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Modelling and energy generation possibilities in hybrid sailboat

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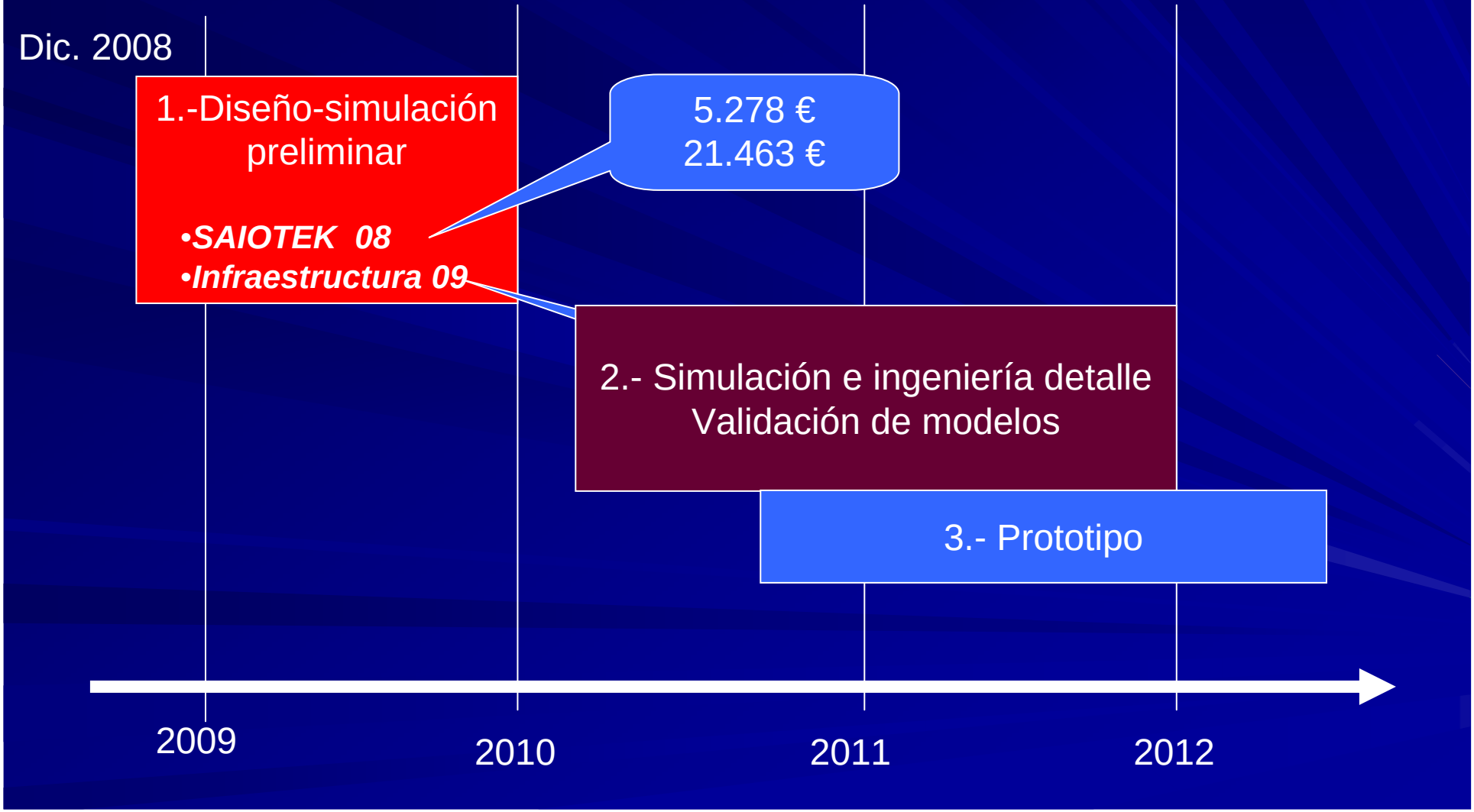
Summary

Modelling and energy generation possibilities in hybrid sailboat

- Introduction
- Objectives
- Material and methods
- Results
- Conclusion

2.- **Introduction** : proyectos I+D



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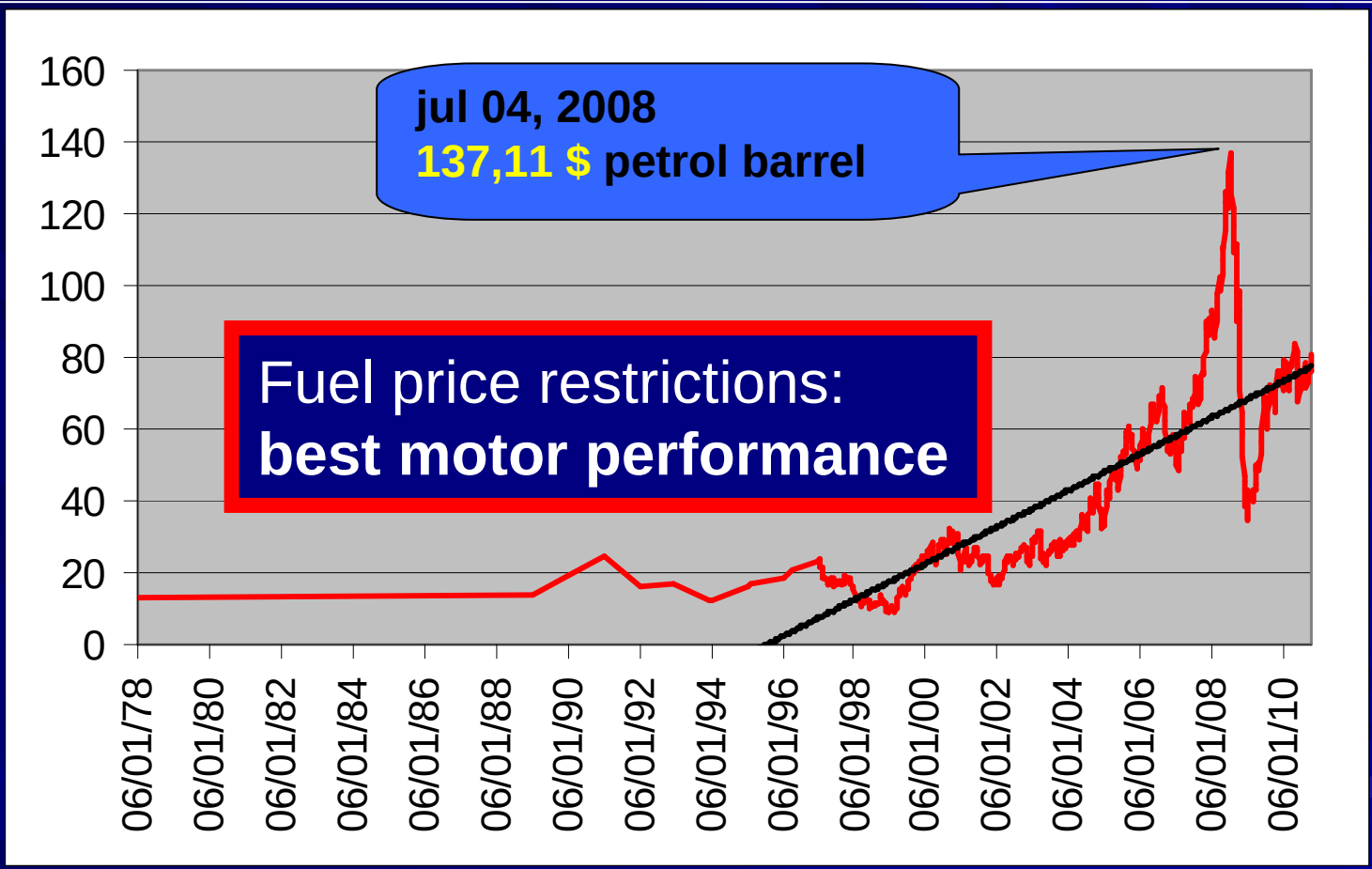
Introduction



Weekly All Countries Spot Price FOB Weighted by Estimated Export Volume (Dollars per Barrel)
Source: US *Energy Information Administration, www.eia.doe.com*

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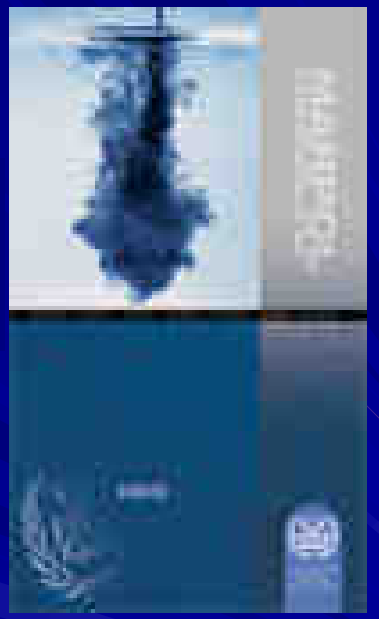
Introduction

Restriction in gas emission : laws

IMO MARPOL 73/78 annex VI regulation 13, in force since 2005

Future regulation will be more restrictive.



