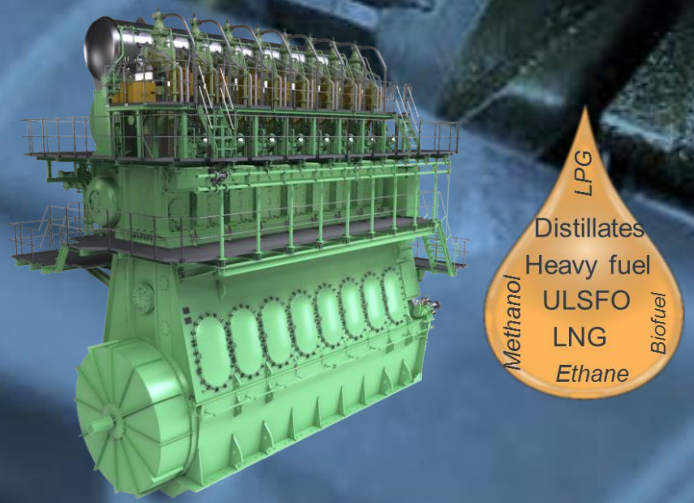
Fuel 2020

Circle

SMM in Hamburg Sep. 2018.

Kjeld Aabo
Director
New technologies
Promotion 2 stroke
MAN Diesel & Turbo
Member: ISO 8217 WG
Chairman: CIMAC WG7 Fuels

Charlotte Røjgaard
Global Technical Manager
Bureau Veritas, VeriFuel
Member: ISO 8217 WG
Secretary: CIMAC WG 7 Fuels



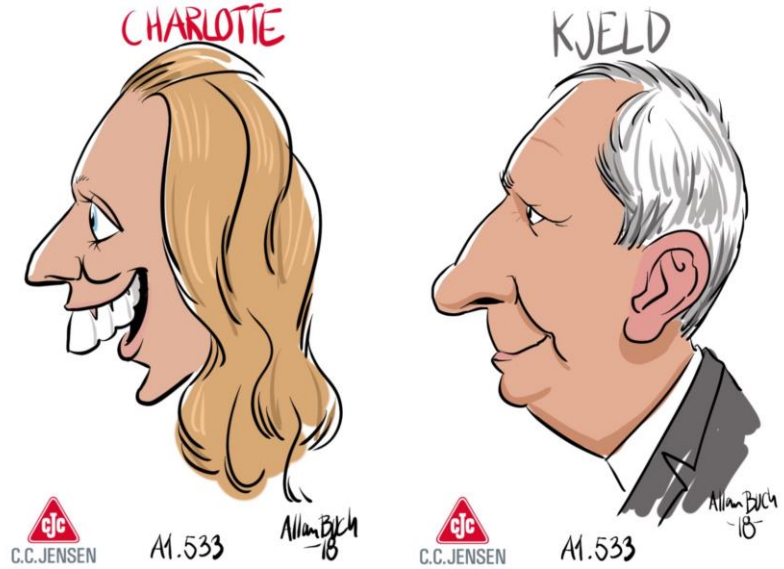
Agenda

Part 1: Fuel 2020 seen from an engine maker's perspective

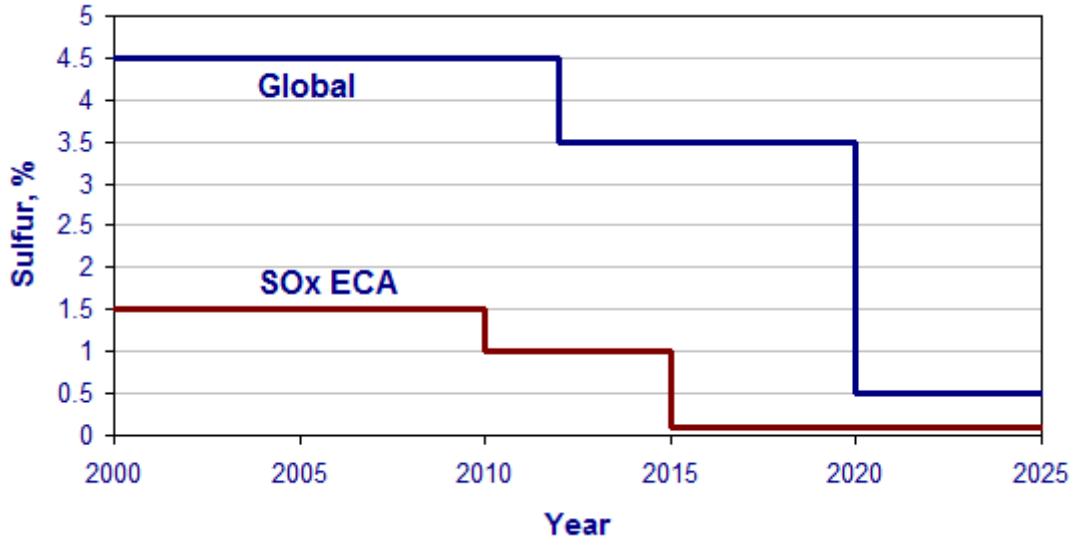
/Kjeld Aabo, Chairman of CIMAC WG7 Fuels

Part 2: Fuel 2020 seen from an fuel testing agency's perspective

/Charlotte Røjgaard, Secretary of CIMAC WG7 Fuels



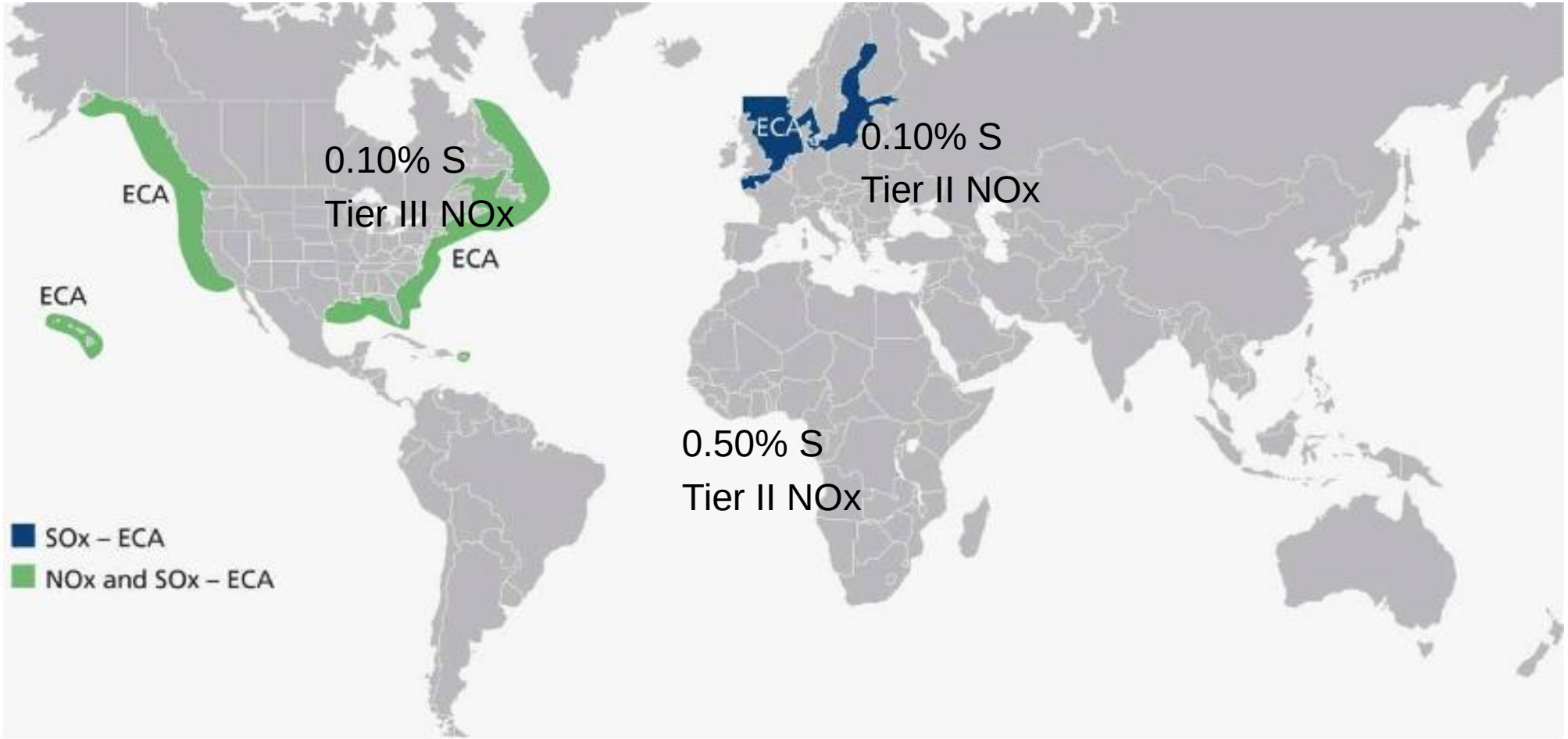
SO_x rules



Methods for SO_x compliance:

- Operating on low sulfur fuel
- Using SO_x scrubbers

Emission Controlled Areas (ECAs)



Source DNV GL

What fuel will be used in 2020 and beyond?

