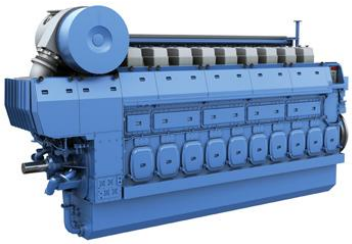
Energy Efficient Gas Propulsion Systems with Hybrid Shaft Generator

Tobias Haack – Sales Manager

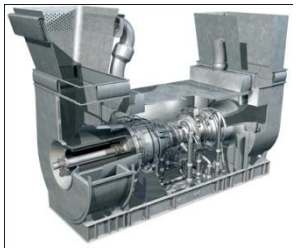
A comprehensive range of products….

Ship design and integrated ship systems

Diesel and gas engines

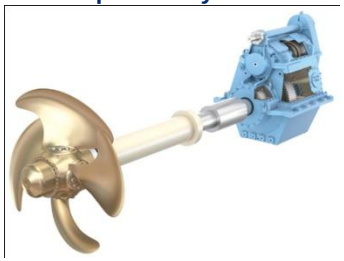


Gas turbines

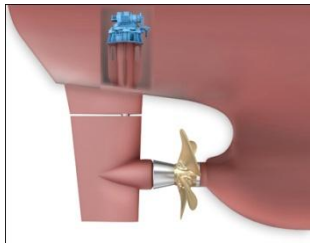


Automation and control (DP)

Propulsion systems



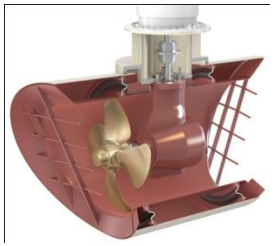
Steering systems



Electrical podded propulsors

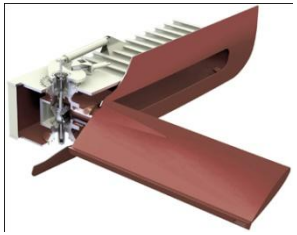
Azimuth thrusters

Tunnel thrusters

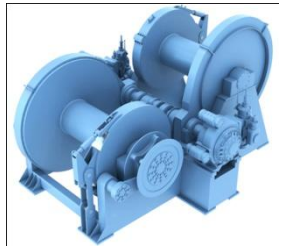


Waterjets

Stabilising systems



Winch systems

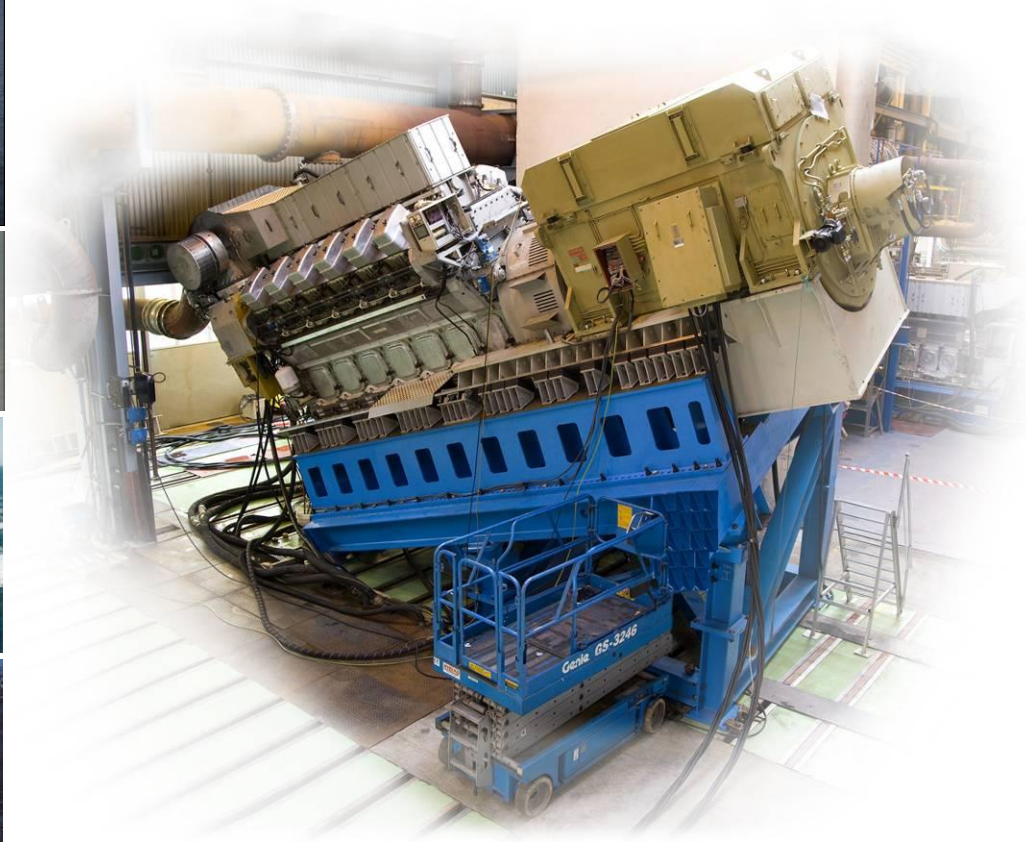


Rolls-Royce Marine Engines Bergen

- New engine block, cylinder head and connecting rod machining centres (end 2008)
- Over 6300 engines sold world wide, and more than 4000 engines still in operation
- 8 test cells + development test cell
- Docking facility for sea transportation
- RRM Foundry nearby
- **History:**
  - Established in 1943
  - First diesel engine delivered 1946
  - First HFO engine delivered in 1963
  - First lean-burn gas engine delivered in 1991
  - First marine gas engines for gas electric propulsion delivered 2006
  - First 2nd generation marine gas engine delivered primo Dec. 2010

