MAN Energy Solutions
Future in the making

Uptime Anytime

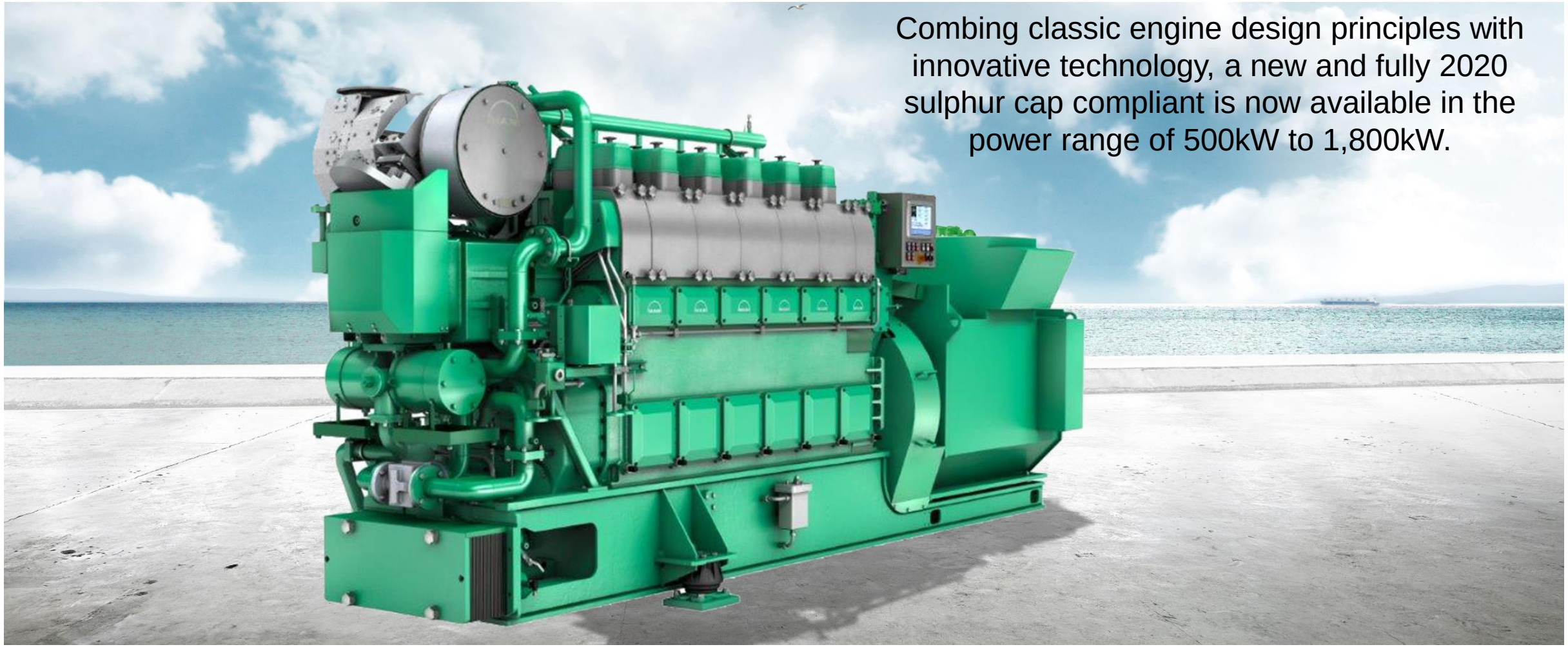
L23/30H Mk 3 – EcoGen

500kW – 1,800kW

Paw Houmann-Poulsen
Senior Specialist
Head of Promotion & Customer Support
Marine GenSets

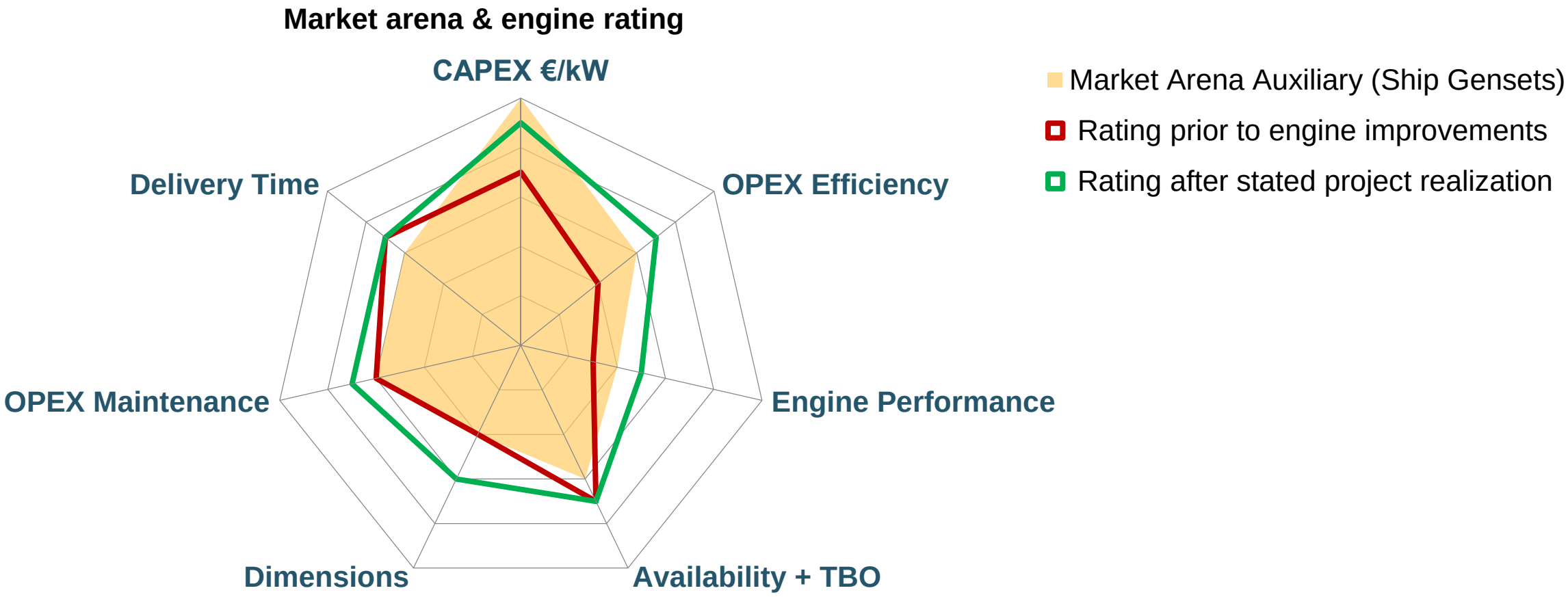
New L23/30H Mk 3

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap



L23/30H Mk 3

Planning analysis



Project realization will improve the most important selling points

Port Folio: Marine GenSets in 500 – 1800kW

4-Stroke Medium Speed Small Bore Marine GenSets – Overview

New L23/30H Mk 3

EcoGen – Benefits at a Glance

- Engine design based on L23/30H Mk 2 for Reliable and Stable Operation
- Designed for optimal performance under 2020 SOx-regulation
- Enlarged Power Range, now from 500kW – 1,800kW
- Higher power output per cylinder
- Reduced Fuel Oil Consumption
- Longest Time Between Overhaul in Class
- Minimum ”Black Smoke”
- Improved con-rod design applying the marine-head-type design
- Two-Part Piston design for Easy and Cost-Effective Maintenance
- Fast and easy installation with unique base frame design / “Plug and Play”
- Modern Safety and Control System by genuine MAN SaCoSone

- Perfect choice for Shipping Companies who operates a diverse fleet of merchant ships because EcoGen can be applied in most ships, thereby reduce spare part stock and makes planning of sign on schedule for the technical staff

Reference List – January 2019

Four-Stroke Small Bore Marine Engines

Engine Type / Engine Builder	L16/24	L23/30	L21/31	L28/32	L27/38	L32/40	L23/30DF	L28/32DF	Total
CMP	1.015	3.932	627	399	218	46	6	6	6.249
CXZ/SQE	145		29						174
SXD	231		171			90			492
HND	171		43						214
Weichai	18		79		124	56			277
STX Korea	623	3.937	904	1.175	575	1.630	3	9	8.856
Doosan	4	856	102	34	112	633		3	1.744
Adria & Split		317							317
HCP/FSA	41	95	18	442	27	9			632
MDT FRH	12	391	59	264	447				1.173
MDT Holeby	217	526	66	632	84				1.525
MDT India			66		79	1			146
Others	265	2.352	50	1.331	1.069	902			5.969
Total	*2.742*	*12.406*	*2.214*	*4.277*	*2.735*	*3.367*	*9*	*18*	*27.768*

L23/30H **Mk 3 vs** L23/30H **Mk 2**

Power Comparison

- Power output increased by:
  - 20% (720/750rpm)
  - 15% (900rpm)
- Cover the Widest Power Range in the Market 500kW – 1,800kW
- De-rated 5 cylinder version for 500kW with ECR
- 9 cylinder version for 1,800kW

EcoGen

Engine Type		L23/30H Mk 3		L23/30H Mk 2	
Bore x Stroke [mm]		225 x 300		225 x 300	
Speed [rpm.]		720	900	720	900
Output [kW/cyl.]		170	200	142	175
Power Output [kW]	5 cyl.	850	-----	710	-----
	6 cyl.	1,020	1,200	850	1.050
	7 cyl.	1,190	1,400	995	1.225
	8 cyl.	1,360	1,600	1.135	1,400
	9 cyl.	1,530	1,800	-----	-----

NEW

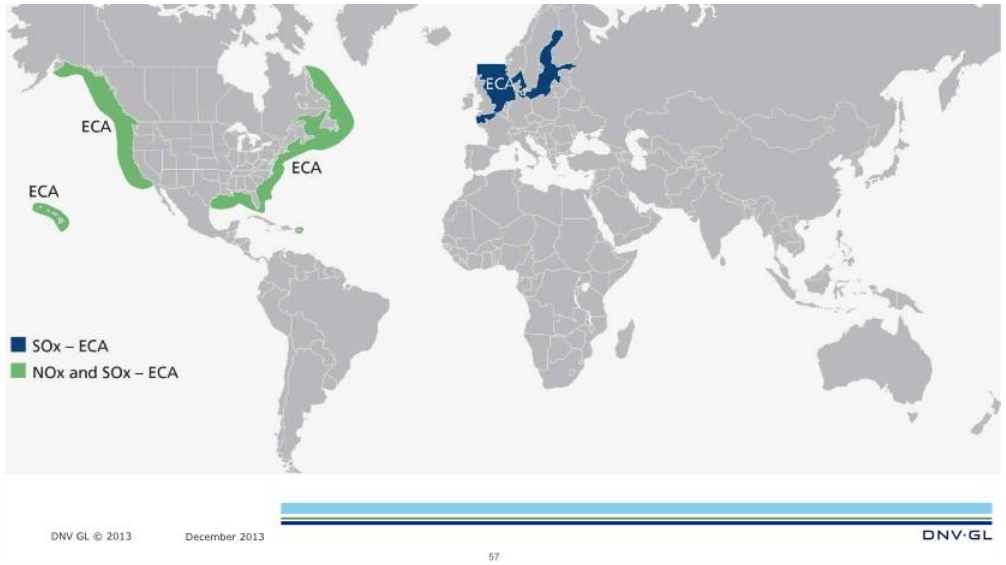
Engine Type	5L23/30H Mk 3 – ECR	5L23/30H Mk 2 – ECR
Speed [rpm.]	720	720
Output [kW/cyl.]	170	142
Power Output[kW]	500	580

