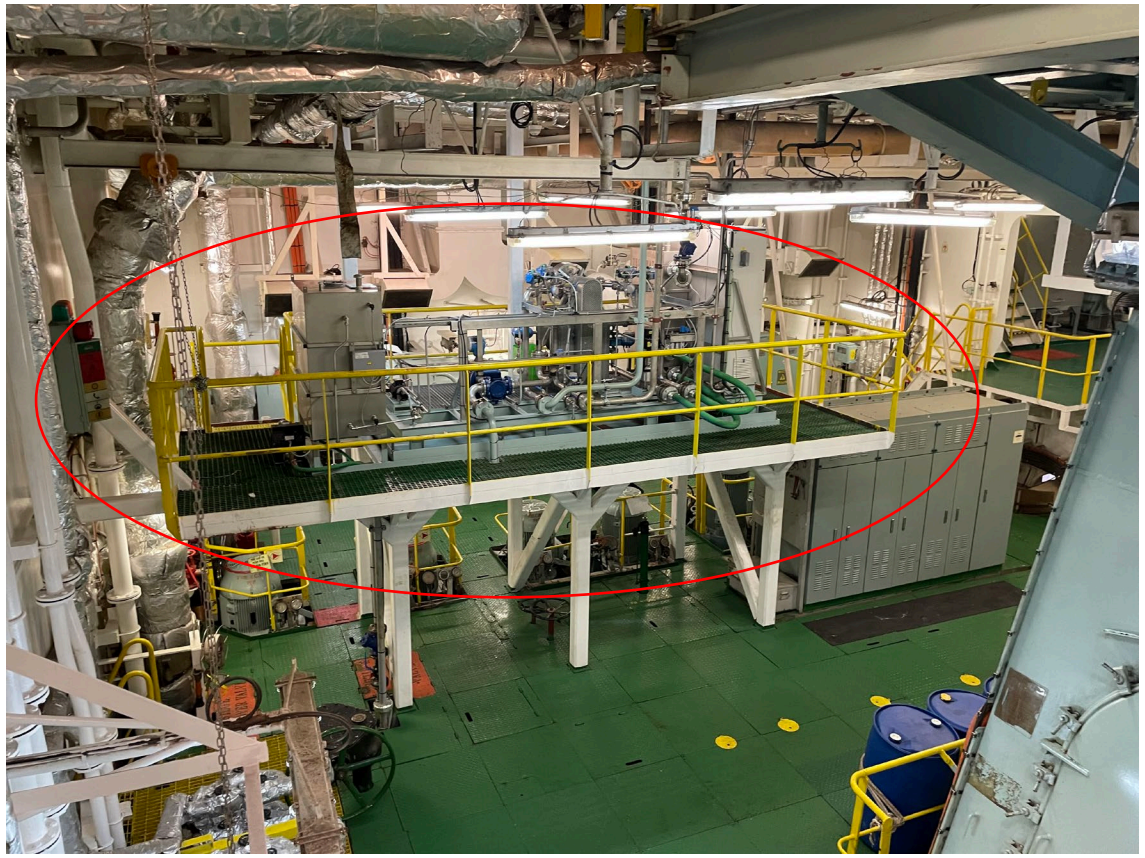


Installation, finalized

Maximum 50% engine load during operation of the WIF unit

– WIF pump unit

– WIF mixer unit



3. “WIF” Fuel

”WIF” fuel

The WIF fuel is a Mixture of Ultra Low Sulphur diesel, Water & Emulsifier

Final mix: 41% Water and 0,5% Emulsifier into the diesel

4. Sea trials

First Sea Trial

March / April 2022

Commissioning test from London – Hamburg – Rotterdam

Due to wrong Emulsifier the commissioning of WIF system was not possible.

Only diesel mode was tested during the voyage and performance test was done.