Rolls-Royce marine engines

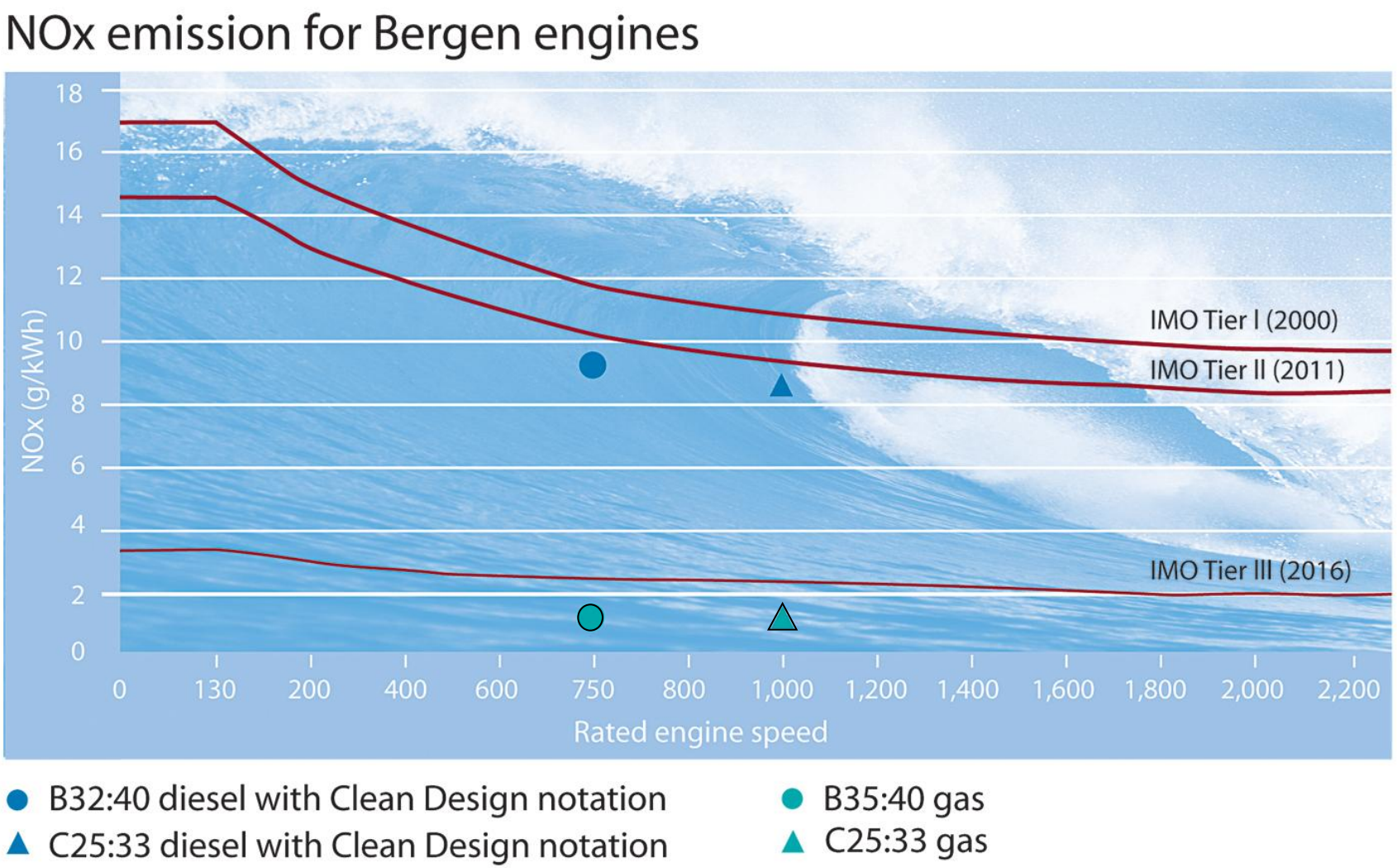
Designed for robustness, harsh operational environments, and exceptional levels of reliability



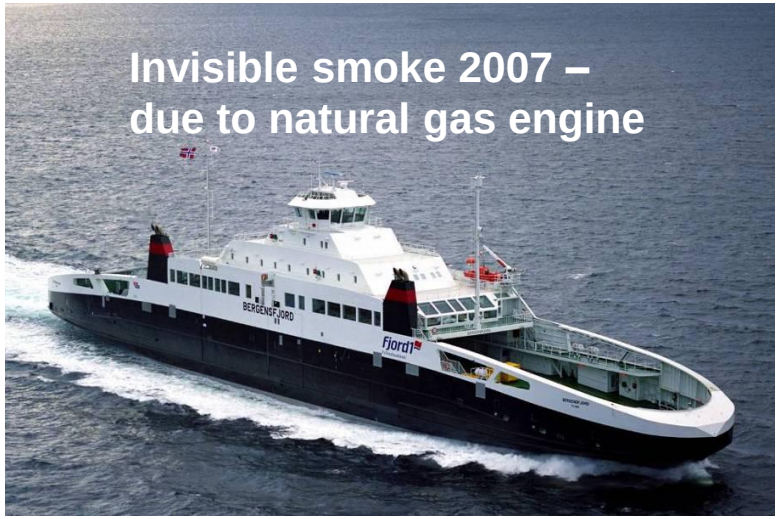
Technology Drivers

- Emissions
  - NO_x
  - SO_x
  - Smoke / Particulates
  - CO_2
- Fuel availabylity and price!!!
  - BP statistics: Reserve for gas is 63 years but only 46 years for oil
  - Prof.Dr.-Ing. Rulfs, TUHH:
    After 2030 HFO will not be the dominating cheap ship fuel anymore and will disappear around 2040
  - Exept for short periods LNG was always cheaper then HFO:
    - HFO currently approx. 650$/t
    - MGO currently approx. 1000$/t
    - LNG currently approx. 500$/t (depending on shipping costs)

NOx Emission limits IMO



Smoke issues…..



EEDI: CO_2 Emissions

IMO has introduced the *Engergy Efficiency Design* Index for newbuildings
to decrease CO2 Emmissions from the shipping sector:

Using the numbers of MEPC.1/Circ.681:

- **1 ton** of Oil lead to **3.206 tons** of CO2 Emmisions
- **1 ton** of LNG lead to **2.75 tons** of CO2 Emissions
- The fuel oil consumption of a typical Diesel engine is **183g/kWh**
- The fuel oil consumption of a Rolls-Royce gas engine is **150 g/kWh**

CO2 Reduction of approx.30%
Means a 30% lower attained EEDI

But what about the Methan Slip?

