Siemens Marine Solutions

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Vessel System Design & Application of Technology For a Responsible and Sustainable Maritime Industrial Sector

Hybrid Drives and Application to Arctic Operations.

MARITECH - 2009

Premise

Marine transport as a major global transport system has been and remains instrumental to globalisation.

In order for this Industry to demonstrate:

- **Responsibility for its impact on the sensitive Global Environment, and;**
- **a Commitment to its Customers for the Economical, Efficient and Effective delivery of the Transportation role.**

…

Premise

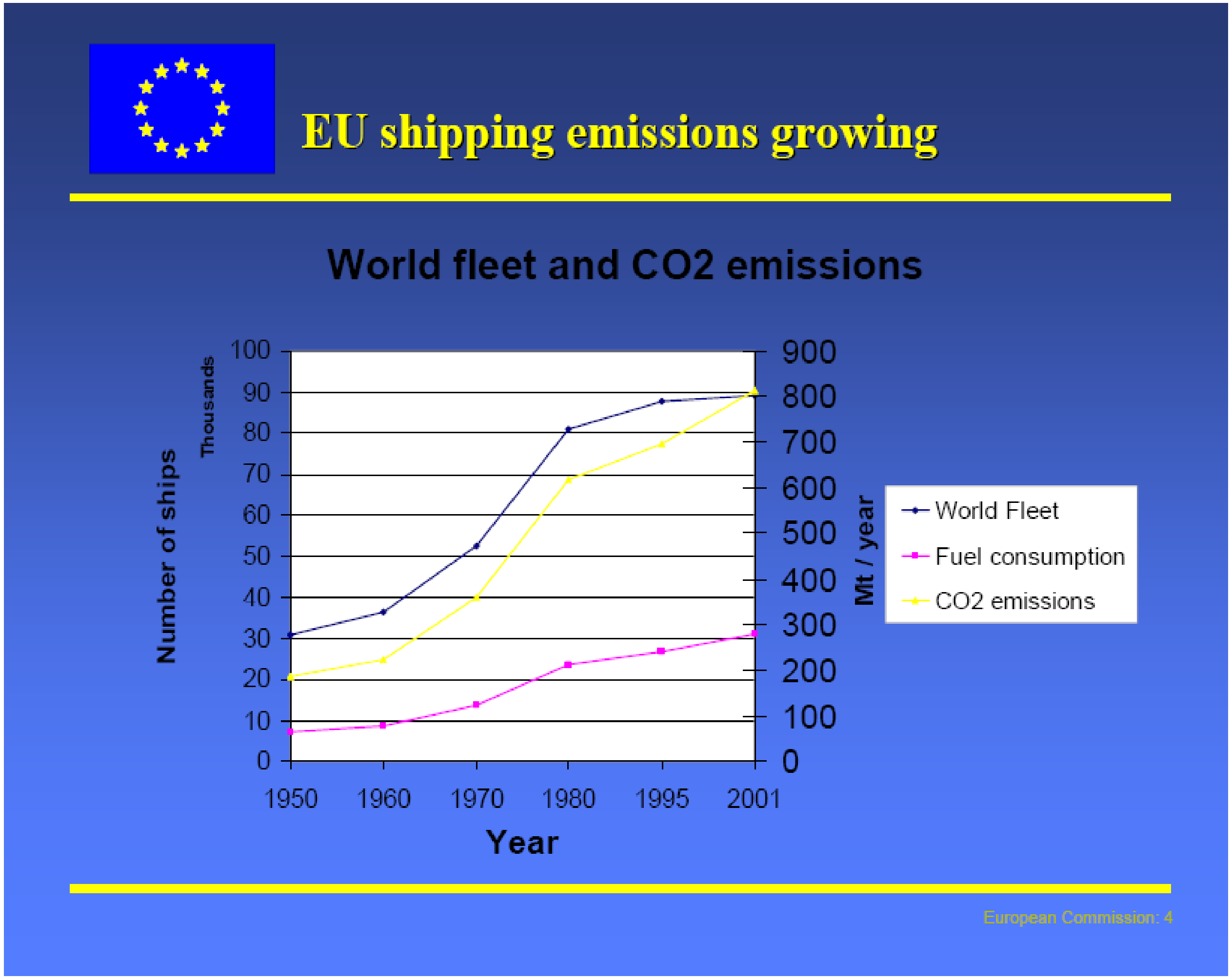
It must make every effort to innovate and stretch the capabilities of available technology to;

- **Achieve the most efficient use of hydrocarbon fuels,**
- **Provide least cost/tonne-mile,**
- **Release least emissions possible into the atmosphere and oceans, seas, lakes and rivers of the world,**
- **While delivering the lowest vessel „cost to own“ for a life-cycle which averages in excess of 3 decades.**

Fortunately, all of these undertakings have a common aspect in that they are positively affected by a focus on Efficiency.

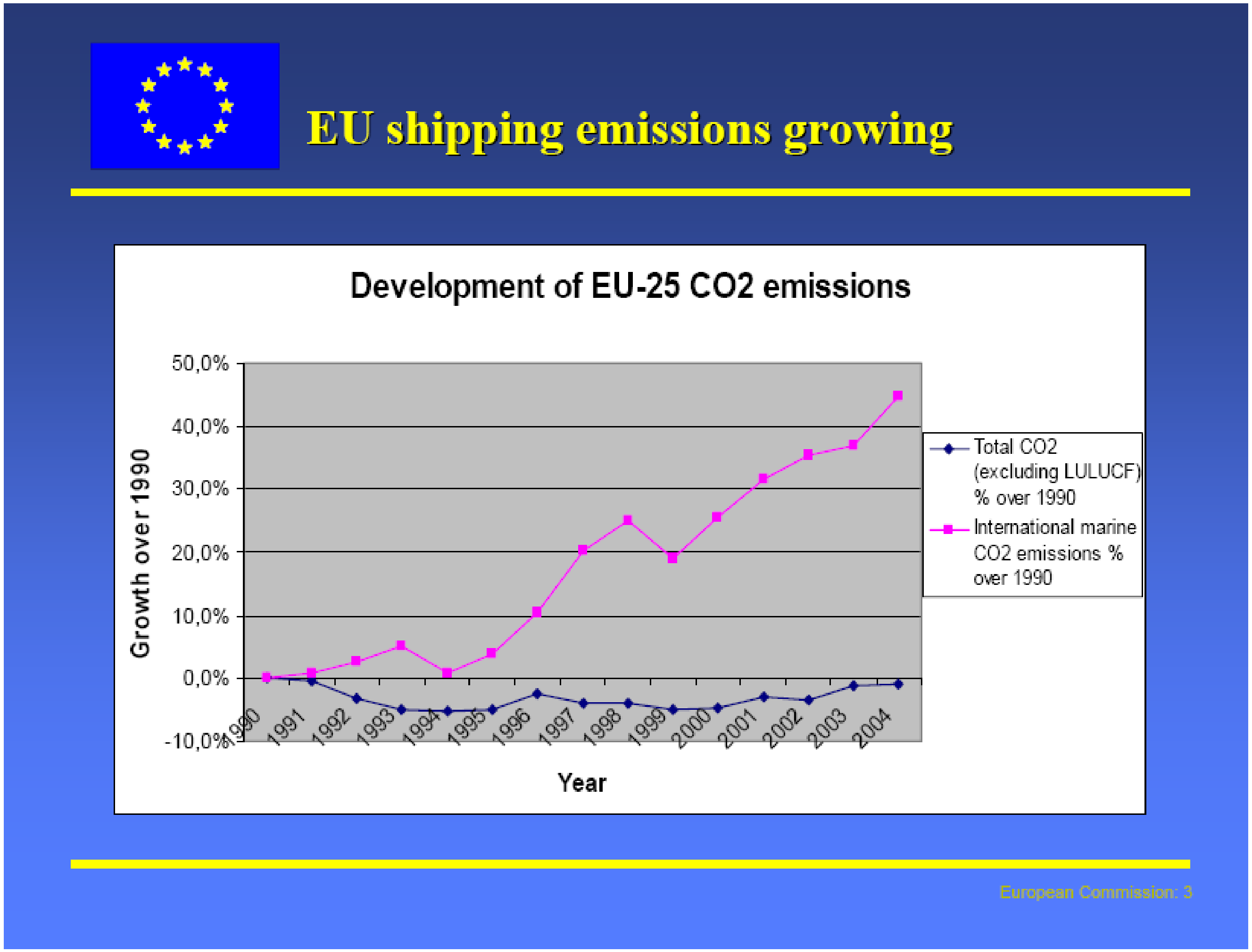
Gaseous emissions – „Stoker‘s greetings“

Background



EU shipping emissions growing
World fleet and CO2 emissions
Thousands
Number of ships
100
90
80
70
60
50
40
30
20
10
0
900
800
700
600
500
400
300
200
100
0
Mt / year
1950
1960
1970
1980
1995
2001
Year
World Fleet
Fuel consumption
CO2 emissions
European Commission: 4

Background


EU shipping emissions growing
Development of EU-25 CO2 emissions
Growth over 1990
50,0%
40,0%
30,0%
20,0%
10,0%
0,0%
-10,0%
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
Total CO2 (excluding LULUCF) % over 1990
International marine CO2 emissions % over 1990
European Commission: 3

Market - Commercial Marine
New Orders by Main Shipbuilding Areas
China overtakes Japan