New L23/30H Mk 3

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap

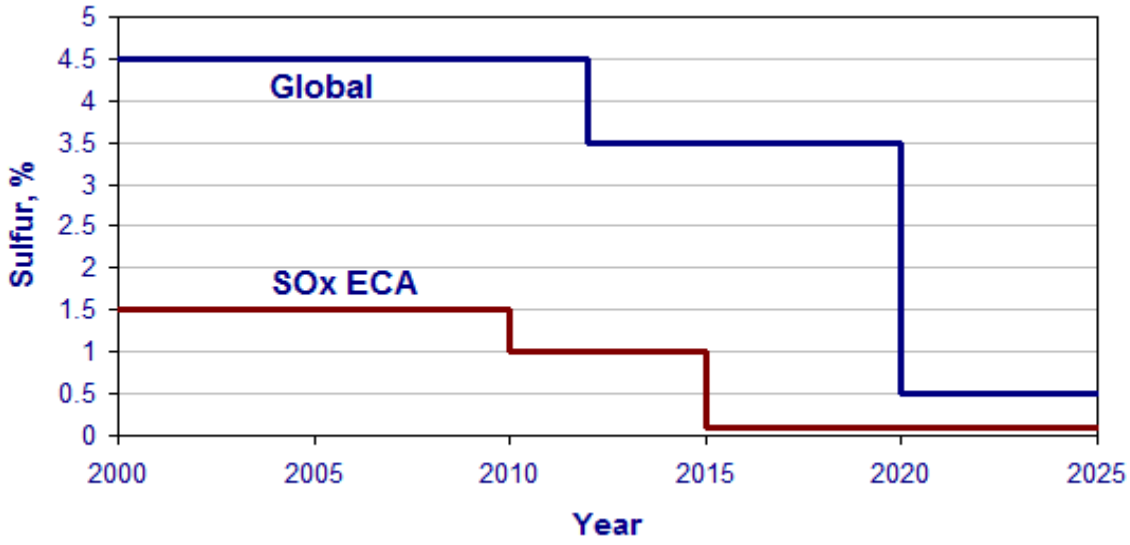
Methods for SOx-compliance:

- Operating on Low Sulphur Fuel
- Using SOx-Scrubbers



Regardless, L23/30H Mk 3 is the Perfect Choice

EcoGen



L23/30H Mk 3 – New Fuel pump designed for ULSFO

EcoGen – Green Power for a Blue Planet

In-house Developed Fuel Pump, featuring:

1) DLC Coated plunger:

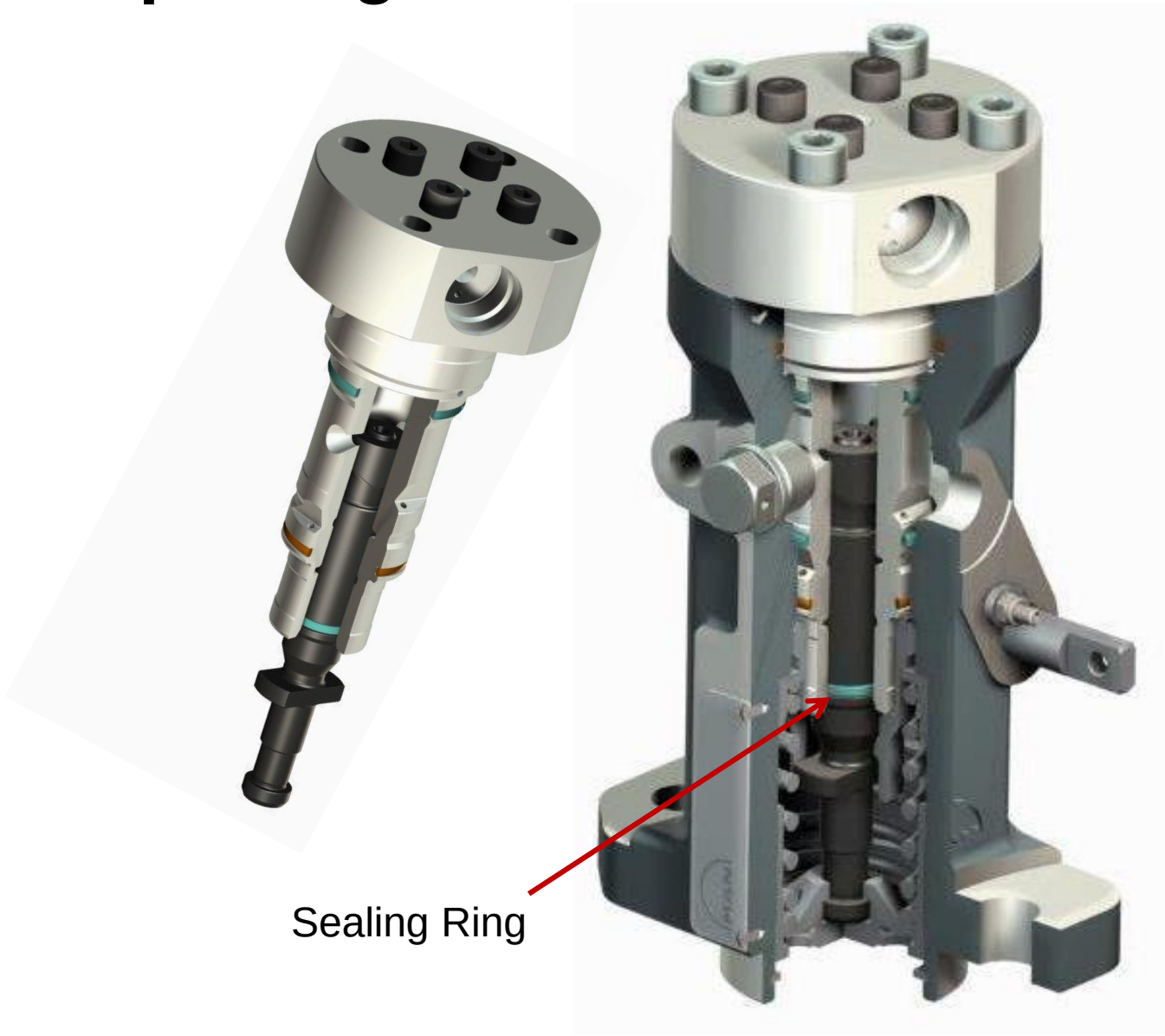
- Compensate for less lubricity of ULSFO
- Ensures Long Life Time and TBO's

2) SP-technology

- Fuel oil: No contamination with LO
  Reusable leak fuel oil
- Lube Oil: No contamination with Fuel oil
  Less deposits in drive areas
  Less oil changes
- Bilge: Reduced amount

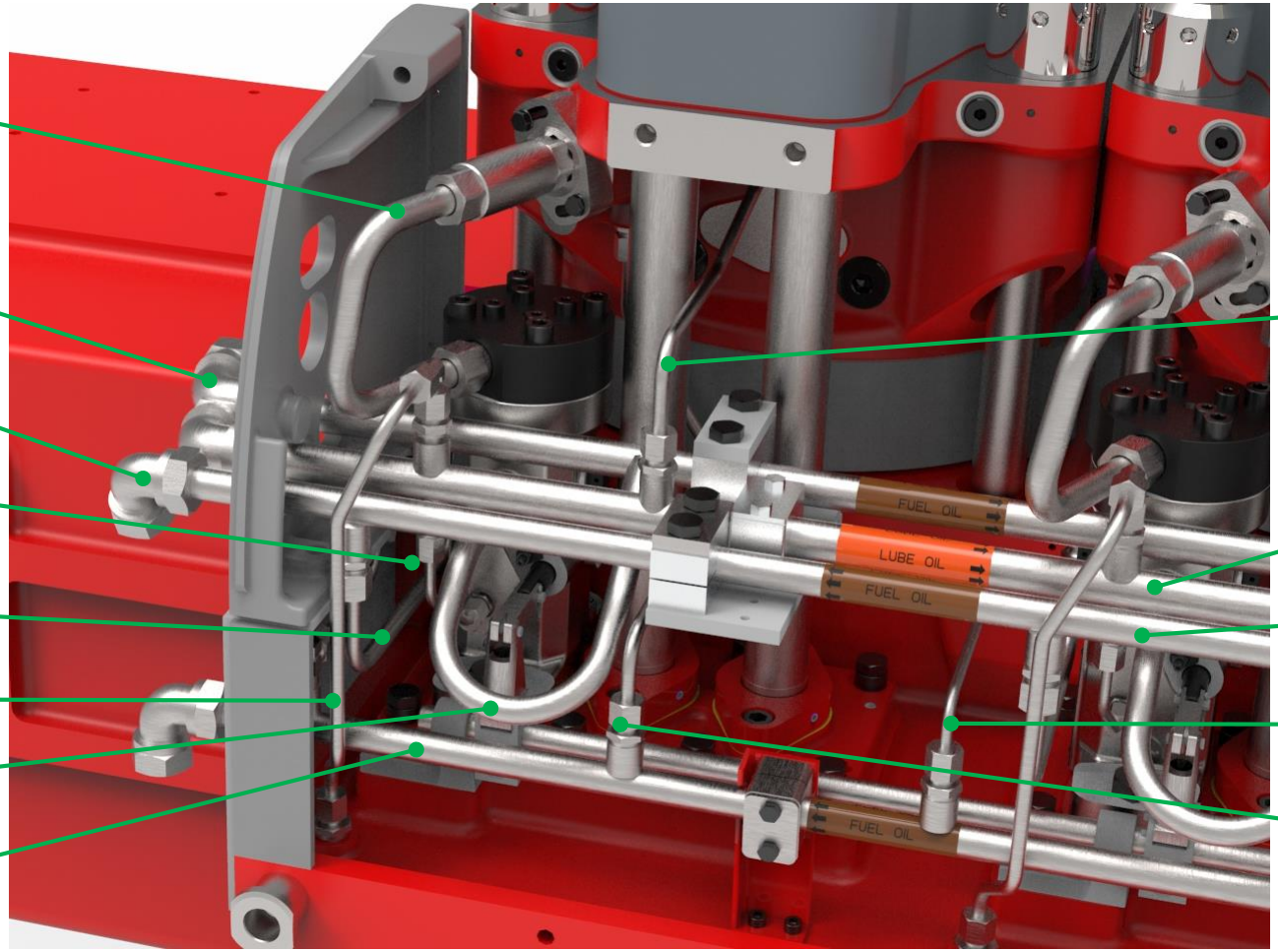
3) Internal drain system

- No external dripping in hot box
- No fuel mess in case of cut O-ring



New Piping for Fuel Oil Pump

L23/30H Mk 3



Fuel oil high pressure pipe

Fuel oil inlet

Fuel oil outlet

Lub. of pump

Fuel oil return

Lub. oil camshaft

Fuel oil inlet to pump

Drain from pump and high pressure pipe (clean)

Media labels EN690D

Lub. oil cyl. head / valve gear

Lub. oil main pipe

Fuel oil outlet

Drain fuel pump

Drain high pressure pipe / lance

L23/30H Mk 3 – Designed for ULSFO

EcoGen – Green Power for a Blue Planet

- Inlet/Outlet Valves of new material, Tribaloy™ T-800 Allloy
- For Higher Heat Resistance and Less Lubrication
- Ensures Long Life Time

SOx-Scrubber - Requires more Power

Open / Closed Loop Solutions

Additional Power Needed

~ 100 – 250kW

Tankers	Additional Power for SOx-Scrubber
MR Tanker	100 – 200kW
Aframax	150 – 250kW
Suezmax	125 – 200kW
VLCC	125 – 200kW

Bulk Carriers	Additional Power for SOx-Scrubber
Handymax	80 – 150kW
Panamax	150 – 250kW
Kamsarmax	150 – 250kW
VLOC	150 – 250kW

Scrubber Installation for M/V Tor Ficaria

Choosing Low Sulphur Fuel or SOx-Scrubbers?