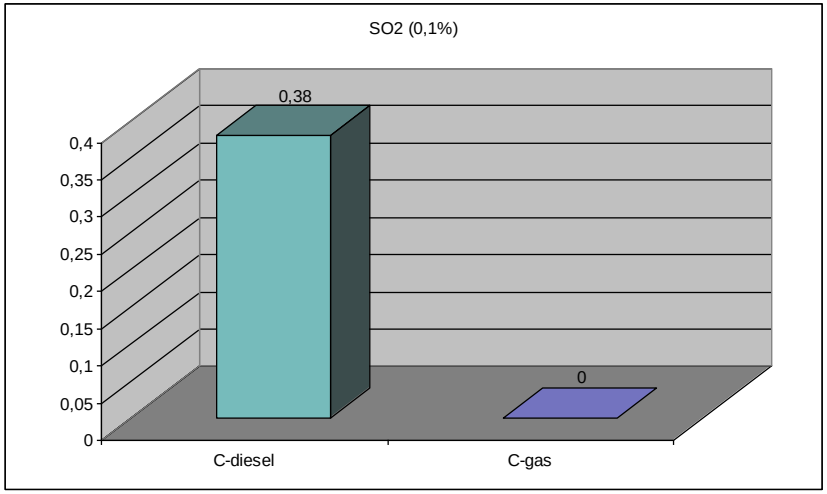
- Methan has a approx. 20 times the Greenhouse effect of CO2
- The Rolls-Royce lean burn gas engines have a Methan Slip of about 3 g /kWh (measured an confirmed by 3rd parties)

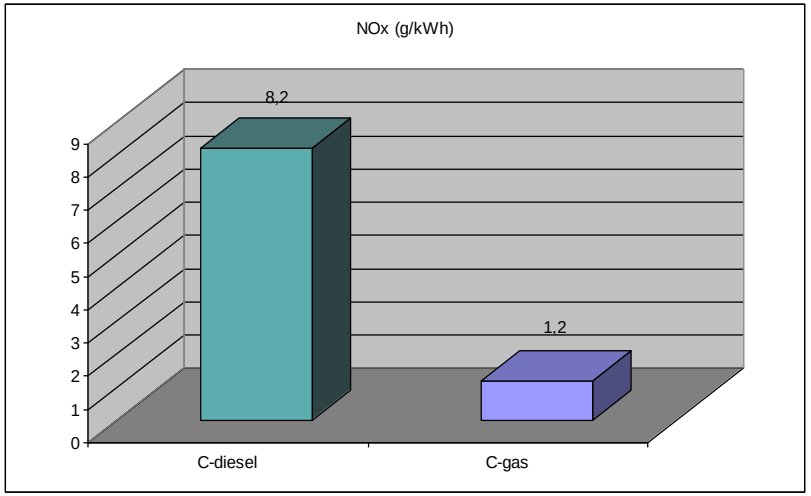
Taking MPEC conversion factors into consideration this still means approx.