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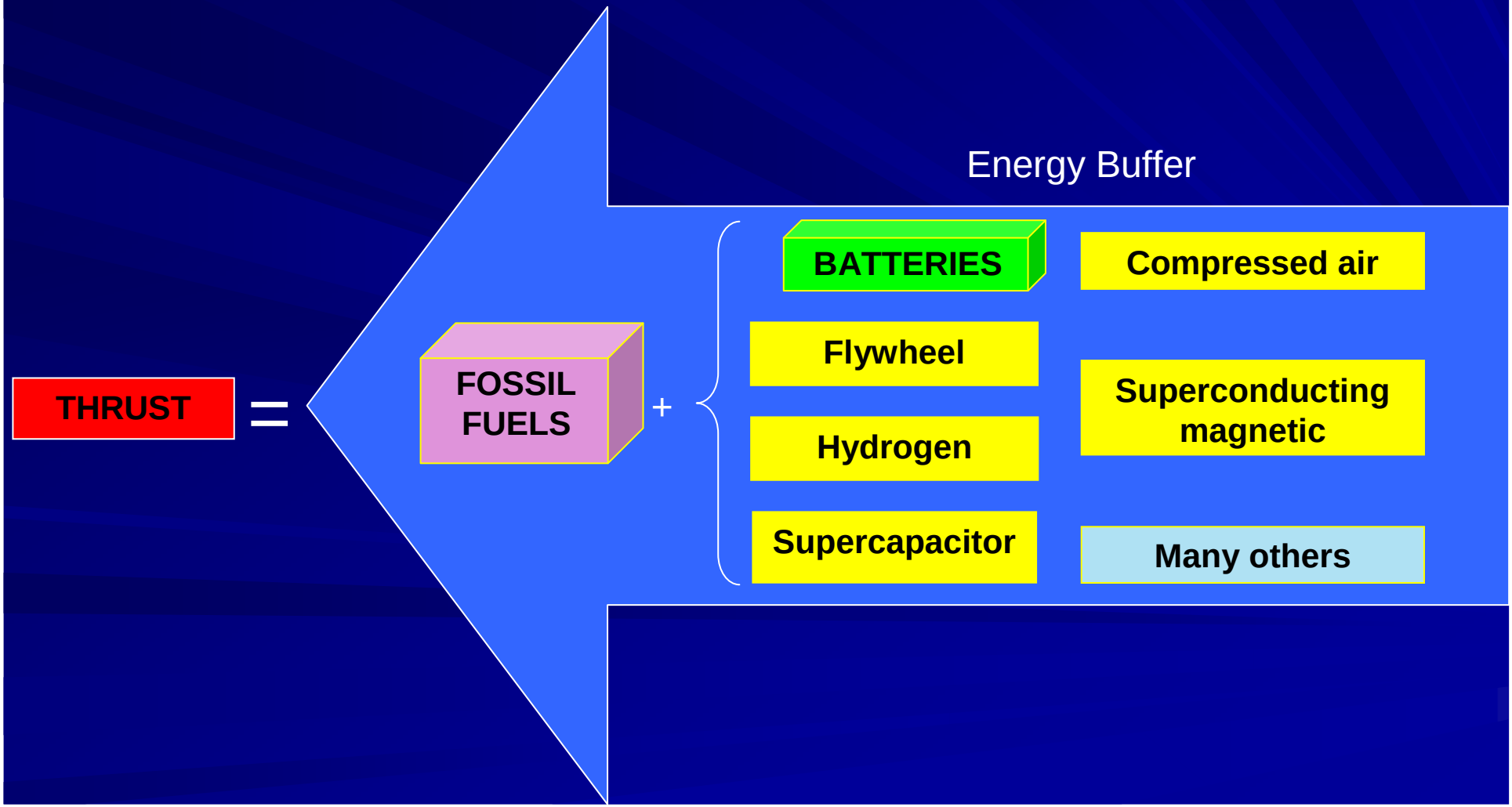
Introduction

Hybrid propulsion: uses 2 or more distinct energy sources to **thrust** the ship



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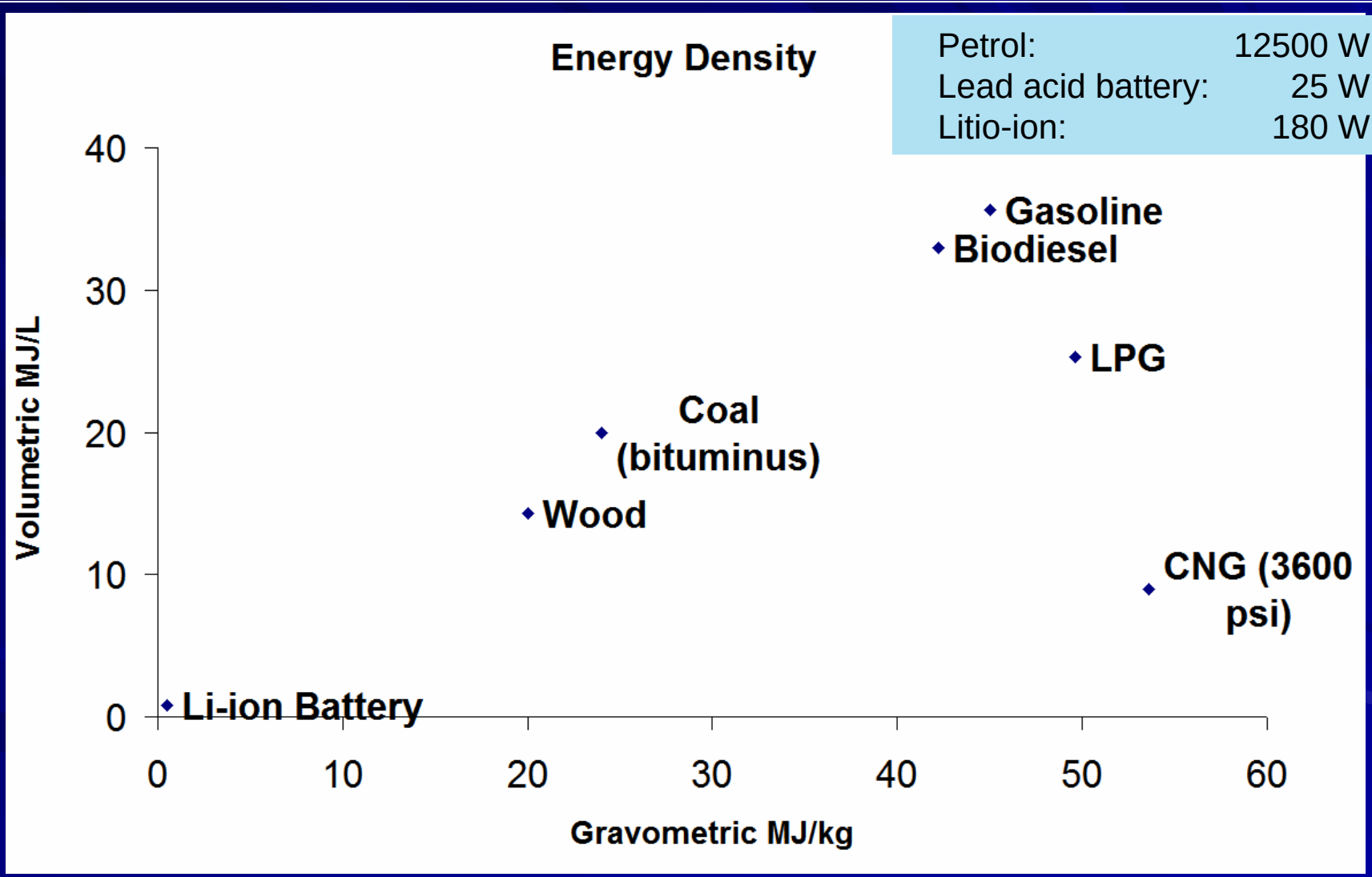
Introduction