Some Examples with

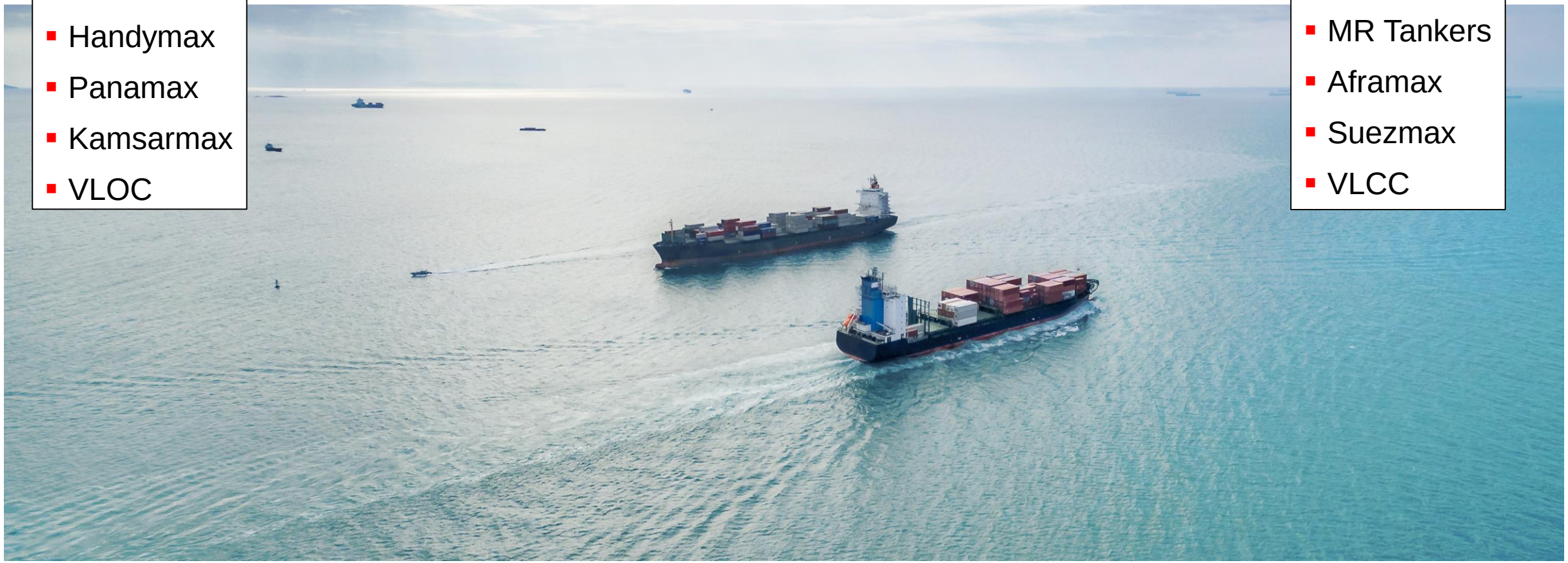
EcoGen – The Perfect Choice for Your Fleet

Bulk Carriers

- Handymax
- Panamax
- Kamsarmax
- VLOC

Tankers

- MR Tankers
- Aframax
- Suezmax
- VLCC



Choosing Low Sulphur Fuel or SOx-Scrubbers?

An Example of Bulk Carriers – KAMSARMAX

Power Requirement w/o SOx-Scrubber	Configuration with Mk 2	Configuration with EcoGen	Advantages
3 x 600kWe	3 x 5L23/30H Mk2 – 720rpm	3 x 5L23/30H Mk 3 – 720rpm	Only Few Changes in Engine Room Design

Power Requirement Open Loop Scrubber	Configuration with Mk 2	Configuration with EcoGen	Advantages
3 x 750kWe	3 x 6L23/30H Mk2 – 720rpm	3 x 5L23/30H Mk 3 – 720rpm	3 Cylinder Less => Lower Maintenance Costs Space Saving => More pay-load

Power Requirement Closed Loop Scrubber	Configuration with Mk 2	Configuration with EcoGen	Advantages
3 x 800kWe	3 x 6L23/30H Mk2 – 720rpm	3 x 5L23/30H Mk 3 – 720rpm	3 Cylinder Less => Lower Maintenance Costs Space Saving => More pay-load

Choosing Low Sulphur Fuel or SOx-Scrubbers?

An Example of Tankers – Aframax

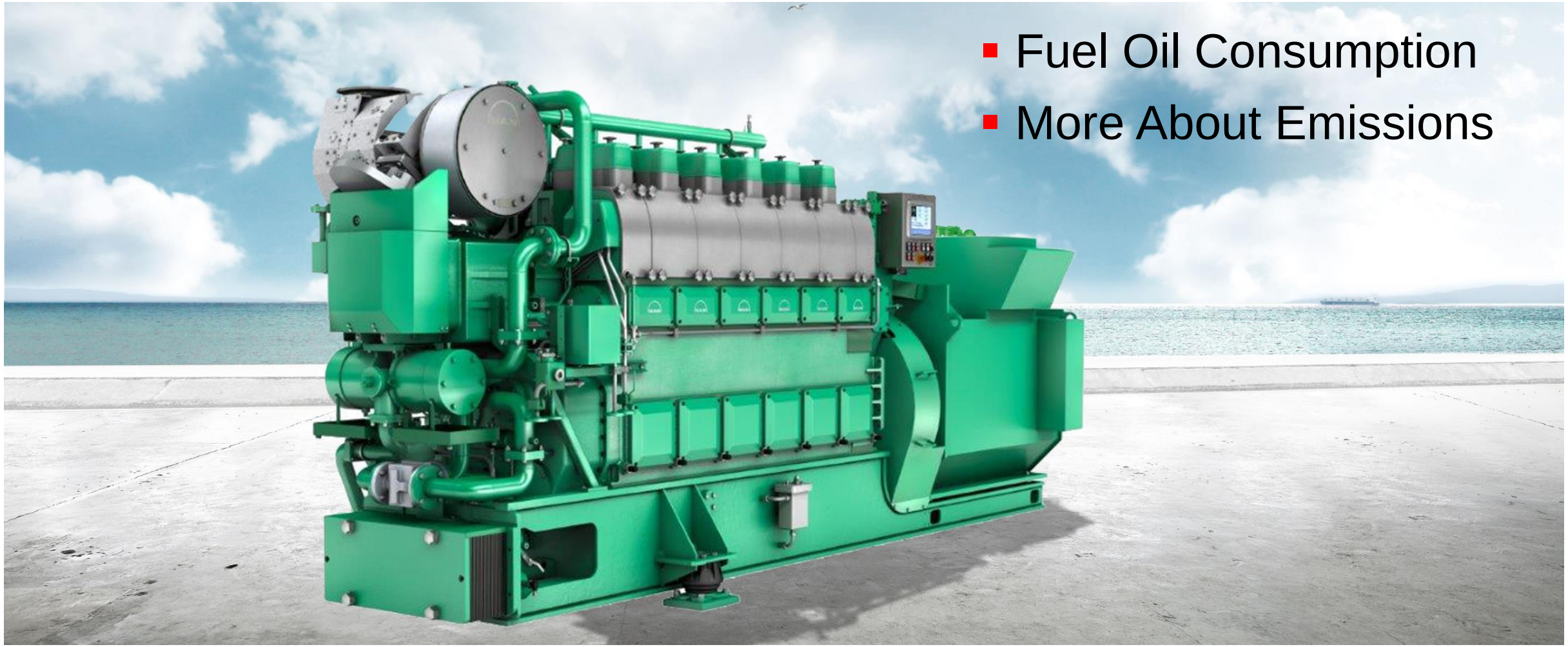
Power Requirement w/o SOx-Scrubber	Configuration with Mk 2	Configuration with EcoGen	Advantages
3 x 900kWe	3 x 6L23/30H Mk2 - 900rpm	3 x 6L23/30H Mk 3 - 720rpm	Longer TBO => Lower Maintenance Costs

Power Requirement Open Loop Scrubber	Configuration with Mk 2	Configuration with EcoGen	Advantages
3 x 1.050kWe	3 x 7L23/30H Mk2 - 900rpm	3 x 6L23/30H Mk 3 - 900rpm	3 Cylinder Less => Lower Maintenance Costs Space Saving => More pay-load

Power Requirement Closed Loop Scrubber	Configuration with Mk 2	Configuration with EcoGen	Advantages
3 x 1.150kWe	3 x 7L23/30H Mk2 - 900rpm	3 x 6L23/30H Mk 3 - 900rpm	3 Cylinder Less => Lower Maintenance Costs Space Saving => More pay-load

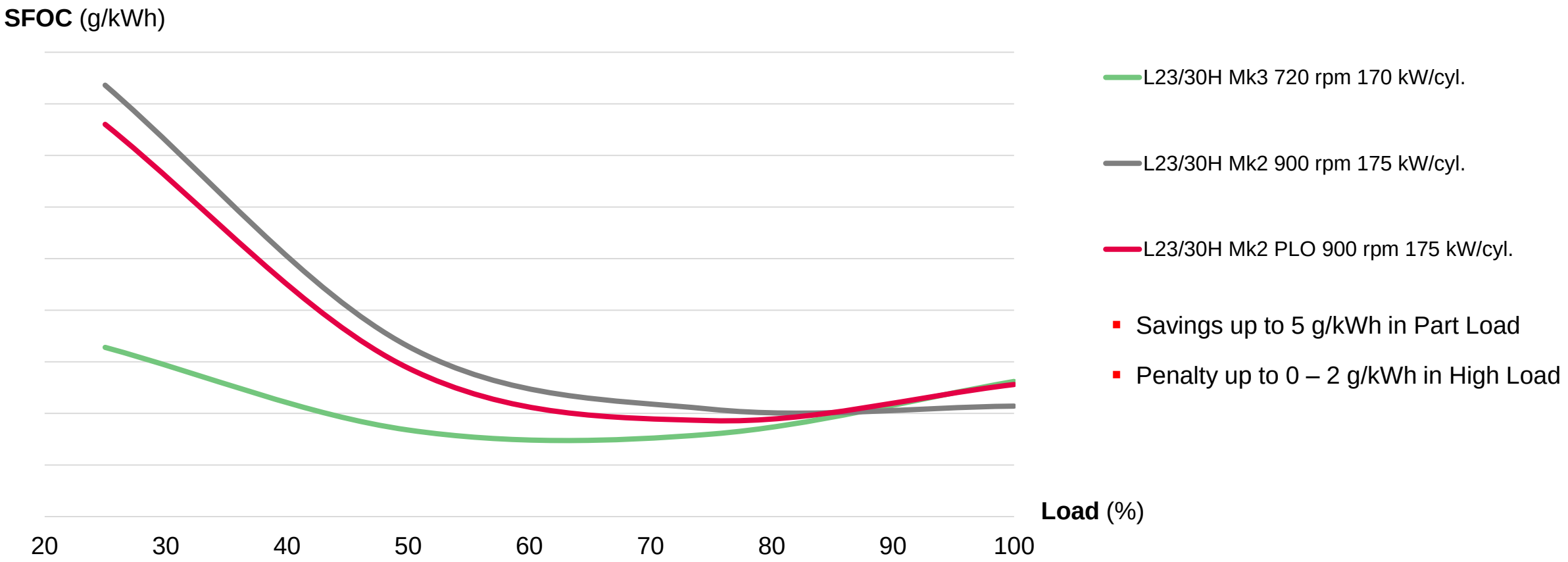
New L23/30H Mk 3

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap



SFOC Comparison with ~175kW/cylinder

Reduced Fuel Oil Consumption in Low Load and Part Load

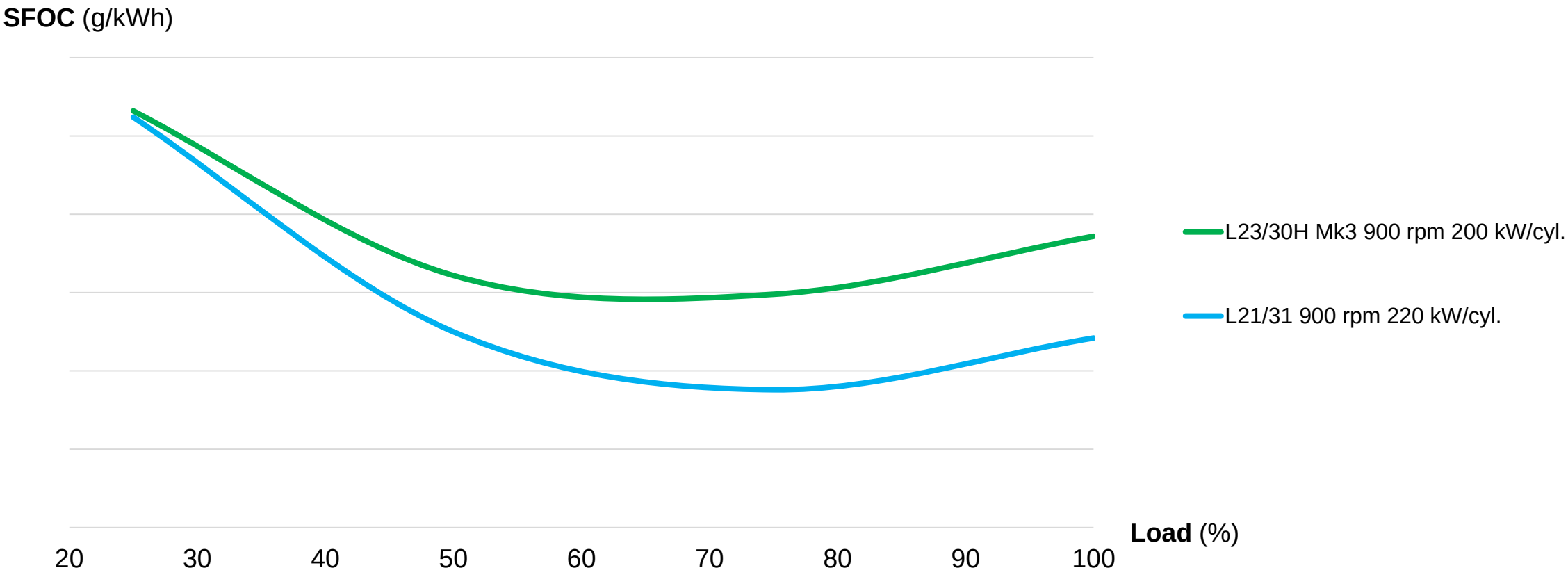


- Savings up to 5 g/kWh in Part Load
- Penalty up to 0 – 2 g/kWh in High Load

- Based on Project Guide figures for IMO Tier II engines
- ISO reference condition, HFO/MDO, without pumps, tolerance +5% (not included)
- Figures for MK 3 is calculated SFOC-values and has to be verified on testbed