CIMAC
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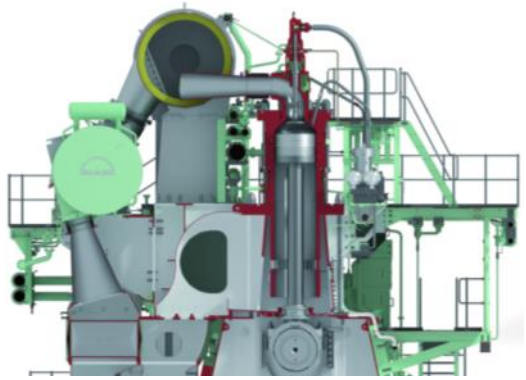
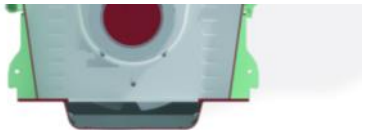
Compliant fuel

MC/ME/-C engine
Single Fuel:
0.1%S fuel, 0.5%S fuel

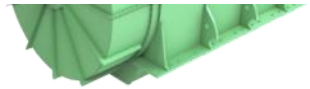


COMBUSTION CHAMBER:
WILL BE DESIGNED WITH A FULL CERMET RING PACK



ME-GI / ME-LGI engine
Dual Fuel:
LNG, Ethane, LPG,
MeOH ……..