Petrol:	12500 Wh/kg
Lead acid battery:	25 Wh/kg
Litio-ion:	180 Wh/kg



Source: http://en.wikipedia.org/wiki/Energy_density

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Introduction

Energy Equivalency

(Smart cdi 40)

Gas

3.79 litres

135 MJ of energy

=

Batteries

21 Li-ion batteries (Car battery size)

2.7 kg

Bilbao-Cartagena
56 l (875 km)
5000 kg 3014 l

340 kg

205 litres

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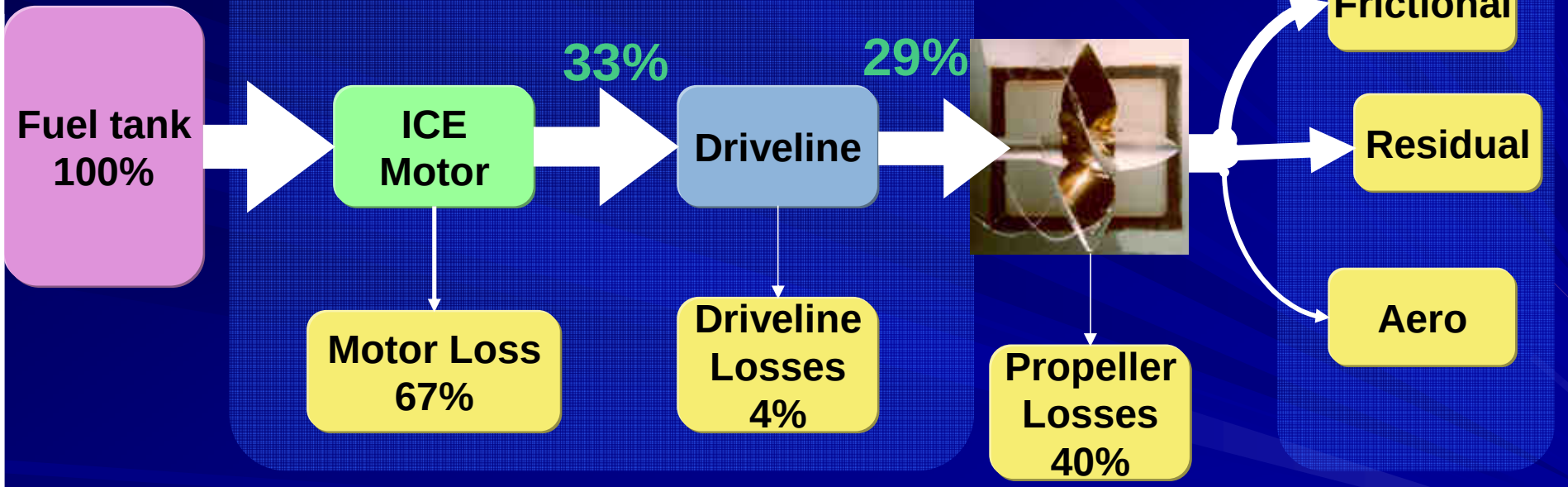
Introduction



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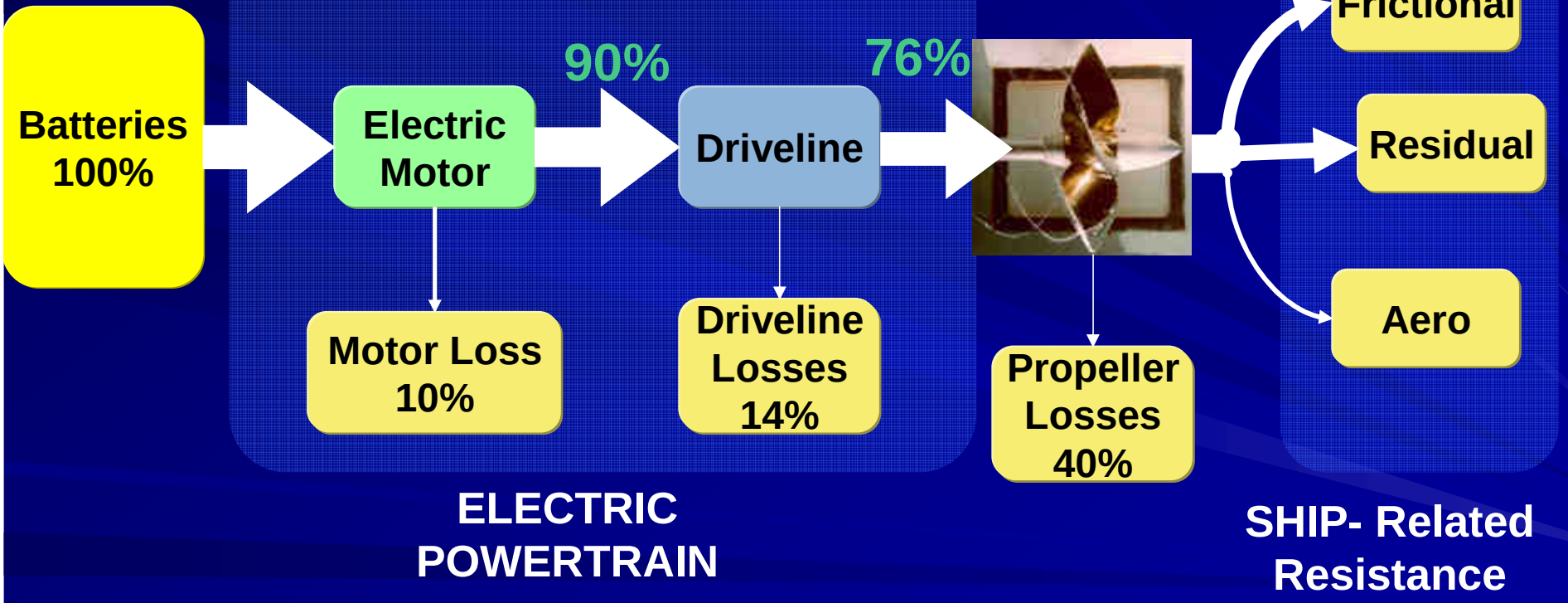