SFOC Comparison with ~200/220kW/cylinder

Expected: L21/31 with slightly Lower Fuel Oil Consumption than L23/30H Mk 3

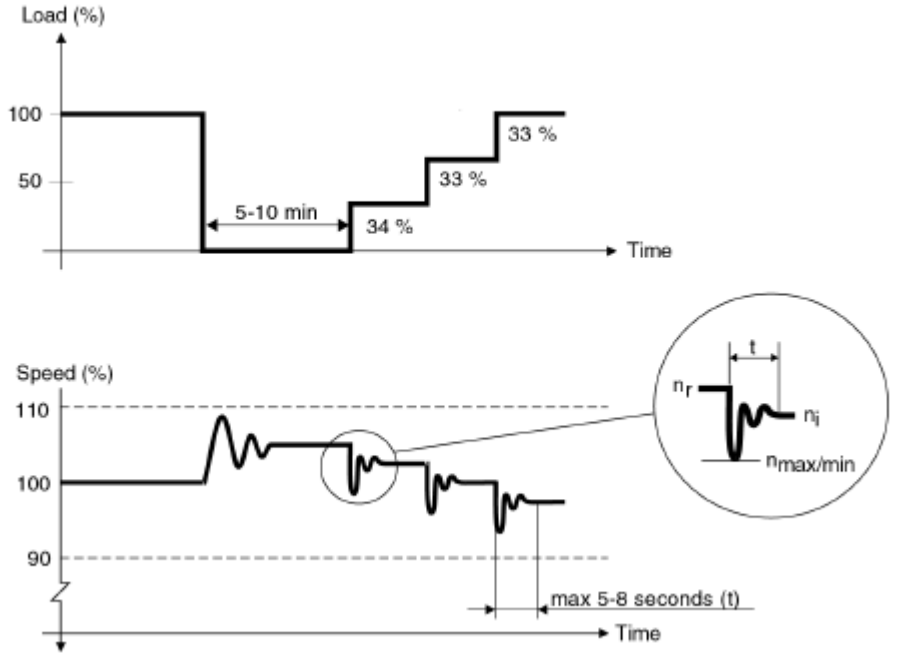


- Based on Project Guide figures for IMO Tier II engines
- ISO reference condition, HFO/MDO, without pumps, tolerance +5% (not included)
- Figures for MK 3 is calculated SFOC-values and has to be verified on testbed

Minimum of “Black Smoke”

Green Power for a Blue Planet

- Heavy “Black Smoke” can occur in engines because of insufficient air amount in the combustion during load changes
- MAN GenSets has proven ability to take 0 – 100% load in only three steps with a minimum of visible smoke
- MAN GenSets has a minimum of “black smoke” because of the well proven Lambda Controller System
- Subsequently:
  - Minimum of “Black Smoke”
  - Lower fuel oil consumption
  - Lower NOx
  - Better engine condition



Minimum of “Black Smoke”

Combustion Process

Good Combustion depends of:

- Fuel Quality
- Fuel Equipment
- Load Conditions
- Fuel Treatment

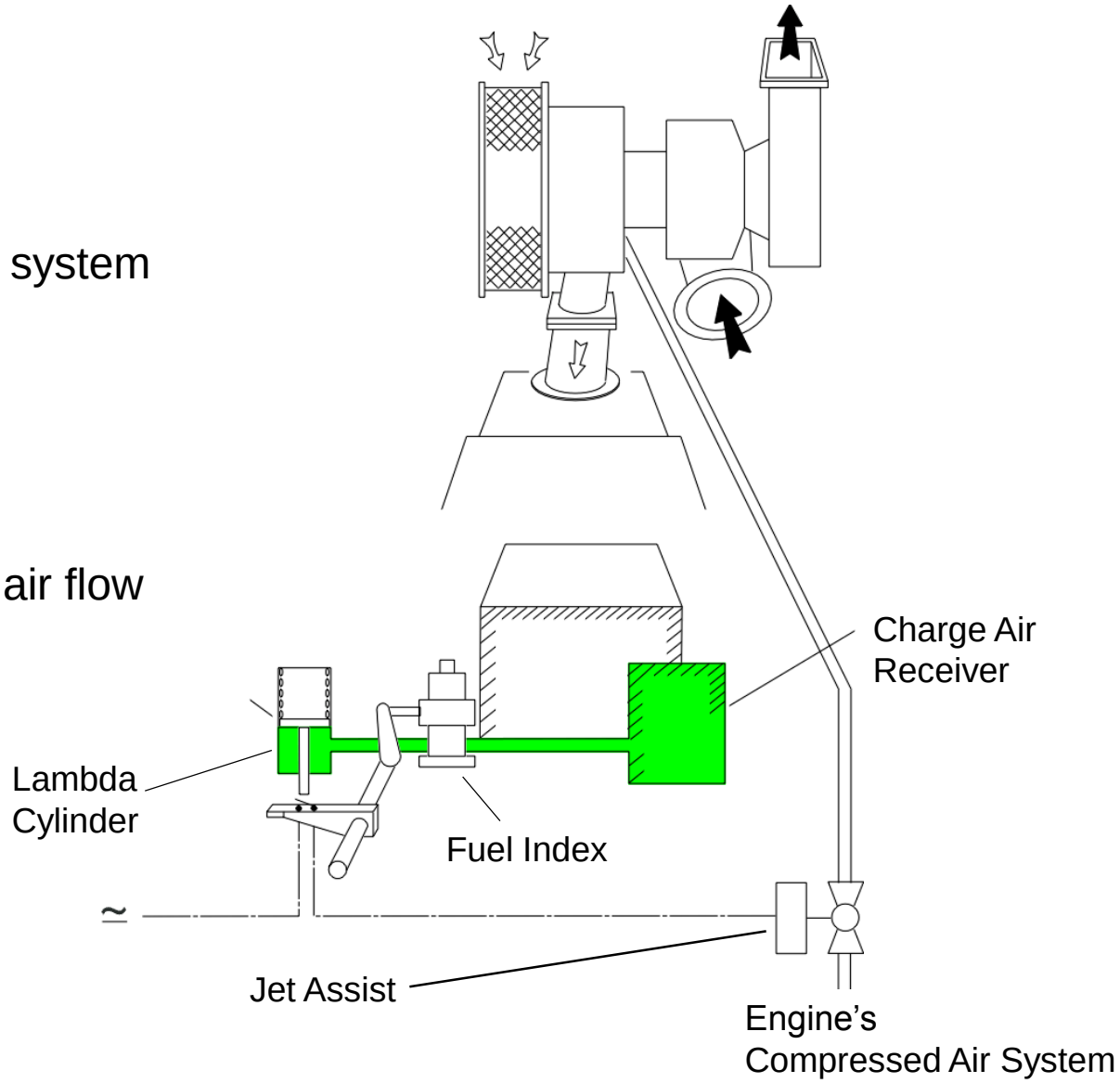
Good Performance

Poor Performance

Minimum of “Black Smoke”

Green Power for a Blue Planet

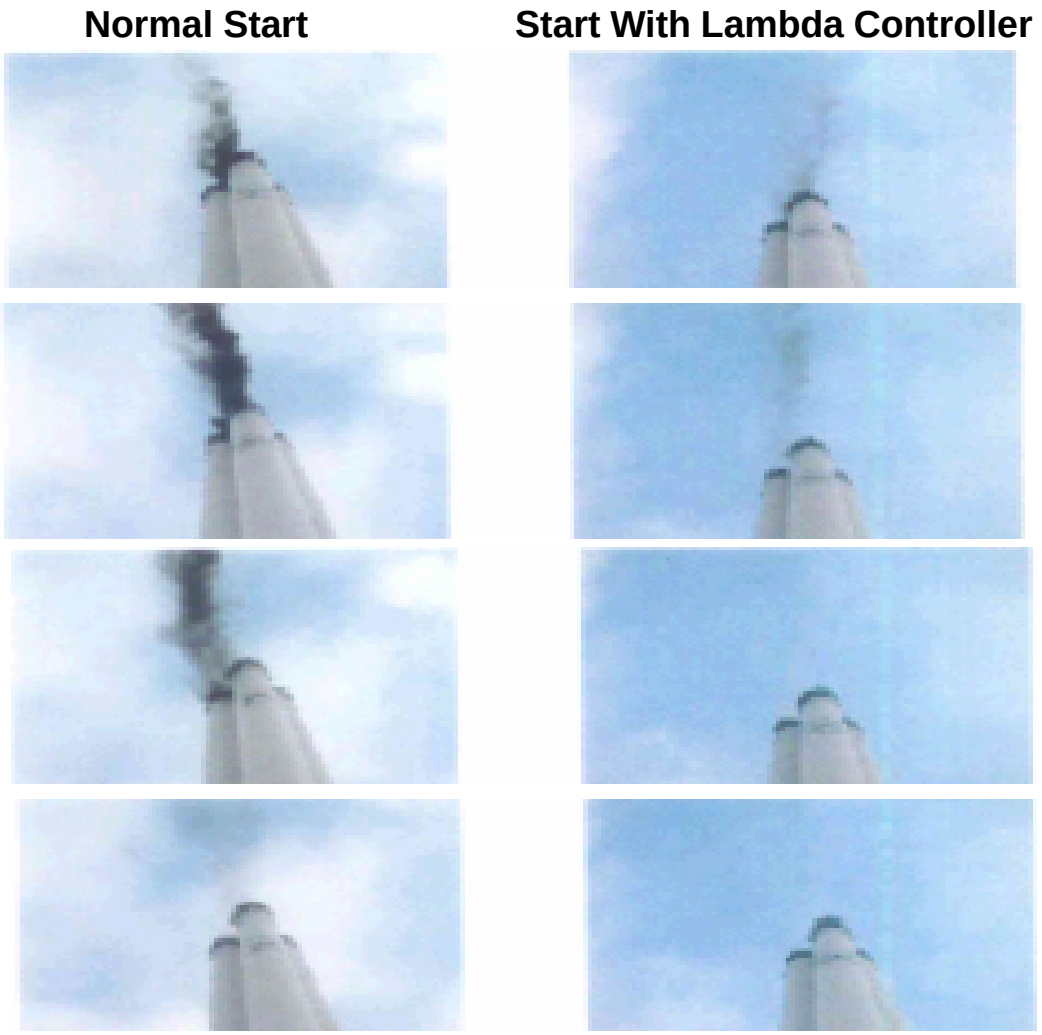
- Increase fuel oil index (higher load / more fuel oil)
- Lambda cylinder switch/sends signal to the jet assist system
- And opens for the engine’s compressed air system
- More air will flow through the T/C on the turbine side
- Compressor side will increase the amount of air and air flow into the charge air receiver
- Adding additional air to the combustion process
- Results:
  - Minimum of “black smoke”
  - Lower fuel oil consumption
  - Lower NOx
  - Better engine condition