COMBUSTION CHAMBER:
ALREADY NOW DESIGNED WITH A FULL CERMET RING PACK

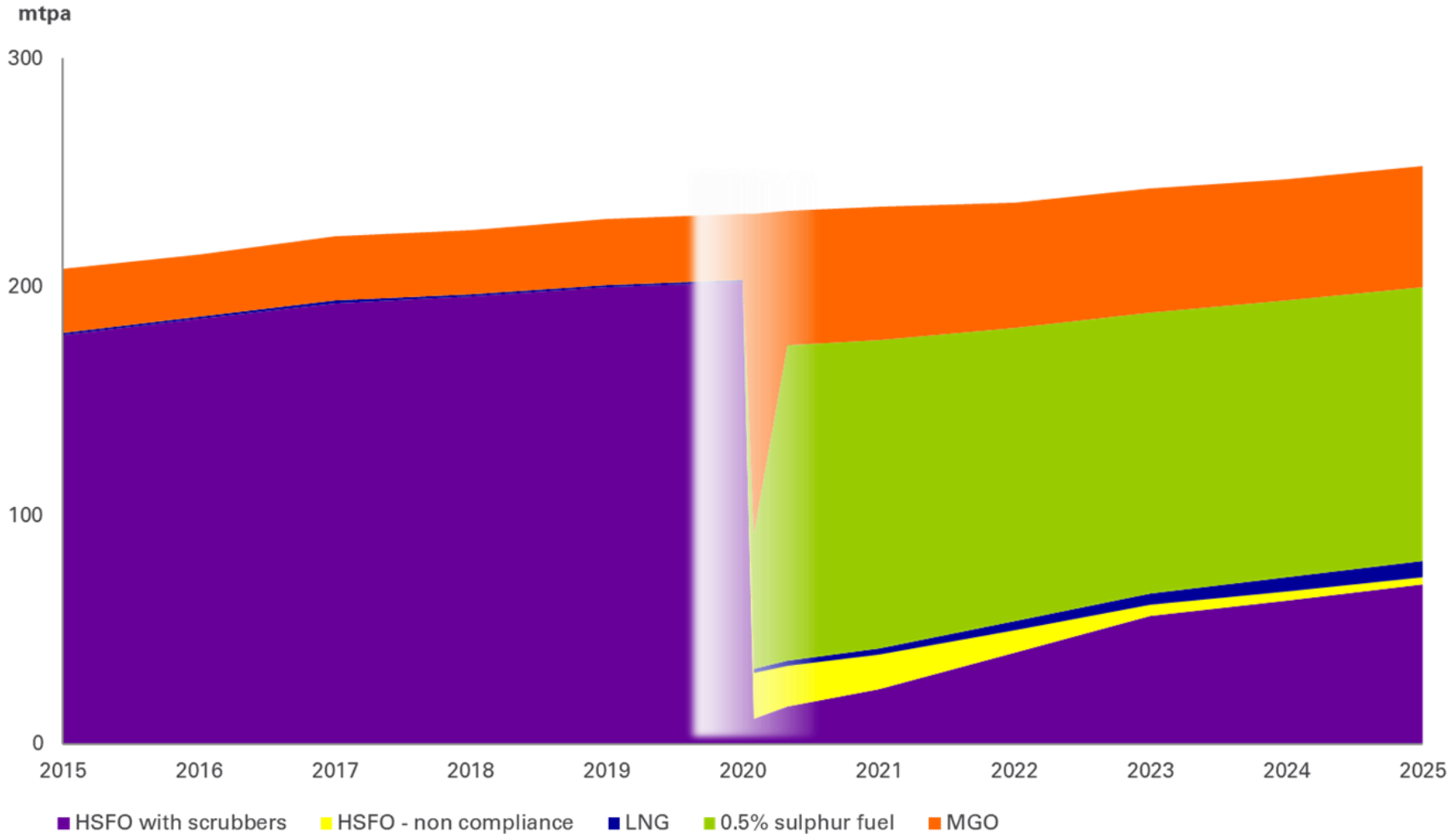


High-Sulphur fuel

MC/ME/-C engine
0-5%S fuels:
HFO/MDO + Scrubber

COMBUSTION CHAMBER:
NO CHANGES AS COMPARED TO TODAY

BP prediction of fuel in the future



20 %

47 %

3 %

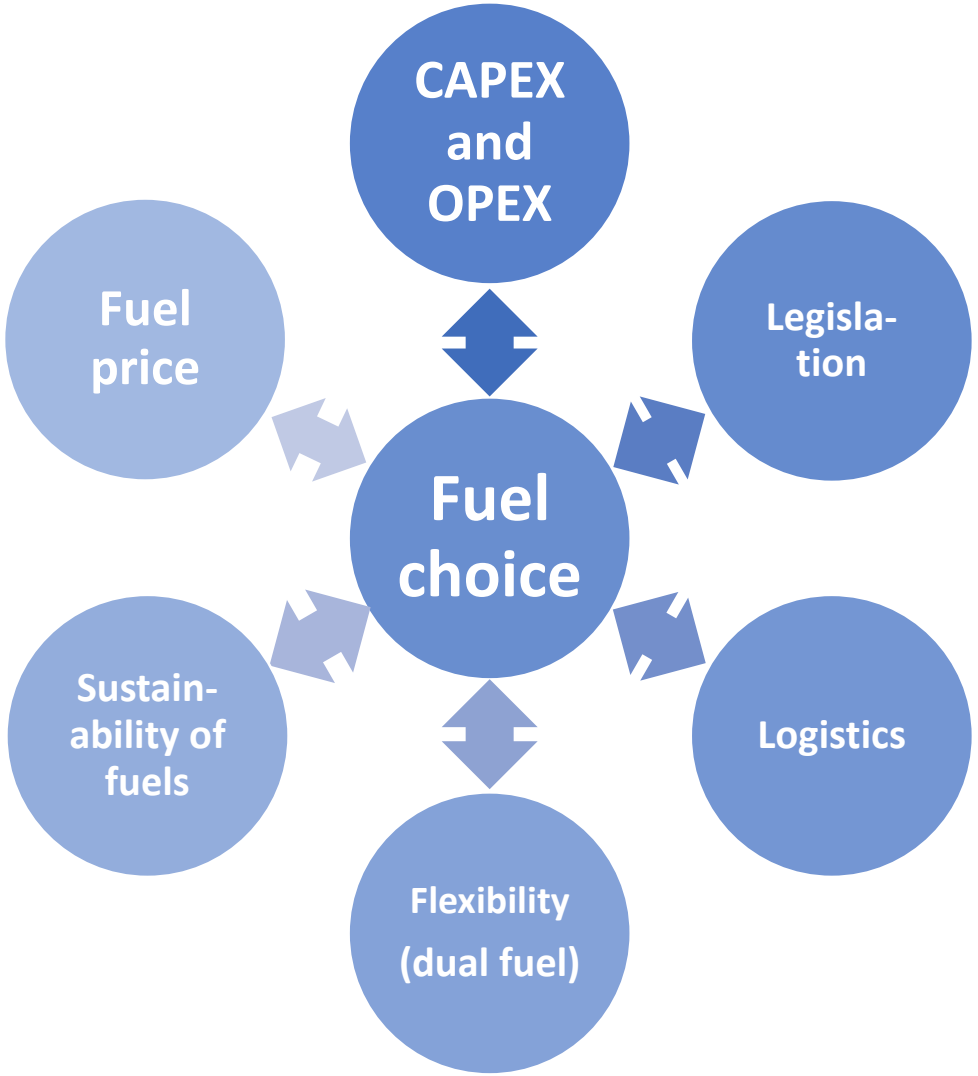
26 %

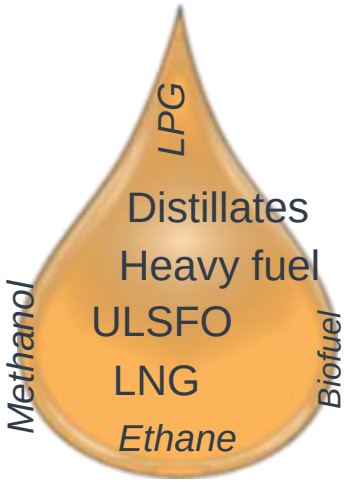
MDT cal.

Initial reaction period

- *Source BP p.l.c., not to be reproduced without BP's permission*

Influencing Factors on Fuel Choice





Fuel Types

Residual
ME / MC

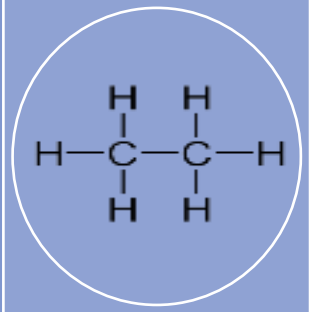
Distillates
ME / MC

ULSFO
ME / MC

Methane
ME-GI

Methanol
ME-LGIM

LPG
ME-LGIP



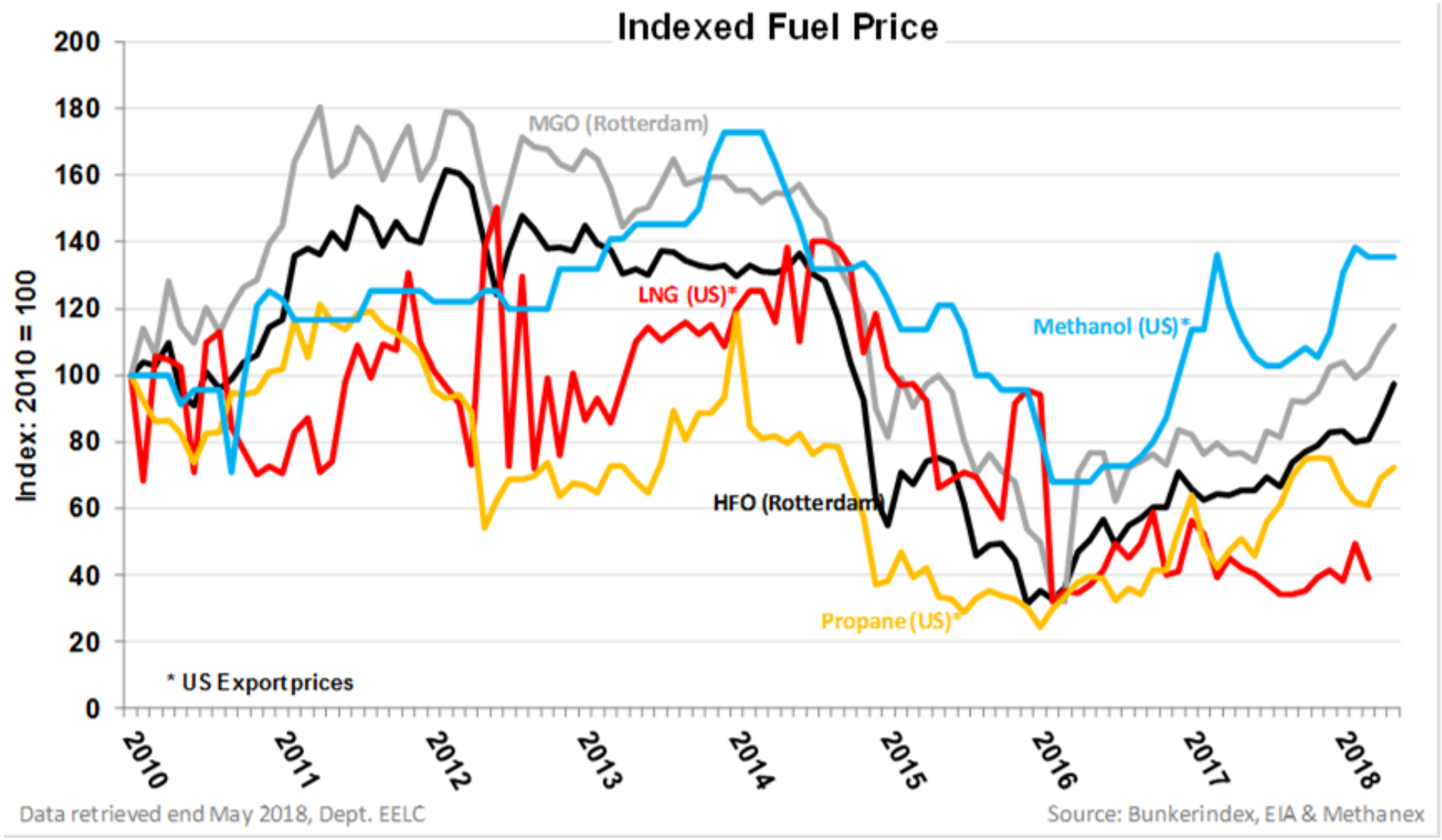
Ethane
ME-GIE

Biofuel
(2nd+3rd gen.)
ME / MC

MAN Diesel & Turbo supports all

Indexed Fuel Prices

Index: January 2010 = 100



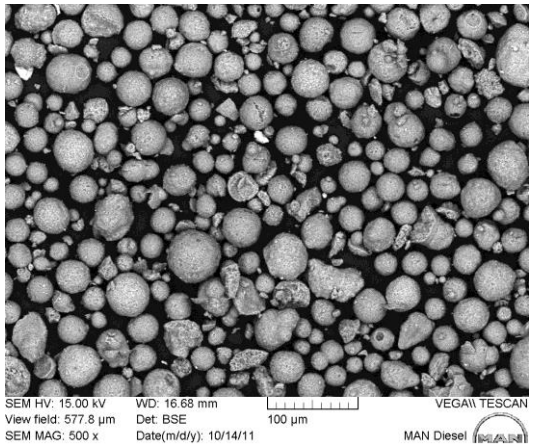
We can learn from the 0.10% SECA
(ULSFO < 0.10% Sulphur)

There are a range of different types fuels.

These are not distillate types, rather new blends or types.