In total 6 performance tests were performed during this Sea Trial

Second Sea Trial

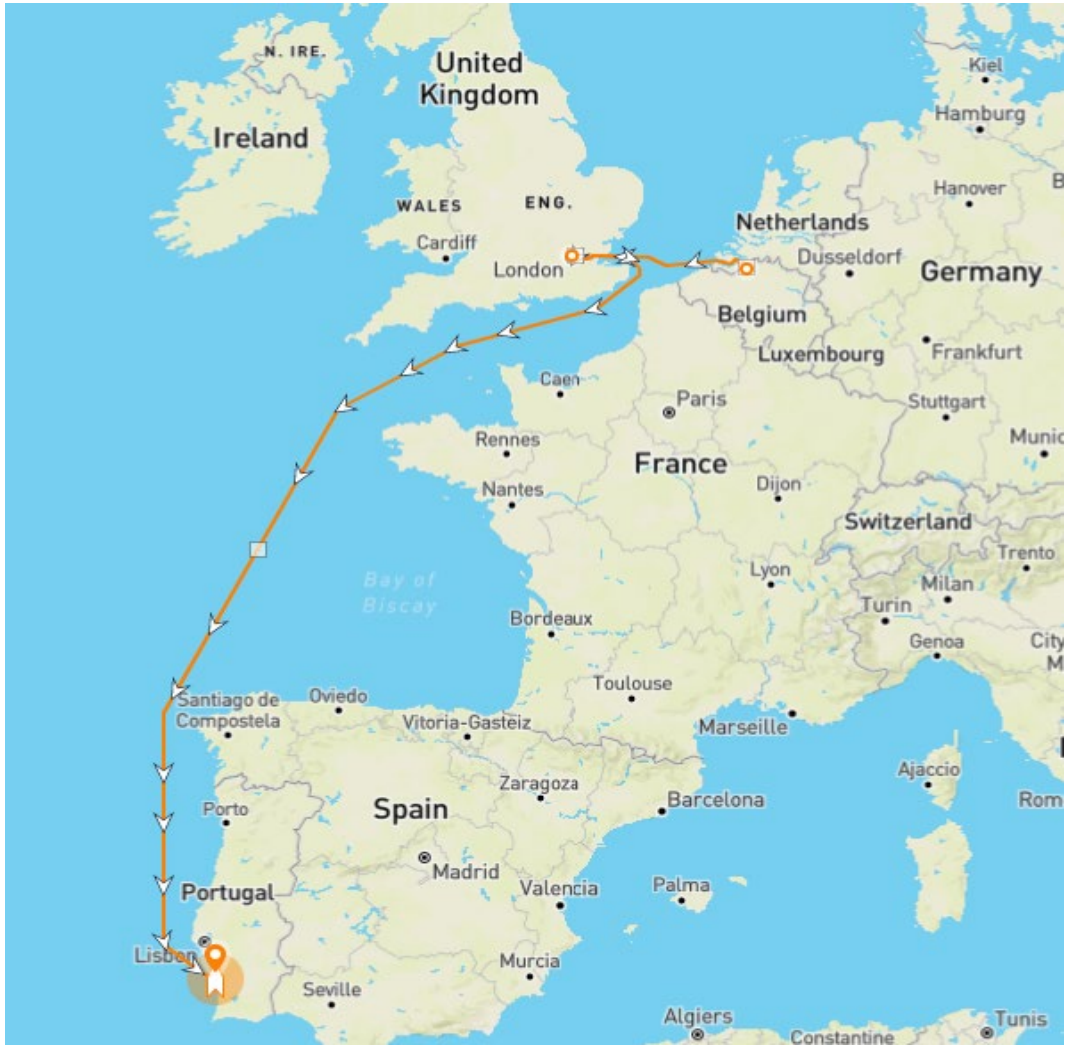
June 2022

Commissioning & initial test performed from Antwerp - London – Sines

Team of 4

Maximum 31% water content in the mixture

In total 17 performance test was performed during this Sea Trial



Third Sea Trial

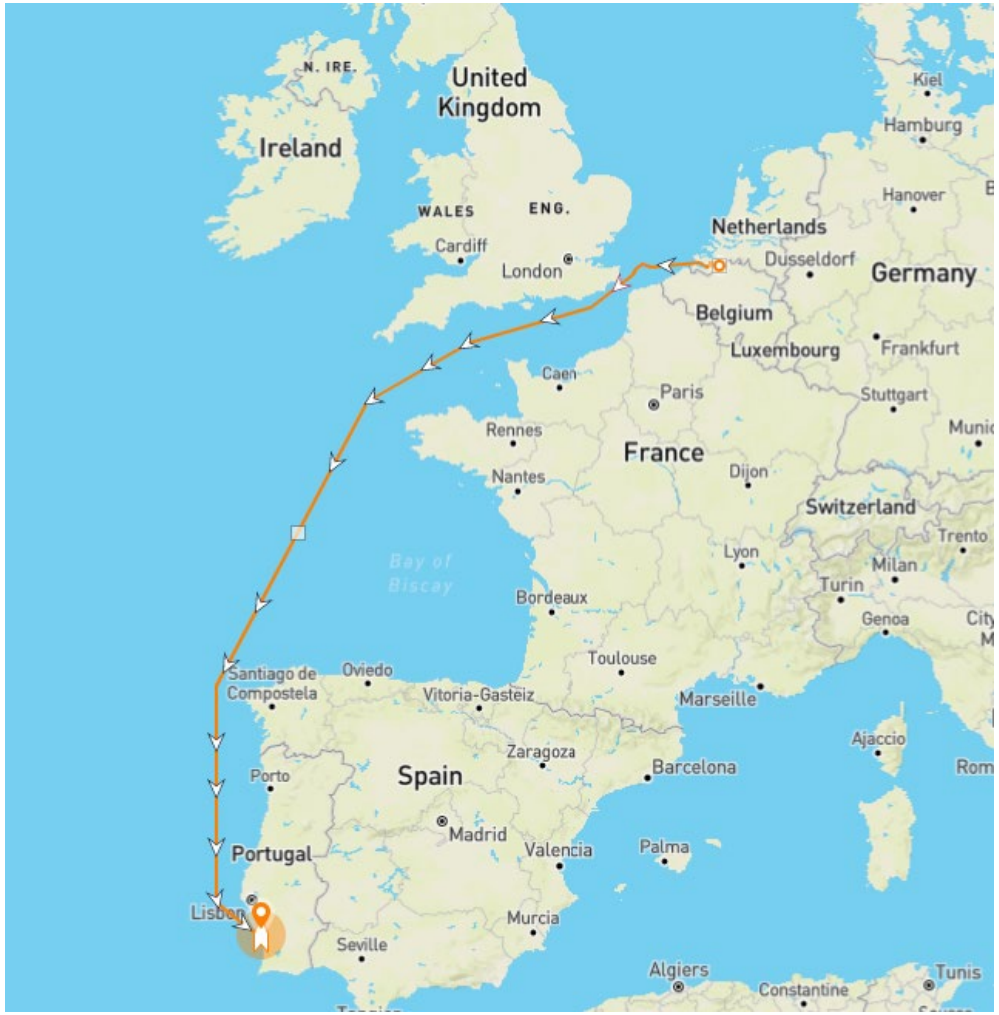
August 2022

Initial test & Final test from Antwerp to Sines

Team of 6

Maximum 41% water content in the mixture

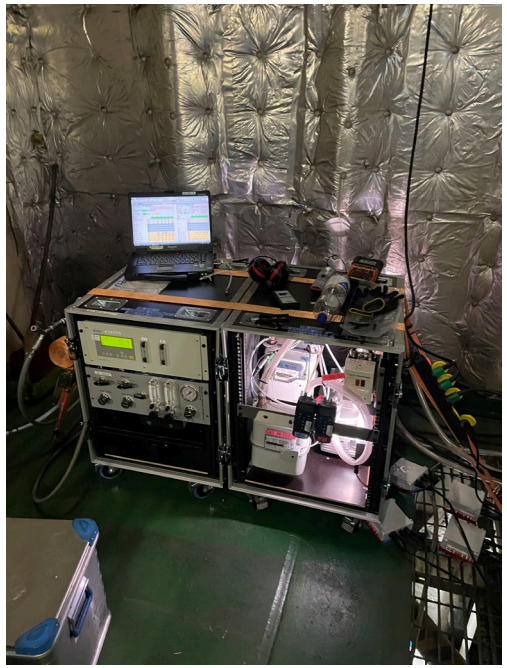
In total 20 performance tests were performed during this Sea Trial