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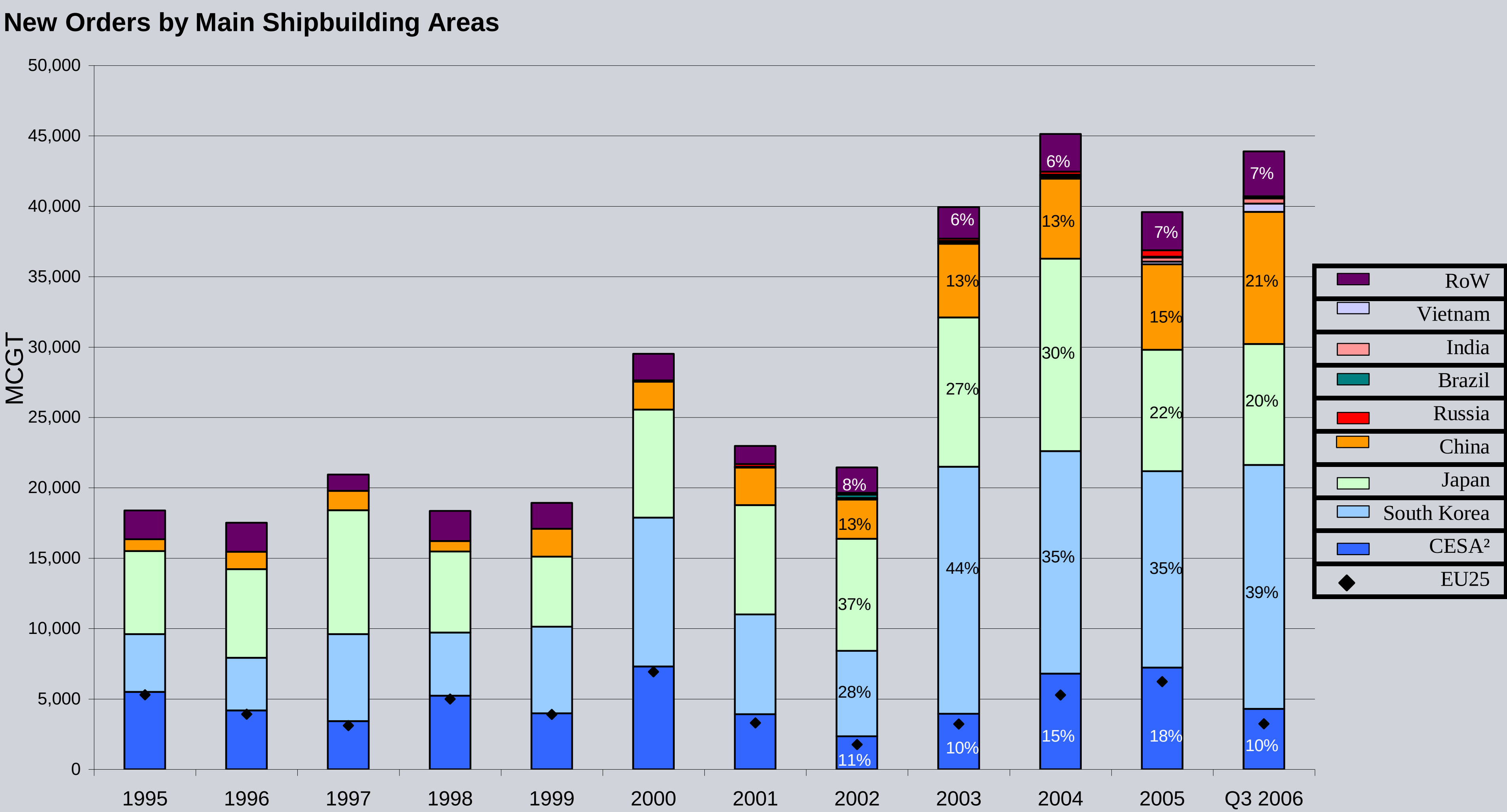

Source: CESA

What does this mean "Globally"?

More shipping tonnage, growing consistently to feed the needs of the world Suppliers and Consumers, thus

More installed horsepower burning ever more hydrocarbons and emitting ever more CO_2. (remember rate of growth of Marine emissions per previous slides).

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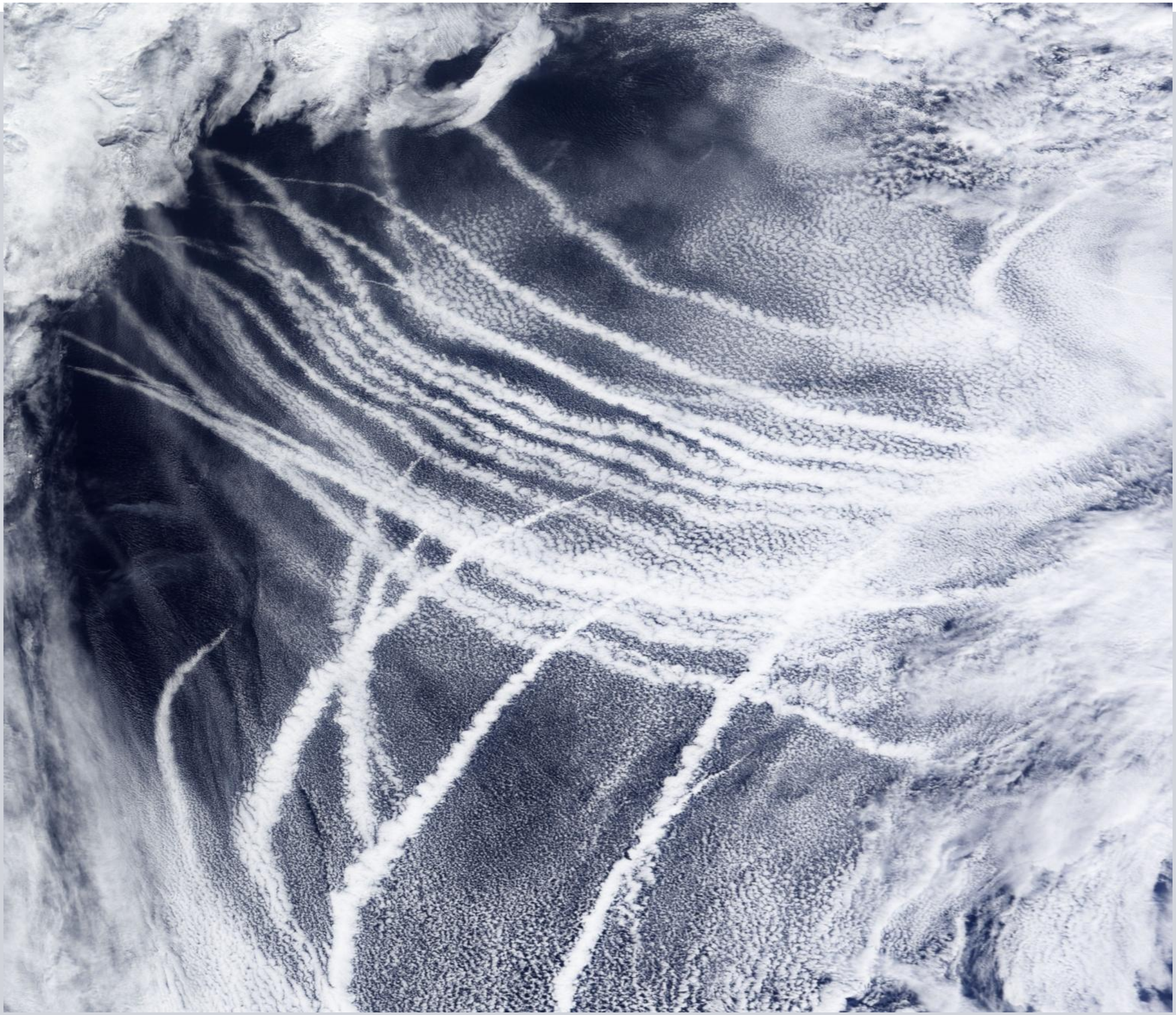
With what Effect?



Limited, I IS IN MAS

Technology Application for environmentally friendly shipping

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There are various ways to reduce vessel emissions. The ones discussed here, deal with optimizing the efficiency of the whole ship (energy) system. This approach is based on the conclusion that **if** the total installed power can be reduced, the required prime movers can be smaller and operated at better load levels and therefore better efficiencies, and by reducing total kW installed power you will necessarily reduce the amount of fuel burnt under any operating condition.

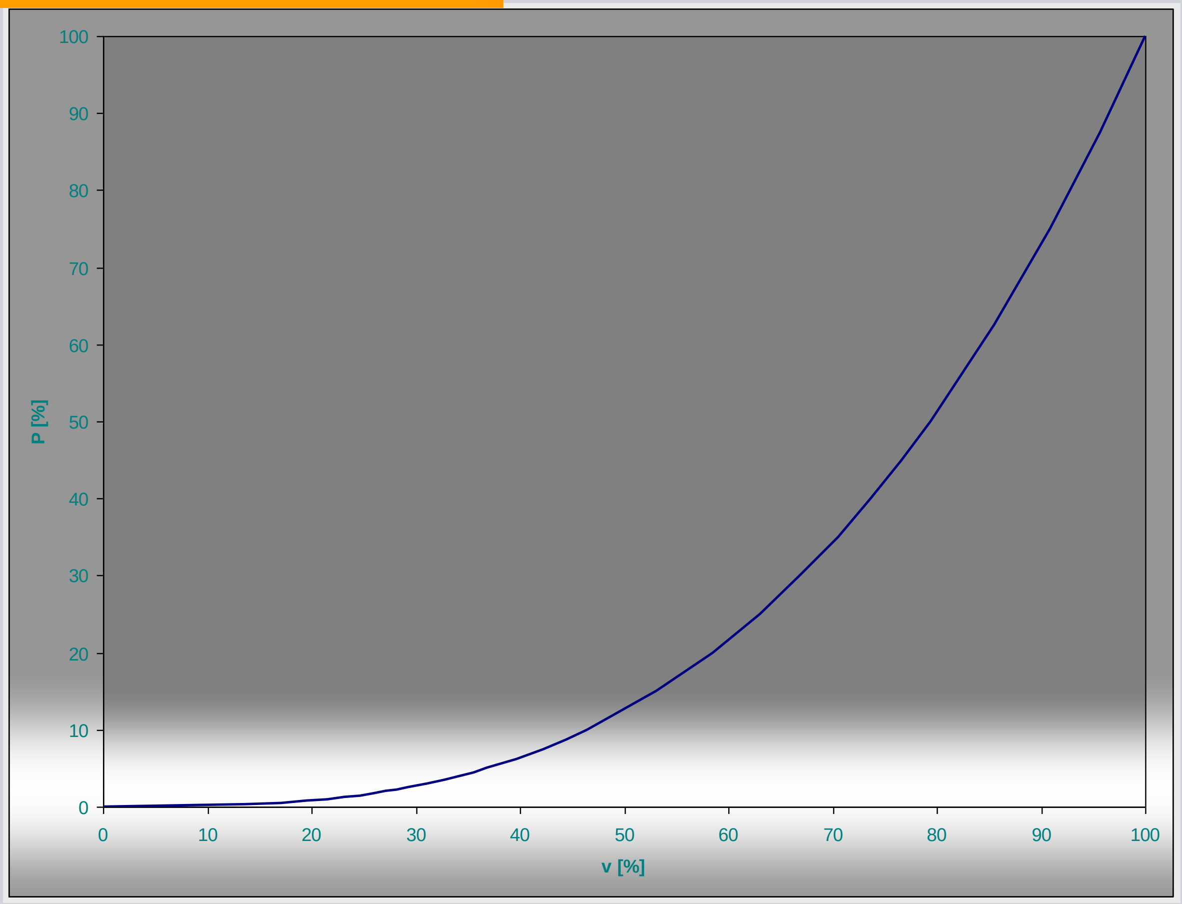
Hybrid Propulsion

- **Definition: Hybrid propulsion is the technical term for propulsion systems which are the combination of a mechanical, and electric propulsion and vessel service system – however holistically integrated.**

