ENERGY EFFICIENCY OPTIMISATION

Genova, September 2013

Martial CLAUDEPIERRE

Business Development Manager

Environmental Services

Green Shipping Summit

Move Forward with Confidence

BUREAU VERITAS

Content

- ► Who we are
- ► How to improve the energy efficiency of ships ?
- ► Energy efficiency tools and solutions
- ► Case studies

Bureau Veritas : what we do

World leader in
Testing, Inspection
and Certification services

OUR SERVICES

Inspections and Audits

Testing and Analysis

Classification

Certification

Asset Management

Training

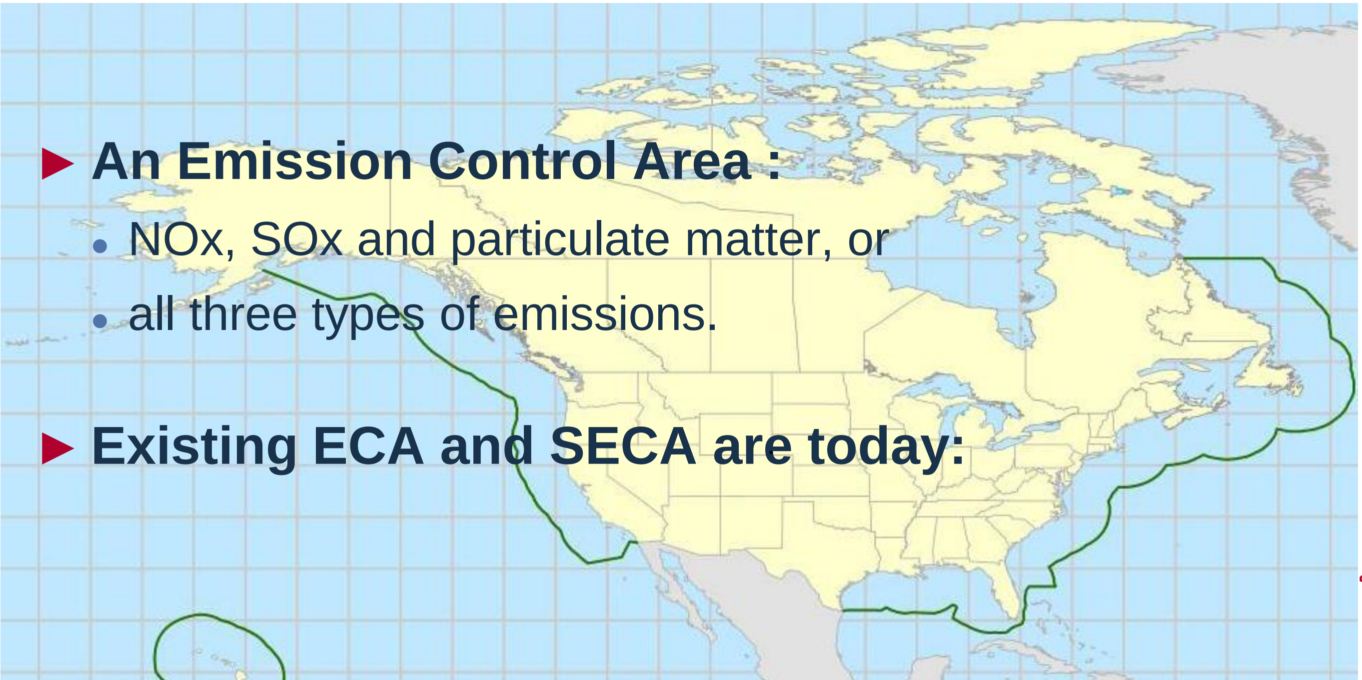
Consulting

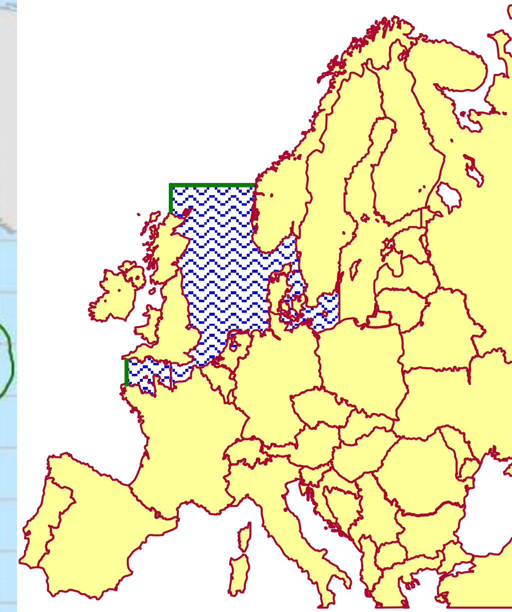
8 global businesses

EMISSIONS REGULATION

UPDATES

Emission Control Areas (ECA)





- **An Emission Control Area :**
  - NOx, SOx and particulate matter, or
  - all three types of emissions.

- **Existing ECA and SECA are today:**

Baltic Sea (SOx)	26 Sept 1997	19 May 2005	19 May 2006
North Sea (SOx)	22 Jul 2005	22 Nov 2006	22 Nov 2007
North American (SOx, and NOx and PM)	26 Mar 2010	1 Aug 2011	1 Aug 2012
United States Caribbean Sea ECA (SOx, NOx and PM)	26 Jul 2011	1 Jan 2013	1 Jan 2014

International Regulations for SOx emissions

<table>
<tr><th rowspan="2">Regulations</th><th colspan="5">Sulphur Content (in mass)</th></tr>
<tr><th colspan="2">2010</th><th>2012</th><th>2015</th><th>2020 or 2025</th></tr>
<tr><td>IMO – Global (except for passenger ships)</td><td colspan="2">4.5%</td><td colspan="2">3.5%</td><td>0.5%</td></tr>
<tr><td>IMO – ECA – SECA

(EU aligned with IMO)</td><td>1.5%</td><td colspan="2">1.0% (since 01.07.2010)</td><td colspan="2">0.1%</td></tr>
<tr><td>EU ports</td><td colspan="5">0.1%</td></tr>
<tr><td>California (< 24 nm)</td><td colspan="2">1.5% (MGO)

0.5% (MDO)</td><td colspan="3">0.1%</td></tr>
</table>

Residual fuels

Distillate fuels

- With effect from 18 December, 2012, the EC Sulphur Directive 1999/32/EC is amended by Directive 2012/33/EU in order to align the EC regulations on sulphur content of marine fuels with the IMO regulations.
- The EC regulations **are aligned** with the revised Annex VI to MARPOL, both inside and outside EU Sox Emission Control Areas (SECA). The 0.50% limit outside EU SECAs will apply in EC waters from 1 January, 2020, **regardless of the outcome** of the IMO fuel availability review, which is due by 2018.
- Emission abatement methods (e.g. exhaust gas cleaning systems) **are permitted** for ships of all flags in EC waters as long as they **continuously achieve** reductions of SOx emissions which are **at least equivalent** to using compliant marine fuels.

EEDI and Design innovations

The EEDI of ships is to be calculated according to IMO guidelines:

- Original document : MEPC Circ.1/681
- Calculation guidelines adopted at MEPC 63: Resolution MEPC 213(63)
- Formula:

Impact of Main Engines

Impact of auxiliary power demand

Impact of PTI reduced by electrical innovations

Reduction of impact due to mechanical innovations

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot CF_{ME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE} *\right) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME} **\right)}{f_i \cdot f_c \cdot Capacity \cdot f_w \cdot V_{ref}}$$

Ship’s work in normal operating condition

f	**Correction factors**
CF	**CO_2 emission coefficient**
SFC	**Specific fuel consumption**
"AE"	**Subscripts for auxiliary engines**
"ME"	**Subscripts for main engine(s)**