General characteristics are:

- Higher viscosity than distillate
- Some contain cat fines (Al+Si)
- Some have high pour points
- Compatibility with other fuels may also be an issue.



Service letter SL2014-593

ULSFO < 0.10% Sulphur
...but what about level of cat fines for VLSFO < 0.50% ?

	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F	Supplier G	Supplier H	Supplier I
Density (kg/m3 @ 15 C)	895-915	910	857	868	932	845	868	928	870-930
Viscosity (cSt @ 40 or 50 C)	40-75 (40ºC)	65 (50ºC)	17.6 (50ºC)	8.8	22.6 (50ºC)	8.8	8.5 (50ºC)	40C: 45-65. 50C 30-40	8-25 (50ºC)
Sulphur (% m/m)	0.1	0.095	0.08	0.05	0.1	0.03	0.09	0.1	<0.1
Pour Point (C)	15-30	20	<-12	-12	30	21	27	20-25	18-21
Flash Point (C)	>70	60	>200	72	90	>70	>70	70	60-80
Water (% v/v)	0.05	0.1	<0.2	0.004	<0.05	0.01	0.05	0.2	0.05-0.1
Acid Number (mg KOH/g)	<0.1	2.5	0.3	0.27	0.06	0.04		2.5	0.1-0.2
Al+Si (ppm m/m)	<0,3	17	<15	?	34	<1	<3	10-20	12-15
Lubricity (µm)	<320	520	-	410	-	326	-	-	-
CCAI	795-810	860	762	-	-	765	789	790-800	790-810

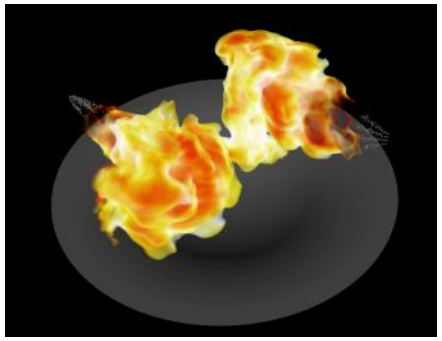
2020: Fuel and lube test plan

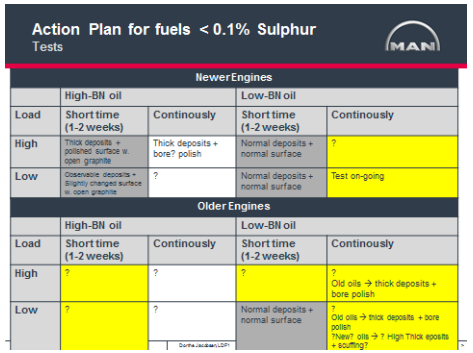
- In order to prepare for the new types of 0.50%S fuels, test engine, service tests and lab tests will be carried out.
- This will be done in collaboration with lube oil suppliers, fuel oil suppliers, ISO 8217 WG, CIMAC WG Fuels, ship owners and other relevant partners.

<u>Potential</u> challenges:

Fuel:
- a. Technical:
  - i. Stability
  - ii. Compatibility
  - iii. Ignition – knocking
  - iv. Burn out – deposits
- b. Commercial:
  - i. ISO 8217 -> ISO/PAS or CIMAC

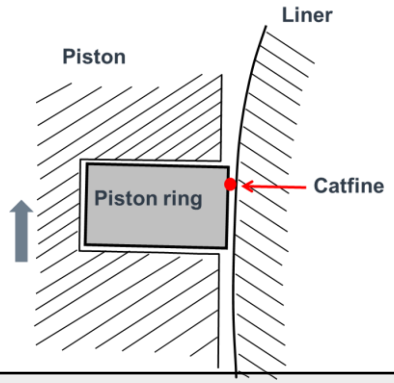
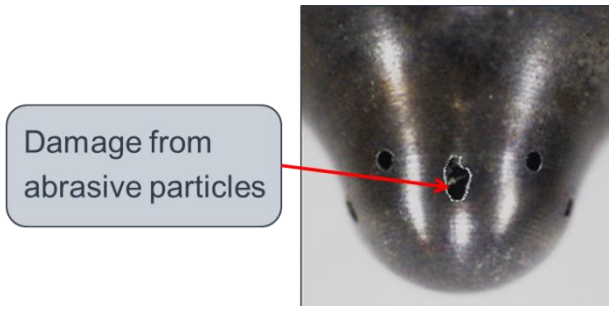
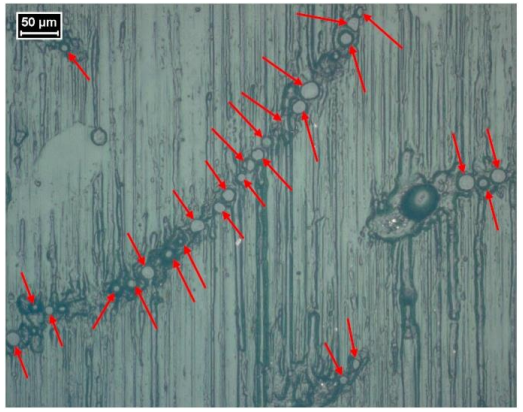
Lube:
- a. Deposit
- b. Corrosion – how much?
- c. Smearing



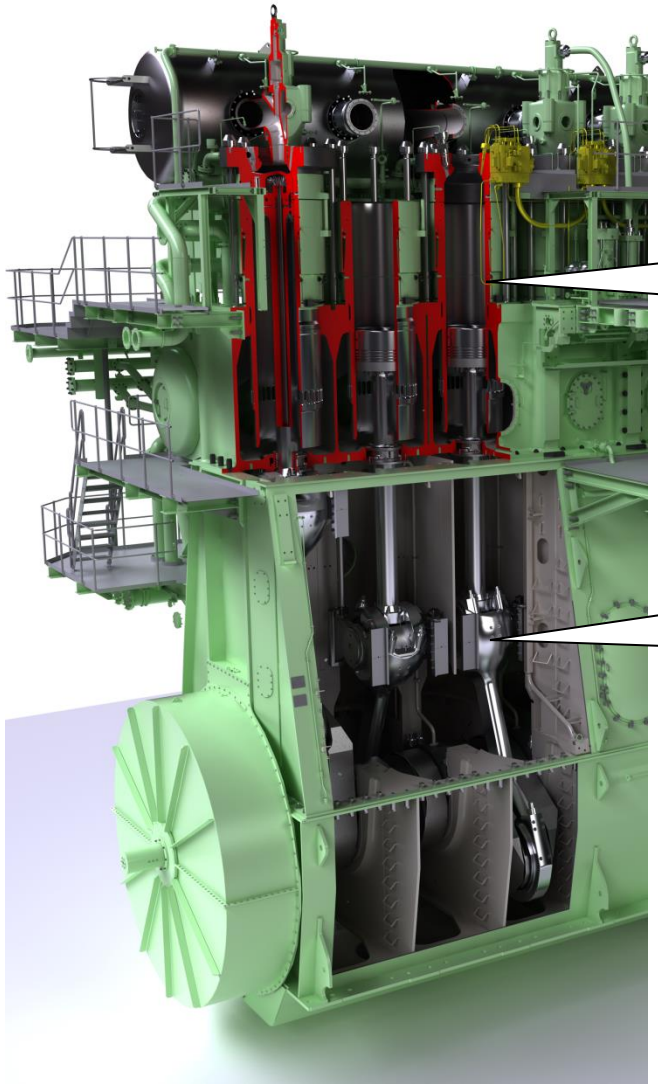


Feedback from market?