- **Some key indicators for potential Hybrid Propulsion candidates:**
  - **Large variations in propulsion- and service power demand**
  - **Max. power demands for prop. and vessel service power systems are not simultaneous**
  - **The max. service power demand does not justify an all electric concept**
  - **The propulsion plant is required to satisfy very different operating conditions**
  - **Significant amount of low propulsion power demand,**

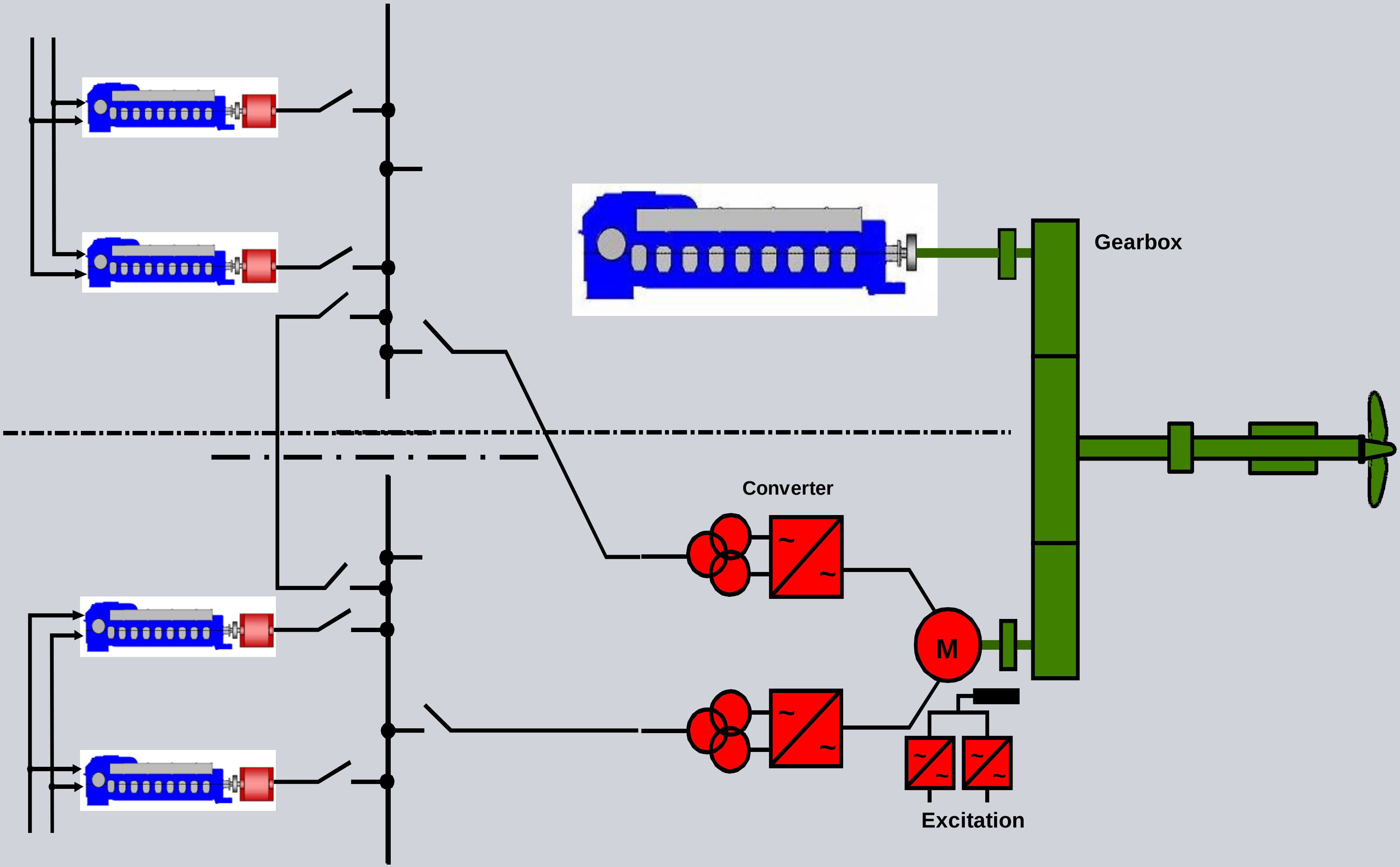
Example of a ship propulsion power diagram

Power / Speed Relation



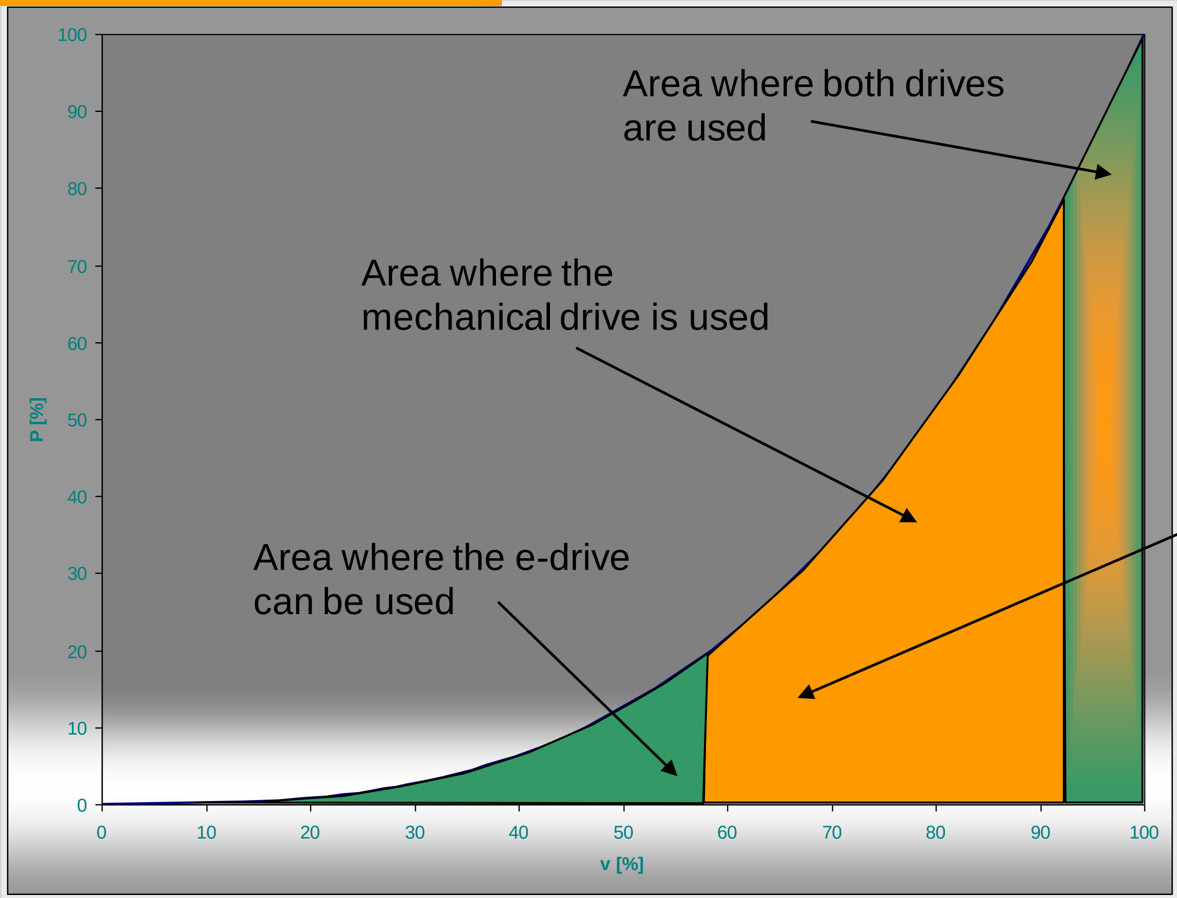
Hybrid propulsion

Electrical Booster Drive Application



Example of a ship propulsion power diagram

Power / Speed Relation



Area where PTO/PTI operation is possible for increased economy and reduced emissions

Hybrid propulsion
Electrical Booster Drive with Waste Heat Recovery System

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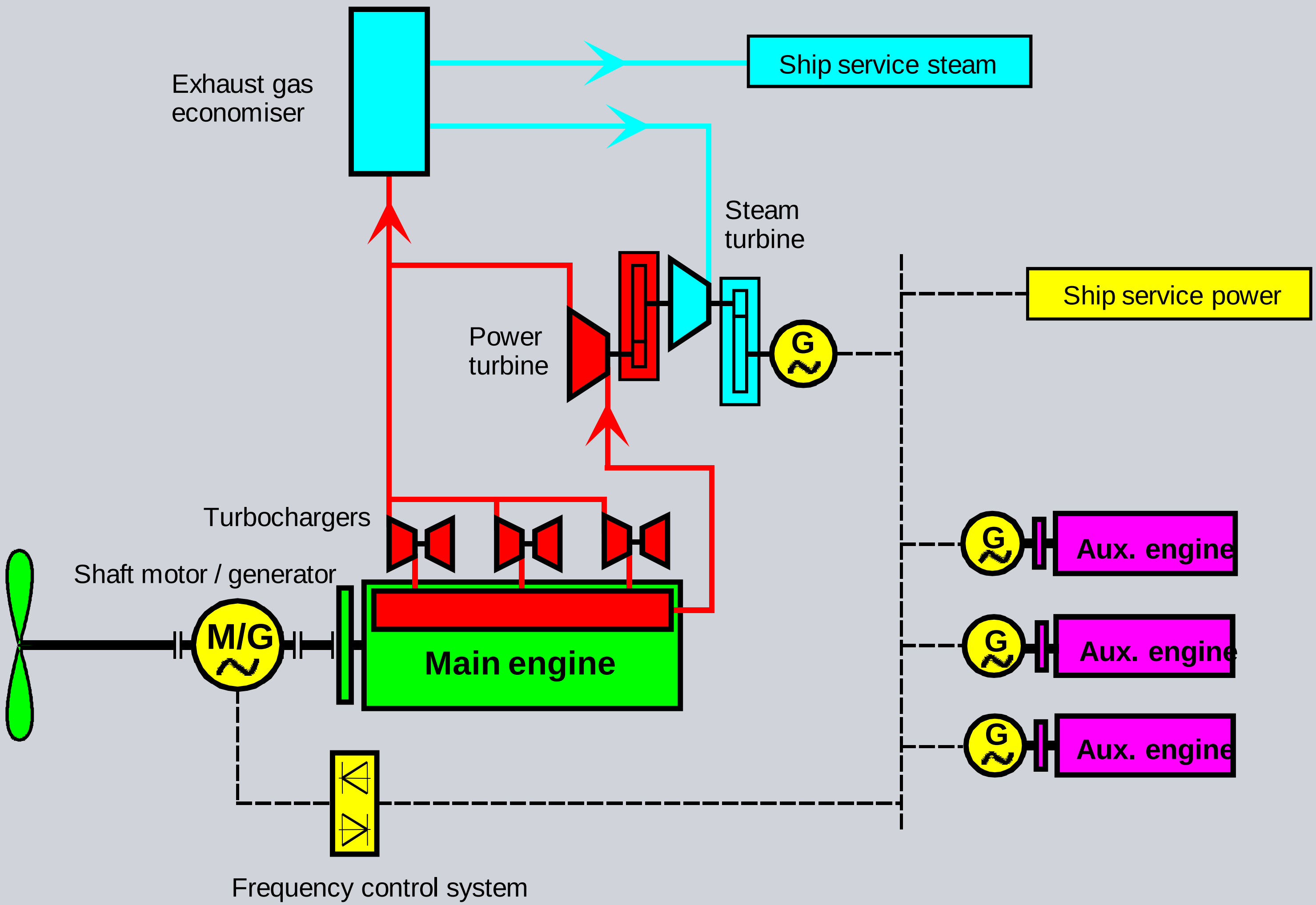