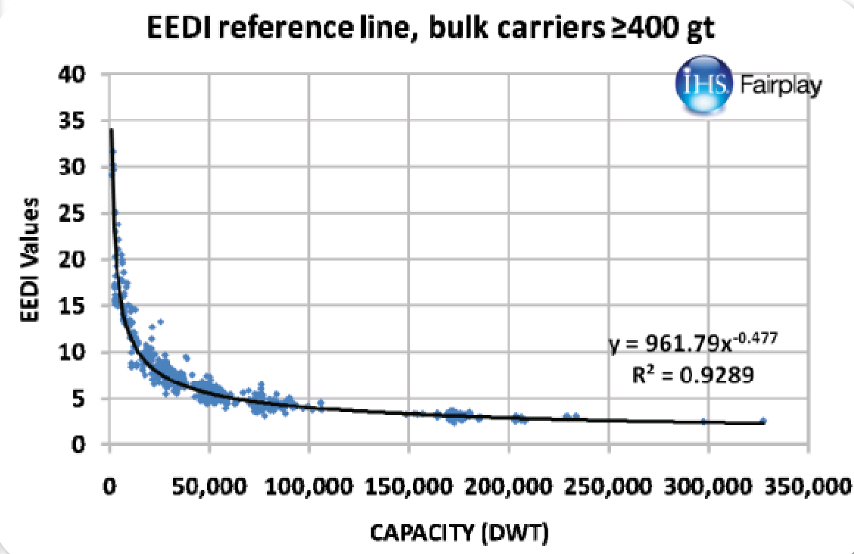
Target Years & Reduction Rates

Draft regulatory text for mandatory EEDI requirements: target years & reduction rates

$$EEDI_{attained} \leq EEDI_{required}$$

$$EEDI_{required} = \left(1 - \frac{X}{100}\right) \times Baseline\ value$$

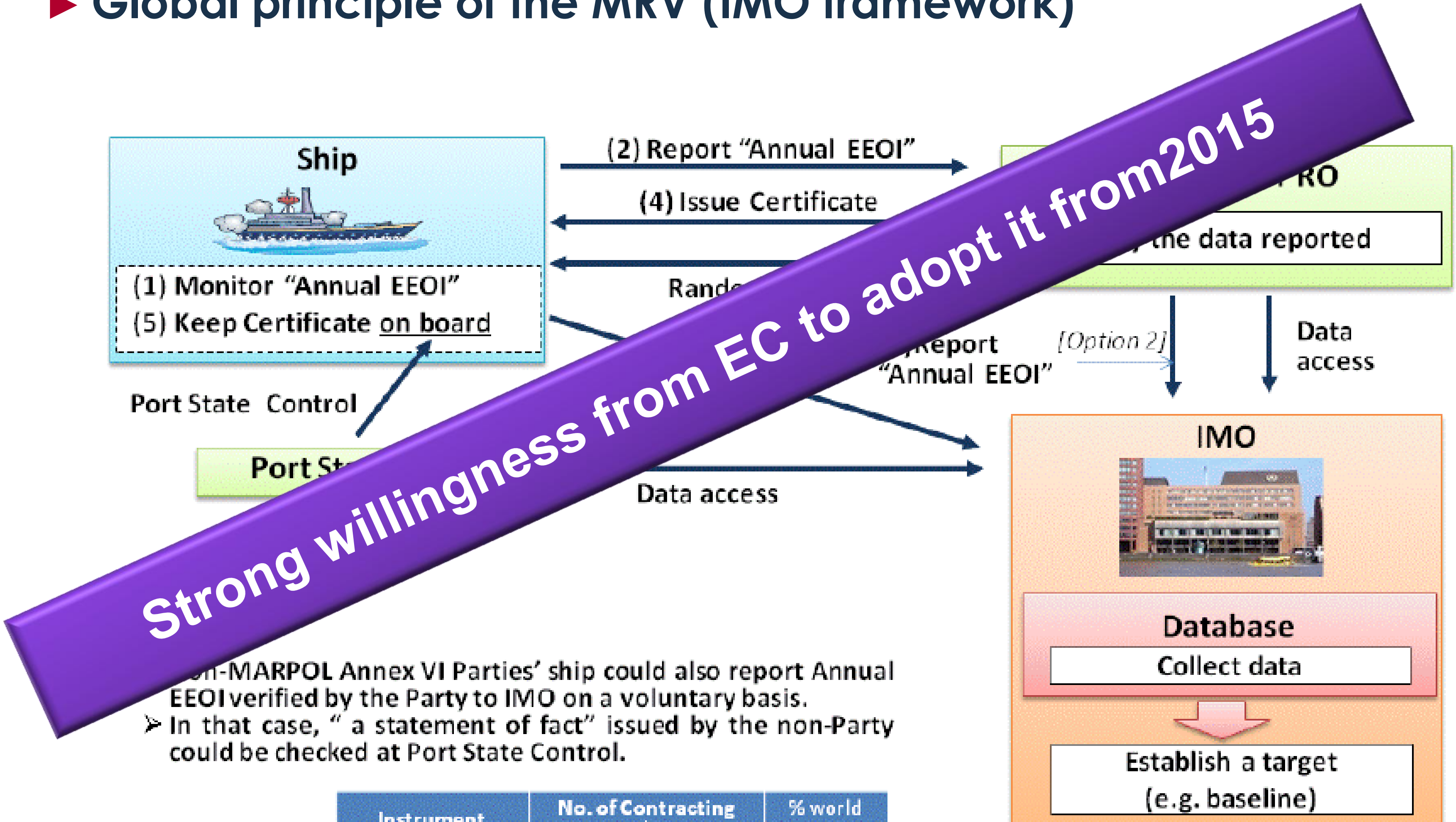
Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 onwards
Bulk Carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Gas tanker	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Container ship	15,000 DWT and above	0	10	20	30
	10,000 – 15,000 DWT	n/a	0-10*	0-20*	0-30*
General Cargo ships	15,000 DWT and above	0	10	15	30
	3,000 – 15,000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000 – 5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20,000 DWT and above	0	10	20	30
	4,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*



**** Factor to be linearly interpolated between two values dependent upon vessel size (the lower value of reduction factor is to be applied to the smaller ship size).***

Monitoring Review and Monitoring MRV

► Global principle of the MRV (IMO framework)



-MARPOL Annex VI Parties' ship could also report Annual EEOI verified by the Party to IMO on a voluntary basis.

➢ In that case, " a statement of fact" issued by the non-Party could be checked at Port State Control.

Instrument	No. of Contracting States / Parties	% world tonnage*
MARPOL Protocol 1997 (Annex VI)	72 (as at 2 January 2013)	94.3%

*Source: IHS-Fairplay -World Fleet Statistics 31 December 2011

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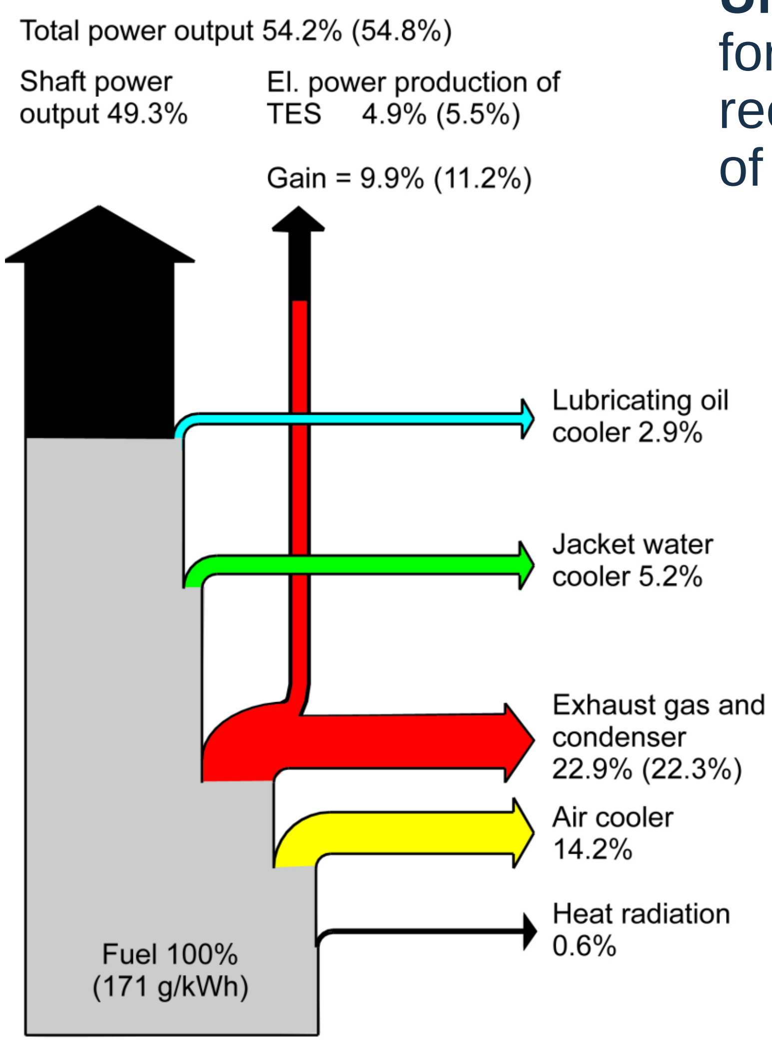
HOW TO IMPROVE ENERGY EFFICIENCY ?

Where energy & money go ?