Overview of damages

Damages found in two-stroke engines	Damages found in small four-stroke Gensets
Wear in combustion chamber parts	Wear in fuel equipment
	
Resulting in high wear	Resulting in poor combustion
	

Lube Oils



Cylinder oil
SAE50
BN = 15-100

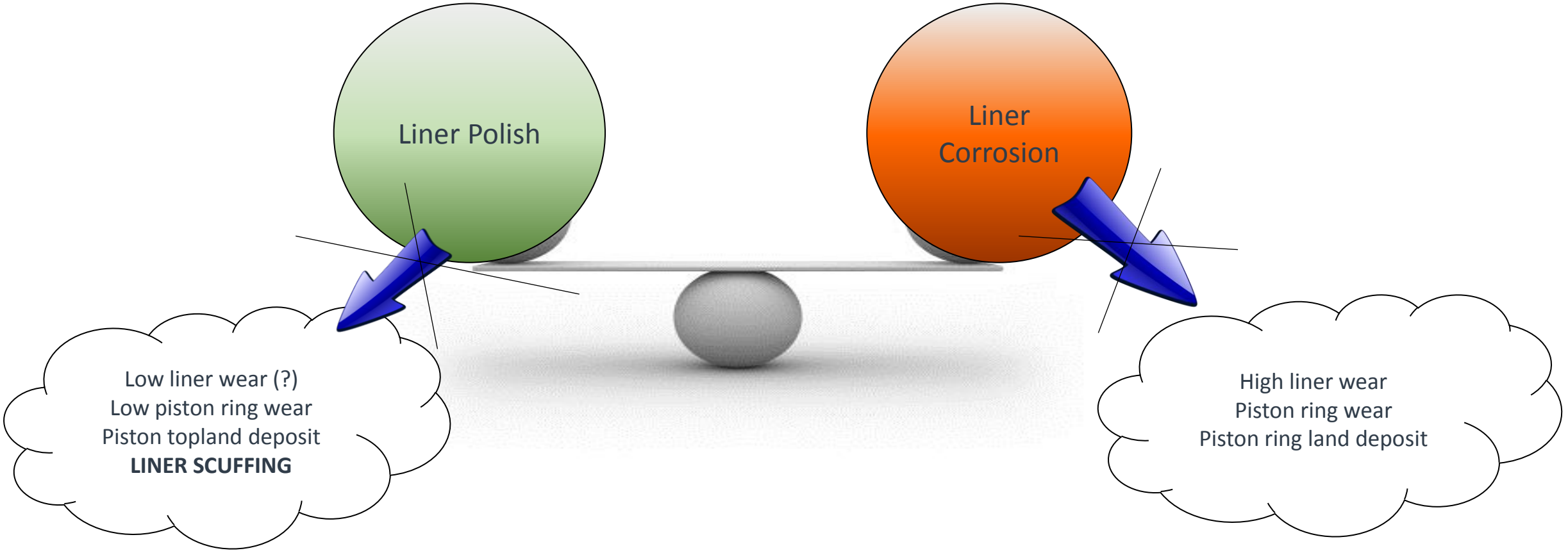
System oil
SAE30
BN = 5-6

Key properties of cylinder lube oil:

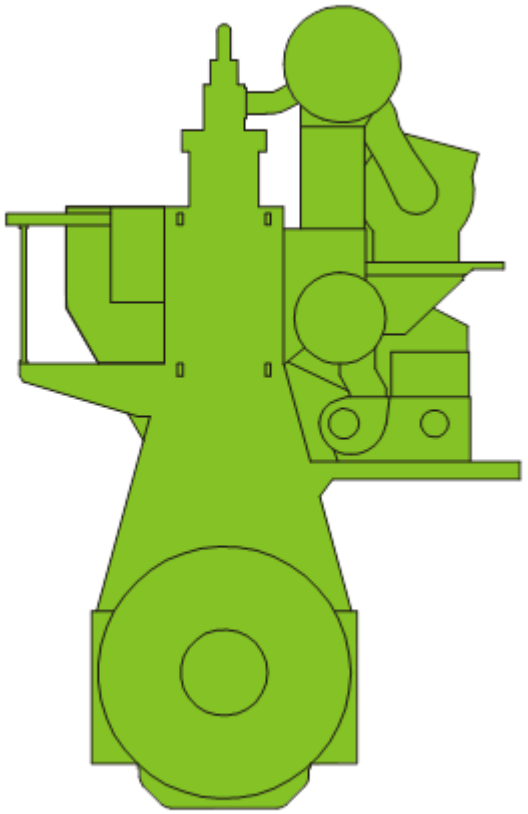
- Lubricate, decrease friction
- Neutralize sufficiently
- Provide a gas-seal between rings and liner
- Keep parts clean:
  - Avoid coke formation (thermal stability of the base oil)
  - Remove coke, additives, impurities and wear particles from liner and piston ring area

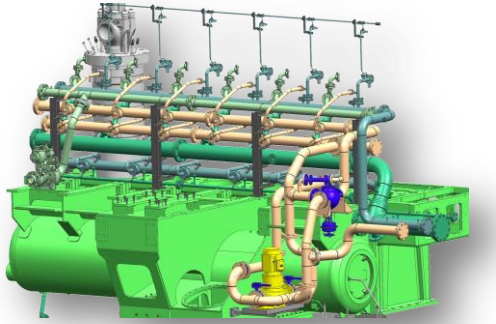
The balance to avoid liner polish and liner corrosion

Cylinder Condition

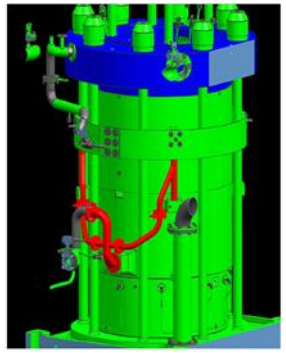


What influence will the choice of fuel have on the engine design/ application ?

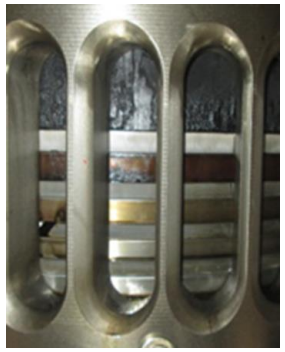




LDCL



RDL liners



Introducing full cermet coated ring packs for ULS operations

Choice of cylinder lube oil

MAN investigation of scrubber technology

Tests and future

Objectives	Participants	Scrubber	Goals	Test results	Ship test	Ship test
Development and test of scrubber for after-treatment	Clean Marine MAN Diesel		PM trapping: >90% SO_X removal: >67%	PM trapping: 35% 80% (salts add.) SO_X removal: 73% 95% (salts add.)	M.V. Banasol 7S50MC-C 9MW	
Development and test of scrubber for after-treatment	Aalborg Industries Alfa Laval DFDS MAN Diesel		PM trapping: >75% SO_X removal: >95%	PM trapping: 79% SO_X removal: 100% (NaOH)	Tor Ficaria 9L60MC-C 20MW	
Development and test of scrubber for after-treatment and EGR	APM MAN Diesel		PM trapping: >75% SO_X removal: >90%	PM trapping: 73% SO_X removal : 96% (NaOH)	Alexander 7S50MC 9MW	

Prediction: The use of scrubbers in 2020 and beyond

	2020	2025	2035
Number of ships with scrubbers	1,800	5,100	16,000
% of global fleet with scrubbers	2	4	13
Million tons HSFO scrubbed p.a.	6	20	72
Cumulative investment $billion	6	18	66

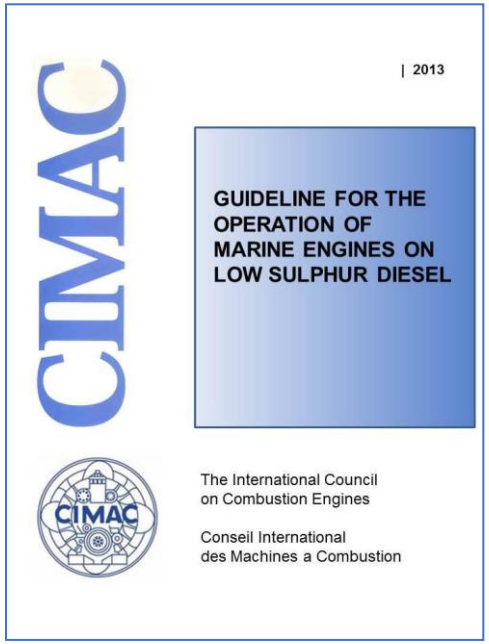
The relative low number could be because of :

- Shortage of investment funds and obtaining a return
- Lack of confidence in future price differential between fuels
- Still some lack of technology confidence
- Uncertainty of future environmental regulations and enforcement.