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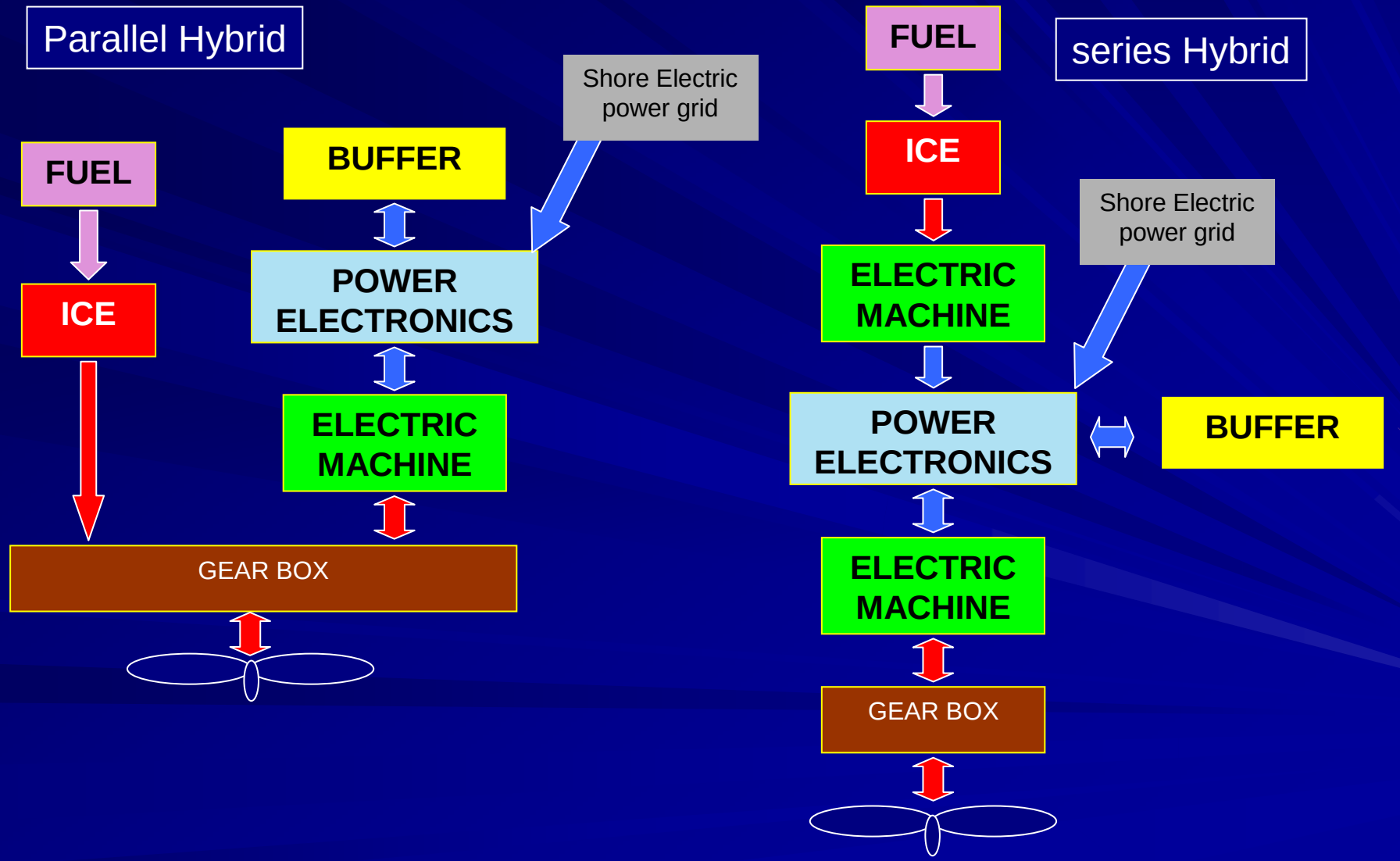

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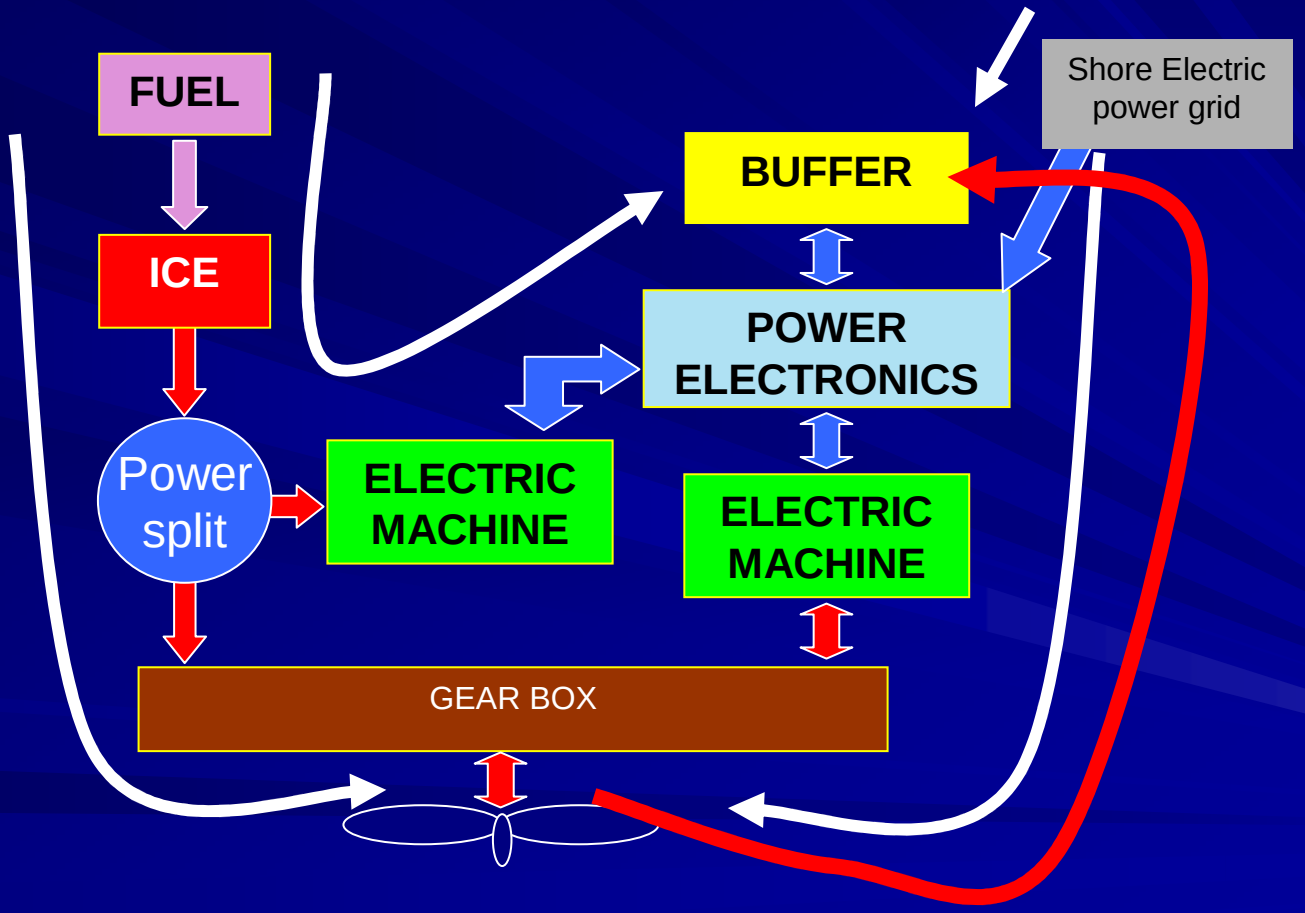
Introduction