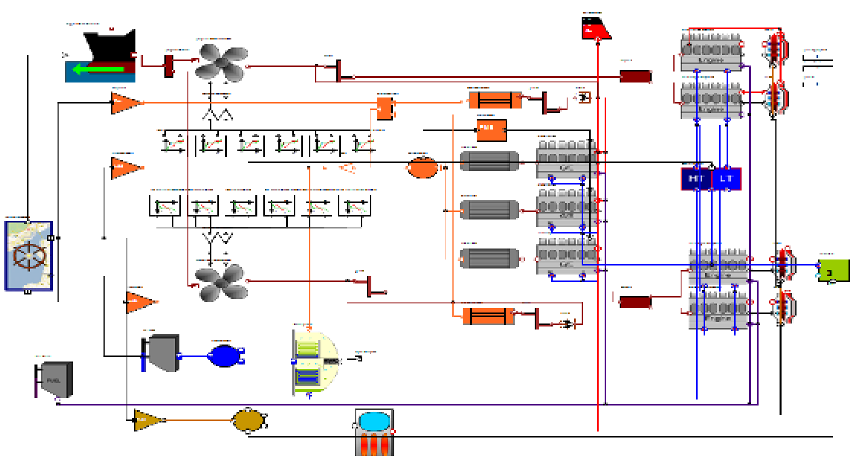
Sankey Diagram (MAN D&T)

Understanding the energy balance is the key for deciding where efforts shall be put for recovering of energy losses and optimisation of the efficiency of your OSV.

The energy balance is to be calculated at design stage, estimated with simulating tool such as SEECAT, and/or measured onboard through initial **energy audit** and **onboard instrumentation** systems.

Different propulsion configurations & potential savings

- Different combinations can be envisaged between Electric propulsion and Mechanical propulsion with CPP
- CAPEX is higher for Electric drive, OPEX is lower
- Savings are possible in the low loads. At low pitch, losses are high due to poor ptimisation of the CPP at that point,
- But an holistic approach is recommended to assess consequences on energy recovery systems for example
- I will introduce our third party verification tool SEECAT further down



Hull & propeller fouling management

Maintenance measures implemented during the scheduled maintenance periods are « low hanging fruits » for improving the energy efficiency without impacting on the design of the ship and her components.

Fouling depends on localisation, season, and operational profile (time spent anchored on tropical sea).

There are big variation in performance between coating solutions on the market.

It is challenging to measure and assess the loss of speed due to growing.

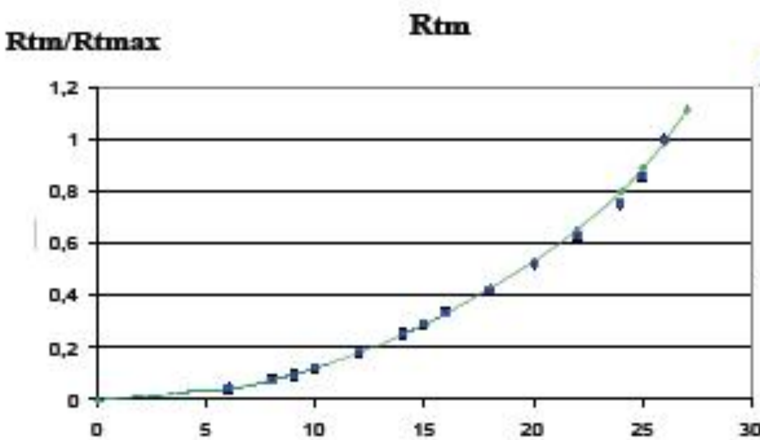
However some models can be elaboreted.

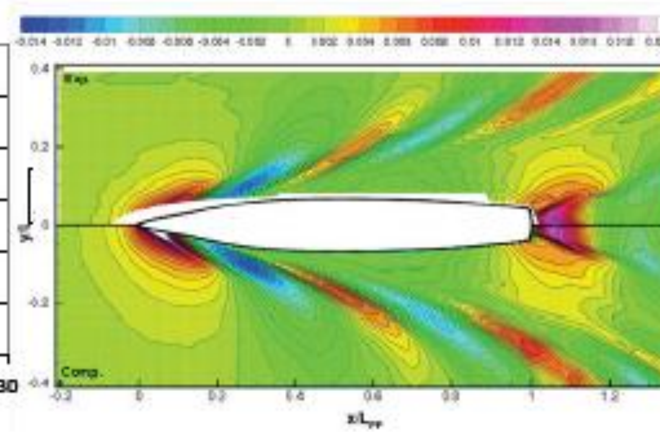
Coating application at a right schedule will improve the efficiency. We will learn from an on-going case study exposed further

But frequent cleanings could deteriorate the coating requiring pre-mature re-coating or leading to decreased vessel performance.

Hull form optimisation by CFD calculation

- Hull form optimization should be based on a selected combination of drafts, trims and speeds.
- **Hull form optimisation requires : Adapted Numerical solvers**
- **Navier-Stokes with free surface flow solvers are** more accurate, very close to model test results but CPU time consuming, and license cost expensive
- Complex automatic meshing for 3D volume meshes
- **Exemple : Optimisation on 10 operational conditions, 50 hull forms**
- • Total of 500 CFD computations
- • 1 CFD calculation needs 1 license for 32 cores, 10 h on 32 cores
- • Total of 10 x 32 x 500 = 160 000 CPU hours



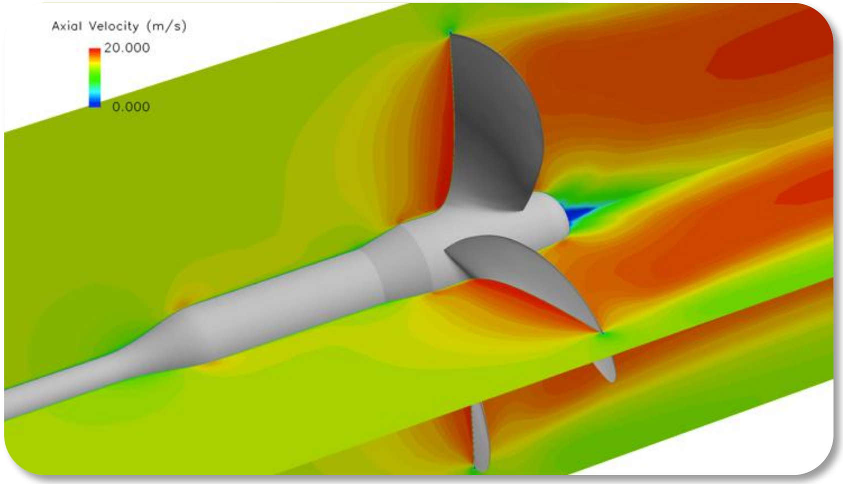


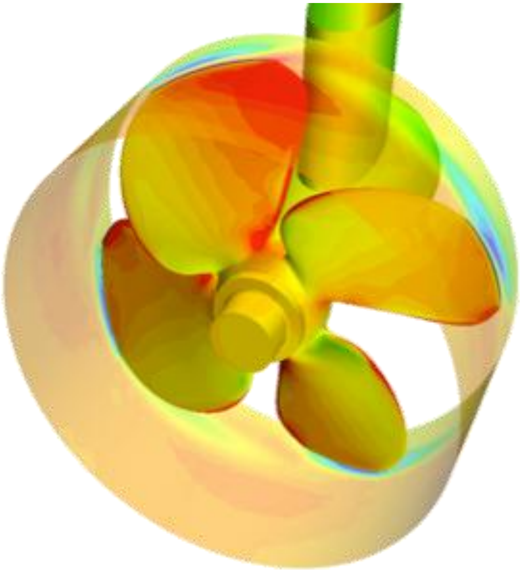
Propeller Optimization by CFD

- Description: unsteady CFD simulations of a rotating propeller

- Outputs of the simulations:
  - Kt, Kq and efficiency of the propeller in open water
  - Estimation of cavitation onset risks

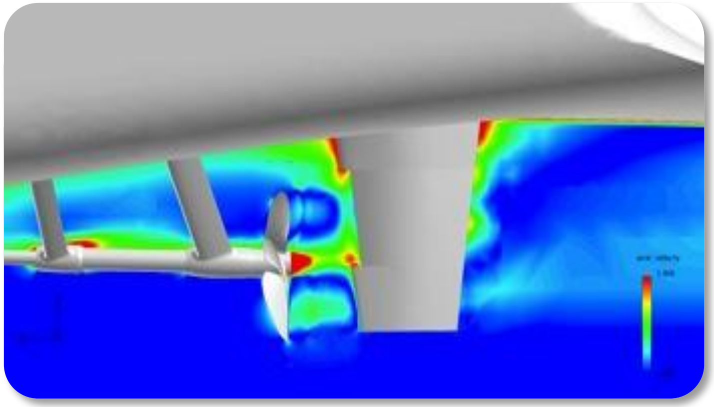
- Example of applications:
  - Evaluation of propeller performances
  - Evaluation Energy Saving Devices close to propeller