5. Test program and measurements

Measurement on board MSC Anzu

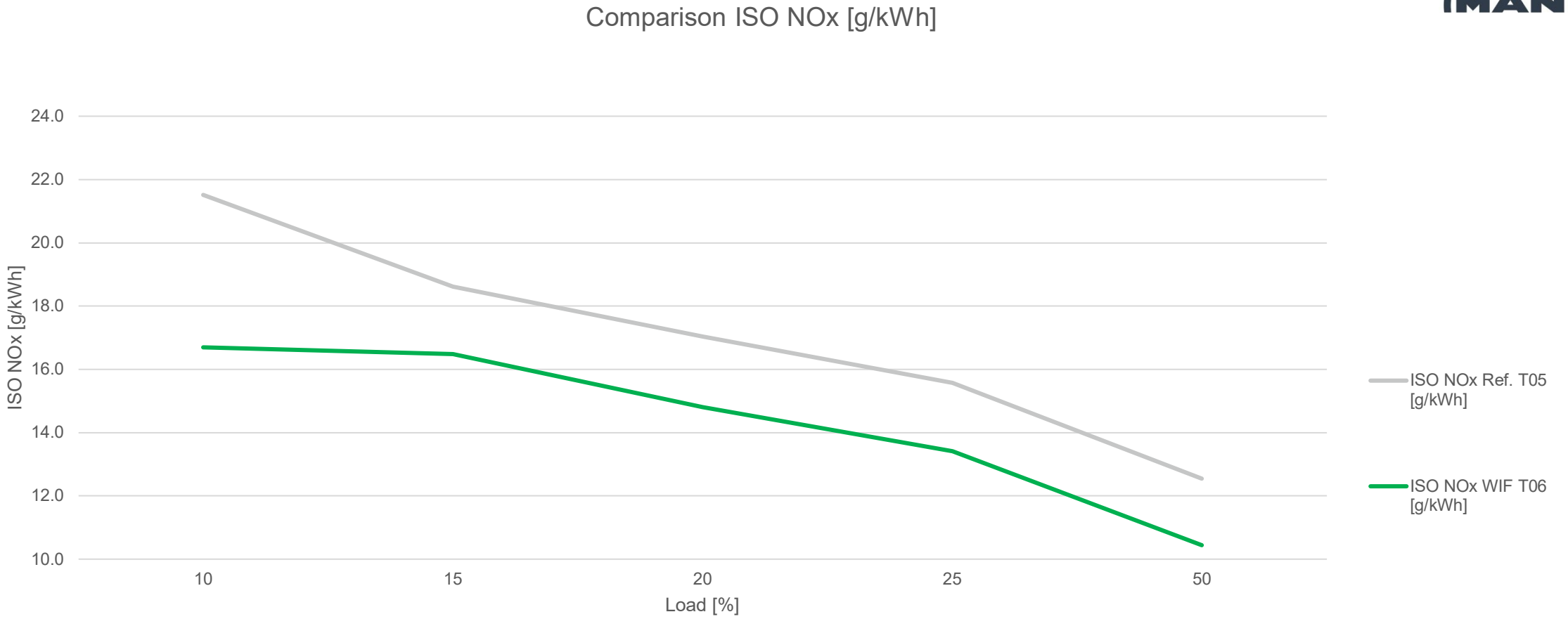
- Performance measurement
- Fuel measurement (Diesel, Water & Emulsifier)
- Emission measurement (NOx, CO_2, CO,O_2,THC)
- Particular Matters measurement
- Filter smoke number (FSN)



Test #	WIF	Emulsifier	Water	Engine power [% SMCR]	Running mode	Date [dd/mm/yyyy]	Measurement time (start) [hh:mm]	Remark
T05_1				10	Ref. MDO	21-08-2022	11:12	
T05_3				15			14:19	
T05_5				20			16:03	
T05_7				25			17:21	
T05_9				50			19:40	
T05_11				75			21:21	
T06_11	70%	0,5%	41%	10	WIF	22/23-08-2022	17:21	
T06_8	70%	0,5%	41%	15			16:14	
T06_5	70%	0,5%	41%	20			15:04	
T06_2	70%	0,5%	41%	25			13:41	
T06_14	60%	0,5%	38%	50			11:53	
T07_1	40%	0,5%	29%	25	WIF	23-08-2022	17:47	
T07_2	40%	2,0%	29%	25			18:55	
T07_3	40%	4,0%	29%	25			20:20	

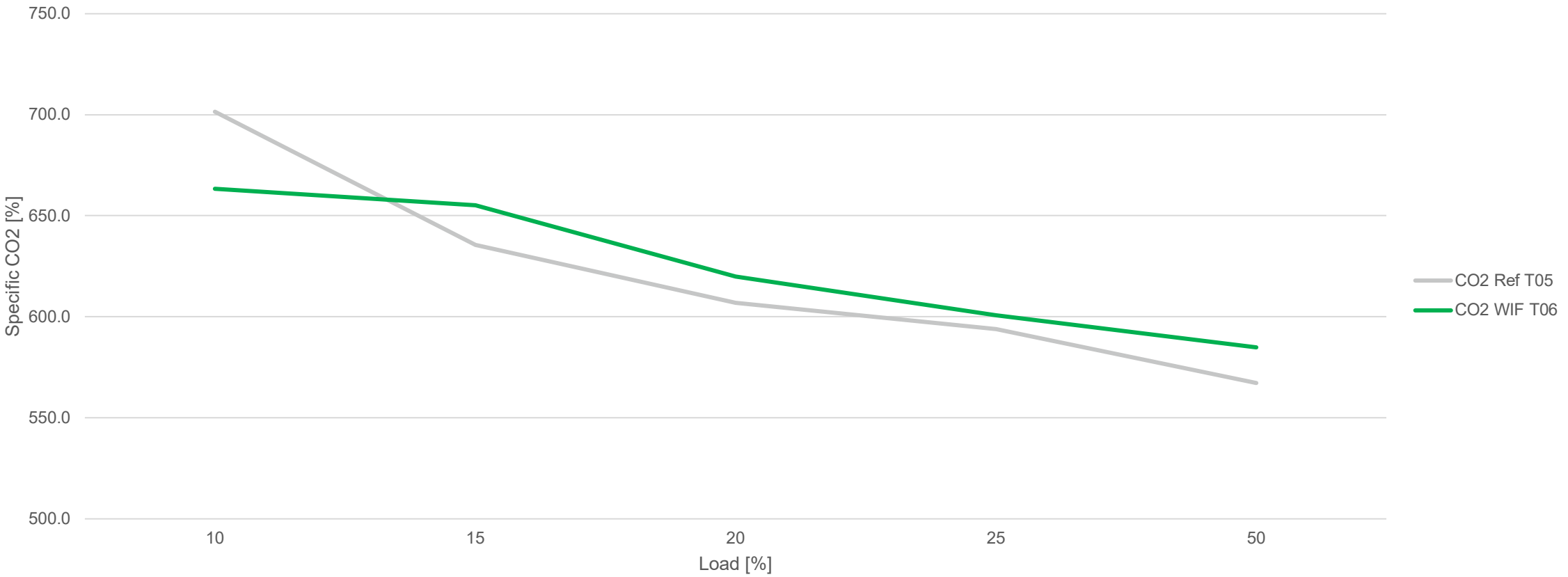
Test program approved by California Air Resources Board