Series/parallel Hybrid



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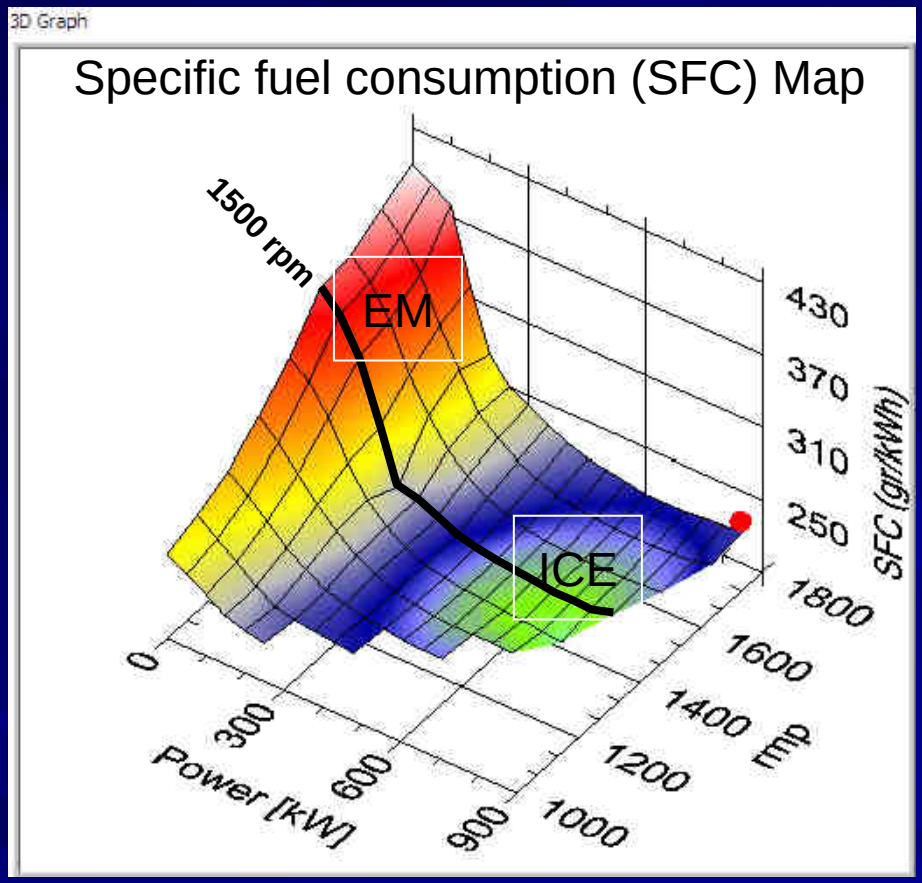
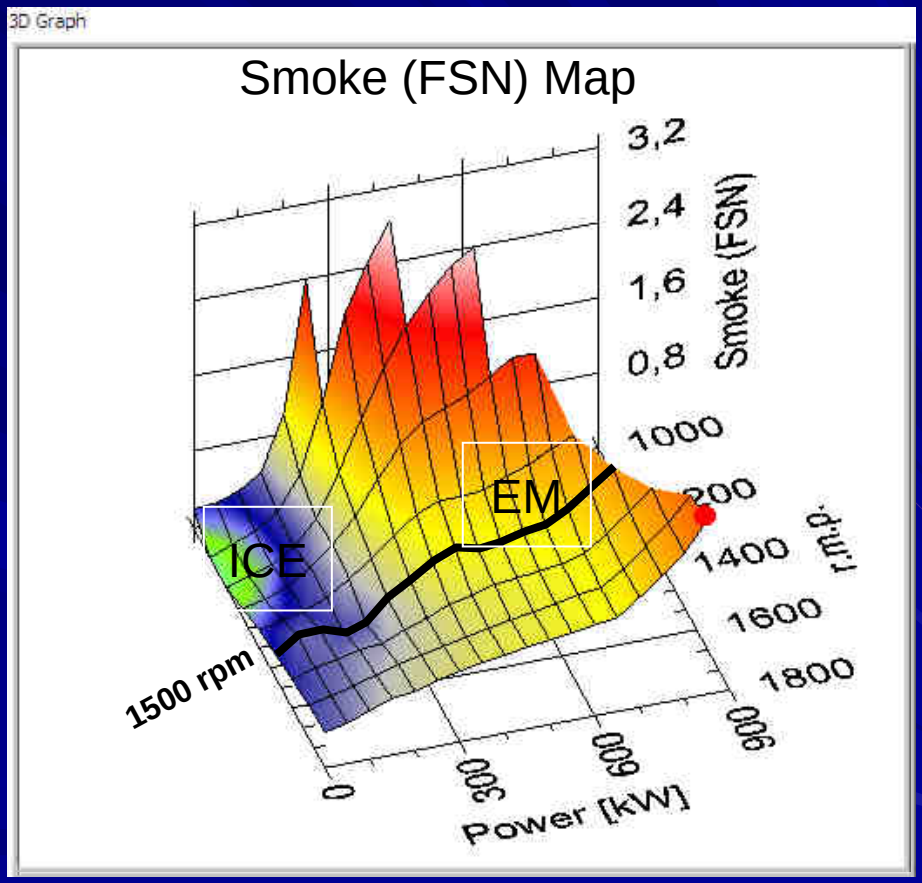
Materials and Methods





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Objectives

1. To model mathematically: hull, propeller and interaction between them. Integrate all components by software for feed-forward simulations.
2. To evaluate available power to use in energy generation.
3. To calculate optimal propeller operation set point.
4. To determine ship speed variations due energy generation.
5. To compute generated energy at different thruster speeds with every apparent wind angle.

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Materials and Methods

Sail thrust

Motor thrust

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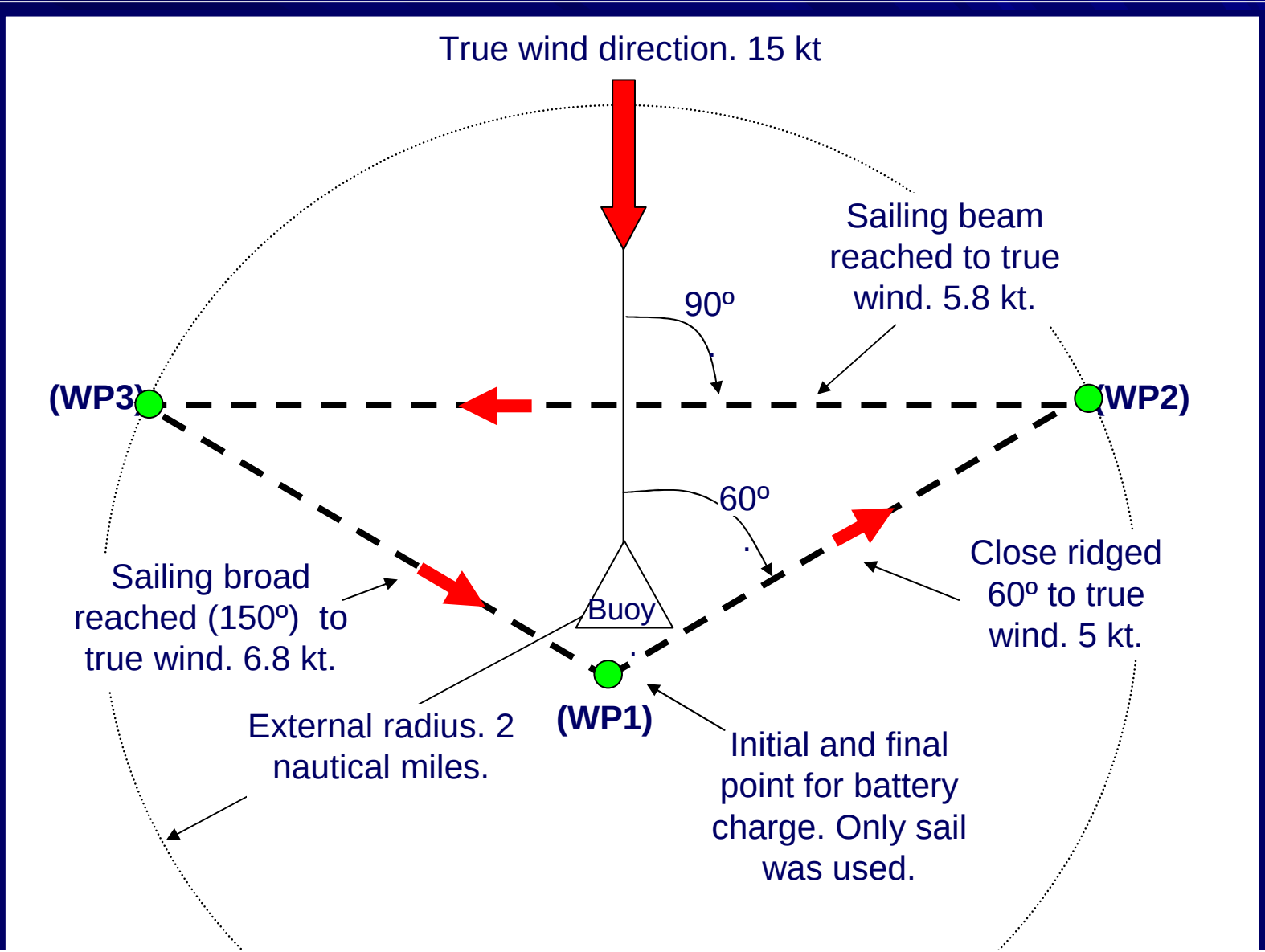
Materials and Methods