Source: Robin Meech

WG7 ‘Fuels’

- 38 members
  - 15 on waiting list
- Represented stakeholders
  - Refiners, Suppliers, OEMs, Ship Operators, Fuel Testing Labs, Classification Societies and others
- Co-operation with
  - All CIMAC WGs in case of common topics
  - ISO8217 fuels group (very close relationship)
- Latest Publications
  - Guideline providing answers to FAQ from ISO 8217:2017 (Mar 2017)
  - Guideline on the Interpretation of Marine Fuel Analysis Test Results (Feb 2016)
  - Guideline on Filter Treatment of Residual Fuel oil (Dec 2015)
  - Position paper: New 0.10% sulphur marine (ECA) fuels (June 2015)
  - Guideline: Cold flow properties of marine fuel oils (Jan 2015)



WG7 ‘Fuels’

Recent and upcoming meetings

- No 75: Sep 2016, The Netherlands
- No 76: Apr 2017, Switzerland
- No 77: Sep 2017, Frankfurt
- No 78: Apr 2018, Copenhagen
- No 79: Sep 2018, Philadelphia, US

Current activities, subgroups

<u>High priority SGs</u>

SG 1-1 CFR (centrifuges and efficiency)

SG4 Guideline on stability/compatibility

SG5 LNG quality

SG6 Ignition/Combustion, 2020 fuels

SG9 “How to order and use 2020 fuels”

<u>Low priority SGs</u>

SG 1-2 Separators

SG 3 pH / Corrositivity

SG 7 Emulsion fuels

SG10 Niche fuels

How is CIMAC WG7 Fuels preparing for 2020 ?

Definitions:

- Ultra low sulphur fuel oil (ULSFO), max 0.10% S
- Very low sulphur fuel oil (VLSFO), max 0.50% S
- Low sulphur fuel oil (LSFO), max 1.00% S

- Close cooperation with ISO 8217
- Assist ISO 8217 taking on some of the investigative work
- Prepare guidelines related to 2020 fuels. Currently two on the agenda:
  - Guideline: Stability / Compatibility
  - Guideline: How to order and use 2020 fuels?
- Investigate if there are other onboard and/or lab measurements available/needed to ensure safe operation on the VLSFO

VERIFUEL – UNDERSTANDING MARINE FUEL

2020 Fuels: What's happening now and what happens next?
6 September 2018

2020 Fuels - Fuel definitions

CIMAC WG7 Fuels definitions:

- Ultra low sulphur fuel oil (ULSFO), max 0.10% S
- Very low sulphur fuel oil (VLSFO), max 0.50% S
- Low sulphur fuel oil (LSFO), max 1.00% S
- High sulphur fuel oil (HSFO), above 1.00% S

- LS MGO – max 0.10% S (no heating required)
- HS MGO – above 0.10% S (no heating required)

Fuels after 2020 - How big is the change?

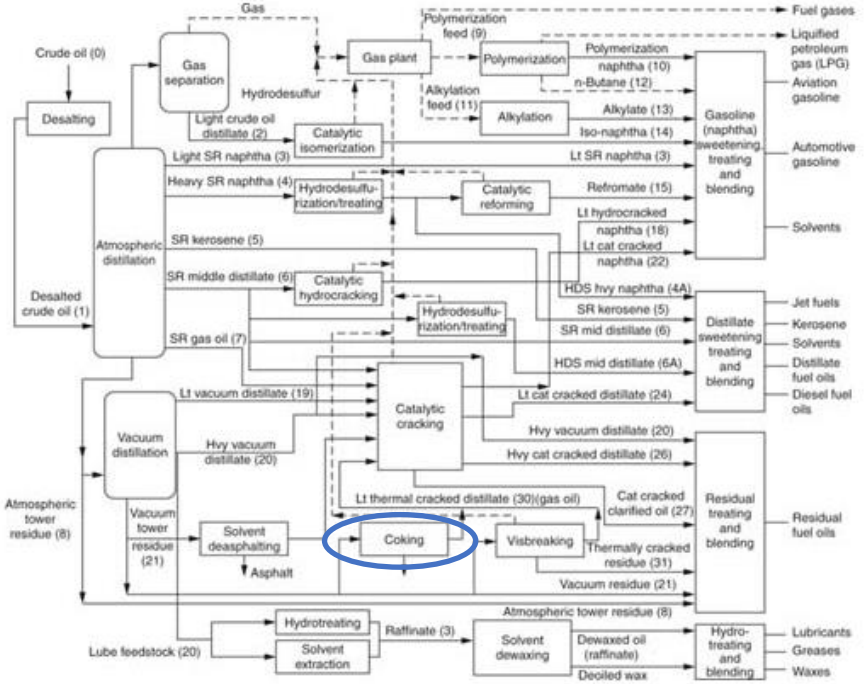
- 0.50% sulphur fuels represents 75% of global demand for marine fuel, i.e. a huge undertaking for bunkering/shipping industry
- In total, 3 million barrels of HSFO per day will need to switch to 0.50% Sulphur with improved logistics segregation

Quote from ExxonMobil:

“The impact on the refineries is significant. When the ECAs kicked in, some of the barge capacity had to be changed. Now we have to convert all the barge capacity and we have to clean all the tanks in the refineries. We cannot estimate the scale of the change. It is profound and one of the biggest in living memory."

2020 Fuels - The refiners perspective

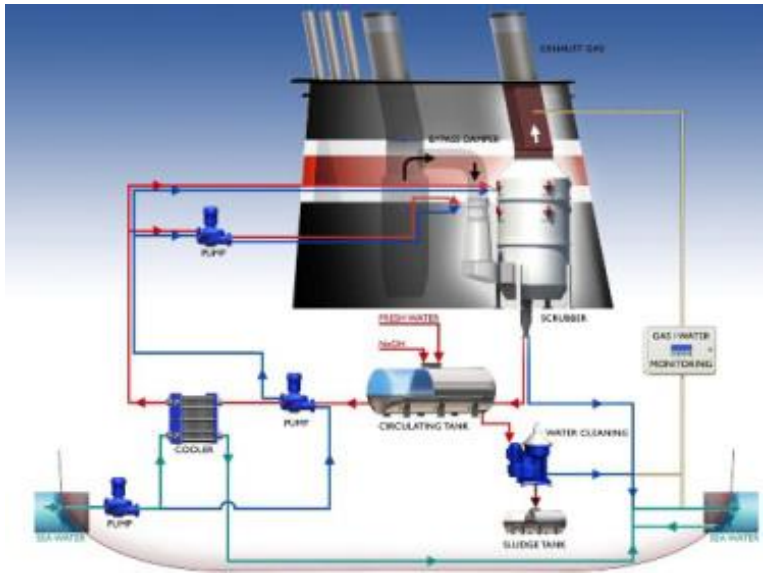
- HFO is a refinery bi-product, sold at a price below crude
  - HSFO accounts for 4% of global refinery production
- Marine engines have been - and still are - a good outlet for HFO
- Alternative takers of HFO:
  - Power plants
  - Deep conversion refineries
- A coker unit is a billion dollars investment which takes ~5 years to install



https://www.globalspec.com/reference/79004/203279/chapter-3-fuels-from-petroleum-and-heavy-oil

2020 Fuels - Scrubbers?

- As of end of May 2018, 964 scrubbers are installed or on order
  - DFDS estimates 1400-1600 scrubbers will be installed / on order by 1 Jan 2020
- 1600 out of a global fleet of 60000 vessels is less than 3%
- Open / closed loop? What to do with sludge?
- Responsibilities? Charterer / Owner?
- *"If you install a scrubber today and it is paid back before 2022, it is feasible to install a scrubber. After that, it is no longer a viable solution"*
  Mel Larson, KBC / Shippingwatch, 1 June 2018
- *"Make sure you negotiate a long term supply contract of HFO with your supplier if you intend to use the scrubber solution"*
  Iain White, ExxonMobil, Future Fuels for 2020, Compliance Seminar, London 13 June 2018



2020 Fuels - HSFO supply post 2020

- May not be viable in smaller ports
  - …unless they have regular calls from vessels with scrubbers
- Major bunker ports with plenty of storage delivery options will probably have HSFO
  - ……if there is a demand…
- In some areas, keeping barges dedicated to HFO may be tricky
  - Operators having fitted scrubbers (or scrubbers planned) should try to secure the barging long term
- HSFO may become a 'niche fuel' available in some ports only after 2020:

''If I sat on a batch of HFO in a specific port and you arrive with a ship using a scrubber, I would not sell my HFO too cheap''

Fuel trader, Danish Shipping seminar, Nov 2017

2020 Fuels - What may / will happen in 2020?

Key parameters for 0.50% sulphur Marine Fuel Oil blending will be:

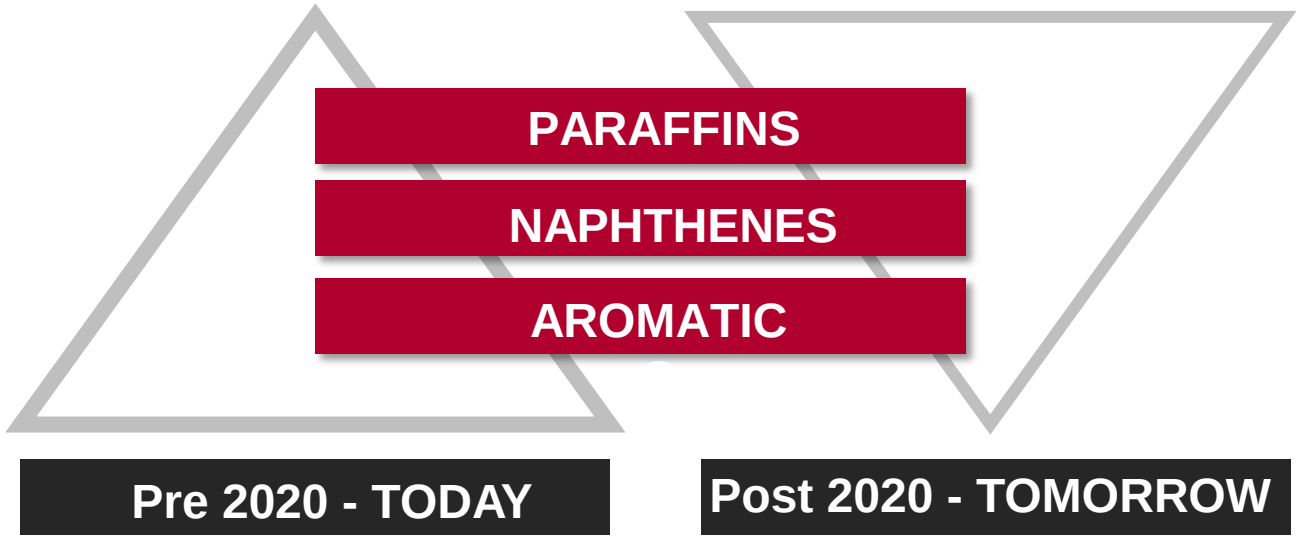
Stability (Total Sediment)
- Paraffinic vs Cracked blend components

Pour Point
- ULSFO /VLSFO close to PP limits

Acidity
- Sweet crude sources with high AN (e.g. DOBA)

Viscosity
- No minimum limit in ISO 8217, Table 2

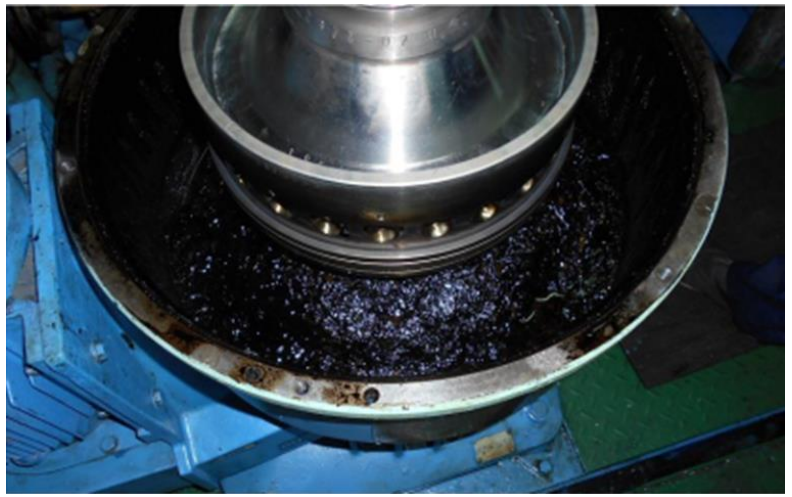
CCAI
- Larger difference between viscosity and density



Ref: KBC/Mel Larson

2020 Fuels - stability

- Asphaltenes are present in residual fuels in a colloidal suspension
- Stability of fuels typically refers to the fuels ability to keep the asphaltenes suspended
- In the fuel, aromatic components keep the asphaltenes apart;
  - Prevent agglomeration
  - Prevent precipitation
- Unstable fuels cause sludging due to asphaltenes coming out of solution



2020 Fuels - Fuel blending

Aromatics:

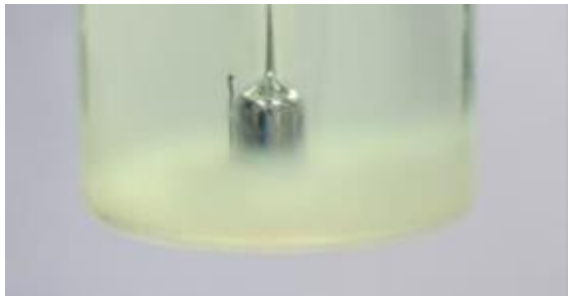
- Improves stability
- Keeps asphaltenes dispersed

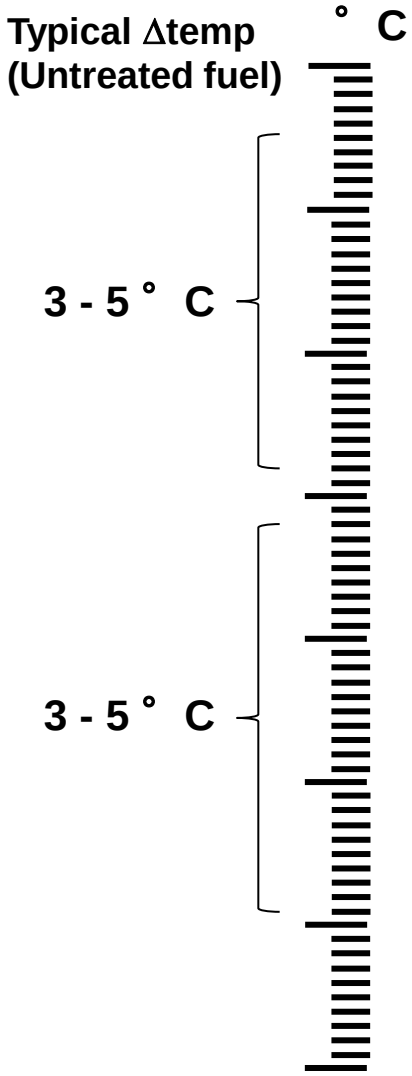
Paraffins

- Wax
- Does not improve stability
- (Excellent ignition/combustion properties)

The balance between asphaltenes, aromatics and paraffins must be right to get a stable blend

2020 Fuels - Cold flow properties





Cloud Point

The temperature at which wax crystals first appear during the cooling of a product under a controlled cooling process.

Cold Filter Plugging Point

The lowest temperature at which a given volume of fluid still passes through a standardized filtration device in a specified time when cooled under certain conditions.