NOx results



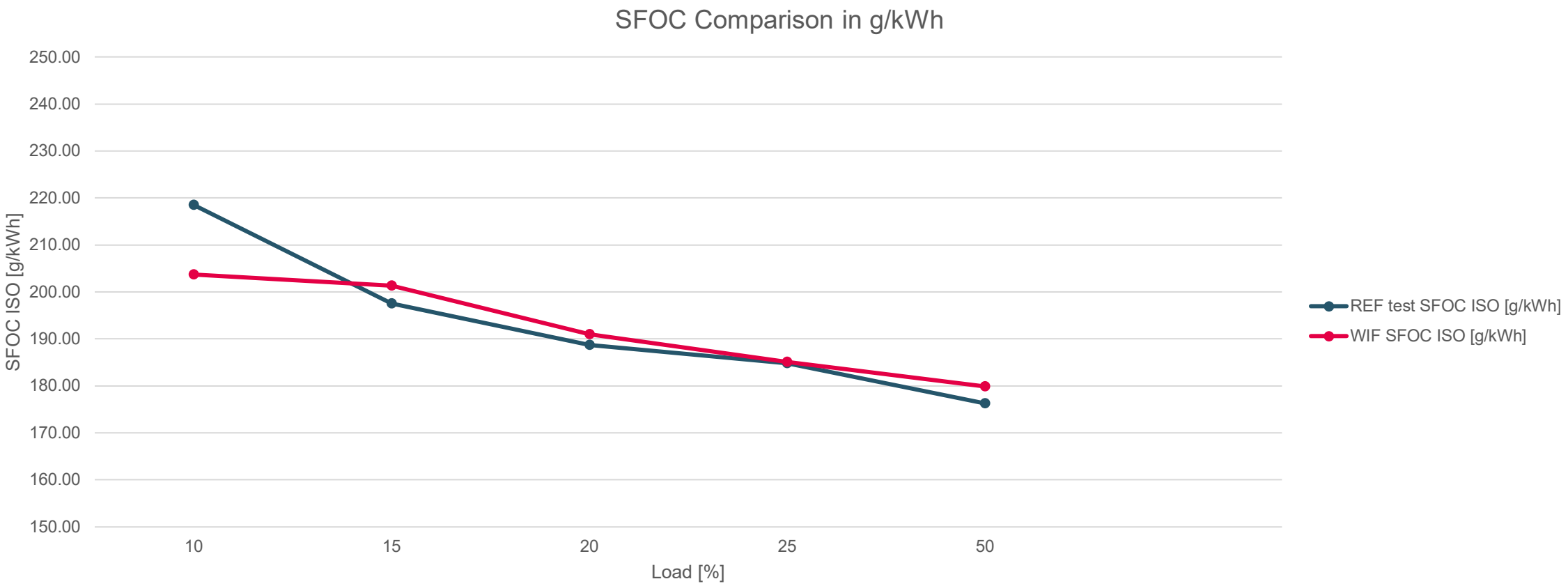
Load [%]	Ref. Test	Ref. ISO Corr. NOx	WIF Test	WIF ISO Corr. NOx	Deviation [%]
10	5_1_1	21,5	6_11_1	16,7	-22,4
15	5_3_1	18,6	6_8_1	16,5	-11,4
20	5_5_1	17,0	6_5_1	14,8	-13,1
25	5_7_1	15,6	6_2_1	13,4	-13,9
50	5_9_1	12,5	6_14_1	10,4	-16,7

CO_2 results



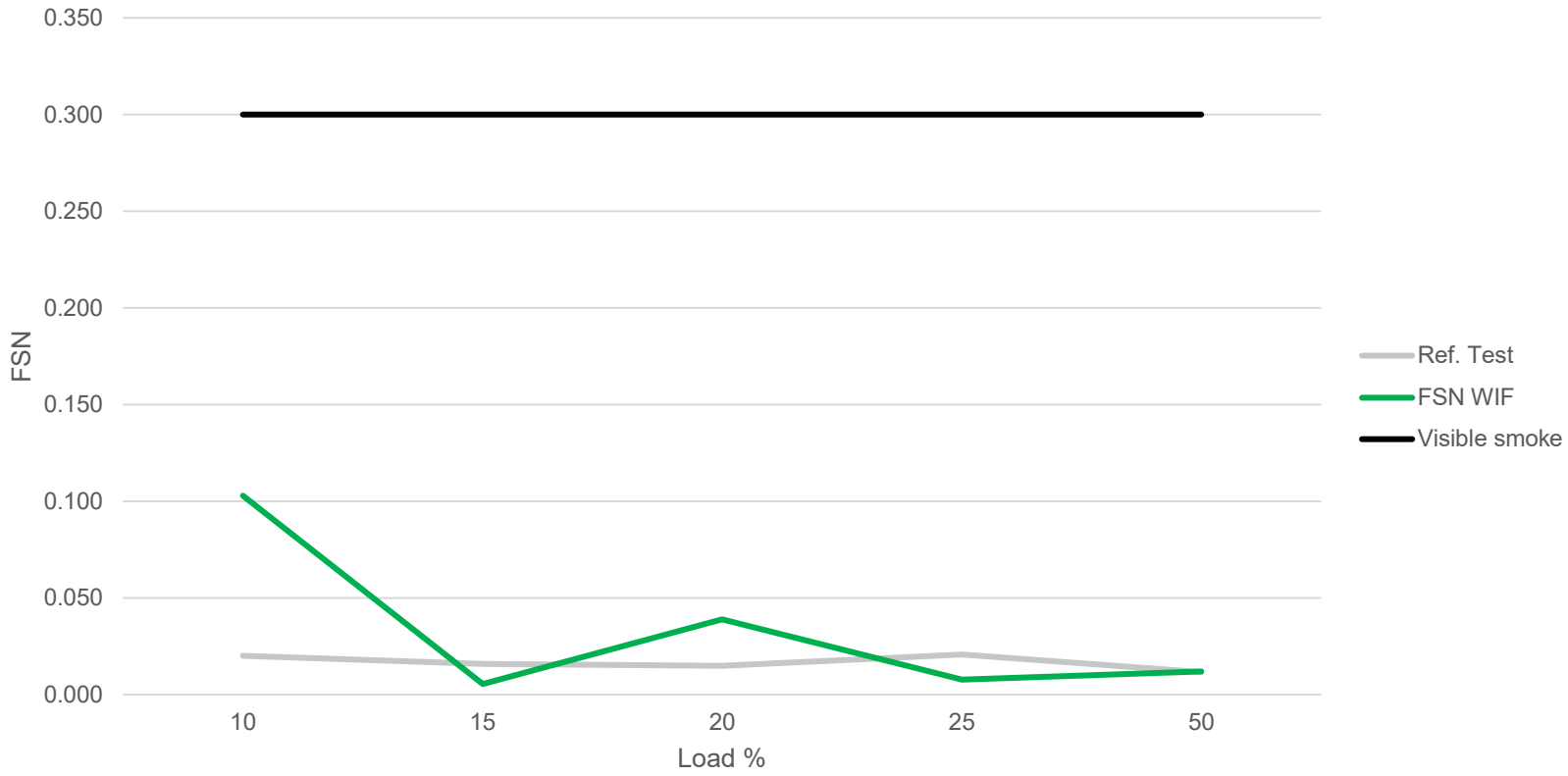
Load [%]	Ref. Test	Ref. ISO Corr. CO2	WIF Test	WIF ISO Corr. CO2	Deviation [%]
10	5_1_1	701,5	6_11_1	663,4	-5,4
15	5_3_1	635,6	6_8_1	655,2	3,1
20	5_5_1	606,9	6_5_1	619,9	2,1
25	5_7_1	593,8	6_2_1	600,6	1,1
50	5_9_1	567,1	6_14_1	584,8	3,1