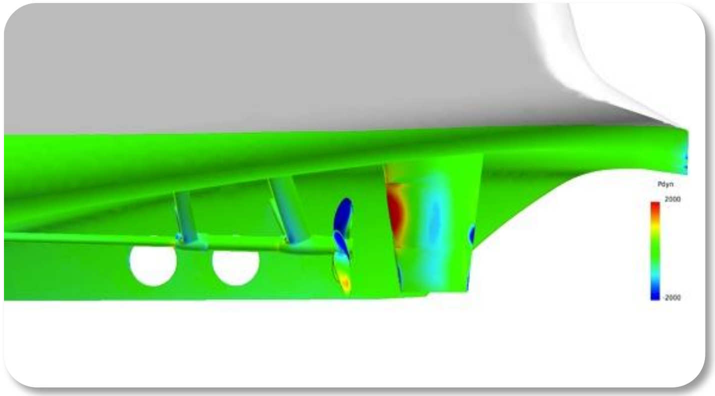




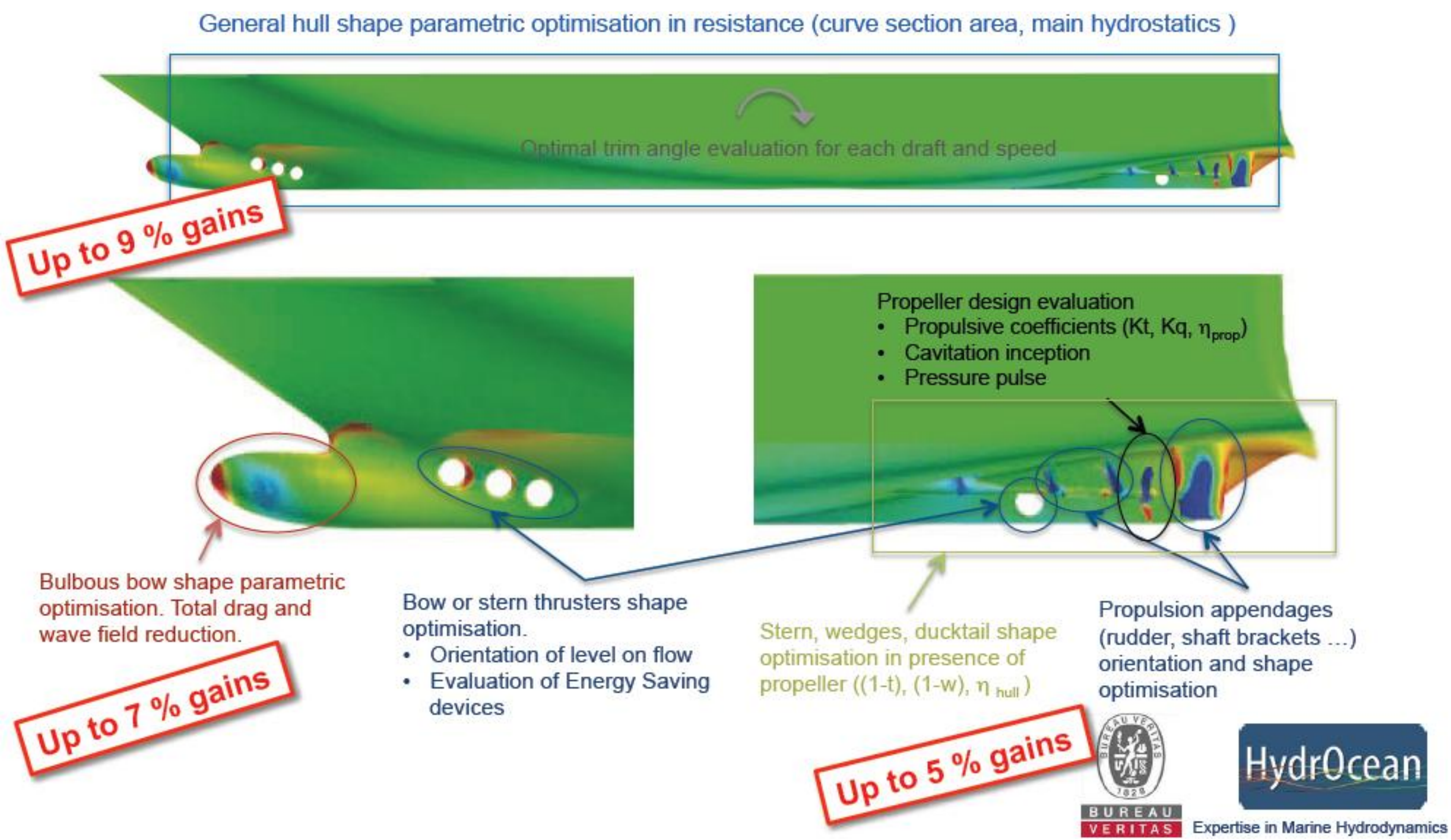
Self Propulsion Simulations by CFD

- Description: unsteady CFD simulations of hull and appendages, including rotating propeller
- Outputs of the simulations:
  - Propulsive performances of the ship
  - Evaluation of hull/ propeller/ appendages interactions
  - Cavitation onset risk, pressure pulses …
- Example of applications:
  - Hull power optimisation
  - Appendages alignment (twisted rudder and shaft brackets …)
  - Evaluation of several propellers performances





VeriSTAR Energy Efficiency – Hull Form Optimisation



LNG as fuel

► NOx emissions reduced by more than 80% (for lean burn engines). …

► SOx emissions eliminated (no sulphur in LNG).

► Particulate matters are close to zero.

► CO2 emissions are reduced by approx. 20% (unburned methane if any should be taken into account as its global warming potential is high).

LNG bunkering solutions

▶ Bunkering arrangements

- For small capacities, non-fixed tanks located onboard the can be arranged, such as containerized tanks or truck trolley tanks.
- Bunkering from land based LNG storage facility is also a solution in some circumstances
- For larger capacities, bunkering from a dedicated bunker ship will be used. Alternatively, bunkering from LNG terminals is also considered subject to relevant agreements **from flag and port authorities** and safety analysis.

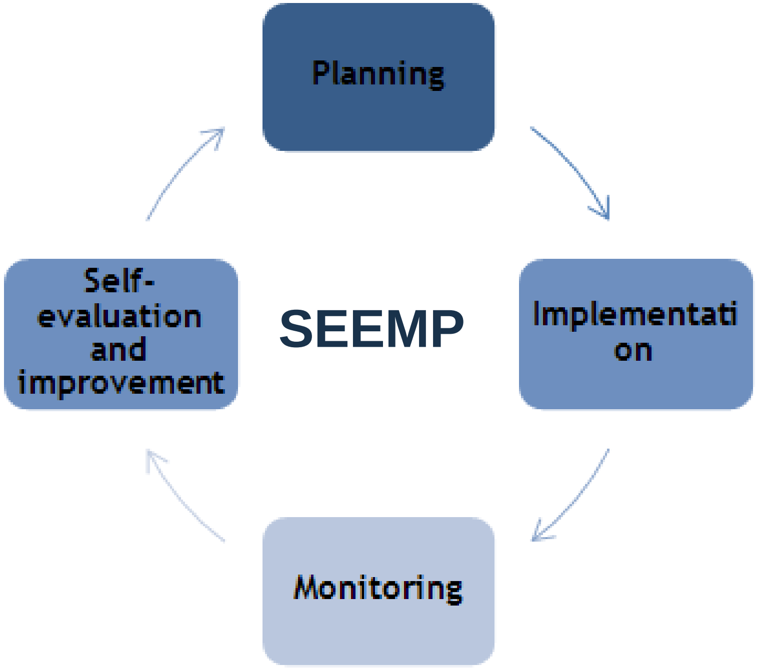
Ship-to-ship LNG transfer system type-approved by BV

HOLISTIC APPROACH FOR

ENERGY EFFICIENCY IMPROVEMENT

SEECAT TOOL

Energy Saving Measures – How to focus on the right ones?



- The challenge is to know how to optimally combine several measures to obtain a fuel efficient and environmentally friendy ship.