Minimum “Black Smoke”

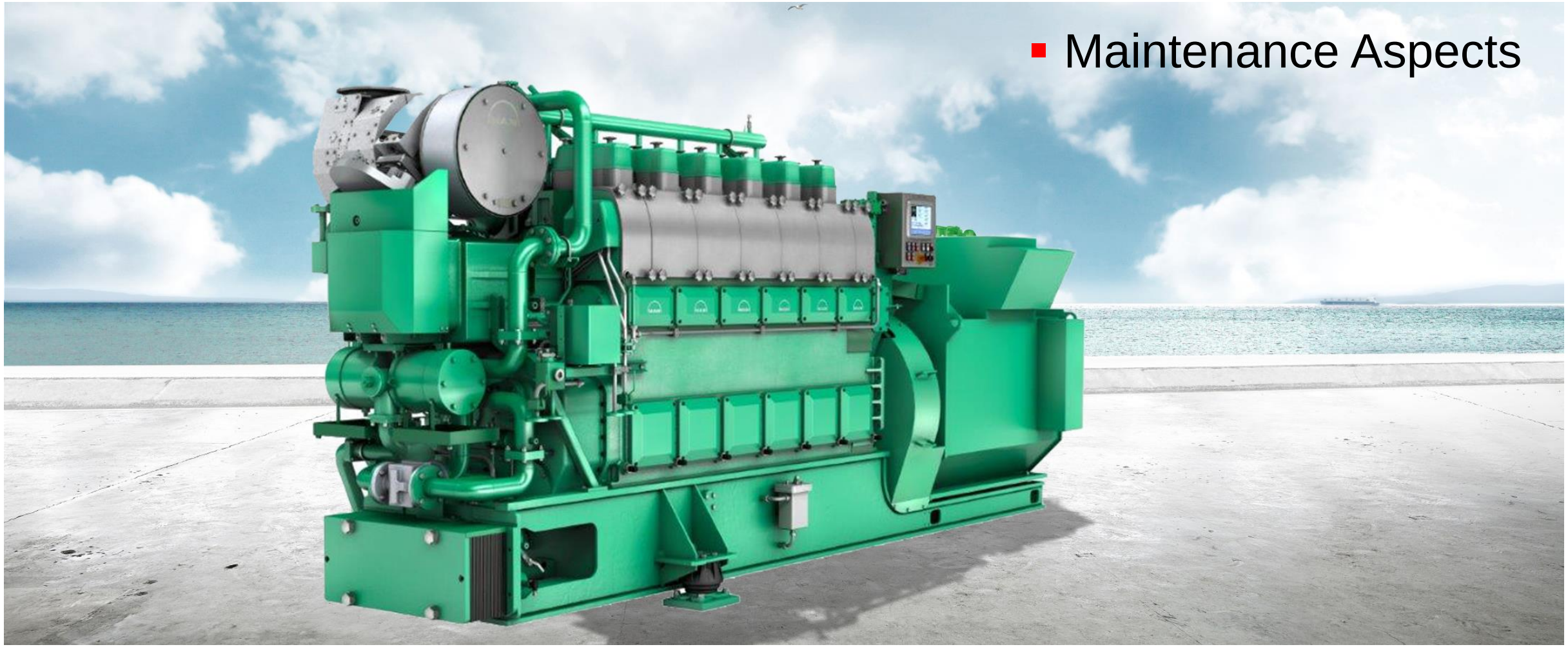
Green Power for a Blue Planet

- Smoke Starts 25 sec. after Start Signal
- Smoke Emission 30 sec. after Start Signal
- Smoke Emission 35 sec. after Start Signal
- Smoke Emission 40 sec. after Start Signal



New L23/30H Mk 3

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap



Time Between Overhaul (TBO)

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap

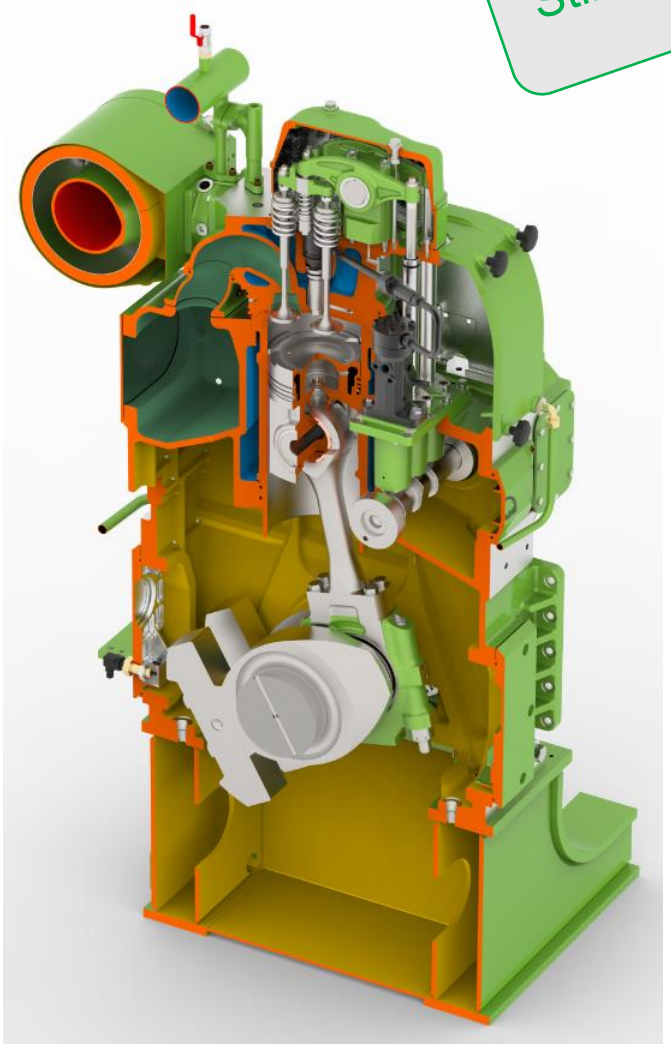
Still Best in Class

- TBO remains unchanged even in ULSFO
- Longest TBO in it's Class
- HFO with 0.5%S (LSFO) or 0.1%S (ULSFO)
  - 720rpm = 20,000hrs
  - 900rpm = 16,000hrs
- MDO/MGO with 0.5%S (LSFO) or 0.1%S (ULSFO)
  - 720rpm = 32,000hrs
  - 900rpm = 20,000hrs

Expected Life Time

EcoGen – Up Time Any Time

Still Best in Class



Exhaust Valve
Inlet Valve
Valve Seats
Valve Guide

32,000hours

Fuel Valves: 8,000hours (improved 2,000hours)

Fuel Pump: 32,000hours

Main Bearing: 48,000hours

Cylinder Liner: 64,000hours

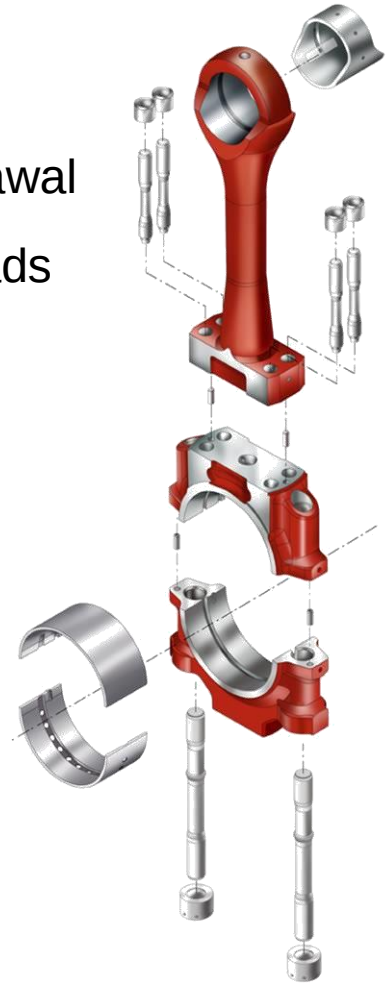
Piston: 64,000hours

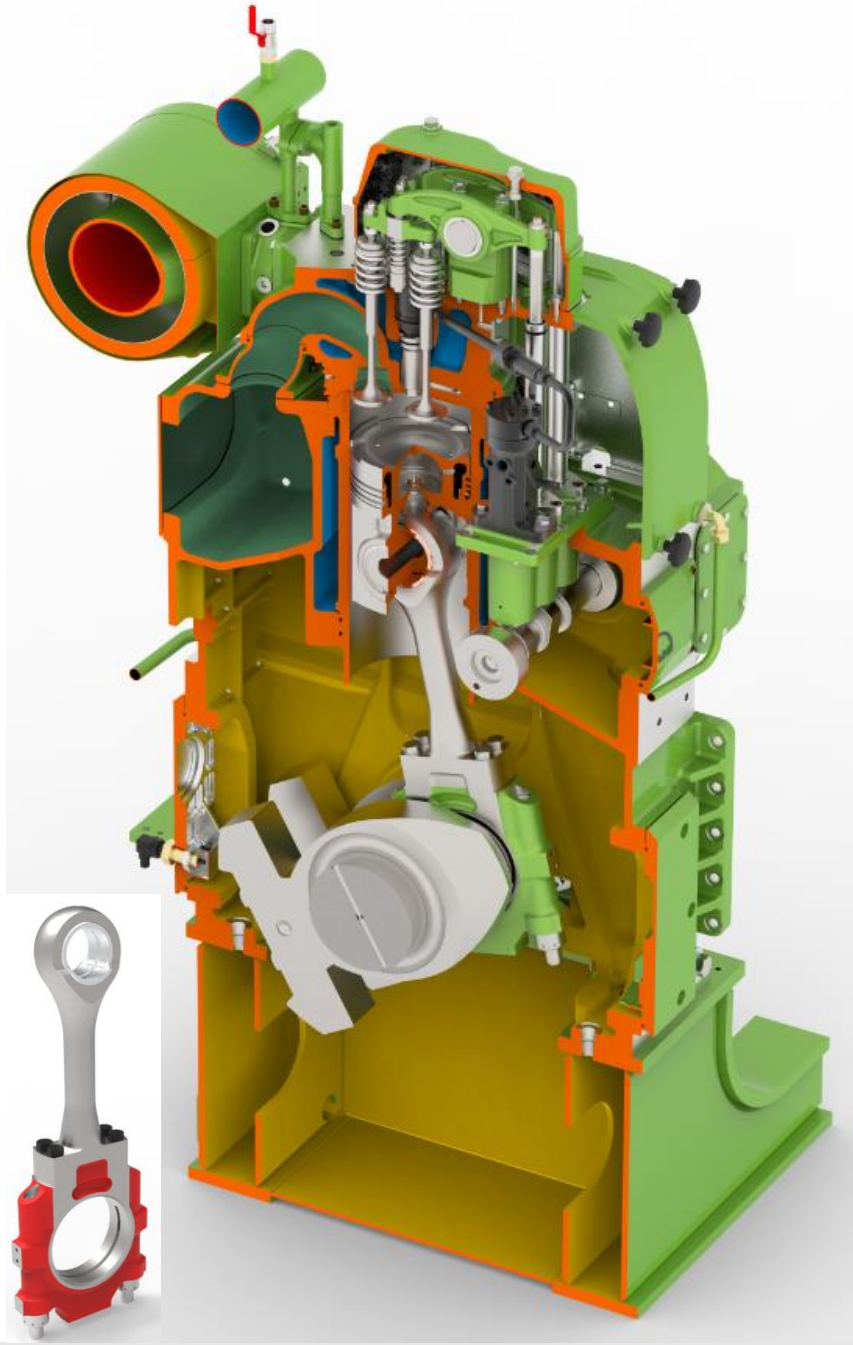
Big End Bearing: 32,000hours

Con-Rod in ”Marine-Head” Design

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap

- New Design proposed by Ship Owners
- No opening of bearing necessary for piston withdrawal
- Optimal flow of piston forces and equal bearing loads
- Easy use of hydraulic tools
- Low lifting height at overhaul
- Good Access
- Faster and Easier Maintenance
- Lower Maintenance Cost