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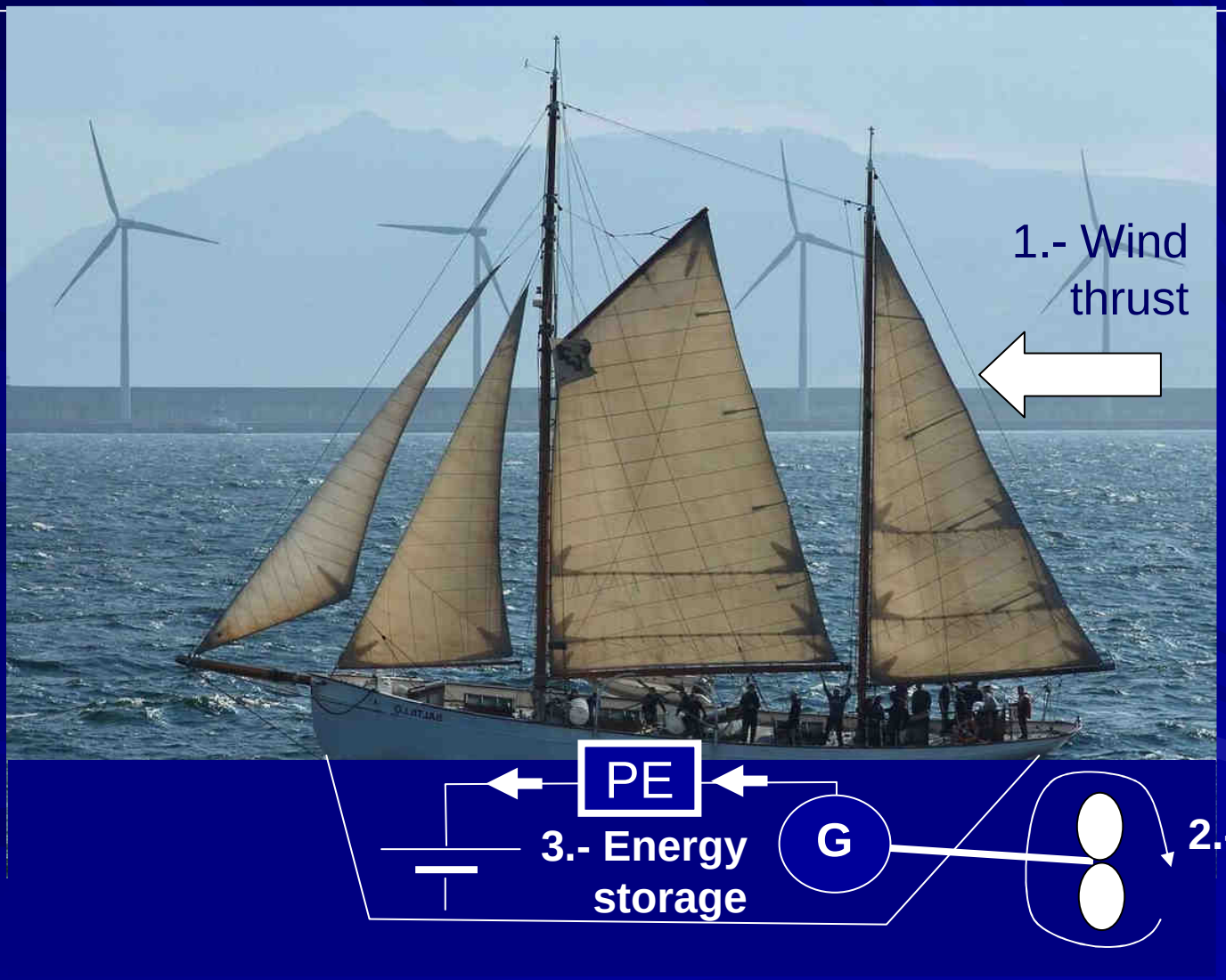
Materials and Methods



Model: training ship “Saltillo”. Scheme of considered energy flow.

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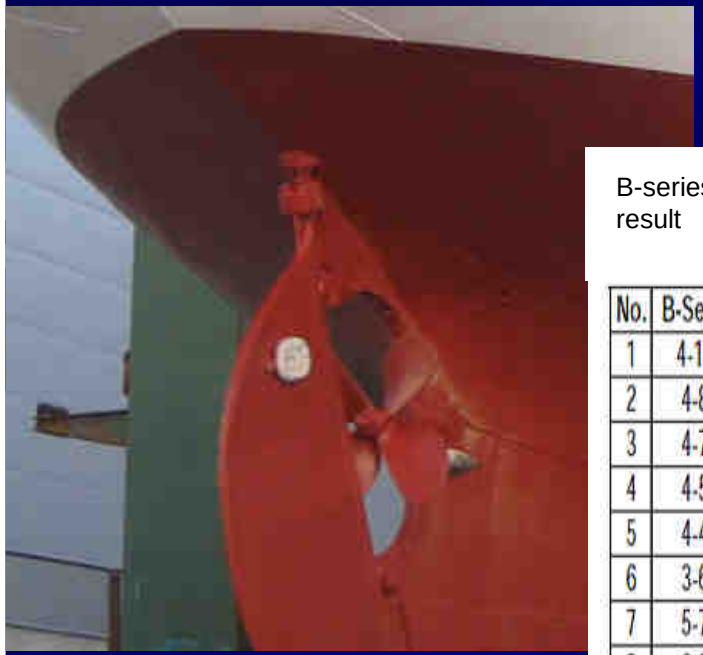
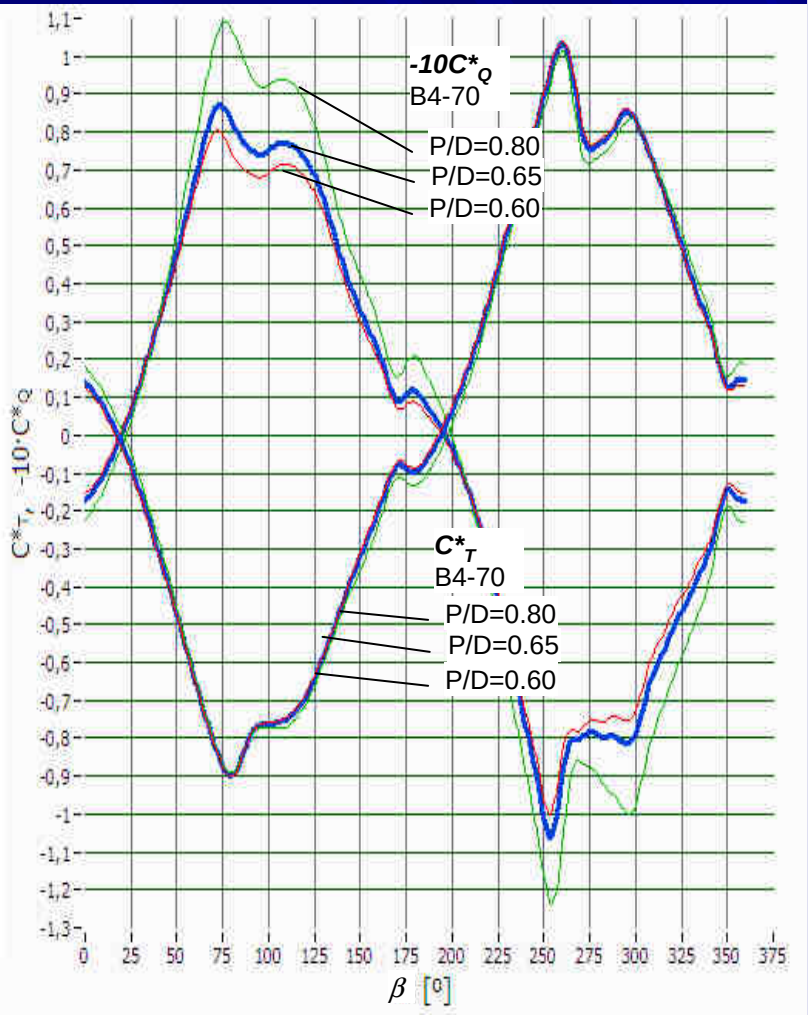
Materials and Methods