Pour Point

The lowest temp at which the surface of the fluid can be seen to move or flow

2020 Fuels - Cold flow properties - wax

CIMAC
INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

Bureau Veritas VeriFuel

Lab Study

BUREAU VERITAS

VeriFuel
Understanding Marine Fuel

Bureau Veritas VeriFuel, Lab Study - Disclaimer

- Our lab study is performed on our own initiative
- Our study makes use of bunker samples available in the labs, samples that were due for disposal
- The intention has been to prepare compliant 2020 fuels to evaluate the potential properties of such products
- None of these fuels have been mixed onboard any ships and as such no operational experience is available for any of the blends
- Price aspects have not been considered choosing the blend components for this study

2020 Fuels - VLSFO (HFO – MGO) blends

Parameter	Santos	Santos / Rotterdam	Fos	Aviles	St. Pete 1	St. Pete 2
Visc@50°C (cSt)	12.1	30.9	5.5	19.4	15.3	10.8
Dens@15°C (kg/m^3)	911.1	940.6	877.4	918.1	910.6	892.8
Sulphur (% m/m)	0.51	0.51	0.49	0.43	0.49	0.49
TSA (% m/m)	0.01	0.01	**0.13**	0.01	0.01	0.01
TSP (% m/m)	0.01	0.01	**0.11**	0.01	0.01	0.01
Ash (% m/m)	0.01	0.01	0.02	0.01	0.01	0.01
Vanadium (mg/kg)	13	16	25	12	14	14
Sodium (mg/kg)	3	3	14	44	7	7
Al+Si (mg/kg)	6	9	21	9	6	6
Pour Point (°C)	0	-6	-15	0	-15	-9
CCAI	824	835	810	821	818	808
NSE (MJ/kg)	42.11	41.73	42.54	42.05	42.12	42.35
HFO Ratio (% m/m)	41	57	30	54	41	37

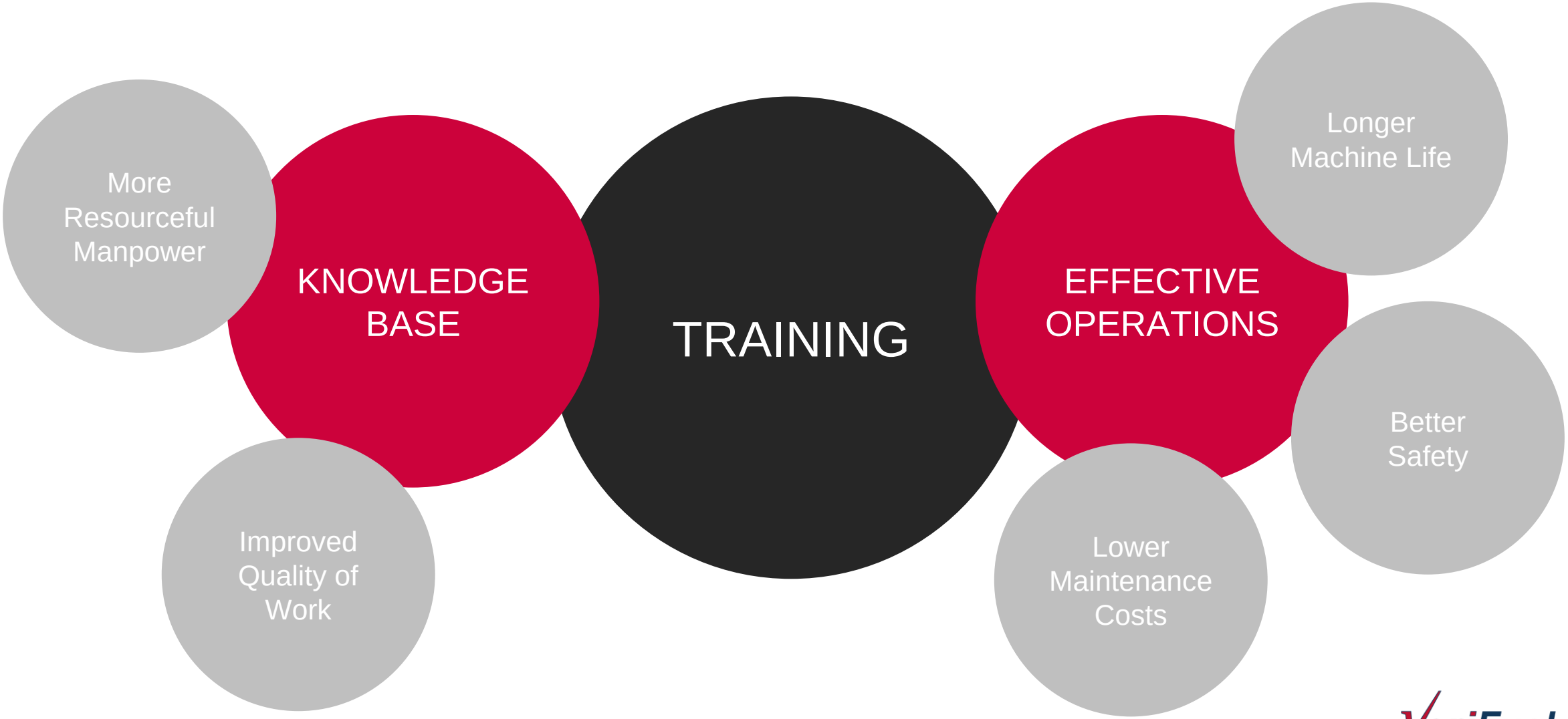
2020 Fuels - VLSFO (HFO – ULSFO) blends

Parameter	St. Pete 3	St. Pete / Rotterdam
Visc@50°C (cSt)	54.8	35.9
Dens@15°C (kg/m^3)	919.6	938.0
Sulphur (% m/m)	0.49	0.49
TSA (% m/m)	0.01	0.01
TSP (% m/m)	0.01	0.01
Ash (% m/m)	0.01	0.01
Vanadium (mg/kg)	14	12
Sodium (mg/kg)	10	9
Al+Si (mg/kg)	7	7
Pour Point (°C)	21	15
CCAI	805	830
NSE (MJ/kg)	42.01	41.77
HFO Ratio (% m/m)	36	33

Different lab study
(ULSFO mixed with different products)...

TSP on blend 50:50	% (m/m)	0.01
Blend Ratio	-	50:50 with on spec DMA (1733353)
Compatibility Rating	-	3
TSP on blend 50:50	% (m/m)	0.04
Blend Ratio	-	50:50 with paraffinic RMD80 (1730697)
Compatibility Rating	-	2
TSP on blend 50:50	% (m/m)	2.58
Blend Ratio	-	50:50 with aromatic RMK700 (1731353)
Compatibility Rating	-	5

2020 Fuels - How does market best prepare?



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Conclusions

VeriFuel
Understanding Marine Fuel

2020 Fuels - Conclusions

Potential challenges in 2020

- Compatibility: Tank segregation
- Cold flow properties: Onboard heating capacities
- Sulphur compliance: Cleaning of tanks

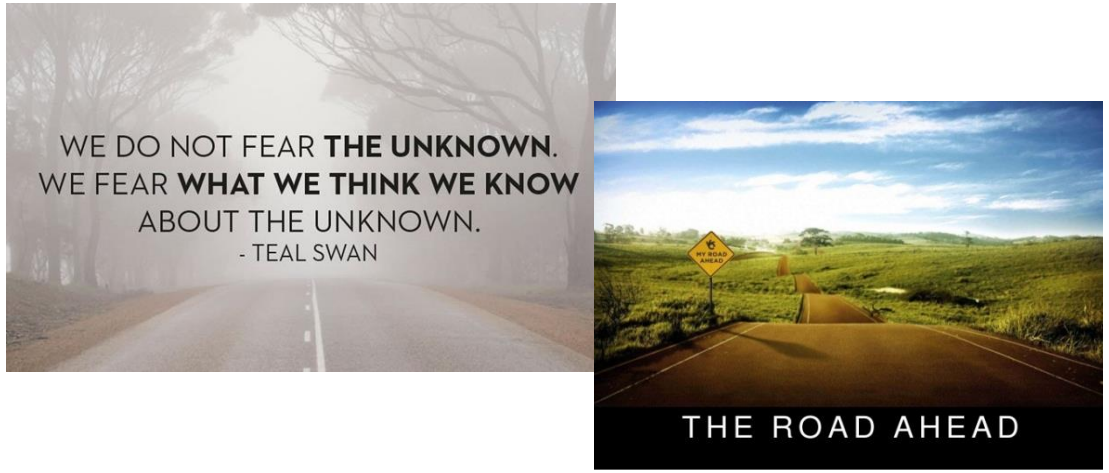
Cooperation

- Purchasers and technical departments should talk
  - Operational pattern
  - Evaluate the ship installations
    - Tanks (cleaning, segregation, heating capacity)
    - Fuel treatment systems (separators, filters)

Challenging to adapt to a new environment

- Training
- Knowledge sharing

Are these challenges new?



Thank you for your attention

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