Operating modes shaft motor/generator

1. **WHR (generally)**

   A. Motor mode

   The heat recovery system generates more electrical power than that needed for shipboard service. The surplus electric power can be utilized via a motor/generator to add power to the propeller shaft.

   B. Alternator mode

   The heat recovery system generates less power than is needed for shipboard service. The shortfall in electrical power is generated by the motor / generator system.

   C. Booster mode

   The propulsion power demands exceeds the main engine MCR. The motor / generator system acts as motor with the required electrical power being generated by the heat recovery system and the auxiliary engines.

   D. Optional operating mode - Emergency propulsion

   The main engine is disconnected from the propeller shaft. The ship is propelled by the shaft motor with power supplied from the auxiliary diesel engines.

2. **Harsh environment- Operation in Ice- condition**

   E. Booster mode, ice

   Additional torque demands, even transients are covered in all speed conditions (ice- milling).

Hybrid Propulsion

Power Requirements – with a special view to operation in ice

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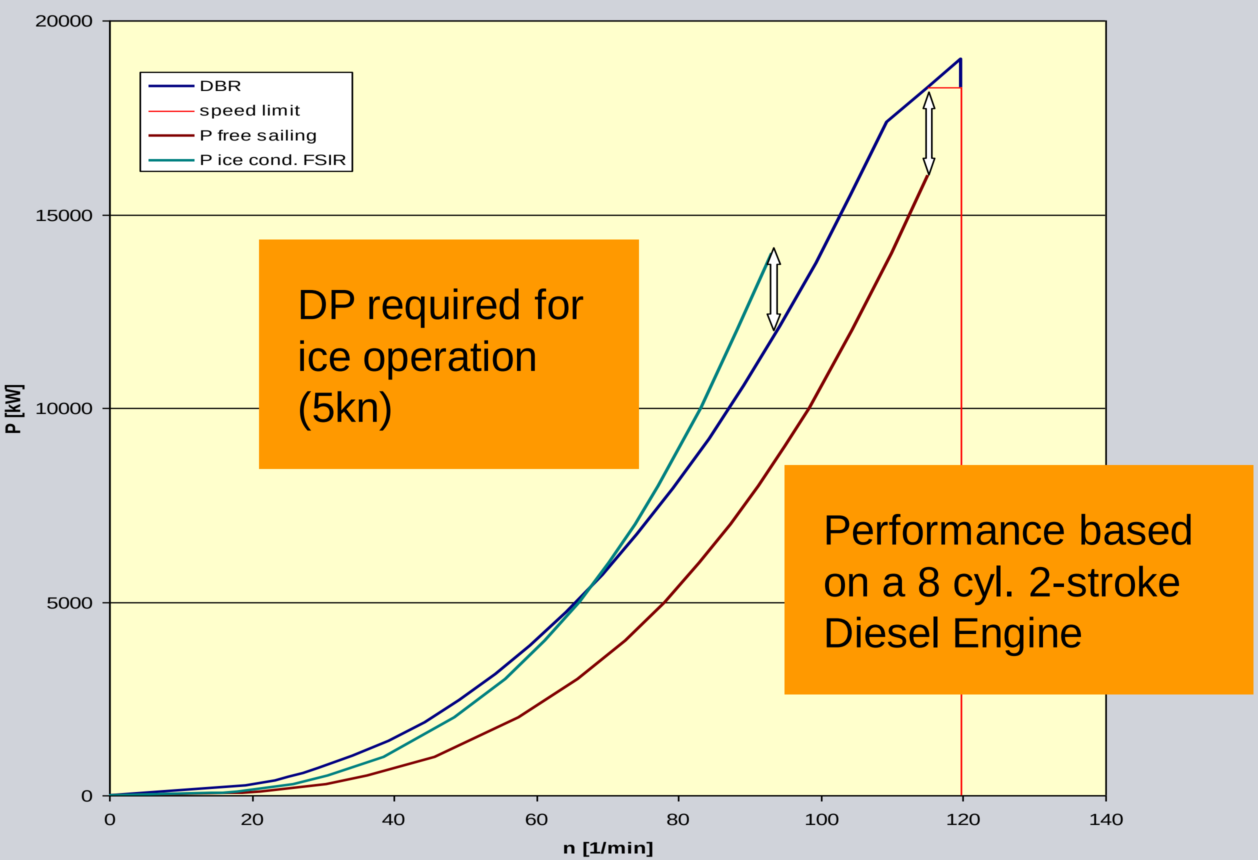
Power Requirement

Torque Requirement

Combined Torque Output Characteristic

Combined Power Output Characteristic



Hybrid Propulsion

Power Requirements – with a special view to operation in ice

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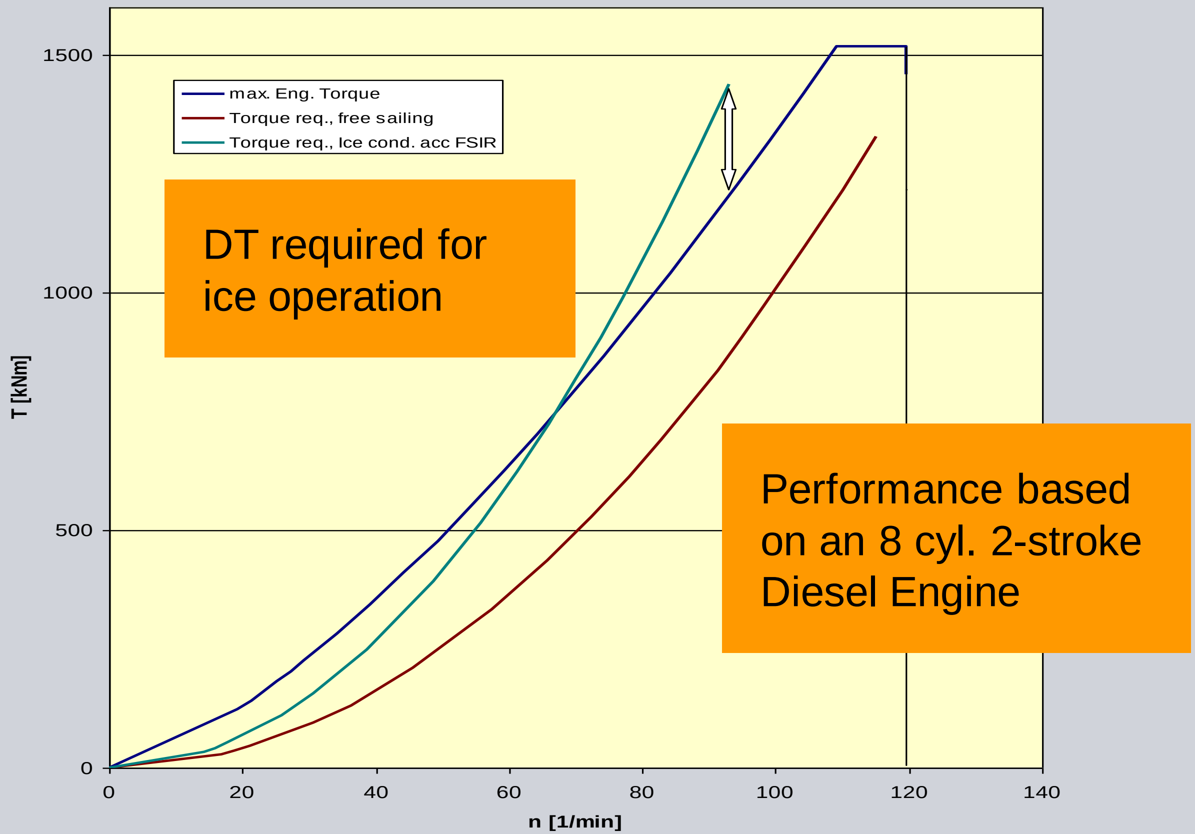
Combined Torque Output Characteristic