Letter	Order of magnitude
A	Saving > 20%
B	10<Saving < 20%
C	5< Saving < 10%
D	2,5 < Saving < 5%
E	1 < Saving < 2,5%
F	Saving < 1%

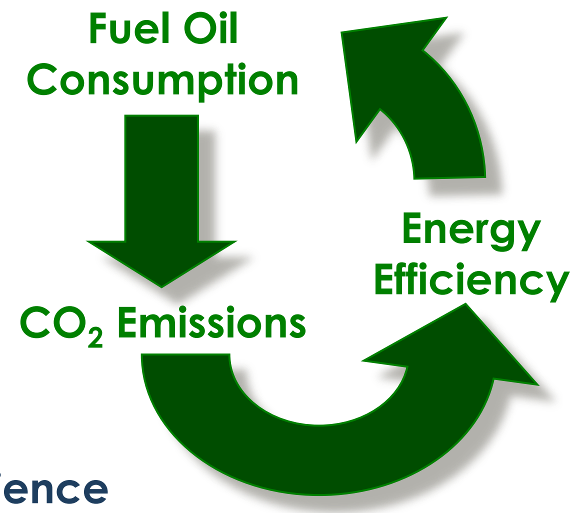
Energy Efficiency improvement measures	Potential energy saving
Weather routing	D
Just in time arrival	D
Speed optimization	D
Super Slow Steaming	A
Optimum trim	D
Optimum ballast condition	D
Hull coating cleaning	C
Propeller cleaning and polishing	C+
Engine auto-tuning	D
Main engine derating	E
Main engine variable turbo area	E
Use of alternative fuels	B
Waste Heat Recovery System	B-C

Global Approach for Improving Energy Efficiency

It is necessary to adopt an **holistic approach** when improving a ship in operation

Only a specific **energy transfer** equations calculation **tool** can provide a third party **global gain prediction at ship scale**

- **Fuel oil consumption for can be reduced by:**
  - Operational measure
  - Improved maintenance measures
  - Retrofitting Energy Saving Devices on hull, propeller, machinery



- **Add all the potential gain (generally communicated by suppliers) and you end up with 50% - did you experience such improvement? Of course not !!**
- **There are so many interactions, for example reducing speed will impact on WHB efficiency, meaning oil fired boilers to be run…**
- **We decided to adopt a fair and global approach**

SEECAT:
Ship **E**nergy **E**fficiency **C**alculation and **A**nalysis **T**ool

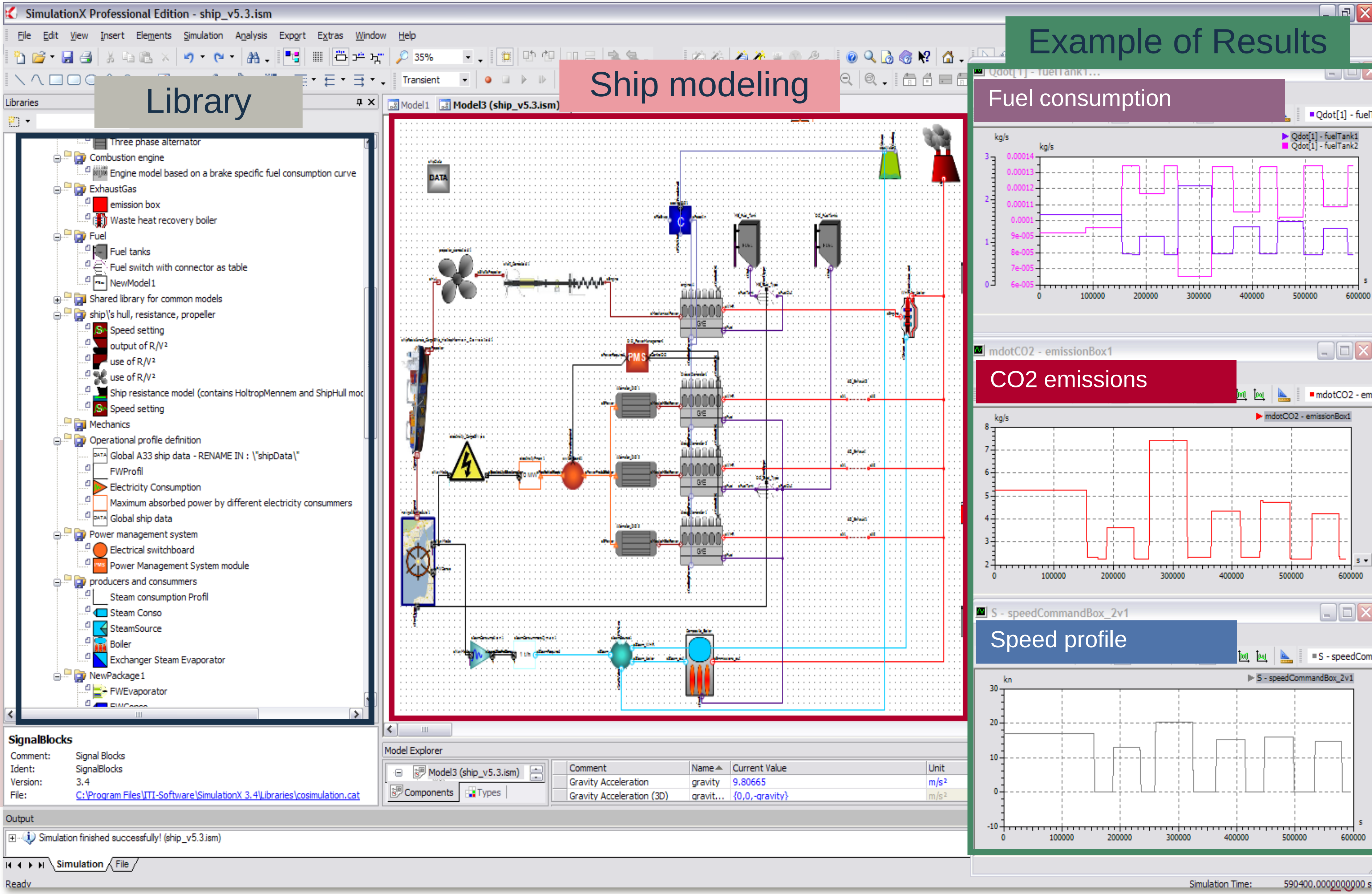
Purpose of the SEECAT tool:

- Create the energy model of a ship
- Establish the energy balance and calculate the energy efficiency of the ship
- Calculate the fuel consumption and emissions (NOx, SOx, CO2)

Energy Flow Modeling – Basic Idea

The ship’s power needs should be fulfilled by the power producing units

SEECAT

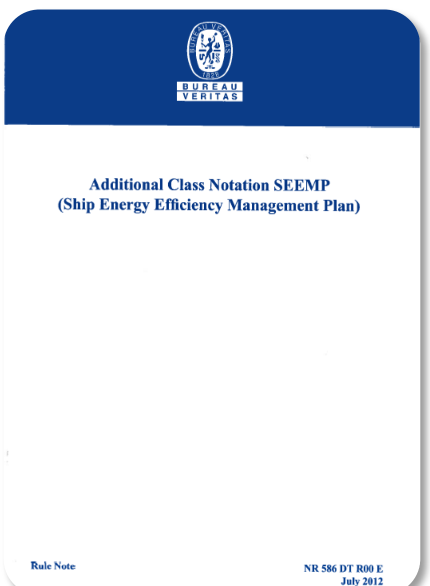

SimulationX Professional Edition - ship_v5.3.ism
Library
Ship modeling
Example of Results
Fuel consumption
CO2 emissions
Speed profile
Combustion engine
Engine model based on a brake specific fuel consumption curve
ExhaustGas
emission box
Waste heat recovery boiler
Fuel
Fuel tanks
Fuel switch with connector as table
Shared library for common models
Mechanics
Operational profile definition
Power management system
Electrical switchboard
Power Management System module
producers and consumers
Steam consumption Profil
Steam Conso
SteamSource
Boiler
Exchanger Steam Evaporator
Simulation finished successfully! (ship_v5.3.ism)

BV Ship Energy Efficient (SEE) Notation

BV Additional Notation SEE, SEE-OP and SEE-MON

- **The additional class notation SEE is defined in BV NR 586 "SEE Additional Class Notation" and deals with the voluntary approval and periodical inspection of the SEEMP.**

- **The (revised) notation SEE includes now:**
  - **Two levels: review of initial plan (SEE) and review of plan and inspections in service (SEE-OP)**
  - **Introduction of SEE-MON for ships fitted with onboard measuring equipment (FO flowmeters, delivered power measurement, torque, draught, trim, navigation info)**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Additional Class Notation SEEMP
(Ship Energy Efficiency Management Plan)