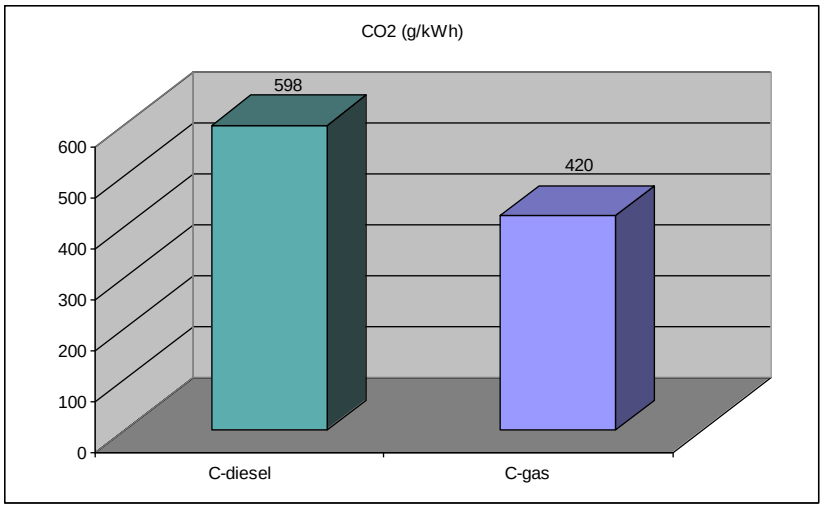
20% less C02

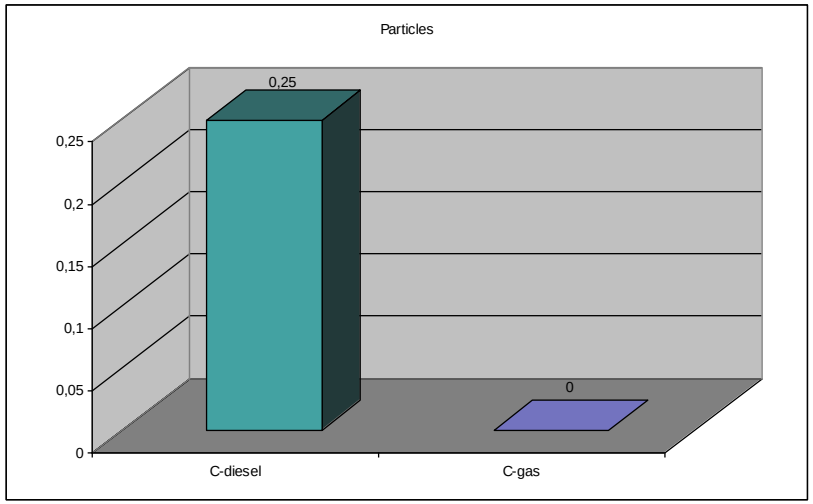
Emissions - MDO versus Natural gas

SO2 med S = 0.1%



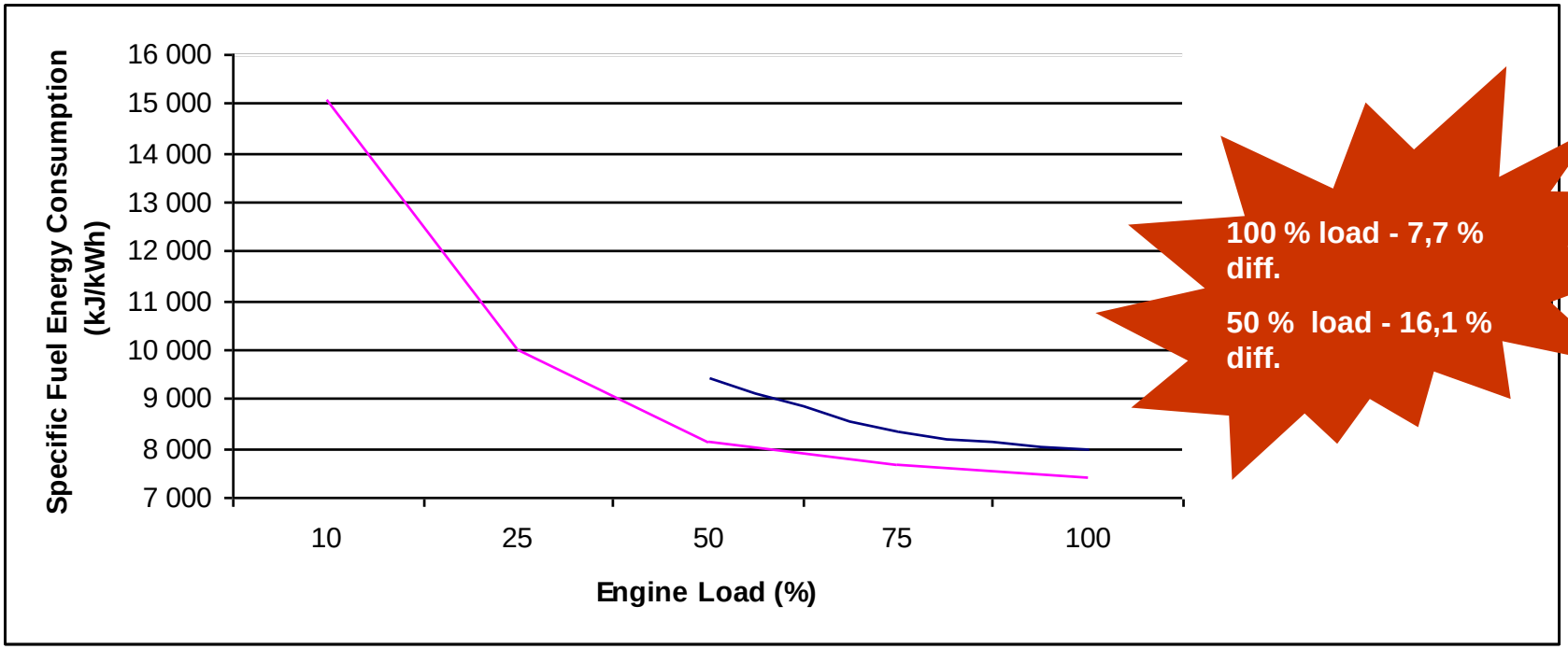






But what about the money ?

Gas consumption comparison –
Generators – constant speed: Single fuel vs Dual fuel



How many years of operation until the ”risk premium” is covered ?

Just a simple example…

6000 running hours @10 000 kW

MGO	**183 g/kWh**	**950 $/t**
Urea	**9 g/kwH**	**800 $/t**
LNG	**150 g/kWh**	**550 $/t**

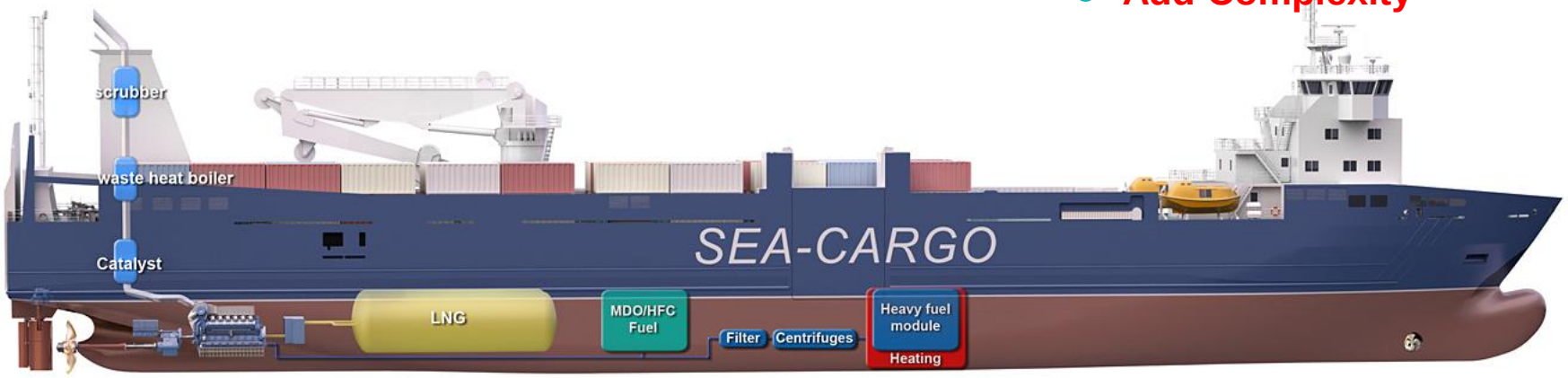
Fuel costs of approx. 5 Million $
vs. 11 Million $

Dual fuel system meeting IMO Tier III :

SCR reduce NOx	Scrubber reduce SOx	Filter reduce PM

More cost due to

- **Add Energy = CO2**
- **Add Urea**
- **Add maintenance**
- **Add Complexity**



Lube oil change over	Fuel change over	Water Separator	Oil Separator	Waste Material

Natural gas system meeting IMO Tier III :

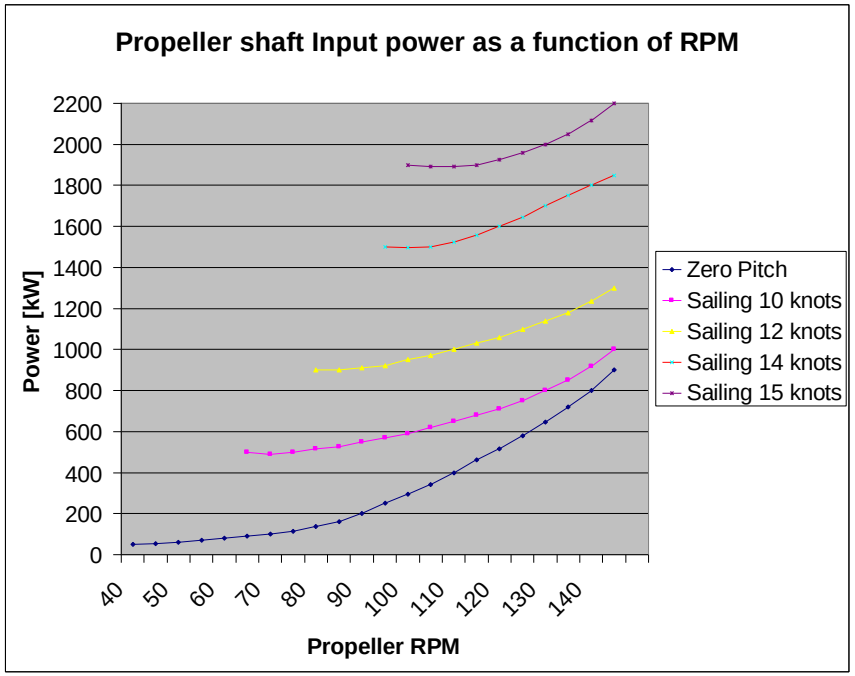
Traditional Merchant Ship Propulsion

- Single engine
- Single mechanically driven propeller through a reduction gearbox
- Shaft generator used for production of electrical power at sea and powering tunnel thrusters during manoeuvring