Combined Power Output Characteristic



Hybrid Propulsion

Power Requirements – with a special view to operation in ice

Power Requirement

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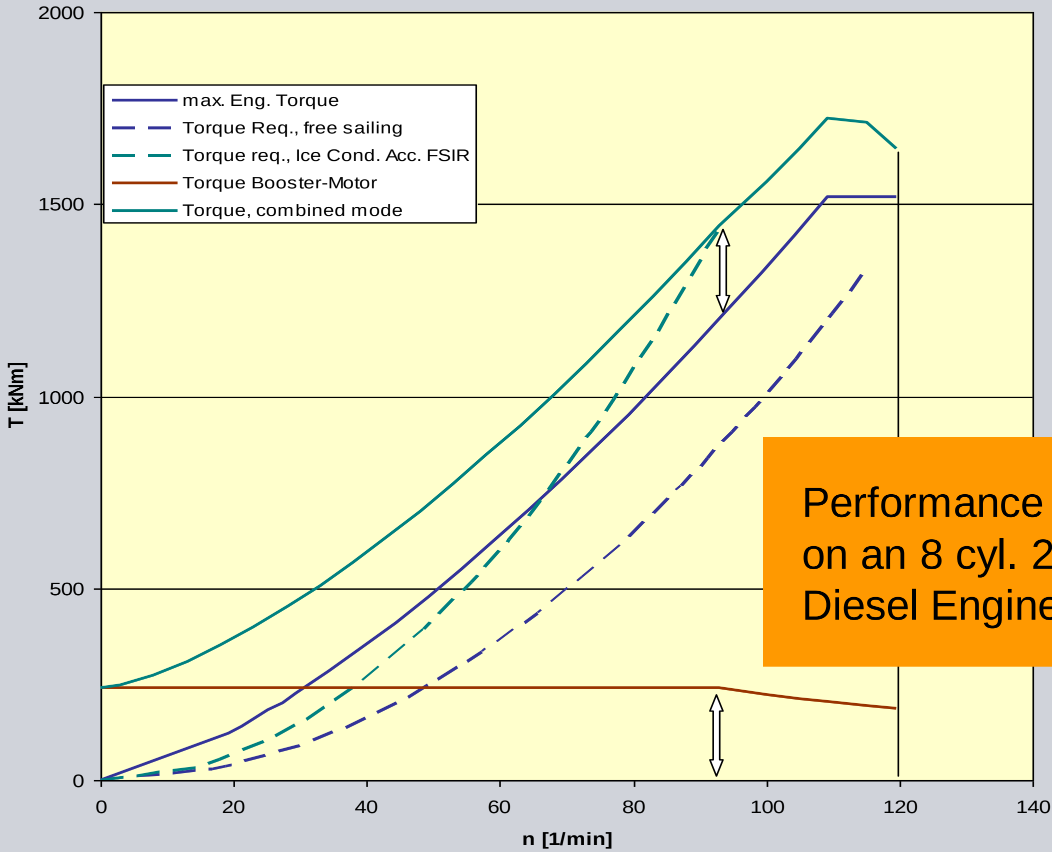
Combined Torque Output Characteristic

Combined Power Output Characteristic



Performance based on an 8 cyl. 2-stroke Diesel Engine

Hybrid Propulsion

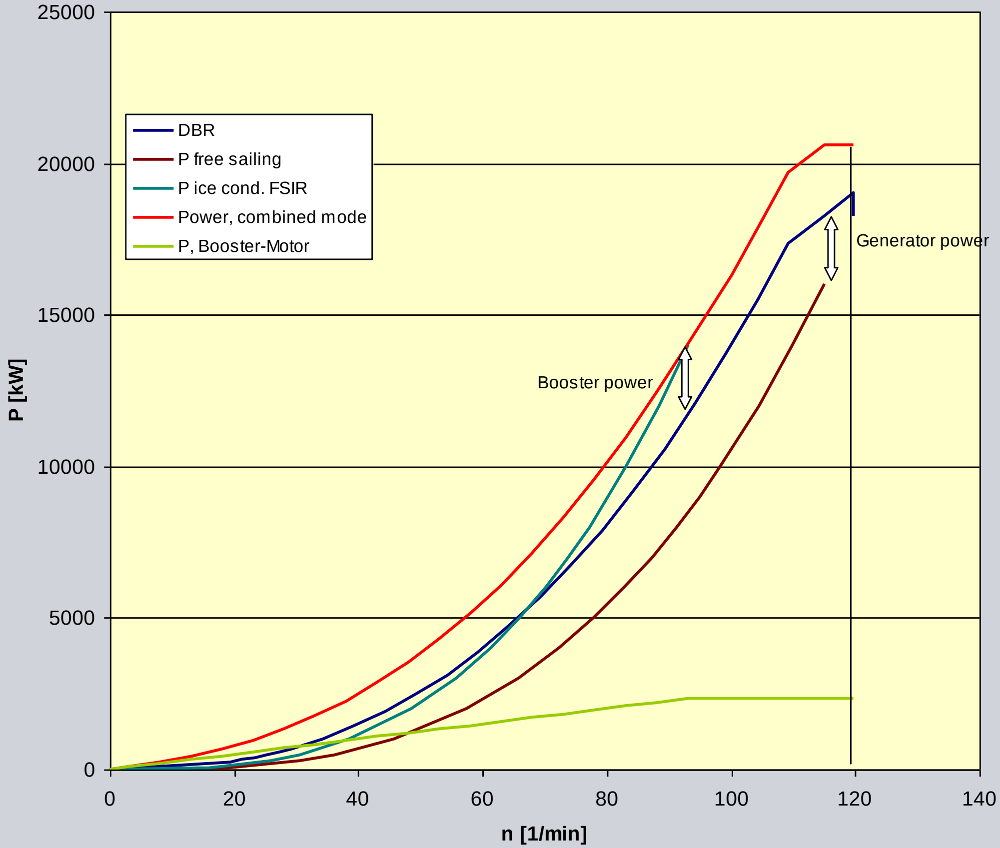
Power Requirements – with a special view to operation in ice

Power Requirement

Torque Requirement

Combined Torque Output Characteristic

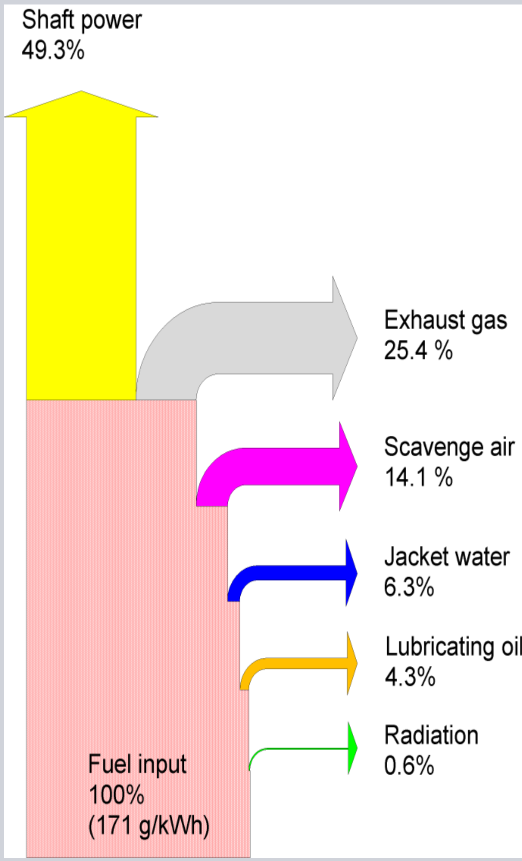
Combined Power Output Characteristic



Efficiency improvement

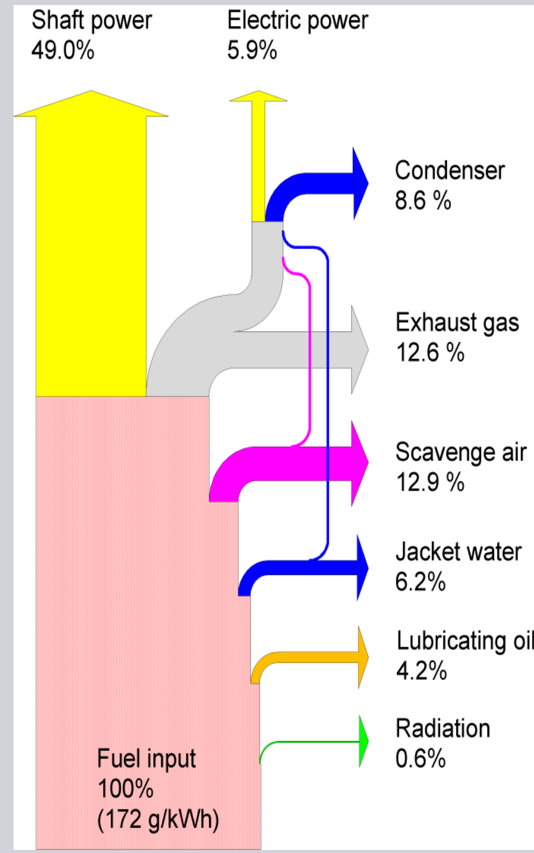
Standard Engine

Heat Balance RTA96C Engine ISO conditions, 100% load



with Heat Recovery

Total 54.9%



Engine efficiency improvement with heat recovery = 54.9 / 49.3 = **11.4%**

Hybrid Propulsion

Performance, Machinery Weight and Volume for operation in ice

8 cyl. 2-stroke engine e.g. 620 Bore

- P= 15995 kW
- n= 115 rpm
- m= **480** to
- L= 9,8 m
- b= 3,6 m
- H= **10,6** m (incl. Crankcase)
- V= **370** m3

Additional Equipment

- E-Machine ~ 25 to
- Converter ~ 5 to
- Trafo ~ 7 to
- (~ 2 MWe from service power)
- **S ~ 37 to**

7 cyl. 2-stroke engine e.g. 720 Bore

- P= 21560 kW
- n= 100 rpm
- m= **640** to **(133%)**
- L= 10,1 m
- b= 4,0 m
- H= **12,3** m (incl. Crankcase)
- V= **504** m3 **(136%)**

Additional Equipment

(full service power generation)

Weight savings [t]