Rule Note

NR 586 DT R00 E
July 2012

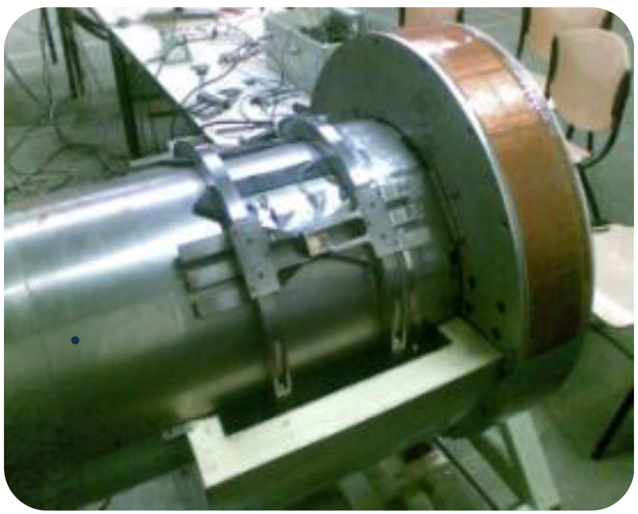
Granting BV Additional Notation SEE - MON

Initial Energy Audit to set the Baseline

Validation of the SEEMP with the SEECAT Tool

Propulsion monitoring – Trim and draught monitoring (water deep in some cases)

Machinery and Auxiliaries instrumentation



Principle : Calibration of the prediction tools with the real measurements (BV certified) onboard in order to get the accurate figures in further predicted consumption.

CASE STUDY 1

Brittany Ferries
UNE AUTRE IDÉE DU VOYAGE

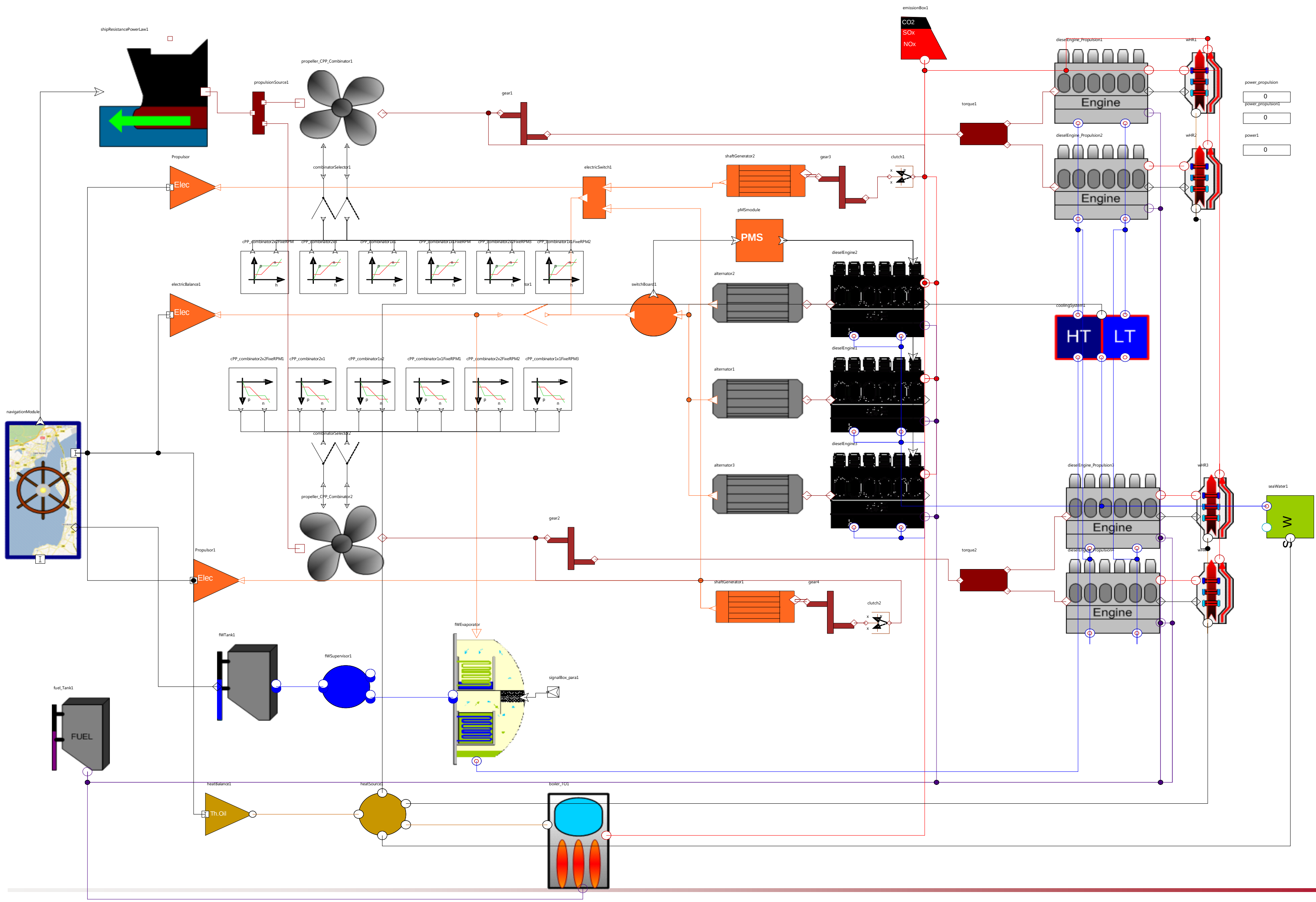
BUREAU VERITAS
1828

Optimising Energy Efficiency in Operation

Guillaume Hagi – Brittany Ferries
Martial Claudepierre – Bureau Veritas

The 35th The Motorship 24-25 April 2013 Copenhagen | Denmark
Propulsion & Emissions Conference

Energy model SEECAT of the Cap Finistère



SEECAT - Cap Finistère – fuel saving example

SEECAT– Application on Cap Finistère – In service optimisation

Configuration with clutched shaft alter ... r unclutched (diesel generators started)

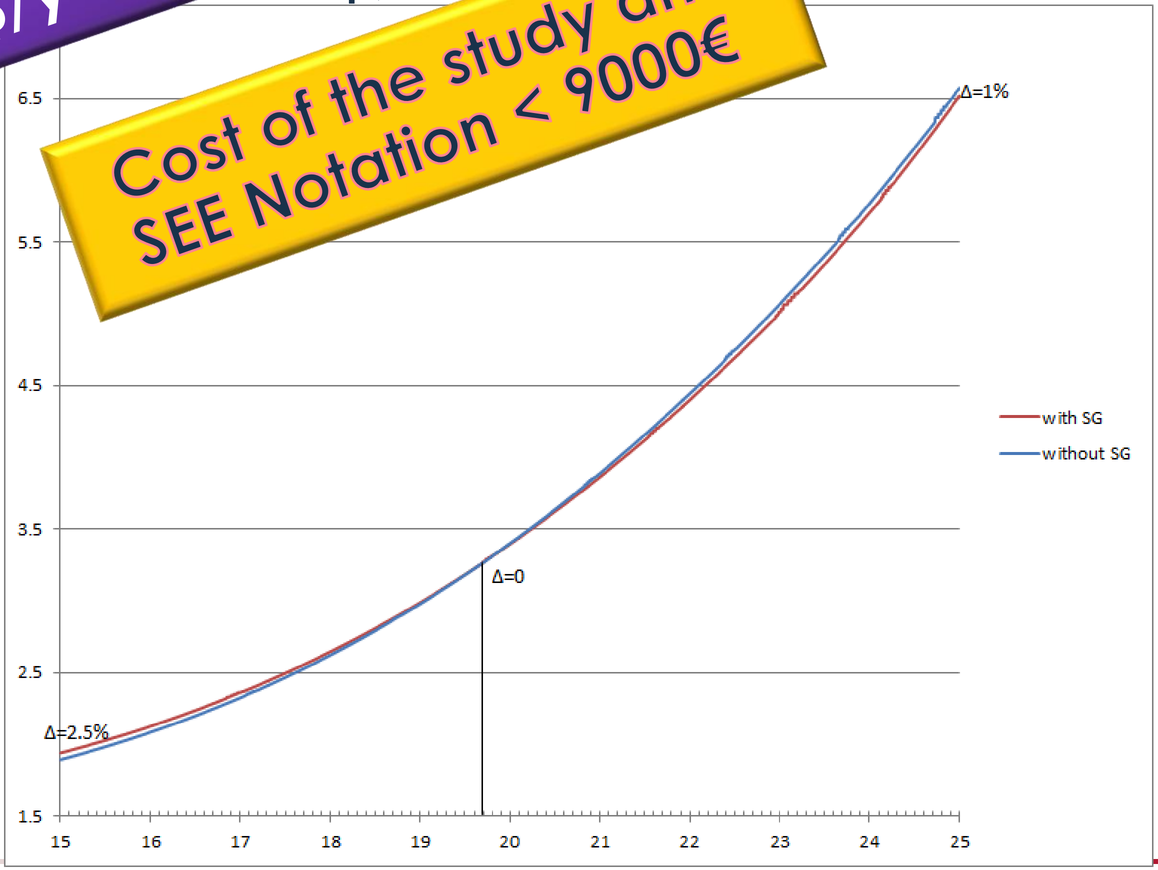
The power gain is ca ... fuel consumpti ... lobal approach according to t ... he ship;