Propeller model: B4-70 P/D-0.65

B-series propellers with 4 quadrants result

No.	B-Series	P/D	Ae/Ao	Z	
1	4-100	1.0	1.00	4	☐
2	4-85	1.0	0.85	4	☐
3	4-70	1.0	0.70	4	☐
4	4-55	1.0	0.55	4	☐
5	4-40	1.0	0.40	4	☐
6	3-65	1.0	0.65	3	☐
7	5-75	1.0	0.75	5	☐
8	6-80	1.0	0.80	6	☐
9	7-85	1.0	0.85	7	☐
10	4-70	0.5	0.70	4	☐
11	4-70	0.6	0.70	4	☑
12	4-70	0.8	0.70	4	☑
13	4-70	1.2	0.70	4	☐
14	4-70	1.4	0.70	4	☐



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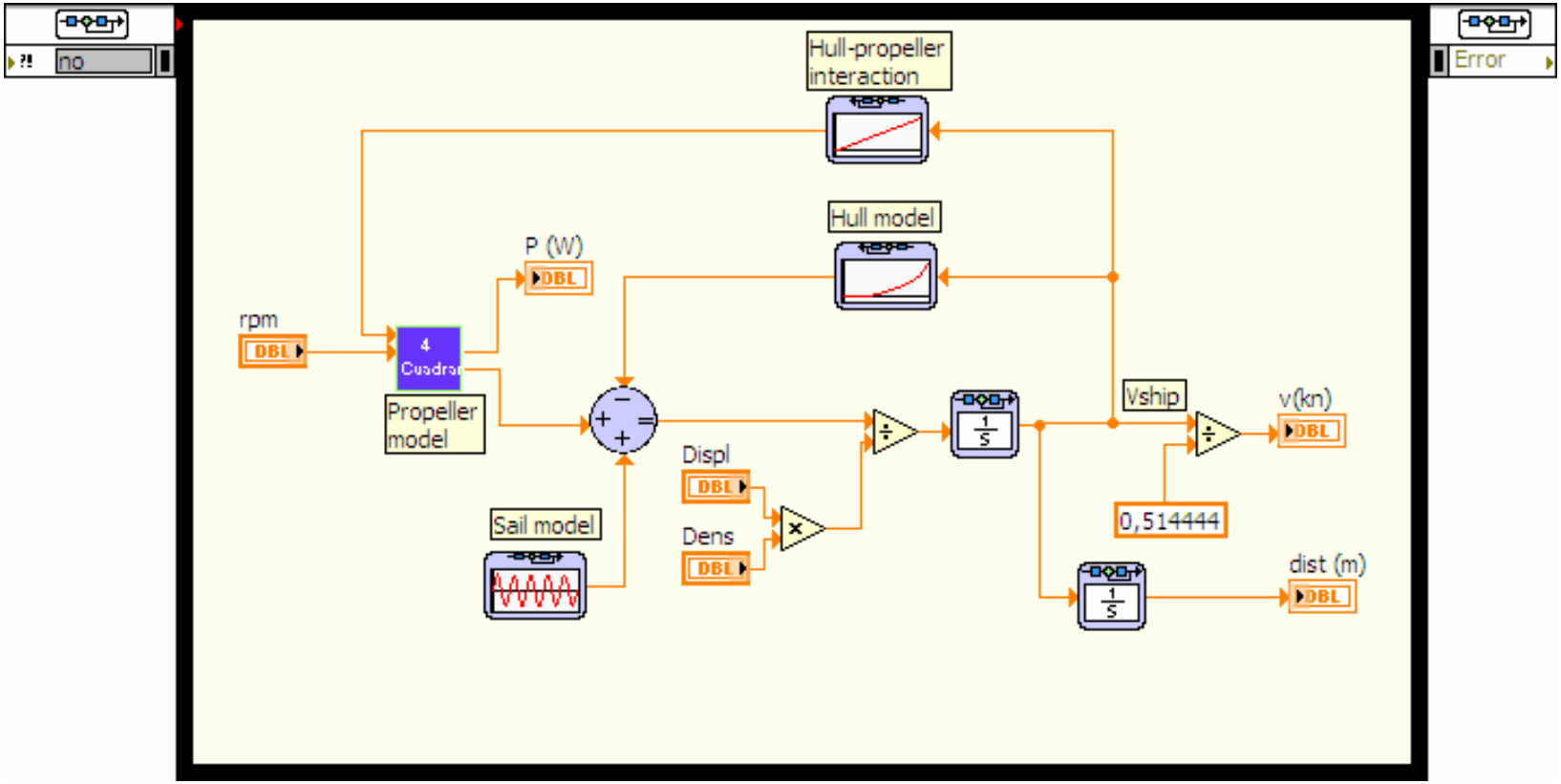
Materials and Methods

Sail ship model



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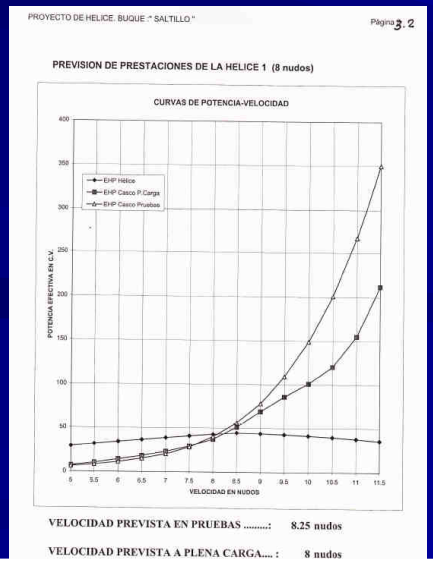
Materials and Methods

Hull model

Lekuona
Oortmerssen
Holtrop


PROYECTO DE HELICE. BUQUE : " SALTILLO "

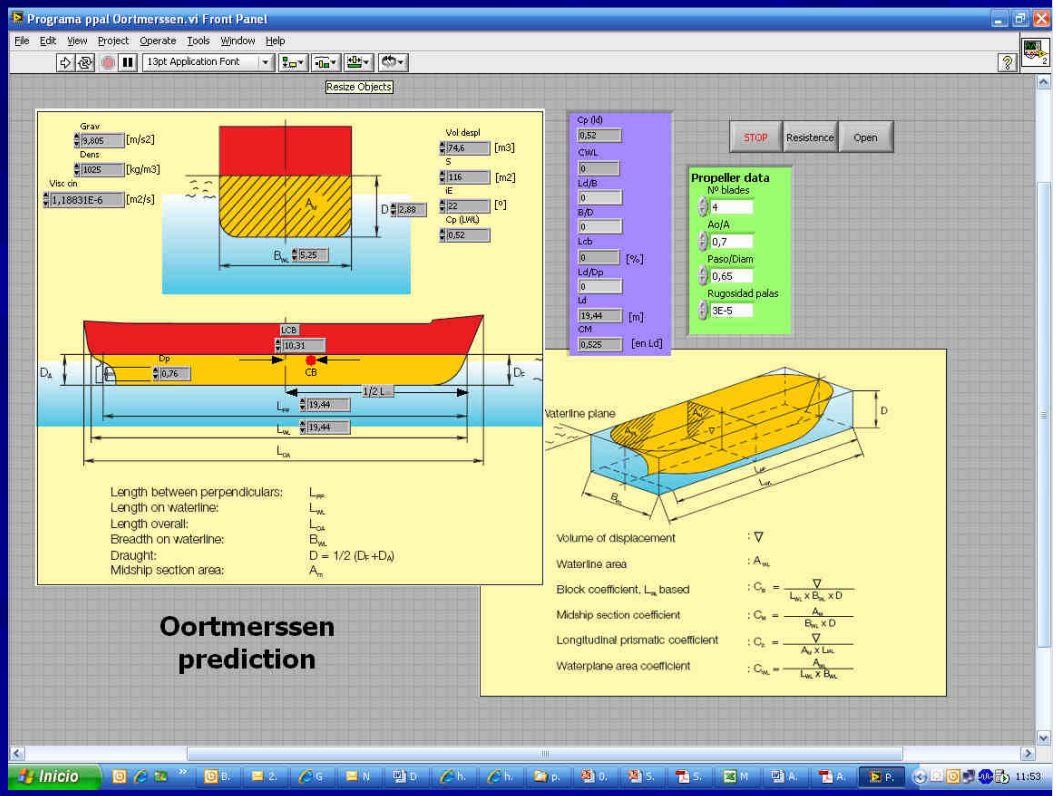
Página 3. 2

PREVISION DE PRESTACIONES DE LA HELICE 1 (8 nudos)