640 – (480+37) = 123

Waste Heat Recovery System – Payback Analysis

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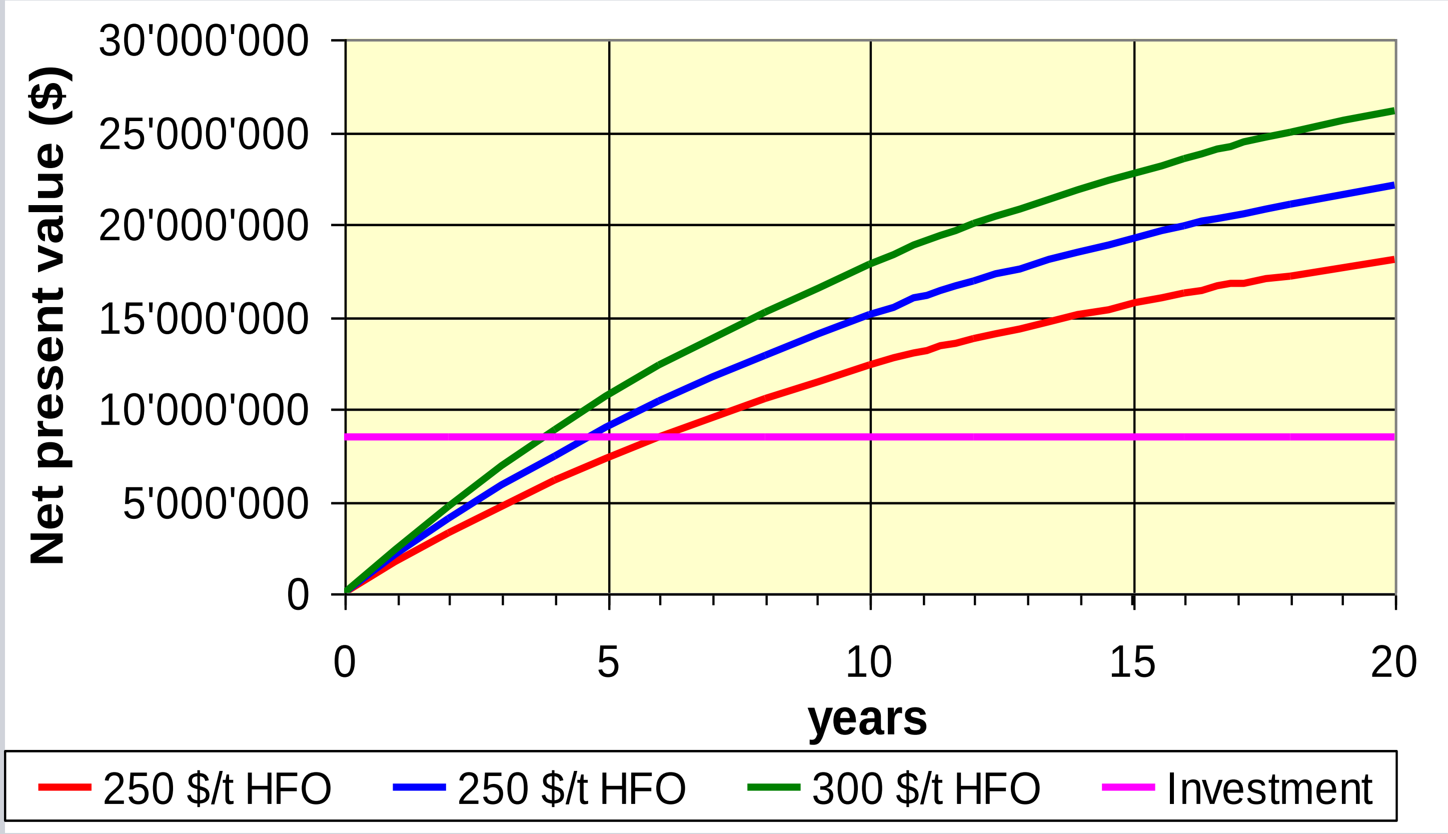
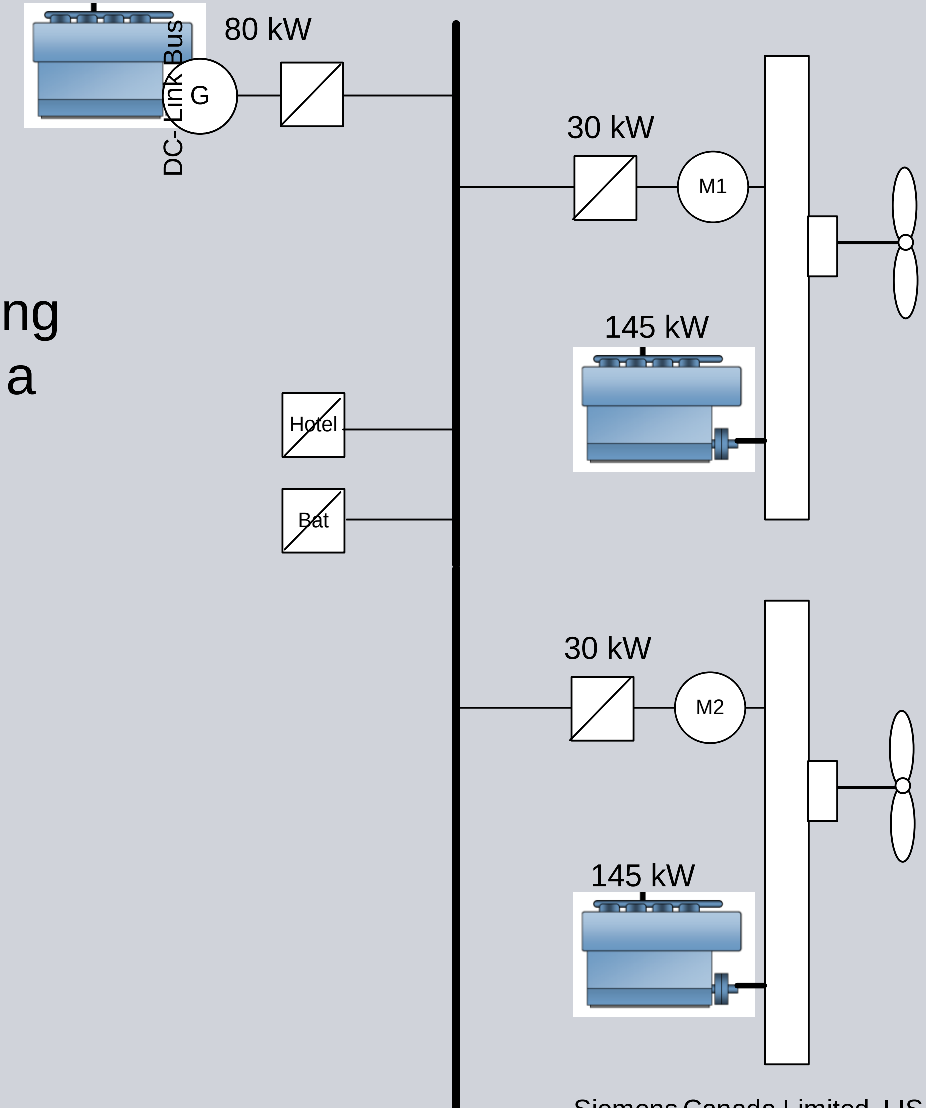
Expected pay-back time



Configuration example
Hybrid version



For a small Tug, Ferry, Fishing Vessel or Yacht, instead of a relatively large propulsion engine – consider hybrid.

Hybrid Version
Energy Flow (1/2)

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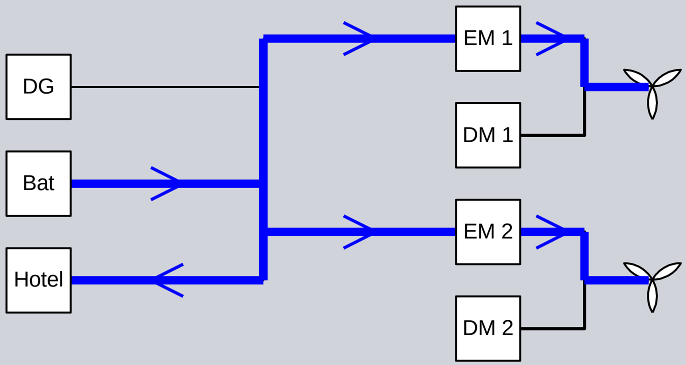
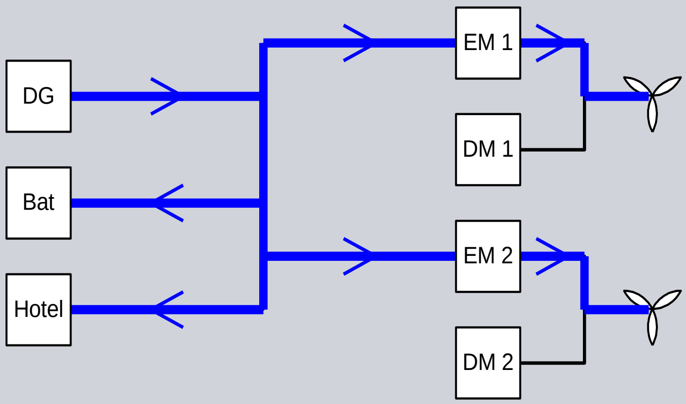


Battery-Mode

for

limited time

Electrical power from Batteries to Hotel and Propulsion load (e.g.: at anchor, loitering in harbour, manoeuvring or at slow speed)



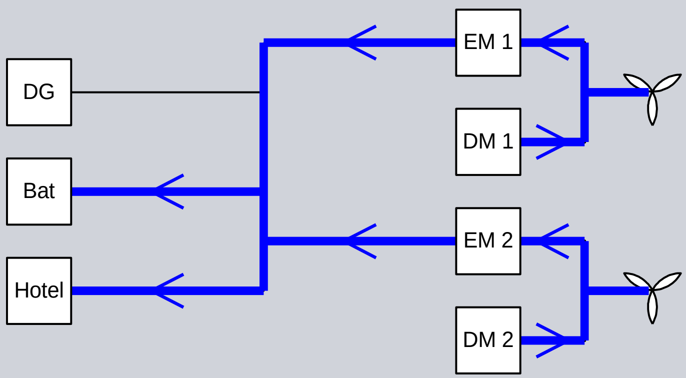
Elektro-Mode

continuous

+ Battery loading

Power from Harbour Generator charging batteries, supplying hotel load and propulsion motors for moderate speed operations (Cruising).

Hybrid Version
Energy Flow (2/2)

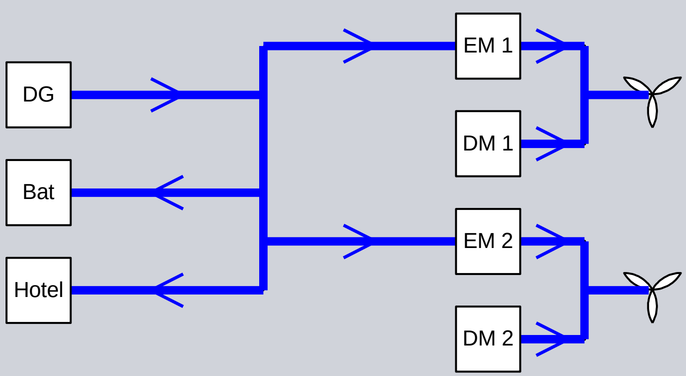


Diesel-Mode

2 x 179 kW

+ Battery loading / Hotel

Power from Propulsion Diesels, driving geared generator which charges batteries and supplies hotel load, while propelling vessel at high speed.