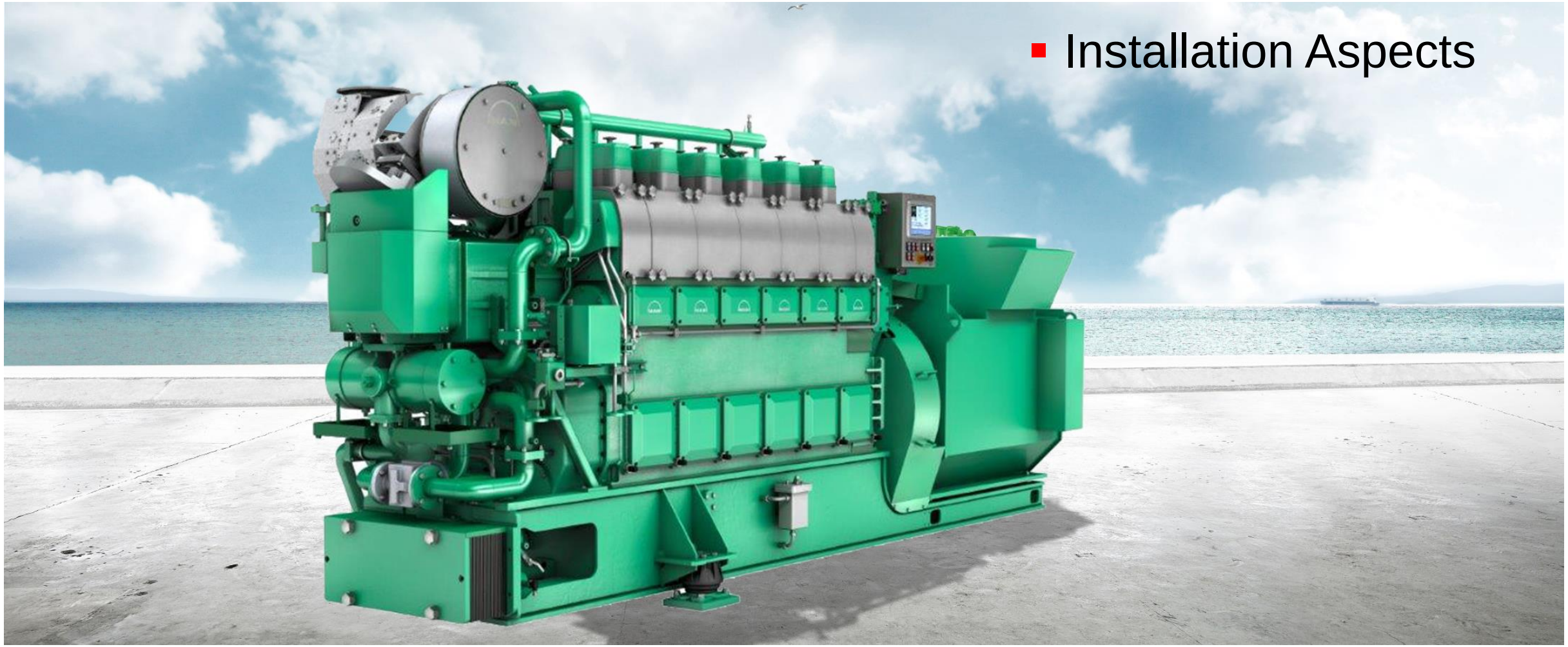
Two-Part Piston Design

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap

- New Design proposed by Ship Owners
- Valves Pockets on Piston Crown
- Only Piston Crown to be Replaced
- Faster and Easier to Replace
- Lower Maintenance Cost

New L23/30H Mk 3

EcoGen – Plug & Play

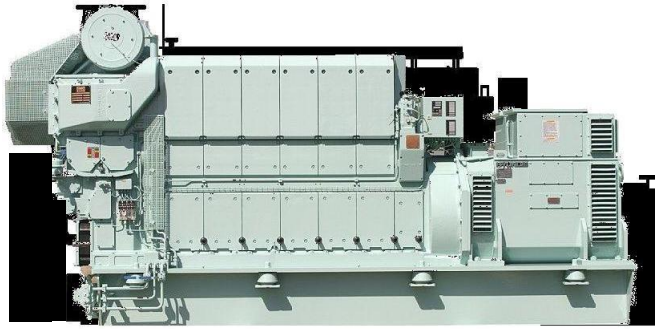


L23/30H Mk 3, Installation – Same Length

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap

- More Cargo Space/Payload Compared to L23/30H Mk 2
- Near Same Length as L21/31
- Lower Structure Cost

EcoGen vs L21/31

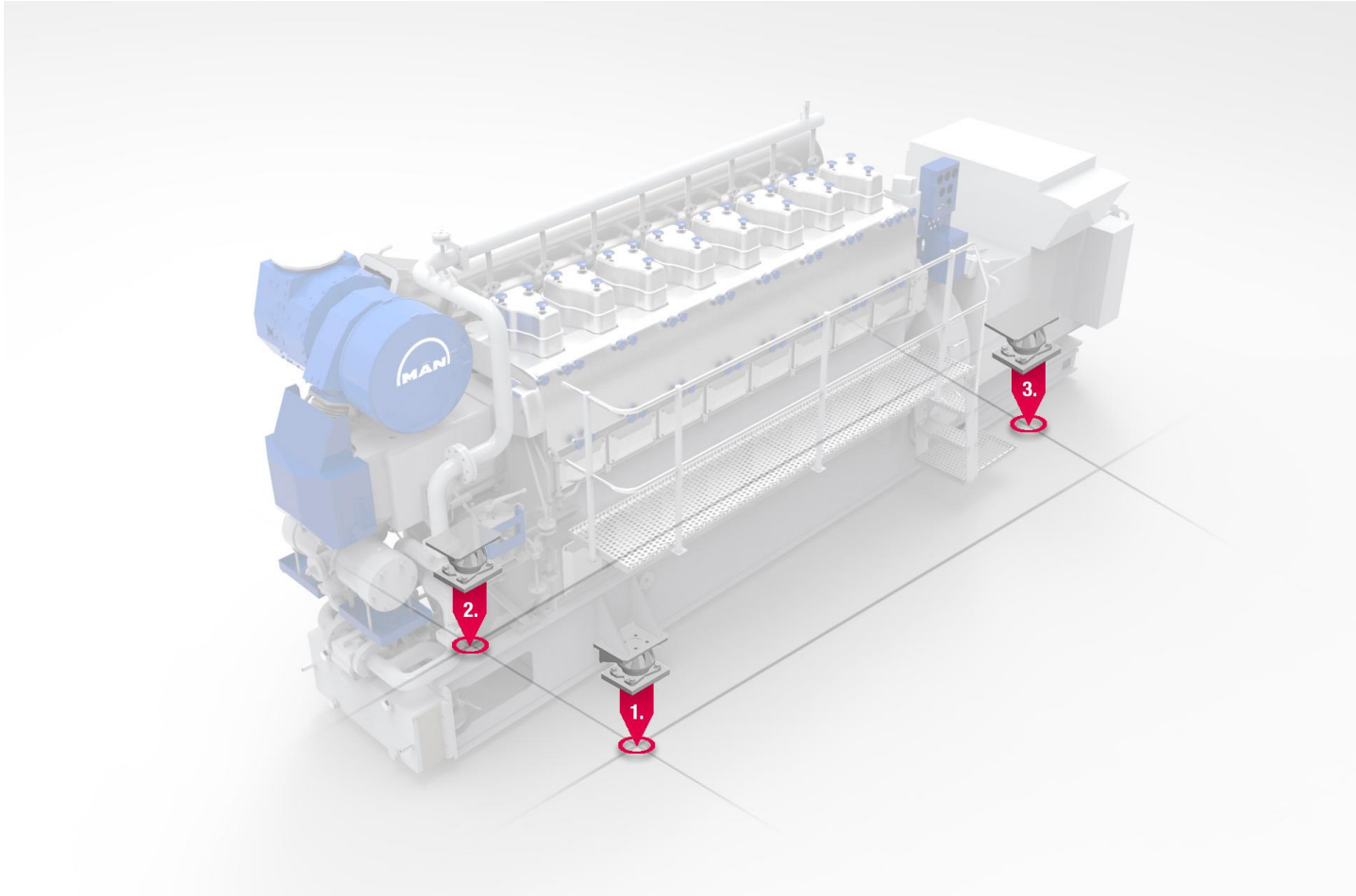


L21/31- 900 rpm			L23/30H Mk 3-900 rpm		
	Engin Power [kW]	Total Length [m]	Total Length [m]	Engine Power [kW]	
5 cyl.	1,000	5.8	5.9	1,200	6 cyl.
6 cyl.	1,320	6.3	6.4	1,400	7 cyl.
7 cyl.	1,540	6.6	7.0	1,600	8 cyl.
8 cyl.	1,760	7.7	7.7	1,800	9 cyl.
9 cyl.	1,980	8.0	------	------	------

Installation Method

Setting New Standards by “Plug and Play”

- Cost Savings
- Faster and Easier Installation
- Less Steel Support Structure Required
- Simplified Ship Structure
- Less Engineering Work
- Less Logistic
- Less Steel
- Less Steel and Welding Work
- Faster and Easier Installation
- Savings x 3 (one shipset = 3 GenSets)

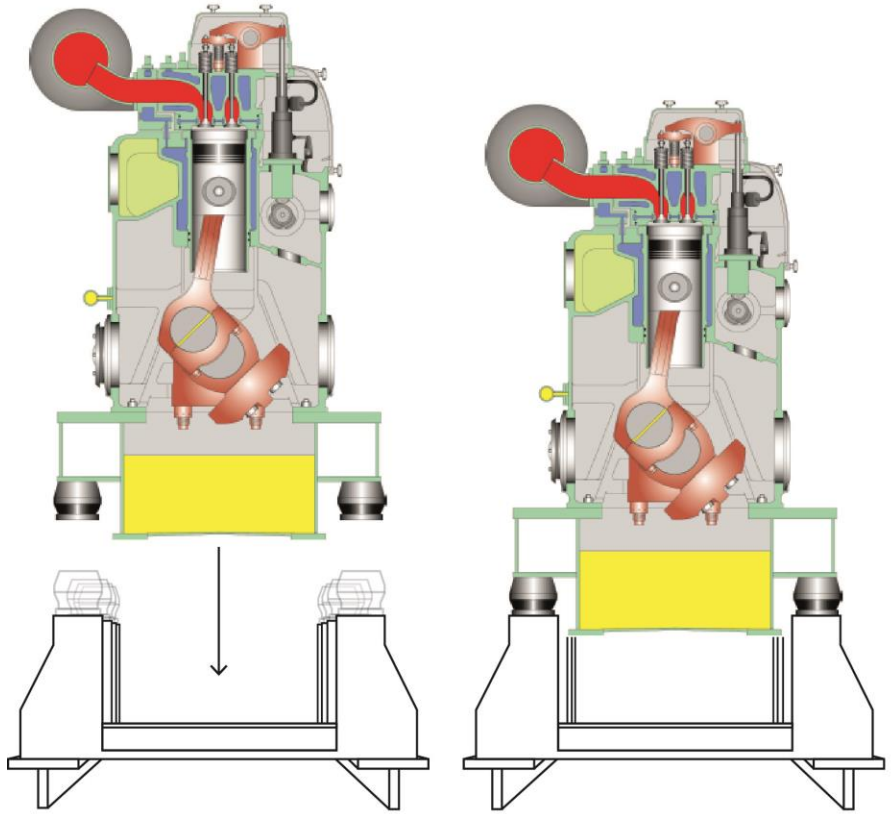


“Plug and Play” by 3-Conicals Support

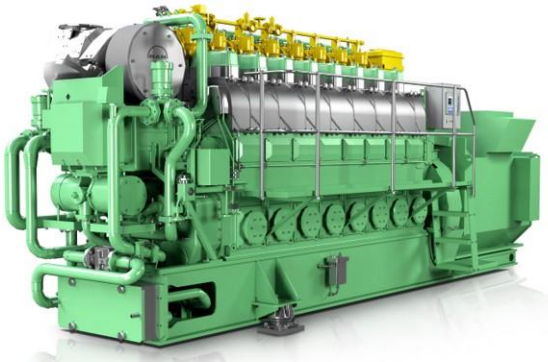
- Conicals reduced from 8 -> 3
- “Self-adjustable”