- Pros
  - High efficiency
  - Simplicity
  - Reliability
  - Low cost
- Cons
  - Shaft generator requires constant RPM
  - Losses at propeller when operating at reduced speed

Variable Speed Operation

- Operation in combinator mode
  - Variable engine speed and propeller pitch
- Maintains efficiency of propulsion system during part load
  - Reduced rotational losses at propeller
  - Engine operates at better specific fuel consumption

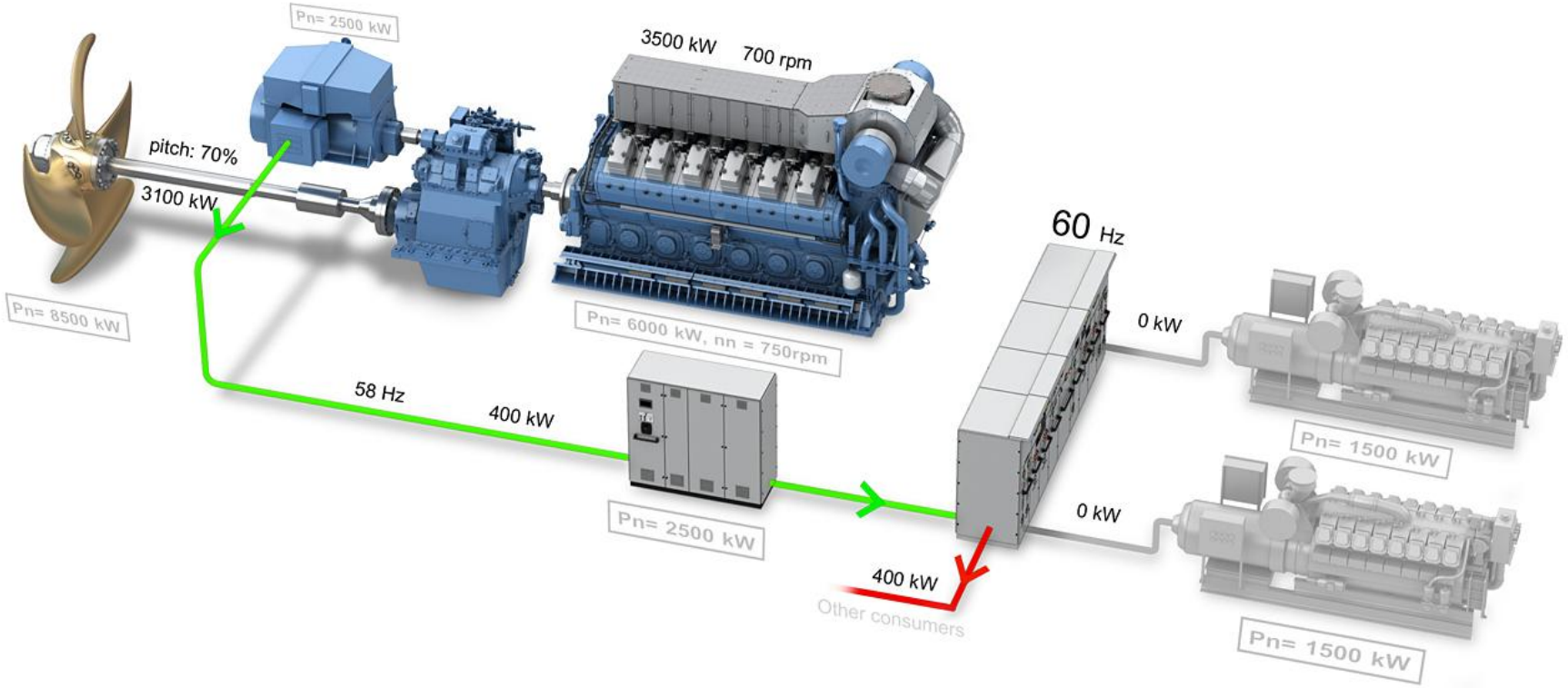


Hybrid Shaft Generator

- Conditions power coming from the shaft generator
- Switchboard is supplied with constant voltage, constant frequency and matched phase angle
- Allows use of combinator mode during generation from shaft generator
- Enables recovery of power previously wasted through propeller rotational losses
- Significant efficiency gains