Hybrid-Mode

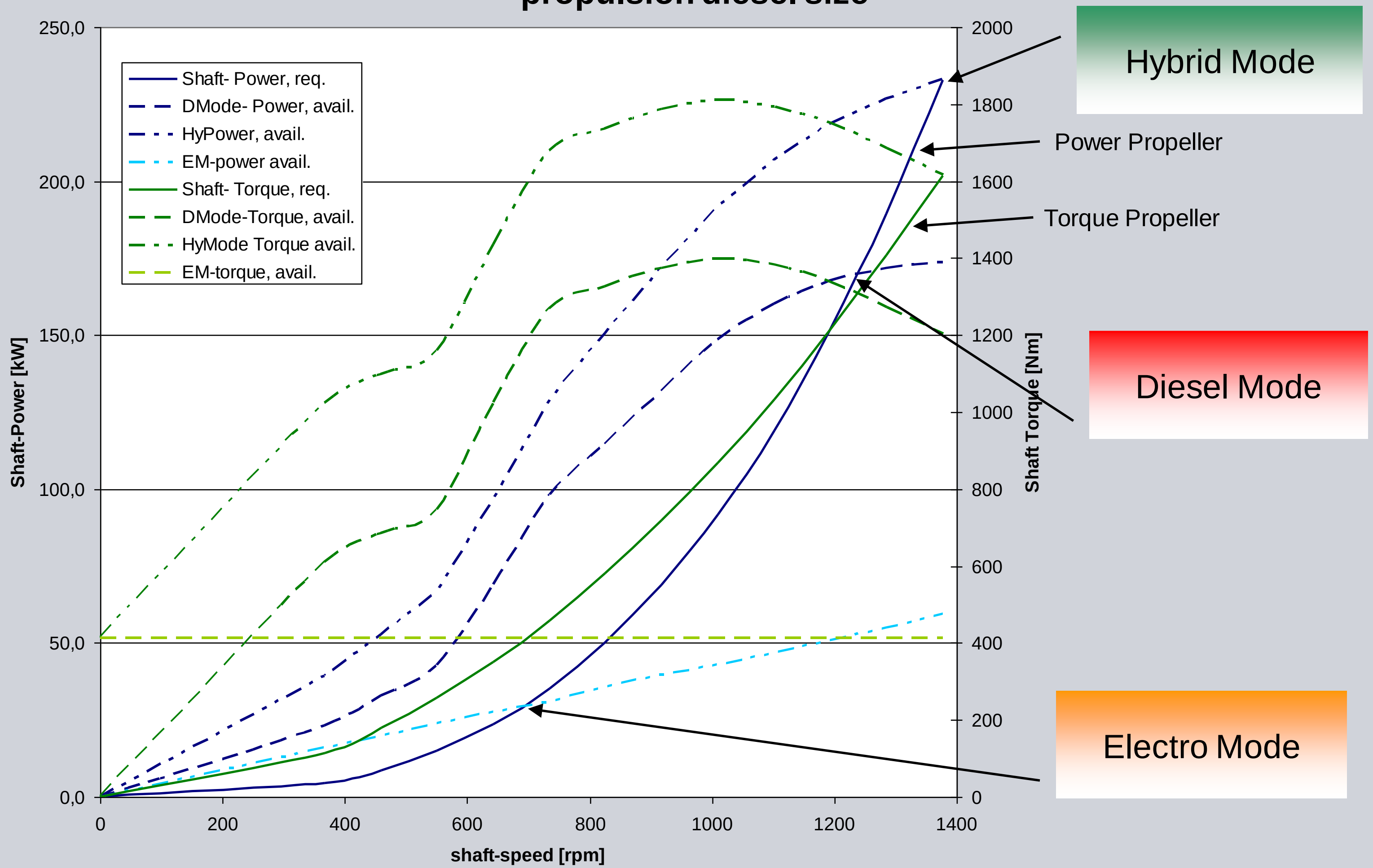
2 x 179 kW

+ 2 x 30 kW

Propulsion diesels propelling vessel (Maximum speed) with additional power from geared motors (PTI), which receive electrical power from Vessel Service Generator.

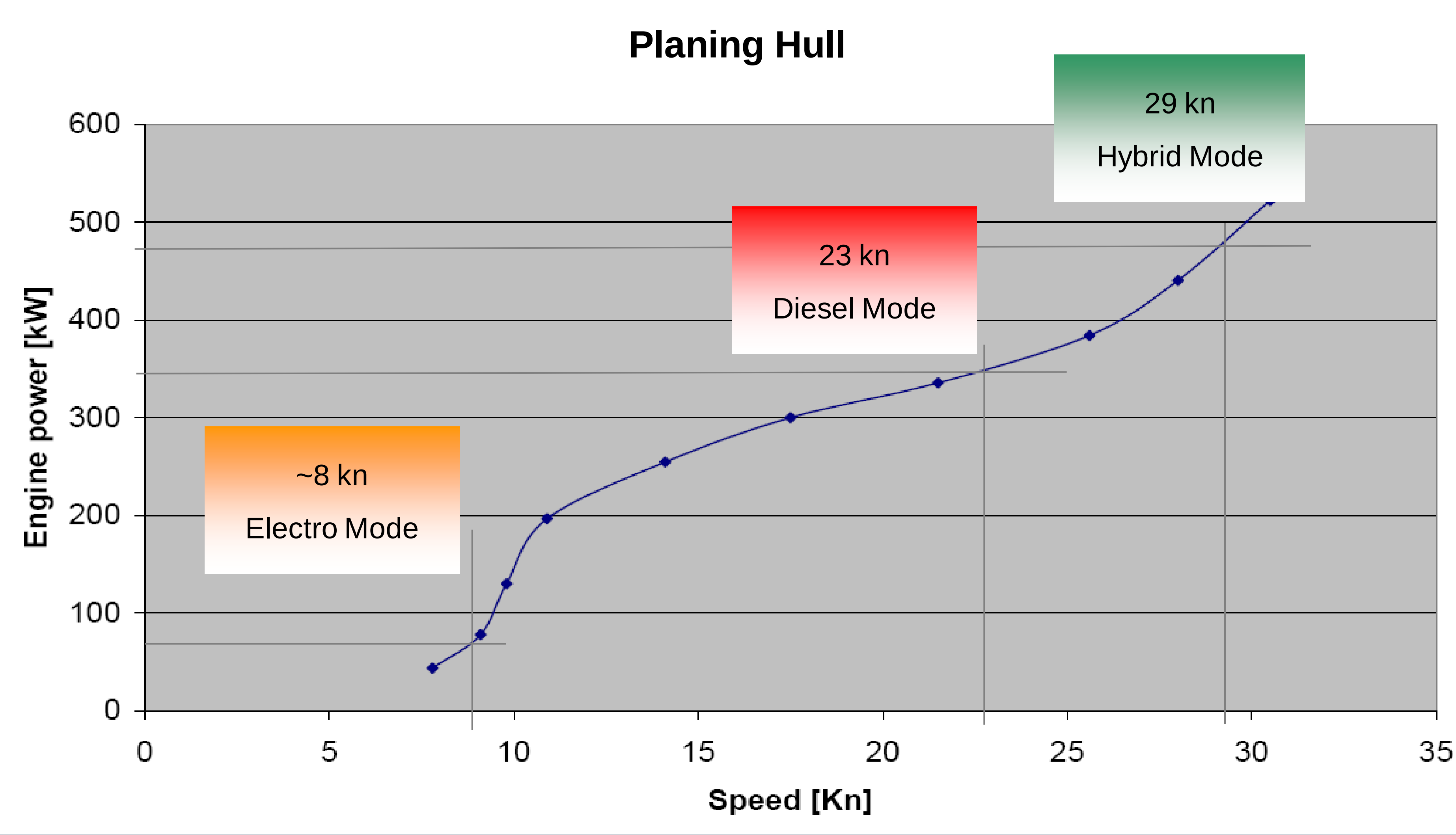
Hybrid Version
System Characteristics

By combining electrical with mechanical power, maximum speed can be achieved with reduced propulsion diesel size



The electric power to the shaft depends on the hydrodynamic limits of the ship

Hybrid Version
Speed Calculation Example



Economy / Ecology fits perfect

Higher efficiency
=
Lower emissions in general

Technology	Emission scenario	Fuel Savings	Status
Waste heat recovery WHRS, TES	8-11% on standard Engine tuning	8 - 11%	Available approved

Summary
Hybrid Propulsion Concepts 1(2)

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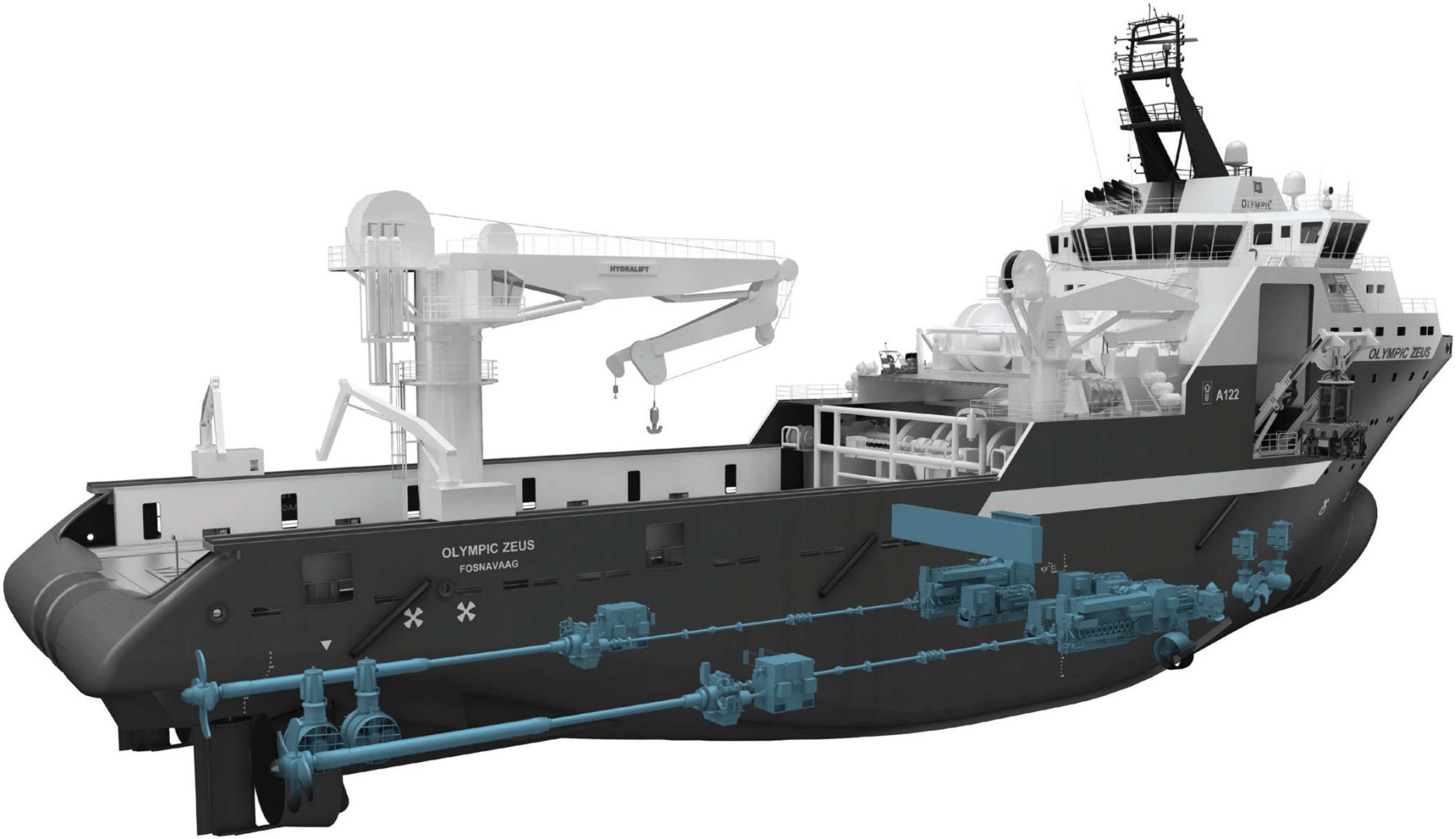
Advantages of Hybrid Propulsion Concepts :