SFOC results – ISO g/kWh



Load [%]	Ref. Test	SFOC Ref. T05 [g/kWh]	WIF Test	SFOC WIF T06 [g/kWh]	Deviation [%]
10	5_1_1	218,50	6_11_1	203,72	-6,8
15	5_3_1	197,55	6_8_1	201,31	1,9
20	5_5_1	188,73	6_5_1	191,02	1,2
25	5_7_1	184,84	6_2_1	185,06	0,1
50	5_9_1	176,26	6_14_1	179,84	2,0

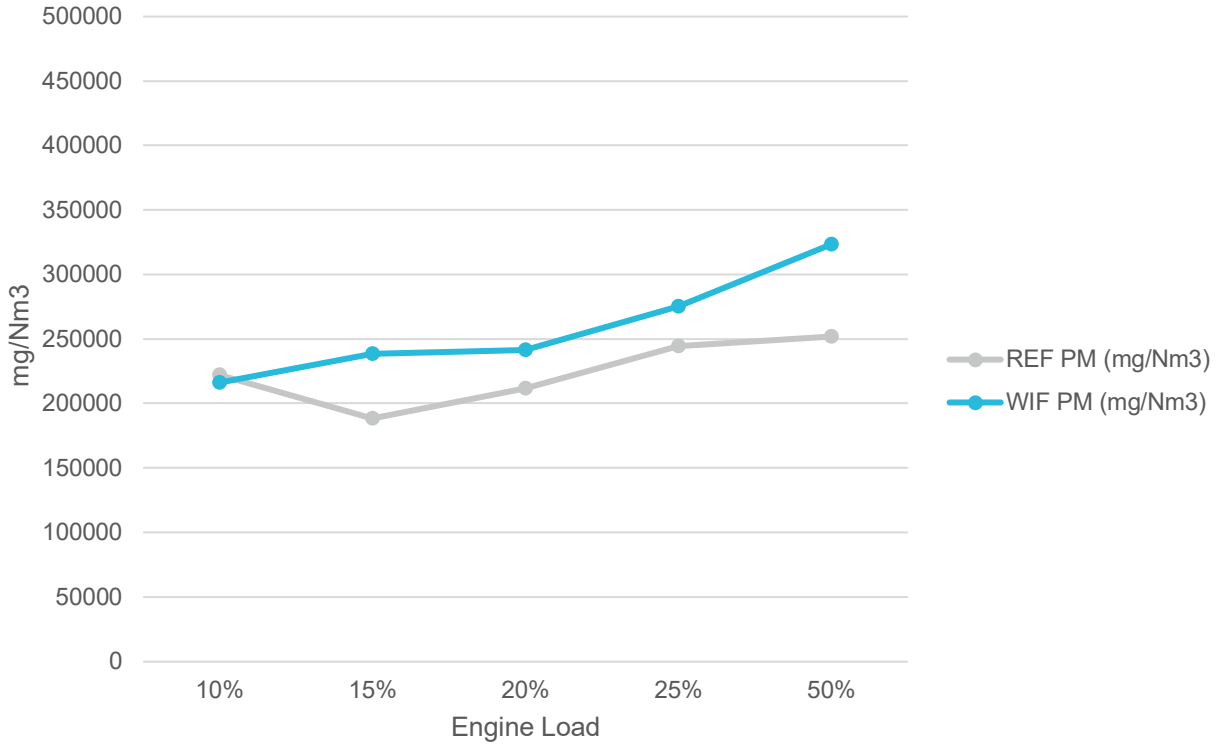
Filter smoke number (FSN)



Load [%]	Ref. Test	FSN	WIF Test	FSN
10	5_1_1	0,020	6_11_1	0,103
15	5_3_1	0,016	6_8_1	0,006
20	5_5_1	0,015	6_5_1	0,039
25	5_7_1	0,021	6_2_1	0,008
50	5_9_1	0,012	6_14_1	0,012