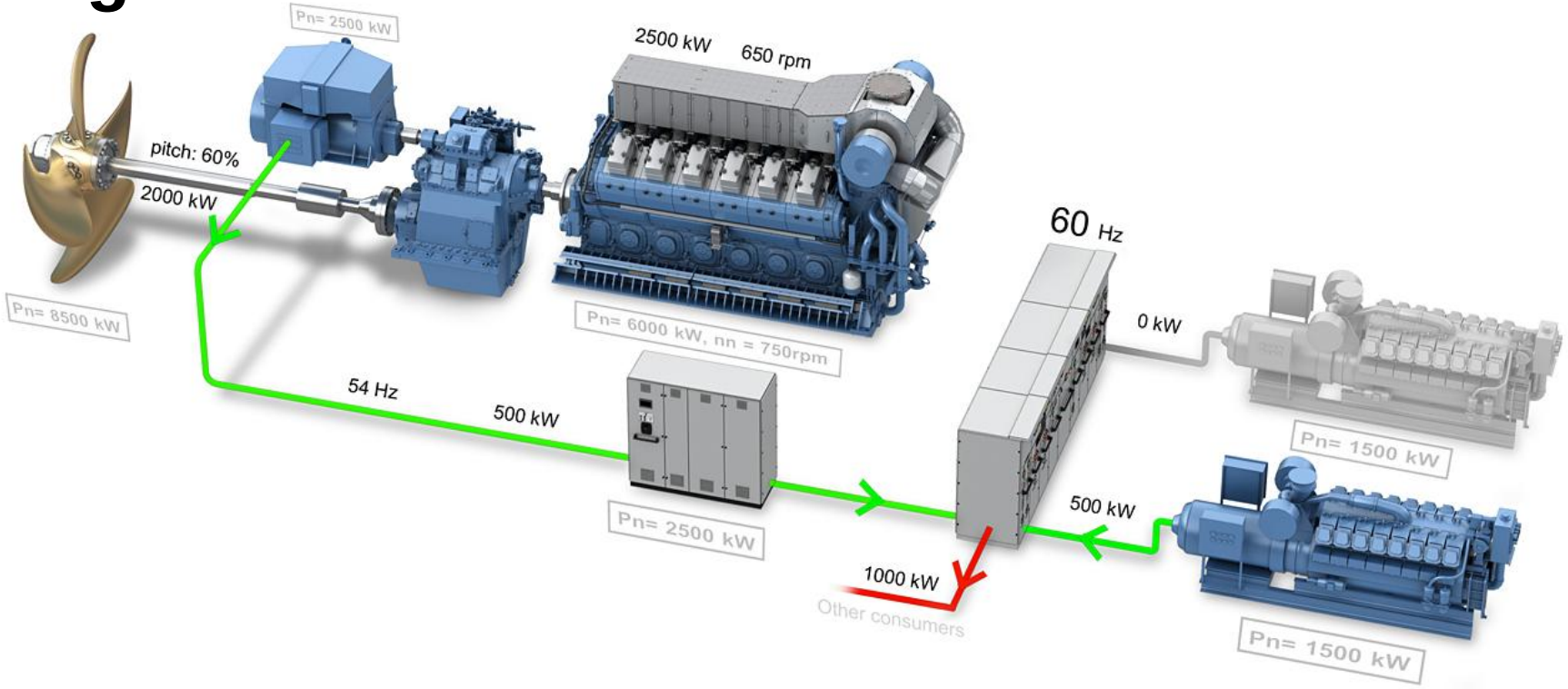
Hybrid Shaft Generator

- **Combinator mode, normal steaming**



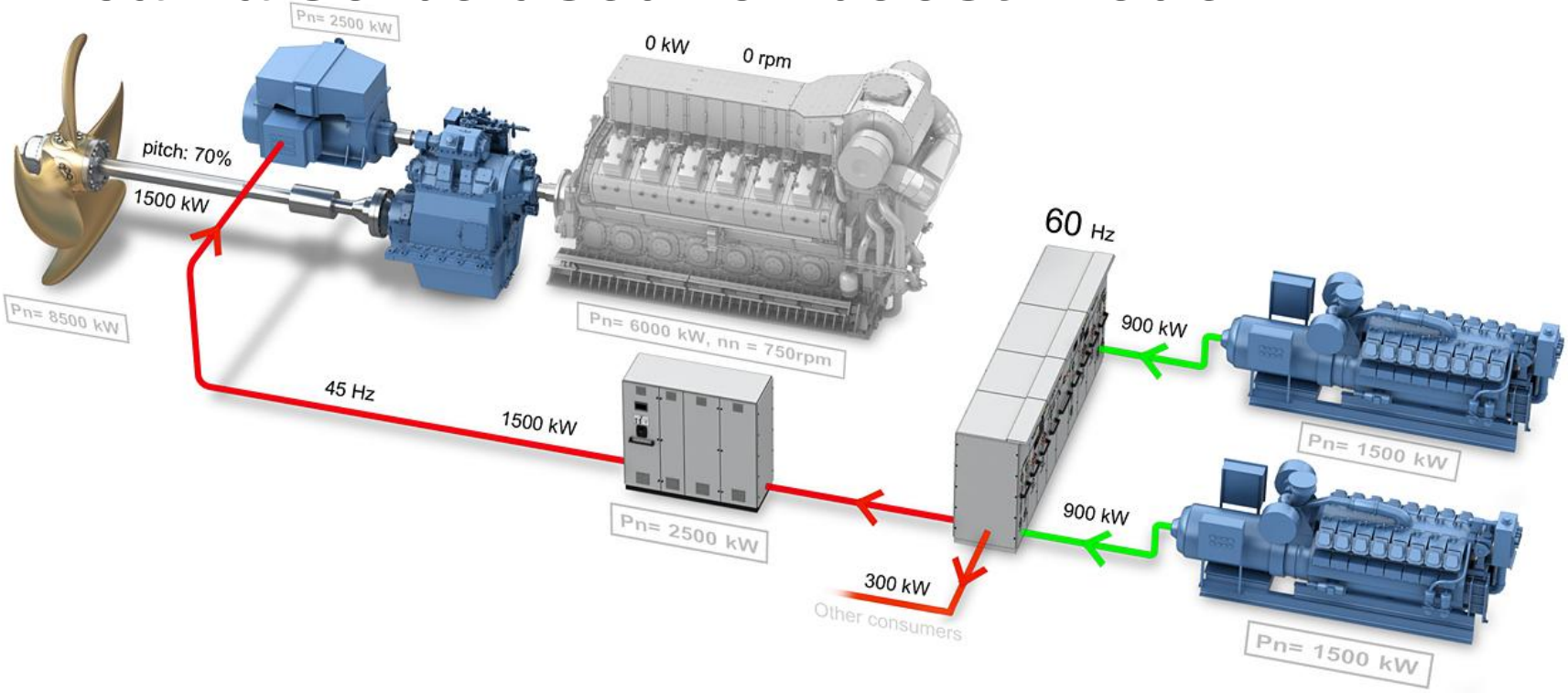
Hybrid Shaft Generator

- **Combinator mode with parallel generation**



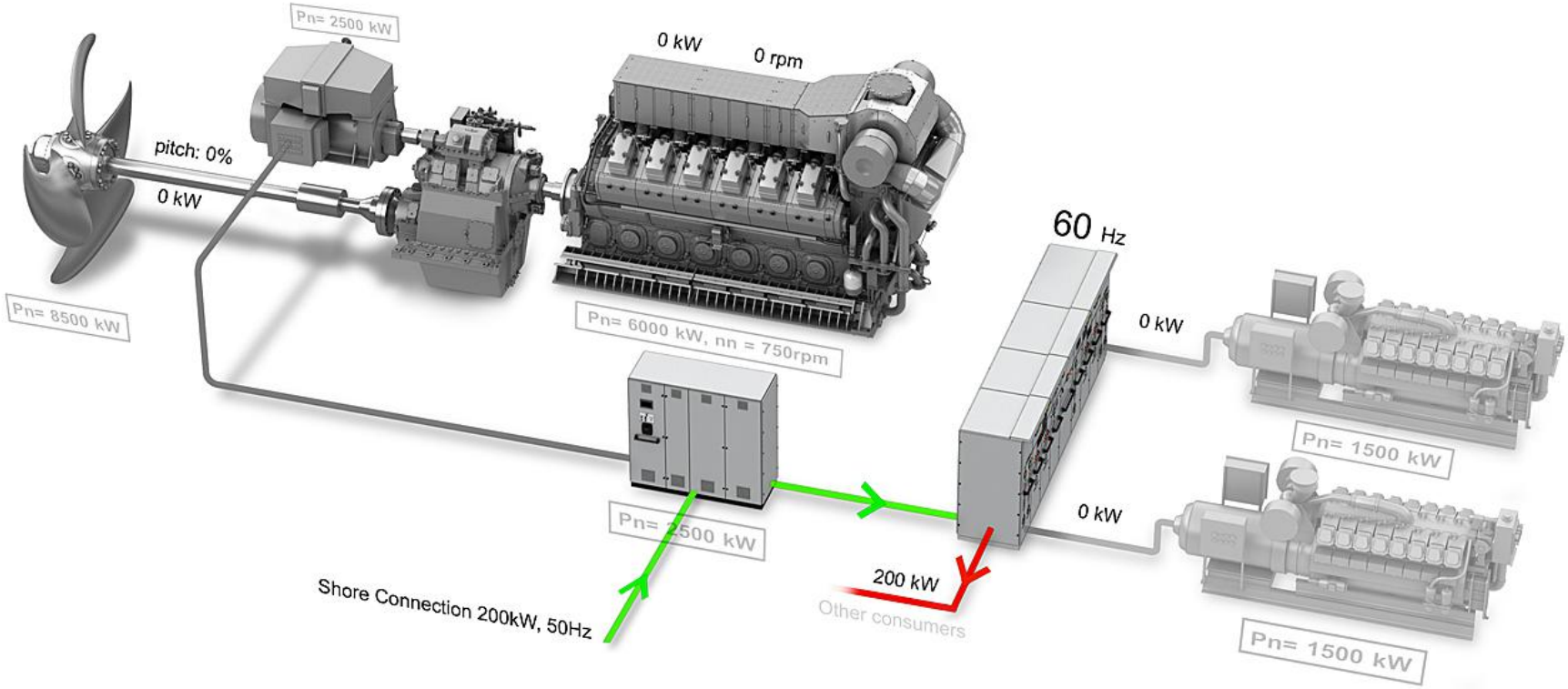
Hybrid Shaft Generator

- **Diesel/gas electric mode, main engine can also be used for boost mode**



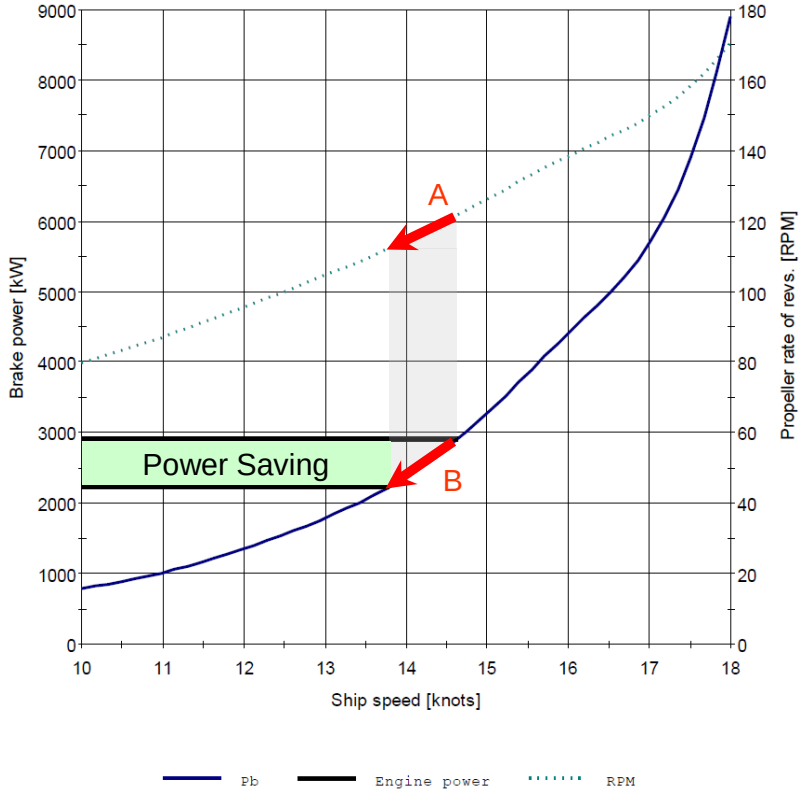
Hybrid Shaft Generator

- **Shore connection mode**



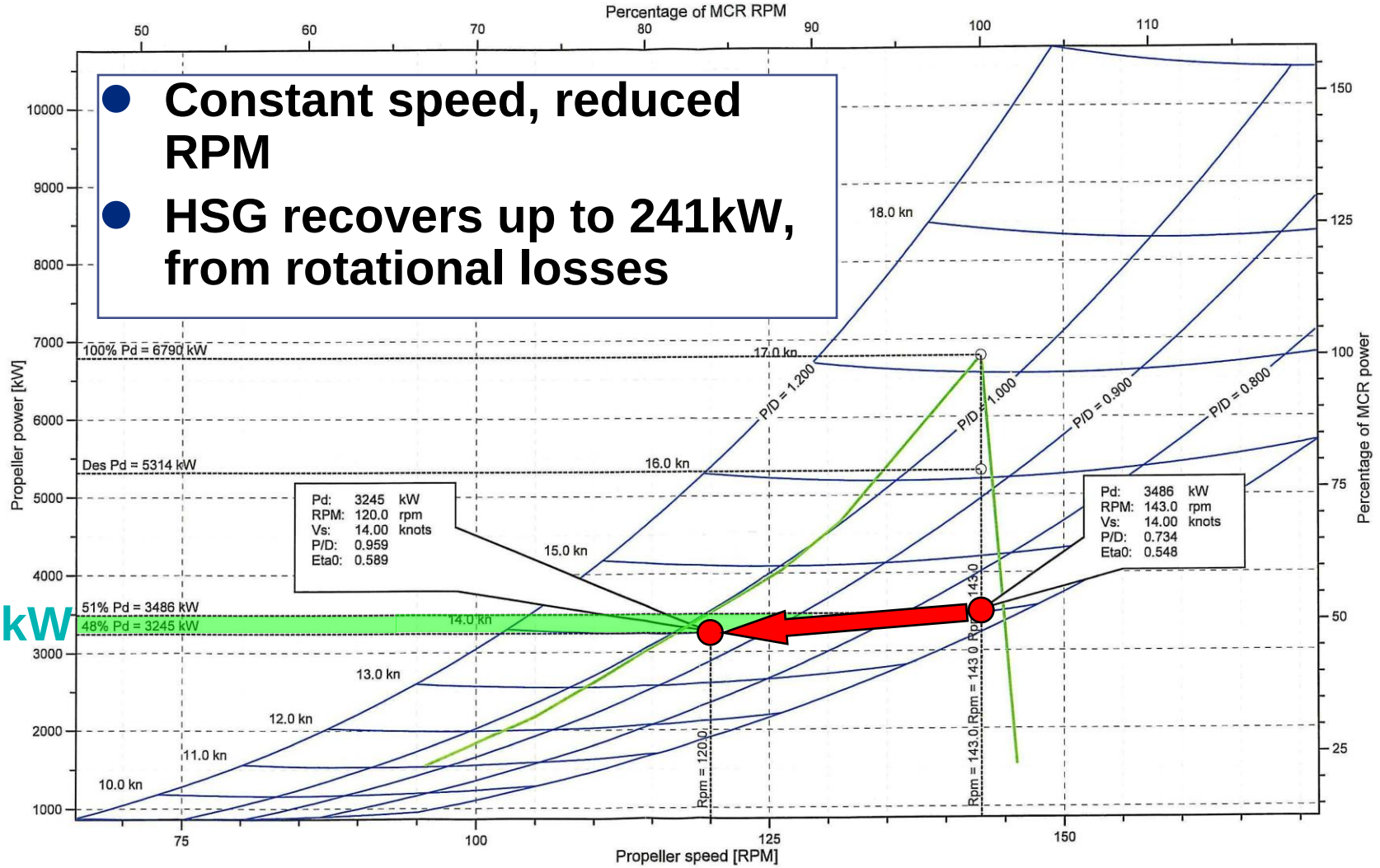
Hybrid Shaft Generator Example 1

- Reduction in vessel speed
- Reduction in propeller RPM (arrow A)
- Vessel propulsion power requirement reduces (arrow B)
- HSG can still supply switchboard with electricity at correct frequency and voltage despite RPM change



Hybrid Shaft Generator Example 2

- Constant speed, reduced RPM
- HSG recovers up to 241kW, from rotational losses



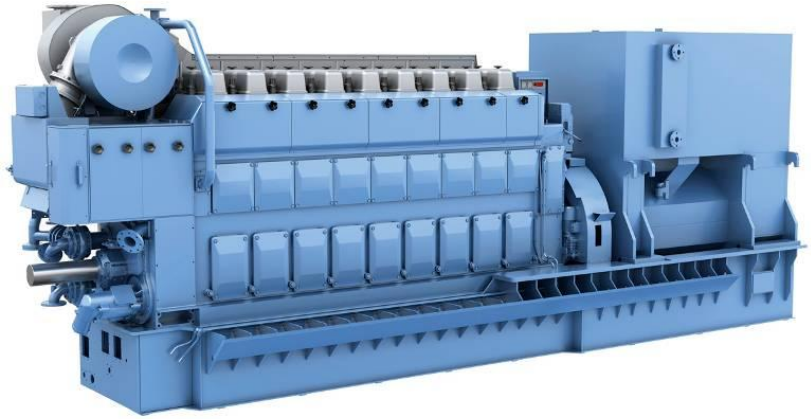
241kW

Ships on Order

- Sea-Cargo 132.8m gas fuelled cargo vessel