- **Optimization of the total installed Power (Prime Mover)**
- **Optimized Load Balancing and power management of E-Service Network and Propulsive Power increasing overall powerplant efficiency**
- **Minimized Life Cycle Costs**
- **Minimized Emissions**
- **Means of alternative propulsion by installation of additional clutch**
- **Enhanced performance ship propulsion in ice**
- **Higher reliability and Availability by elimination of serial failure sequences (e. g. gear)**
- **Higher flexibility in allocation and distribution of power sources and consumers**
- **Retrofitting in general unproblematic**

Current Hybrid Example



EXAMPLE – illustration only

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Improvement of industrial motor driven systems

Key features	▪ The industrial motor driven system consists of a machine (e.g. pump/compressor/air fan system), driven by an energy saving motor and frequency converter ▪ Since machines are used to be mainly driven in partial load during their life time, a concept of system potential analysis requiring the application of drive technology leads to major energy savings
Environ-mental value	▪ Energy saving potential per year EU 25: 43 TWh = 19 Mio. t CO_2, World estimated: 130 TWh = 57 Mio t CO_2 ▪ Energy saving up to 50% in industrial motor driven systems
Customer value	▪ Lower energy consumption ▪ Reduction of operating costs ▪ Less environmental damage ▪ Compliance to legal directives ▪ Production and quality improvement

Impact of Speed reduction on Induction Motor Power Consumption.

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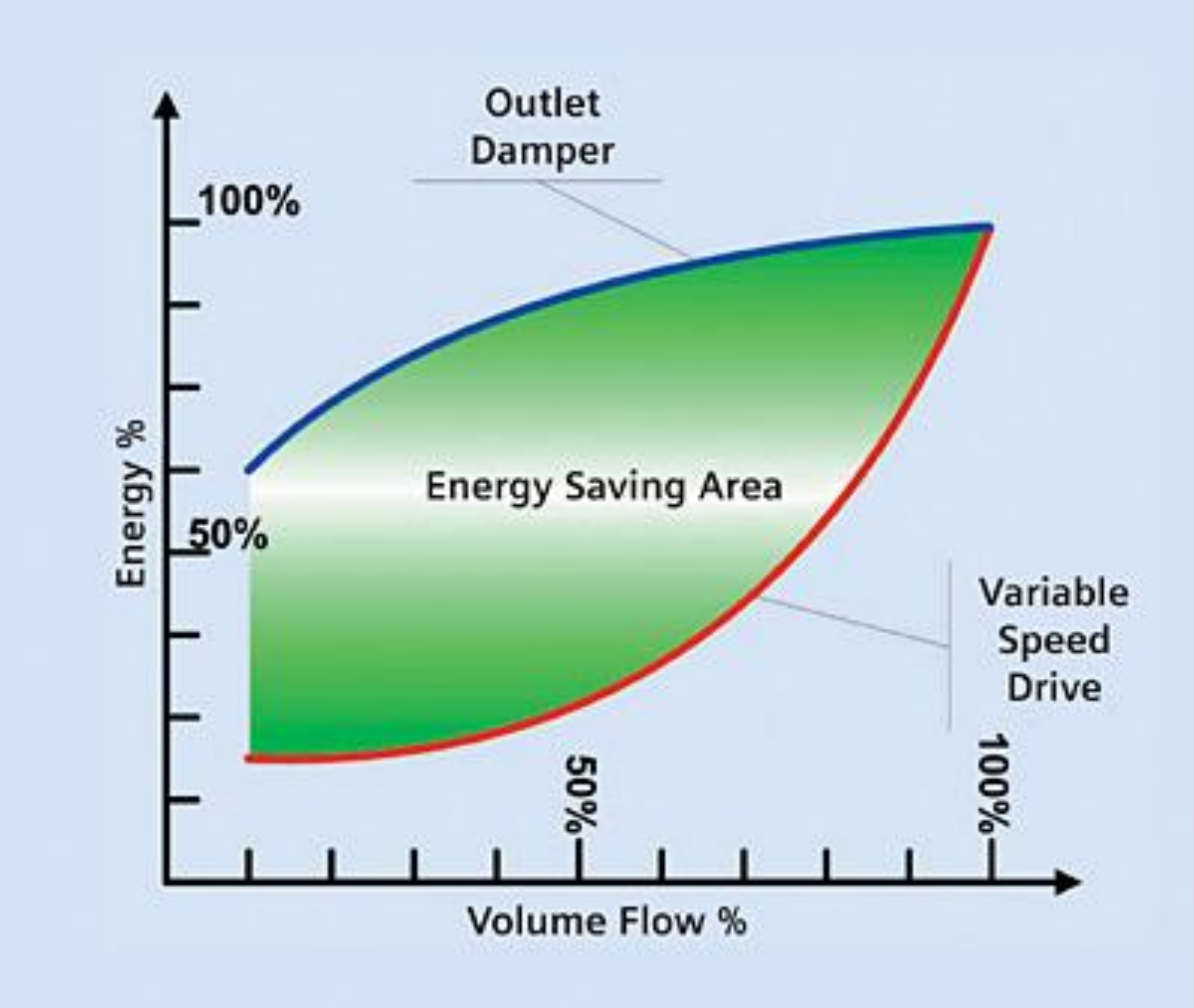
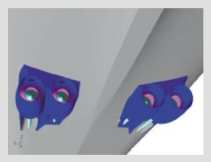
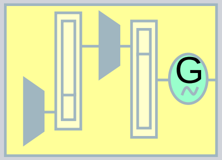


Technology is contributing

Specific and important single and patent-families GJ 06/07 :

Propulsion Systems: 230 patents

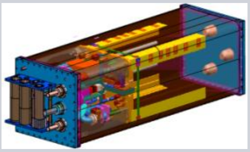


High Temperature Superconducting: 39 patents

Future naval surface vessels: 73 patents

Fuel-Cell Systems: 172 patents



Special Vessels:

4.5 MW HTS High Torque Propulsion Motor

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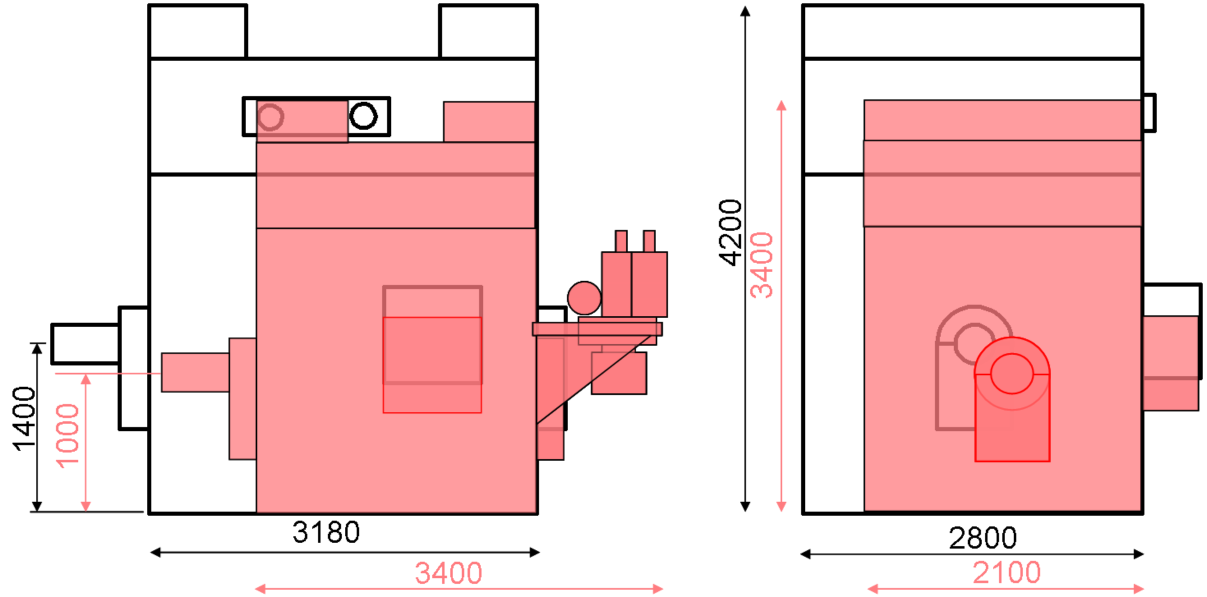
First feasibility study:

Conventional Motor	by comparison	HTS Motor
318kNm	Torque	366kNm (incl. Reserve)
53t, 62m³	Weight, Volume	ca. 38t, 38m³
250kW, 94%	Losses, Efficiency	ca.190kW, 96%



What is required?

- Customer focus on “cost to own”
- Customer ability to commit to Operating Profile
- Freedom for Designers to focus on vessel Power as one System.

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Thank you for your attention

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