Potential saving of 180000 $/year

Cost of the study and SEE Notation < 9000€

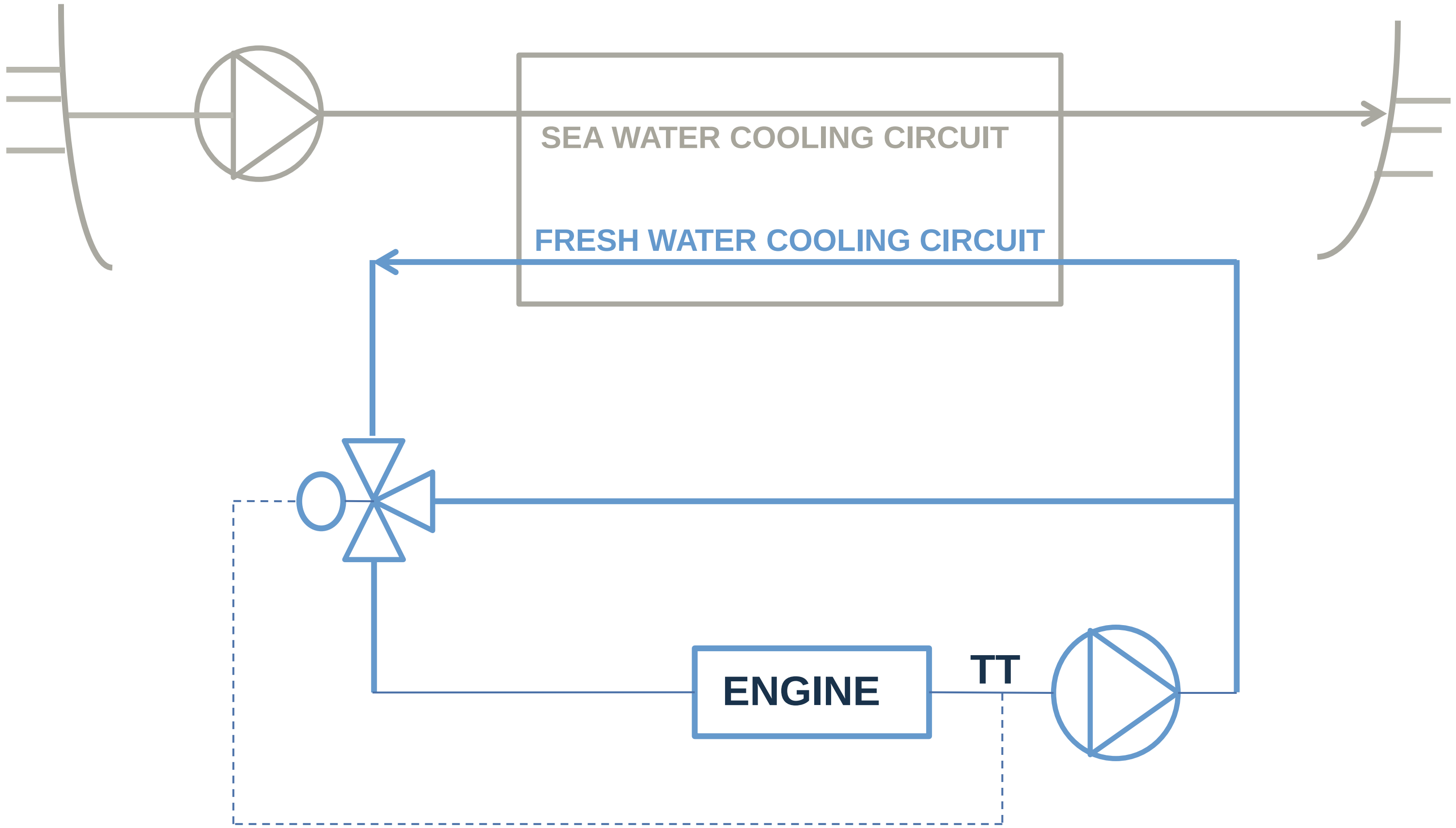
Optimum co... ections of the shaft alternators depending on rotation speed of the shaft lines and needed electrical power and efficiciency of the diesel generators

The best operationnal and lower consumption are highlighted by SEECAT.