  - Believed to be world's first LNG main propulsion vessel with simple mechanical propulsion
  - 5,600 tonnes cargo capacity
  - 1,140 lane-metres RoRo capacity
  - Up to 94TEU of containers on deck
- NSK Shipping 70m fish food carrier
  - Approximately 2000 tonnes fish food pellets capacity
  - DP0 capability
  - Rolls-Royce gas engine, gas system, shaft generator, propeller, tunnel thrusters, controls and automation

The gas engines

- **Types: C26:33L6-8-9**
- **Bore: 260 mm**
- **Stroke: 330 mm**
- **Power: max. 244 / 270 kW / cyl**
- **Speed: 600 – 1000 rpm**
- **Power range: 1460 – 2430 kWmech**



References:

Fjord1 Gas fuelled ferry (3xC26:33L9AG + 1xC25:33L9ACD)

Island Offshore – UT776CDG PSV (2xC26:33L9AG + 2xC25:33L6ACD)

Fjord1 Gas fuelled ferry (1xC25:33L9AG retrofit)

NSK Shipping - Bulk carrier (1xC26:33L6PG)

Rolls-Royce

The gas engines

- **Types:** B35:40L6-8-9 &
  B35:40V12, -16
- **Bore:** 350 mm
- **Stroke:** 400 mm
- **Power:** 420 / 440 kW / cyl
- **Speed:** 500 - 750 rpm
- **Power range:** 2520 - 8750 kWmech

References:

Sea-Cargo, RoRo vessel
(1xB35:40V12PG)

Torghatten Nord, Gas ferry
(2 x 1xB35:40V12PG
2 x 1 x C26:33L9PG)

Lean Burn Gas engines

- More than 500 sold, over 400 gas engines in operation
- More than 20 mill running hrs experiences
- More than 140.000 running hrs
- Plants operating 8.500 hrs/year
- The five car ferries (16 engines) have logged more then 30000 running hours & more than 50000 port calls.

Summary

- Rolls-Royce lean burn Gas engines solve all emission regulations at once
- With the Rolls-Royce lean burn Gas engine the EEDI can be reached even with most current ship designs
- The Rolls-Royce lean burn Gas engine is superior in fuel oil consumption compared to Diesel- and DF engines.
- The small increase in investment costs pays off easily especially in combination with the Hybrid Shaft generator
- The Rolls-Royce lean burn Gas engine is a proven technology and LNG infrastructure is not a problem

Rolls-Royce