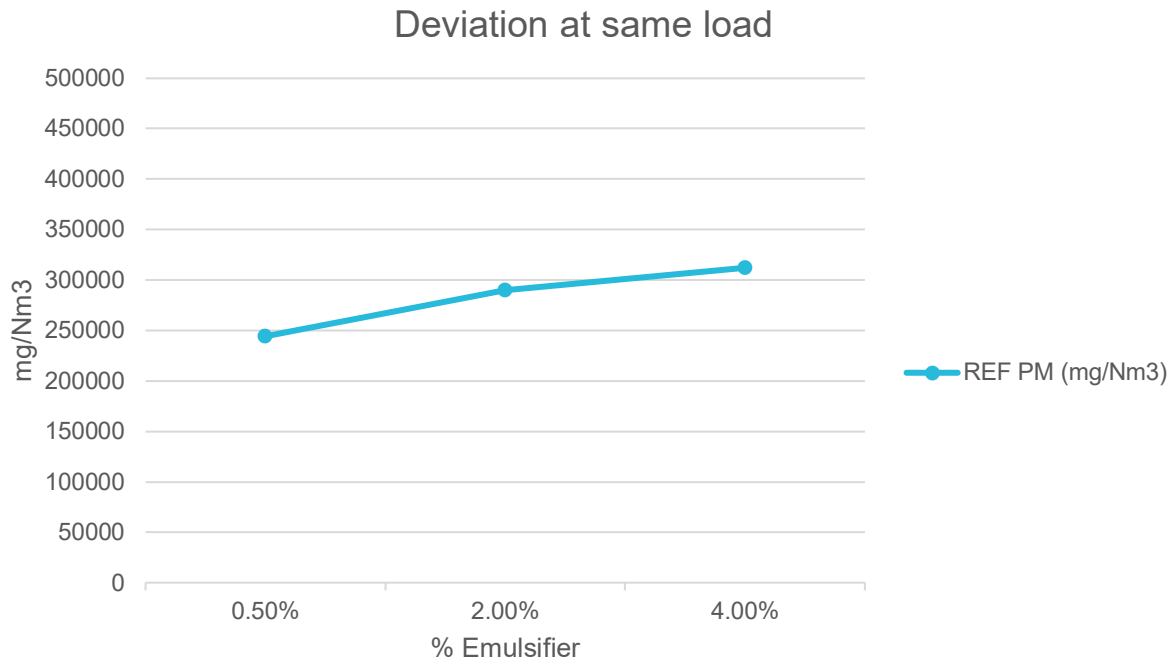
Particular Matters results

PM measurement final test results

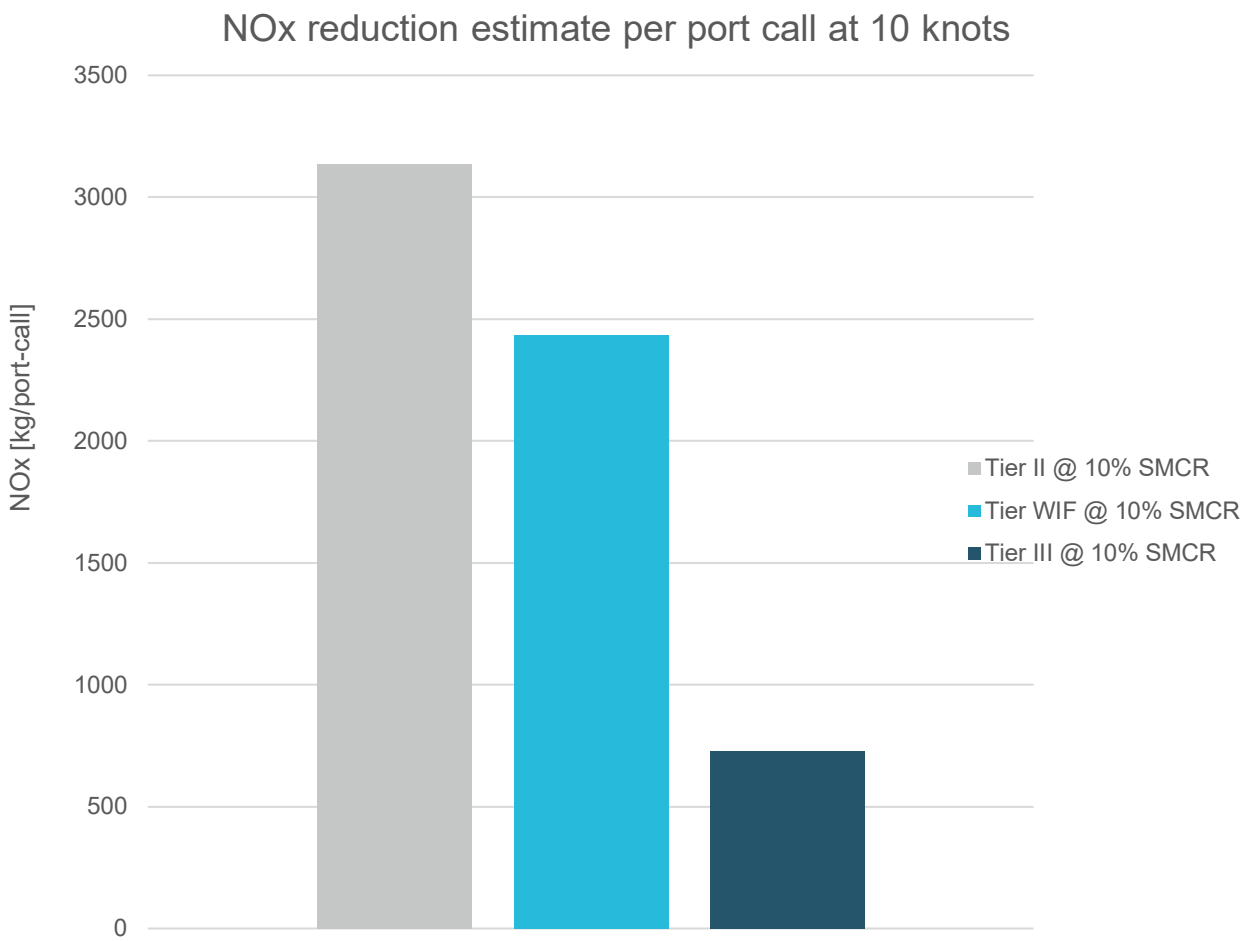


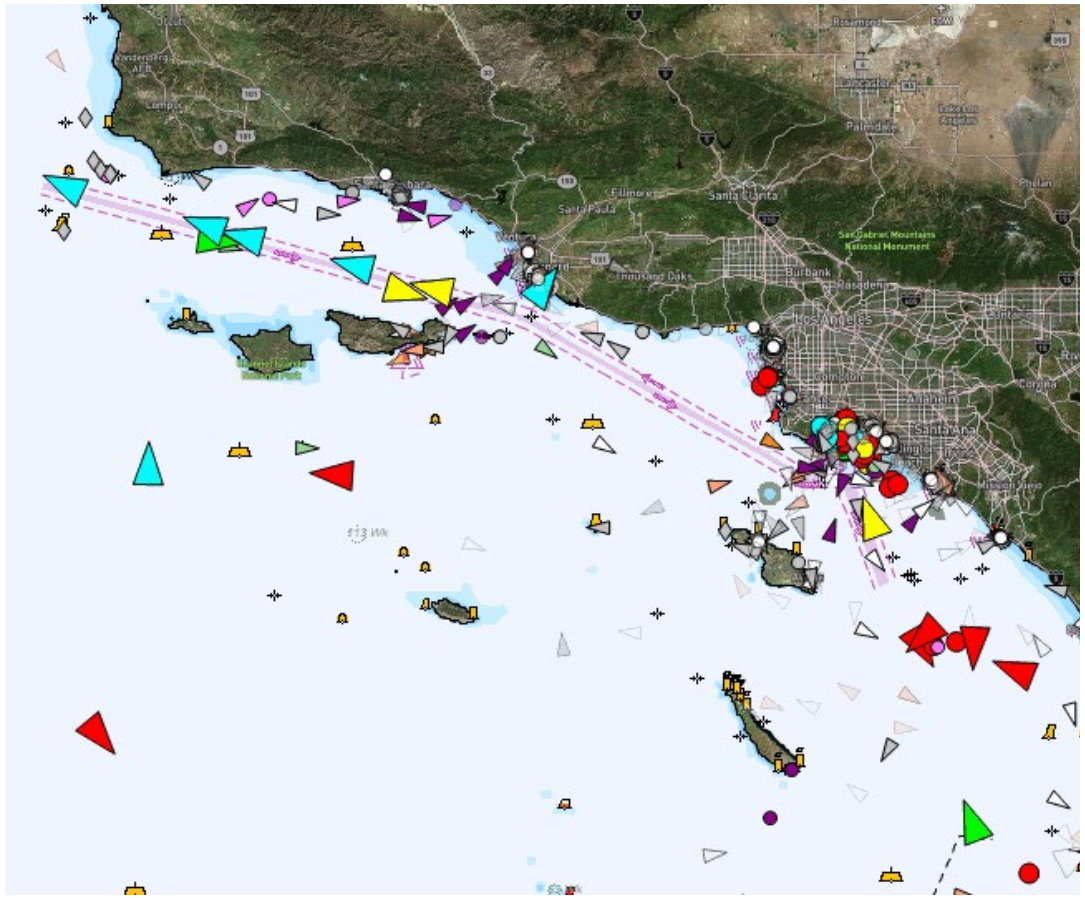
DO Ref.			WIF				
Test No.	Load	REF PM (mg/Nm3)	Test No.	Load	WIF PM (mg/Nm3)	Deviation	Percentage Deviation
T05_1	10%	221959,2874	T06_11	10%	216333,1599	-5626,1274	-3%
T05_3	15%	188284,9388	T06_8	15%	238332,7411	50047,8023	27%
T05_5	20%	211454,4975	T06_5	20%	241366,1617	29911,6642	14%
T05_7	25%	244219,4173	T06_2	25%	274923,7320	30704,3147	13%
T05_9	50%	251913,4438	T06_14	50%	323329,9738	71416,5300	28%