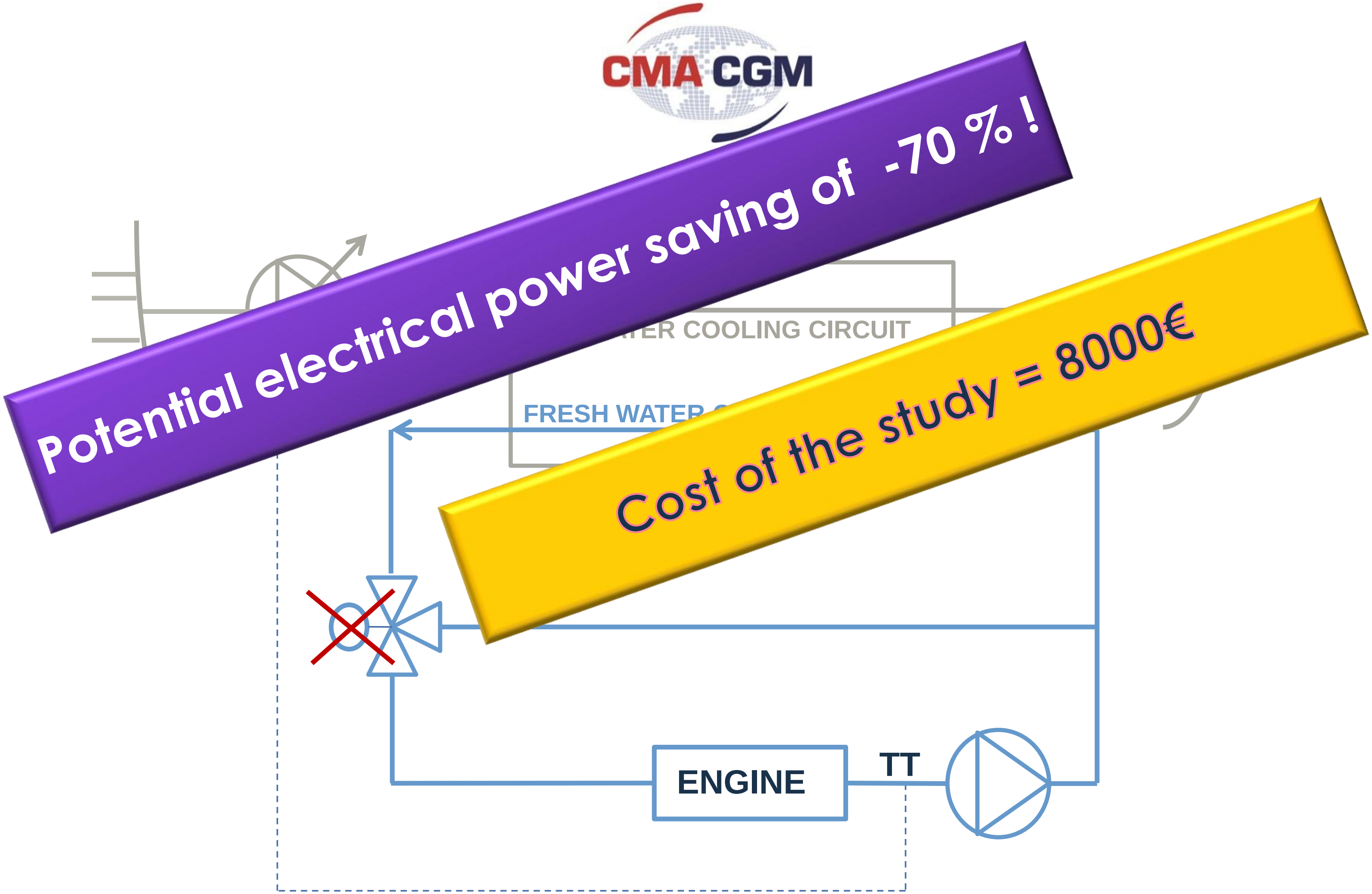


CASE STUDY 2

Cooling of the main engine onboard a 8000 TEU



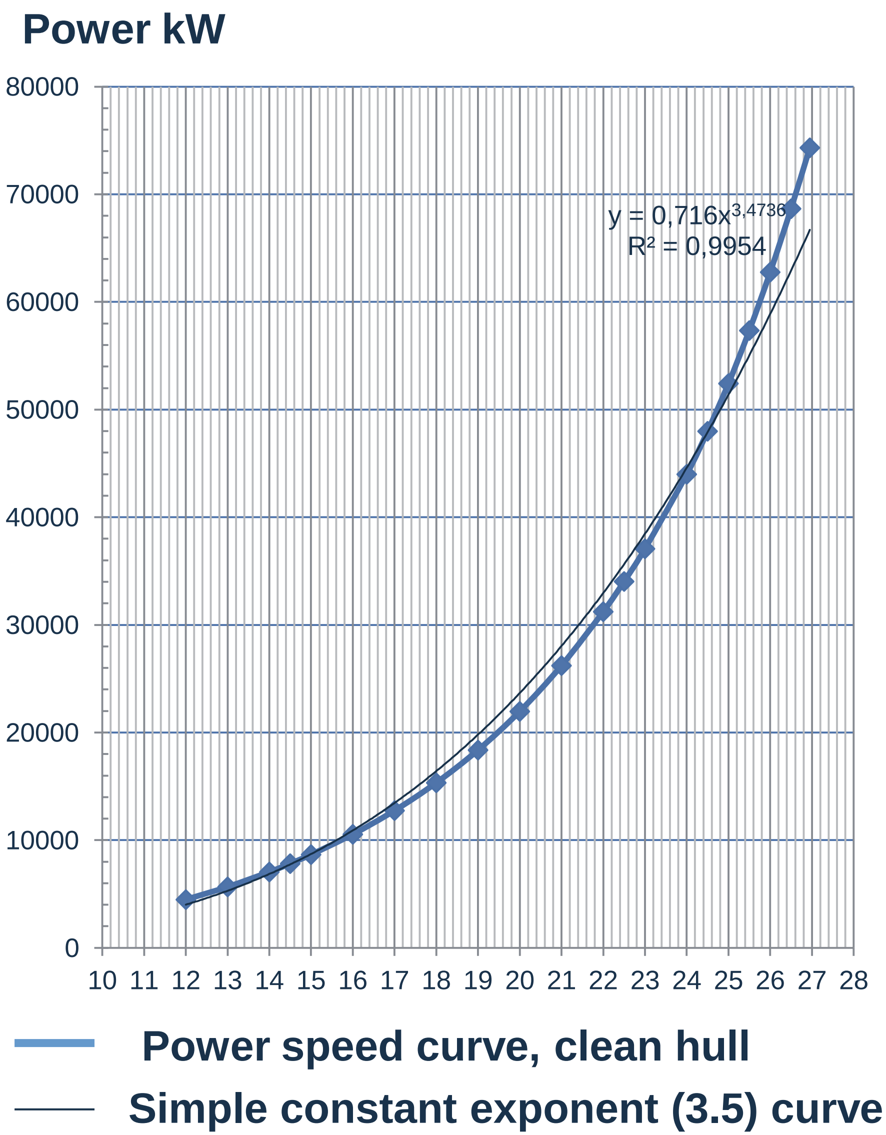
Optimisation of the cooling system with frequency variators



CASE STUDY 3

Slow steaming and change of bulbous bow

- At low speed, the gain in necessary propulsion power can be considered as roughly a 3.5 power law curve.
  - In between 13 and 20 knots for container carriers
  - At 9 knots for a bulk carrier Capesize
- Thanks to the data collected during sea trials, towing tank tests or from CFD, BV will estimate using SEECAT the total fuel consumption at low load,
- Insight for changing bulbous bow will be given by additional CFD calculations from HydrOcean

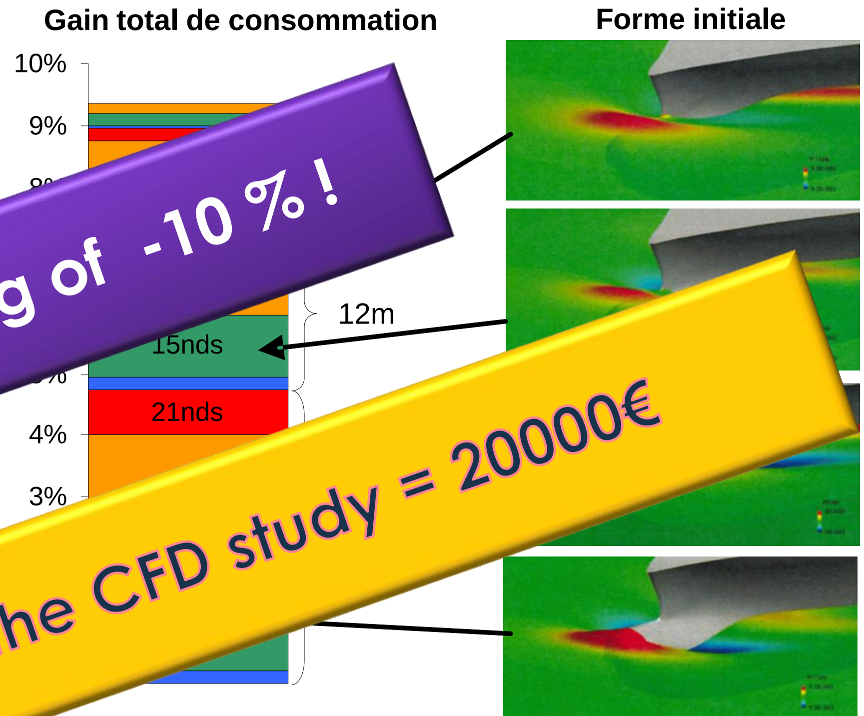


Slow steaming and change of bulbous bow

- Pre requested conditions:
  - The original bulbous bow must have been optimised for high speed and loaded draft
  - The slow steaming operations … drastically different fro… (draft and spee…
- In th… gains … on a large range … onal speeds.
- A large number of nu… calculations can be … parameters variations …

Potential total power saving of -10 % !

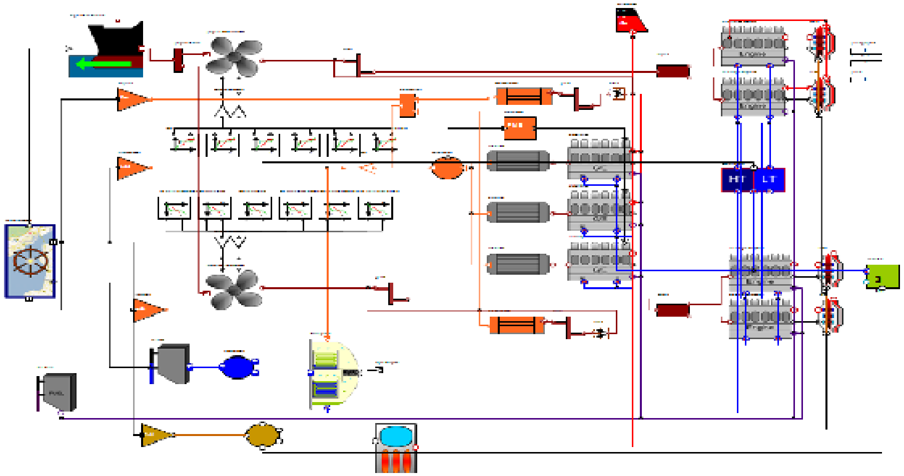
Cost of the CFD study = 20000€



CASE STUDY 4

Shuttle oil tanker in Brasil – effect of fouling on propulsive performance

- rpm, torque and thrust to be measured in both clean and dirty condition, then propeller and hull outputs are separated.
- The variation of the propulsive efficiency between both conditions of the propeller and hull to be calculated from the measurements.
- Predictions from the SEECAT model to be compared to the measurements, then the model to be calibrated for further predictions.



- As the ship displacement, and wind and sea conditions will not be exactly the same at both tests, the corresponding differences will be corrected.

LIST OF REFERENCES

List of references

Brittany Ferries

CMA CGM

TOTAL

MAERSK TANKERS

MARINE NATIONALE

DGA

GLOBAL SHIPPING & LOGISTICS (L.L.C.)

Carisbrooke Shipping

EXMAR

PETROBRAS

SNCM

FINCANTIERI

NCL NORWEGIAN CRUISE LINE® FREESTYLE CRUISING®

Any question?