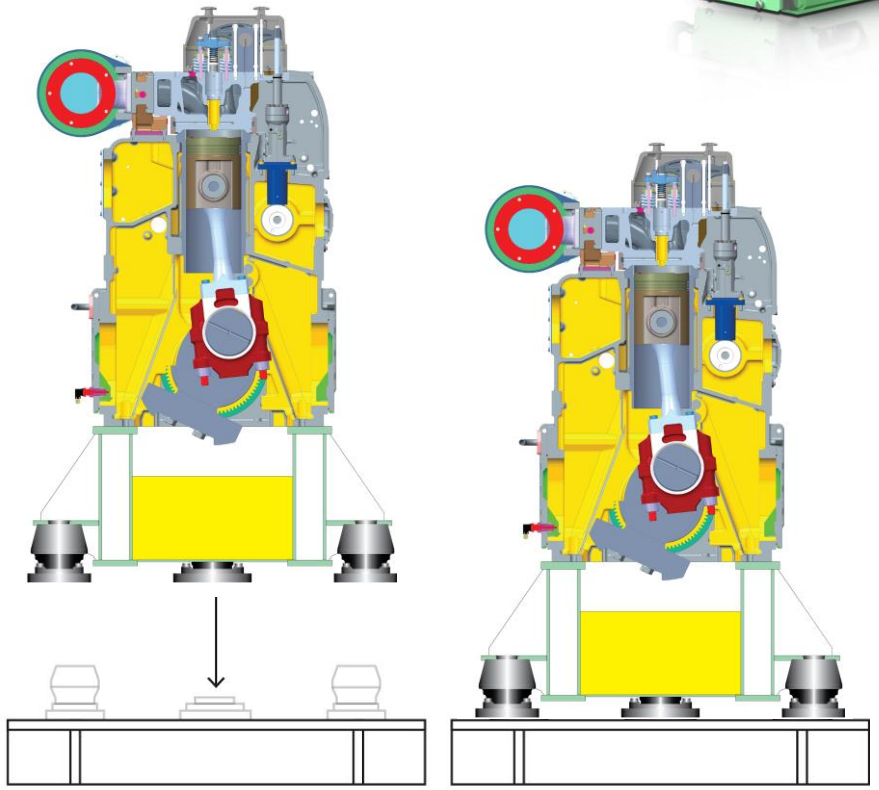
Installation Method

Setting New Standards by “Plug and Play”



Traditional Base Frame



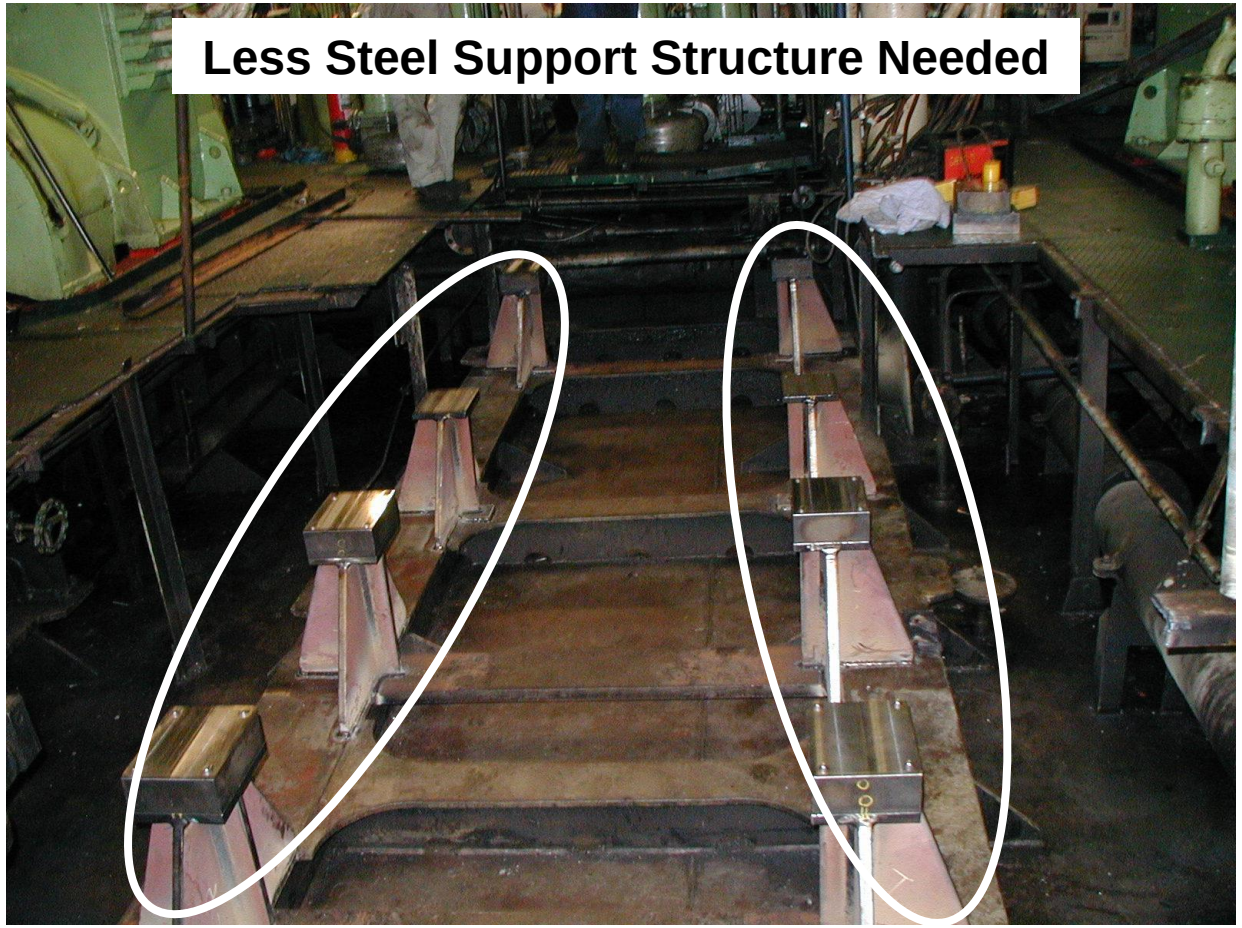


Monocoque Base Frame

Cost and Time Savings

Setting New Standards by “Plug and Play”

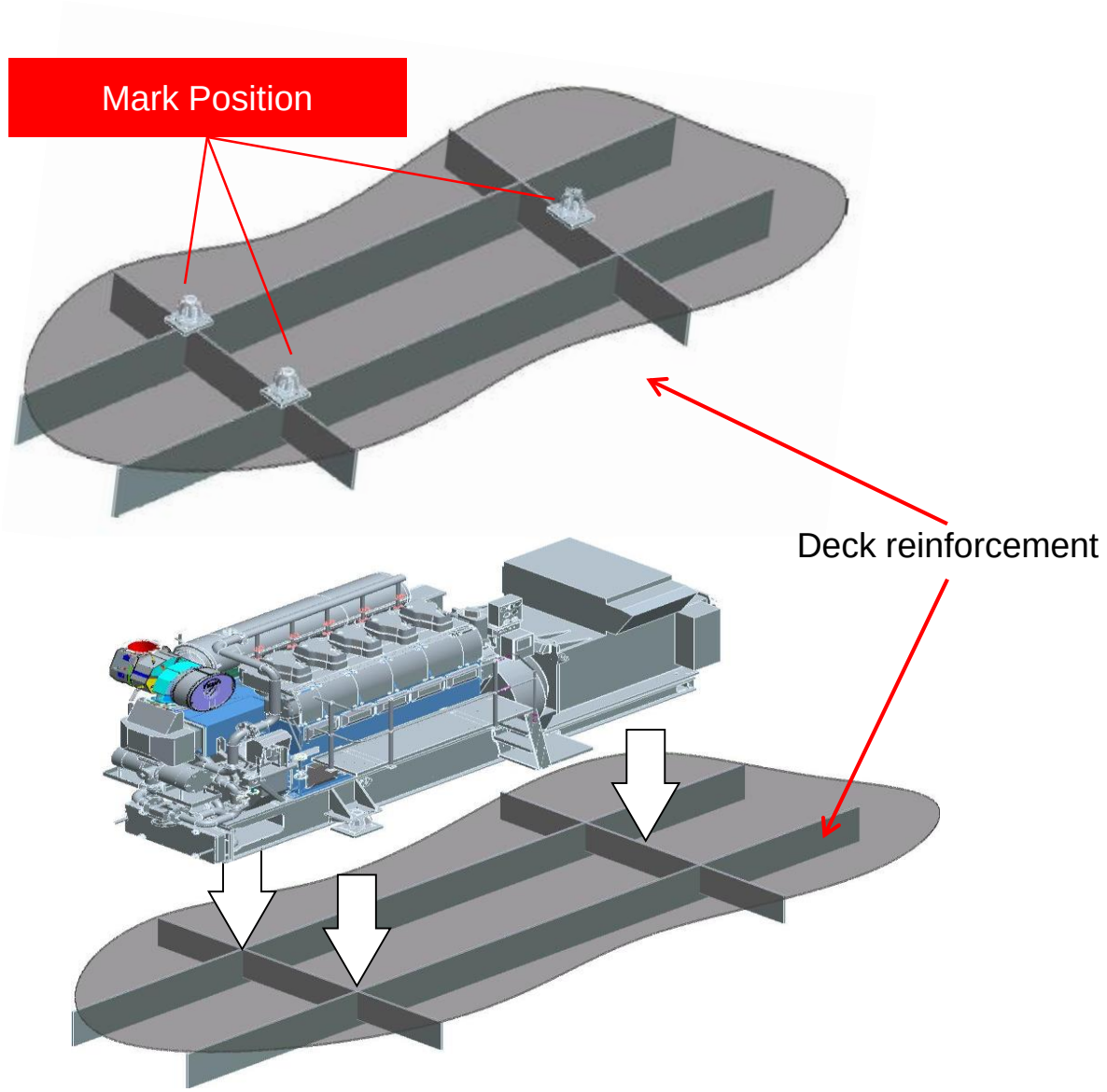
- Less Steel Support Structure Required
- Simplified Ship Structure
- Less Engineering Work
- Less Logistic
- Less Steel
- Less Steel and Welding Work
- Faster and Easier Installation
- Savings x 3 (one shipset = 3 GenSets)



Installation Procedure

Setting New Standards by “Plug and Play”