Test with increase of emulsifier during same load operation on the engine



NOx results compared to Tier II, Tier WIF & Tier III in and out of San Pedro Bay – 290nm voyage



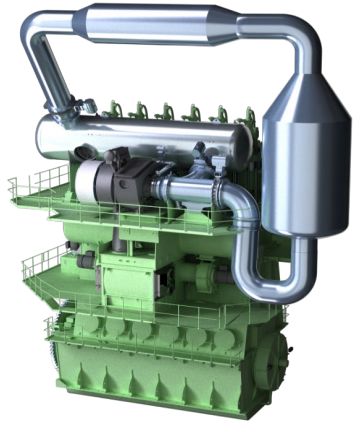


– NOx reduction from Tier II to Tier WIF is estimated to 700 kg / 1543 lb per port call

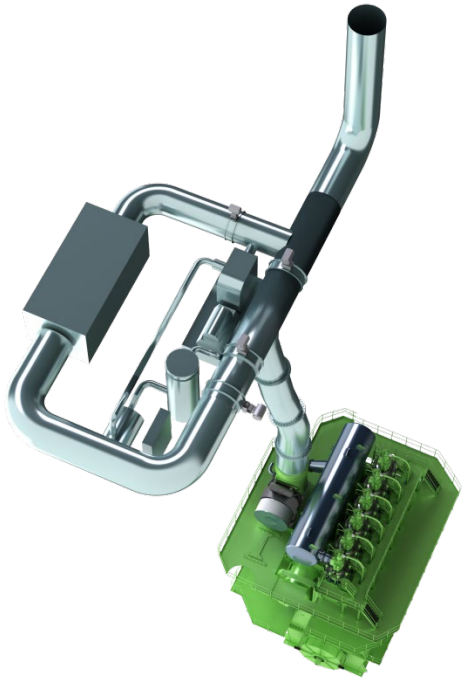
Tier III certification and low load operation

EGR

HP SCR



LP SCR



	25%	50%	75%	100%
IMO NOx weighing factor	0,0545	0,1091	0,5455	0,2909

6. Costs and NOx Reduction

Water in Fuel System Expenses

CAPITAL EXPENSES

Hardware, Installation, Comissioning:

Depends on engine size

For this project we have been testing on a large engine. Which means bigger pumps, flow meters etc needed

Estimated price for a WIF system installed on board a large container vessel

650,000 USD

OPERATION EXPENSES

Emulsifier (8.5 USD per kg)

Power consumption of the WIF system (12kW/h approx)

Maintenance

1,200 USD per round trip

Business case

Assumptions:

Vessel making 8 trips per year to San Pedro Bay Ports

Period of 3 years

1,200 x 8 x 3 = USD 28,800

Initial cost USD 650,000

Total = USD 678,800

Perfect incentive scenario

USD 678,800 / 24 port calls = USD 28,200 incentive per port call

16800 kg of NOx reduction in 3 years per vessel

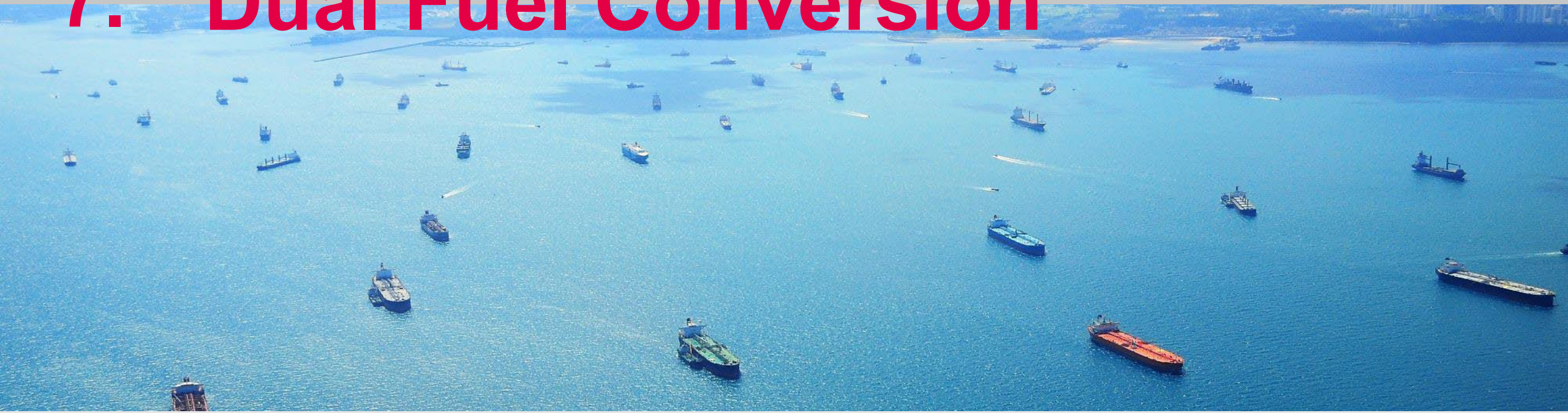
NOx reduction cost with the WIF system:

It is estimated that 1 kilo / 2,2 lb NOx emission cost approx. **40 dollars.**

MAN Energy Solutions
Future in the making

Thank you very much!

7. Dual Fuel Conversion



Alternative Fuels

Properties

Energy storage type	Specific Energy MJ/kg	Energy Density MJ/L	Required Tank Volume m^3. [1]	Supply pressure bar	Estimated PtX efficiency	Injection pressure bar	Emission Reduction Compared To HFO Tier II			
MGO	42,7	35,9	1000	7-8		950	SO_x	NO_x	CO2	PM
Liquefied natural gas (LNG -162 °C)	50.0	22,4	1602	300	0,56	300	90-99%	20-30%	24%	90%
Liquid ethane gas (LEG -88 °C)	47,5	17,1	2099	380		380	90-97%	30-50%	15%	90%
liquefied petroleum gas (LPG -42,4 °C)	46,4	23,5	1527	50		600-700	90-100%	10-15%	13-18%	90%
Methanol	19.9	15,8	2272	10	0,54	500	90-97%	30-50%	5-10%	90%
Ethanol	26	21,2	1693	10		500				
Ammonia (liquid -33 °C)	18,6	11,5	3121	70	0,65	600-700	100%	Compliant with regulation	>95%	>90%
Hydrogen (liquid -253 °C)	120	8.5	4223		0,68					
Marine battery market leader, Corvus, battery rack	0,29	0,33	108.787							
Tesla model 3 battery Cell 2170*. [2]	0,8	2.5	14360							