- Mark Position of Conicals



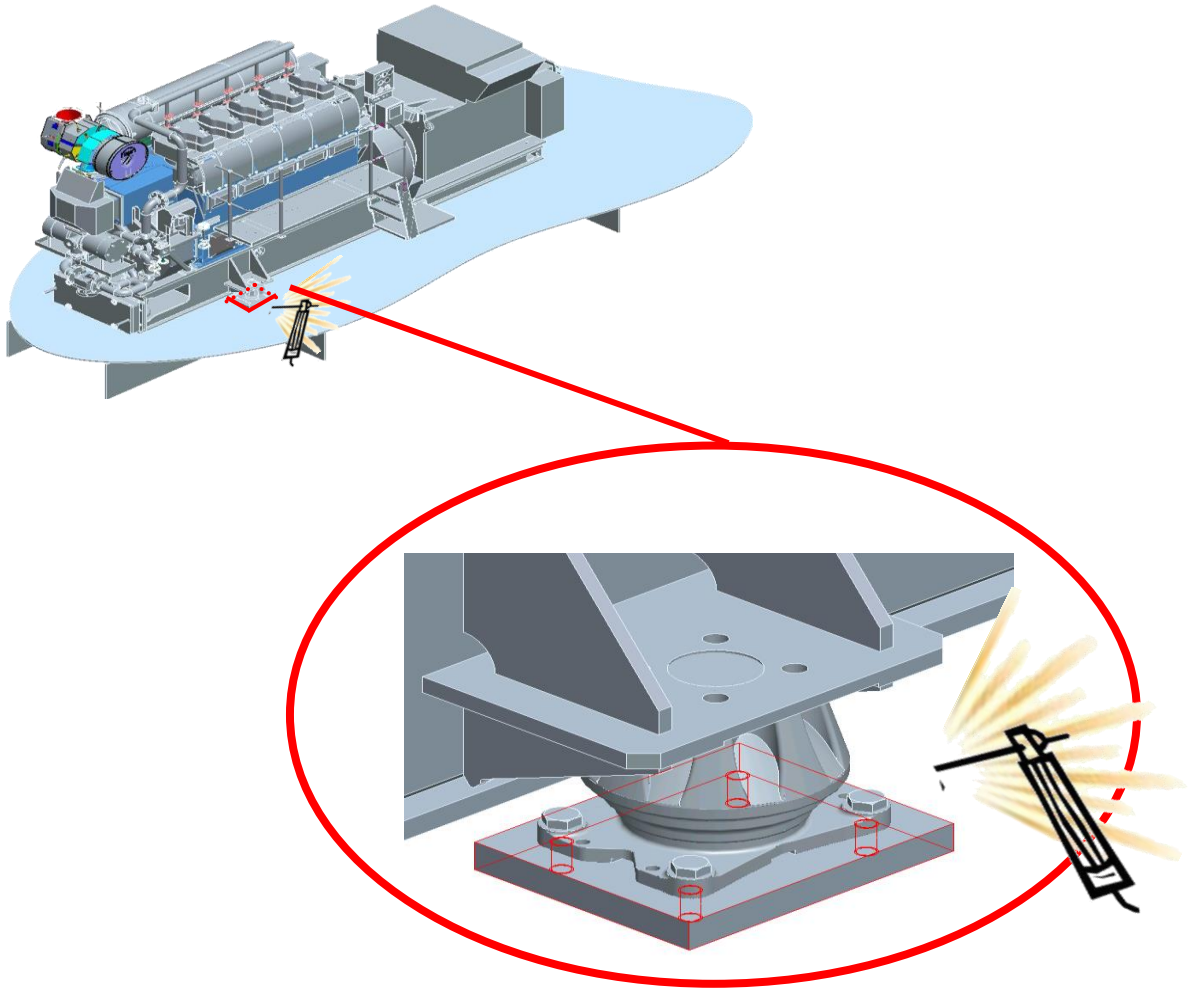
- GenSet lowered to ship’s deck

Installation Procedure

Setting New Standards by “Plug and Play”

- Footplate under conicals welded in place

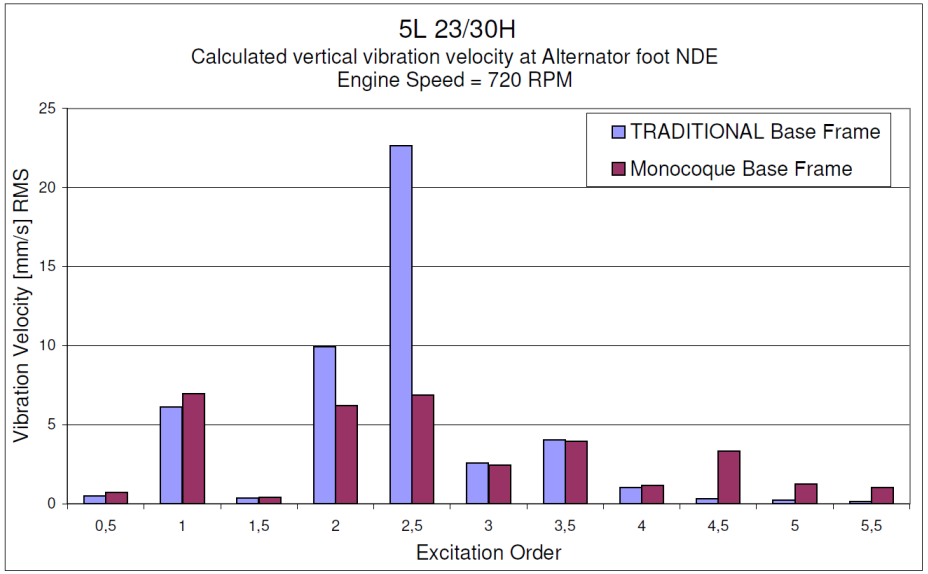
- Connect external supplies:
  - Cooling Water
  - Fuel Oil
  - Lub. Oil
  - Compressed Air System



Verification of Vibration

Setting New Standards by “Plug and Play”

- Vibration Level of 5 and 8L23/30DF was verified in June and September 2017
- Jinling S/Y is positive and confirmed cost- & time savings



June 2017

Reference with “Plug and Play”

Setting New Standards by “Plug and Play”

ESL Shipping

2 + 2 x 25000 DWT Cargo Carrier

Ice Class, **IMO Tier III** compliance

Yard: JinLing Ship Yard / China

Aux. Engine Maker: CMP

Shipset: 1 x 5L23/30DF + 2 x 8L23/30DF

Delivery of first shipset: Q3/2017

1 x 5L23/30DF	**625kW@750rpm**
2 x 8L23/30DF	**1,000kW@750rpm**

L23/30DF – A World Class Performer

Reference with “Plug and Play”

Setting New Standards by “Plug and Play”

Maersk Tanker – Delivery End 2018

10 x 115,000 DWT LR2-Tankers

Yard: DSIC – Dalian/China

Aux. Engine Maker: STX Engine

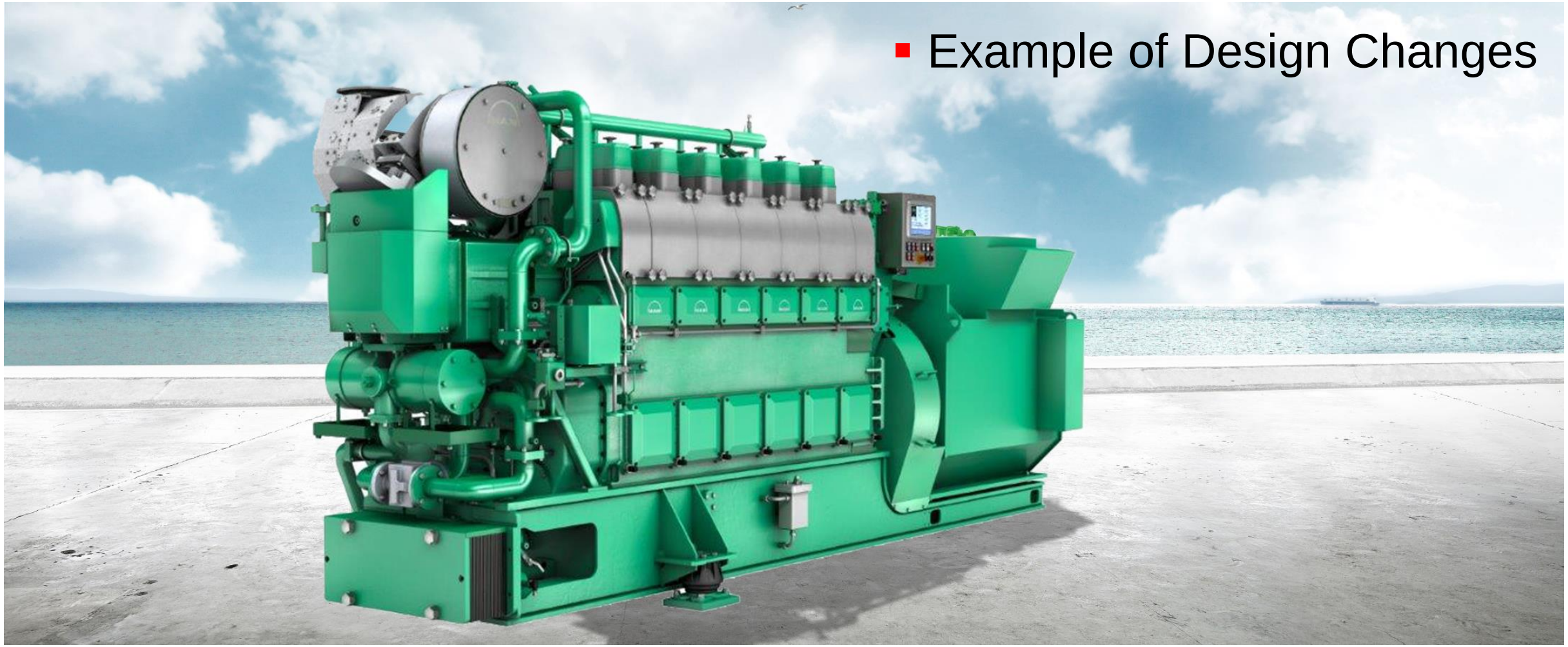
Shipset: 3 x 6L23/30H Mk2

“We have achieved reduction in production cost of a common-bed, 10% reduction in gen-set weight and 27% reduction in average vibration level through the application of MONOCOQUE type. Of course, I do not doubt that the owner will be satisfied.
I am deeply grateful for your support”.

No Byoung-hui,
Strength & Vibration Part / Engine R&D Institute
STX Engine Corporation

New L23/30H Mk 3

EcoGen – A Cost-Effective GenSet for 2020 Sulphur Cap



L23/30H Mk 3

New design

New fuel injection pump (ø21 mm) with sealed plunger

Cylinder head ready for sulphur cap 0.5% w. tribology 400 hard-facing valves

New enforced and continuous grain-flow forged crankshaft

New composite piston w. 2+1 ring configuration for low friction operation

Modulated casted exhaust sections and unified waste-gate for easy assembly

Re-use of SaCoS system for full system monitoring

New cylinder liner optimised for low friction operation

New marine-head connecting rod for high reliability

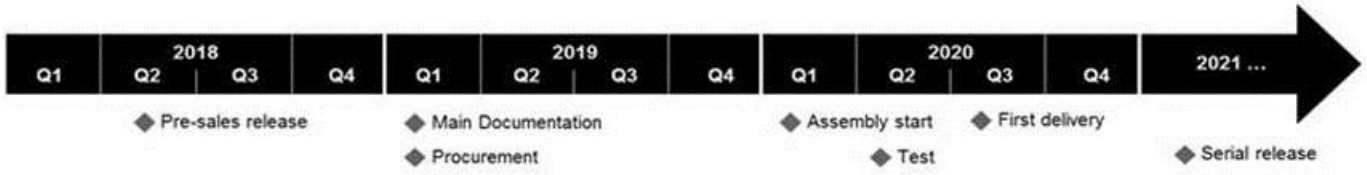
Structural connection between engine & alternator for lowest vibration level

L23/30H Mk. 3 has comprehensive design updates

Delivery Schedule

6L23/30H Mk 3 (1,200kW@900rpm)

- Earliest Delivery: Q3/2020
- Delivery Time: Approx. 10 – 12 months



Testing strategy:
Start of test after assembly of first engine (currently scheduled Q2/2020)

Test of first variant: 900rpm, 200kW/Cyl.
- Testing of Performance and Emission as well as Engine Validation
- Testing time estimated to be approx. 2 months

Test of second variant: 720/750rpm, 175kW/Cyl.
- Conversion time needed, mainly for TC and injection equipment
- Tests performed are to a wide extent the same as for 900rpm
- Testing time estimated to be also approx. 2 months

Test of other variants whenever first of its kind is built:
- 5L23/30H Mk3 500kW
- 8L or 9L 23/30H Mk3 900rpm à first engine with TCR18

Performance and Emission optimization (approx. 2 months)
- TC matching
- Fuel injection optimization
- Liquid fuel type variation
- Heat balance measurement for media system (Lube oil, cooling water)

Engine validation
- Safety system
- Component validation
  - Strain
  - Temperature
  - Pressure
  - Vibration
- Sound measurement
- Lube oil consumption

New L23/30H Mk 3

EcoGen – Benefits at a Glance

- Engine design based on L23/30H Mk 2 for Reliable and Stable Operation
- Designed for optimal performance under 2020 SOx-regulation
- Enlarged Power Range, now from 500kW – 1,800kW
- Higher power output per cylinder
- Reduced Fuel Oil Consumption
- Longest Time Between Overhaul in Class
- Minimum ”Black Smoke”
- Improved con-rod design applying the marine-head-type design
- Two-Part Piston design for Easy and Cost-Effective Maintenance
- Fast and easy installation with unique base frame design / “Plug and Play”
- Modern Safety and Control System by genuine MAN SaCoSone

- Perfect choice for Shipping Companies who operates a diverse fleet of merchant ships because EcoGen can be applied in most ships, thereby reduce spare part stock and makes planning of sign on schedule for the technical staff

Thank You For Your Attention

All data provided in this document is non-binding.

This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.