- *1: Given a 1000 m^3 tank for MGO. Additional space for insulation is not calculated for in above diagram. All pressure values given a high pressure Diesel injection principle.*
- *2: Values for Tesla battery doesn't contain energy/mass obtained for cooling/safety/classification .*

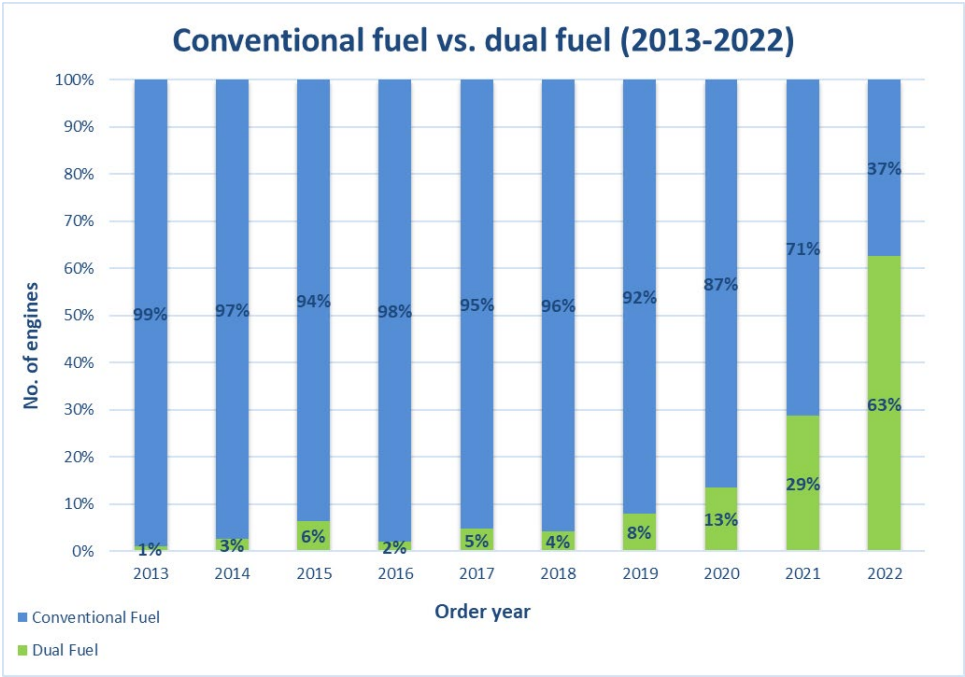
Dual fuel engines (on order & in service)

No. of engines		Engine type			Mk.
538 *187**	60	G	95	ME-C-GI	10.5
	3	S	90	ME-C-GI	10.5
	29	G	90	ME-C-GI	9.5, 10.5
	78	G	80	ME-C-GI	9.5, 10.5
	2	S	80	ME-C-GI	9.5
	11	S	70	ME-C-GI	7, 8.2, 10.5
	229	G	70	ME-C-GI	9.2, 9.5, 10.5
	2	L	70	ME-C-GI	8.2
	15	G	60	ME-C-GI	9.5,10.5
	83	S	60	ME-C-GI	10.5, 10.6
	11	S	50	ME-C-GI	8.2,8.5, 9.5, 9.7
	7	G	50	ME-C-GI	9.5, 9.6
	2	G	45	ME-C-GI	9.5
	6	S	35	ME-C-GI	9.7
214	214	G	70	ME-C-GA	10.5
37 *15**	28	G	60	ME-C-GIE	9.5
	5	G	50	ME-C-GIE	9.5
	4	S	50	ME-C-GIE	8.2
72 *17**	24	G	95	ME-C –LGIM	10.5
	25	G	50	ME-B/ME-C –LGIM	9.3, 9.5, 9.6
	23	S	50	ME-B-LGIM	9.3, 9.6
139 *44**	103	G	60	ME-C-LGIP	9.2, 9.5,10.5
	7	S	60	ME-C-LGIP	10.5
	23	G	50	ME-C-LGIP	9.6, 10.5
	6	S	35	ME-C-LGIP	9.7

Methane
Ethane
Methanol
LPG

** in service*

Totals	
Total dual fuel engines	1000 engines
Total power main engine	21.69 GW
Total dual fuel engines in service	263 engines



MAN ES orders received

MAN ES retrofit track record

22 vessels completed, 4 on order

MAN ES' track record and in-house experience gained		
Nakilat	"Rasheeda"	LNG retrofit of 2 x 2s Main Engines on 1 x LNG Carrier
Hapag Lloyd	"Brussels Express"	LNG retrofit of 2s Main Engine on 1 x Container vessel
Navigator LLC	"Navigator Aurora"	Ethane retrofit of 2s Main Engine on 1 x Ethane Carrier
BW LPG	15 vessels	LPG retrofit of 2s Main Engines on 15 x LPG Carriers
Wessels Reederei	"Wes Amelie"	SNG retrofit of 4s Main Engine on 1 x Container vessel
Baleària	"MV Napoles", "MV Sicilia"	LNG retrofit of 2 x 4s Main Engines on 2 x RoPAX vessels
GIE Dragages-Ports	"Samuel de Champlain"	LNG remotorization of 2 x 4s Main Engines on 1 x Dredger

On order		
Matson Inc.	"Daniel K. Inouye" + sister	LNG retrofit of 2s Main Engine on 1+1 x 3600 TEU
Tianjin Southwest	"Gas Gemini", "Gas Aquarius"	LPG retrofit of 2s Main Engine on 2 x LPG carriers






A potential Methanol conversion

674 containership port calls to Los Angeles, Long Beach Ports between Oct 2021 and Oct 2022

IMO/LR	Ship Name	Operator	Port	Previous Port	Number of port calls	Cyl	Engine type
9719056	DANIEL K. INOUYE	Matson Navigation Co Inc	Long Beach	Shanghai	12	7	S90ME-C10.5
9477907	OOCL TAIPEI	Orient Overseas Container Line	Long Beach	Busan	9	10	S90ME-C9.2
9645918	CSCL EAST CHINA SEA	COSCO Shipping Lines Co Ltd	Los Angeles	Prince Rupert	10	10	S90ME-C9.2
9627978	OOCL BANGKOK	Orient Overseas Container Line	Long Beach	Yantian	9	12	S90ME-C9.2
9719068	KAIMANA HILA	Matson Navigation Co Inc	Long Beach	Shanghai	13	7	S90ME-C10.5
9645853	CSCL SPRING	COSCO Shipping Lines Co Ltd	Long Beach	Ningbo	9	10	S90ME-C9.2
9486087	OOCL UTAH	Orient Overseas Container Line	Long Beach	Busan	9	10	S90ME-C9.2

MAN Energy Solutions
Future in the making

Thank you very much!