CURVAS DE POTENCIA-VELOCIDAD

VELOCIDAD PREVISTA EN PRUEBAS .....: 8.25 nudos

VELOCIDAD PREVISTA A PLENA CARGA.... : 8 nudos



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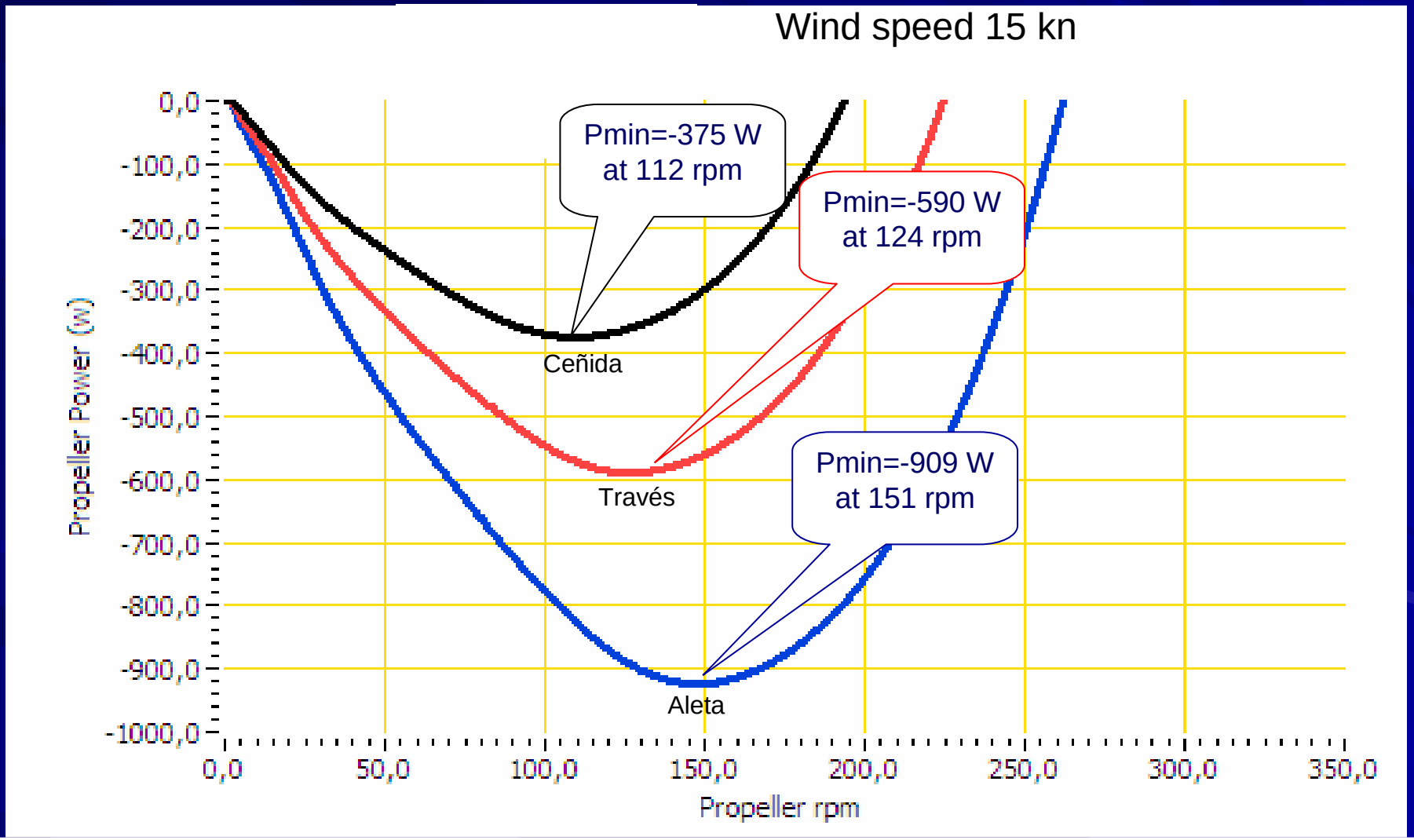
Results

Simulation results of Propeller power and rpm sailing



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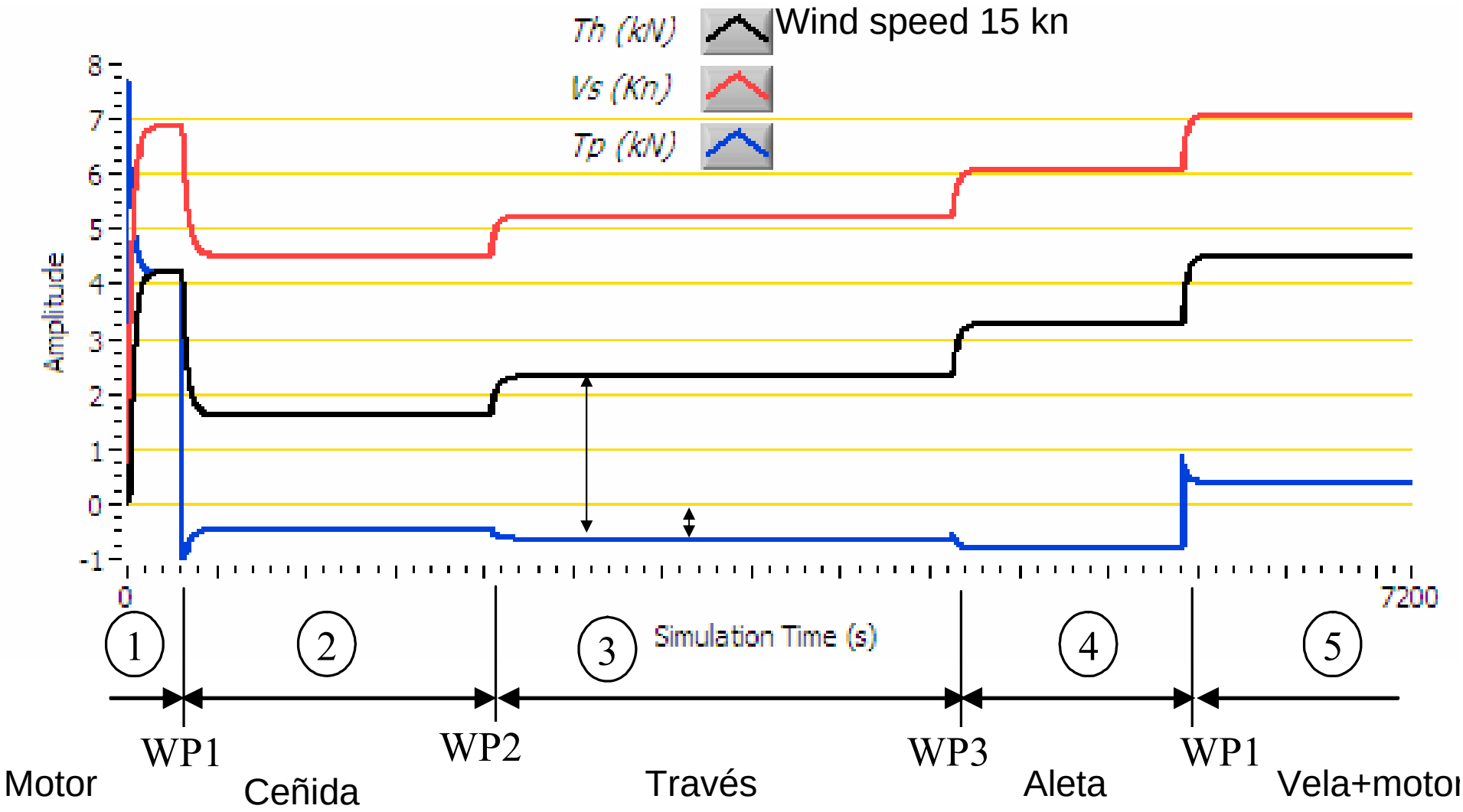
Results

Simulation results of ship speed, hull resistance and propeller thrust



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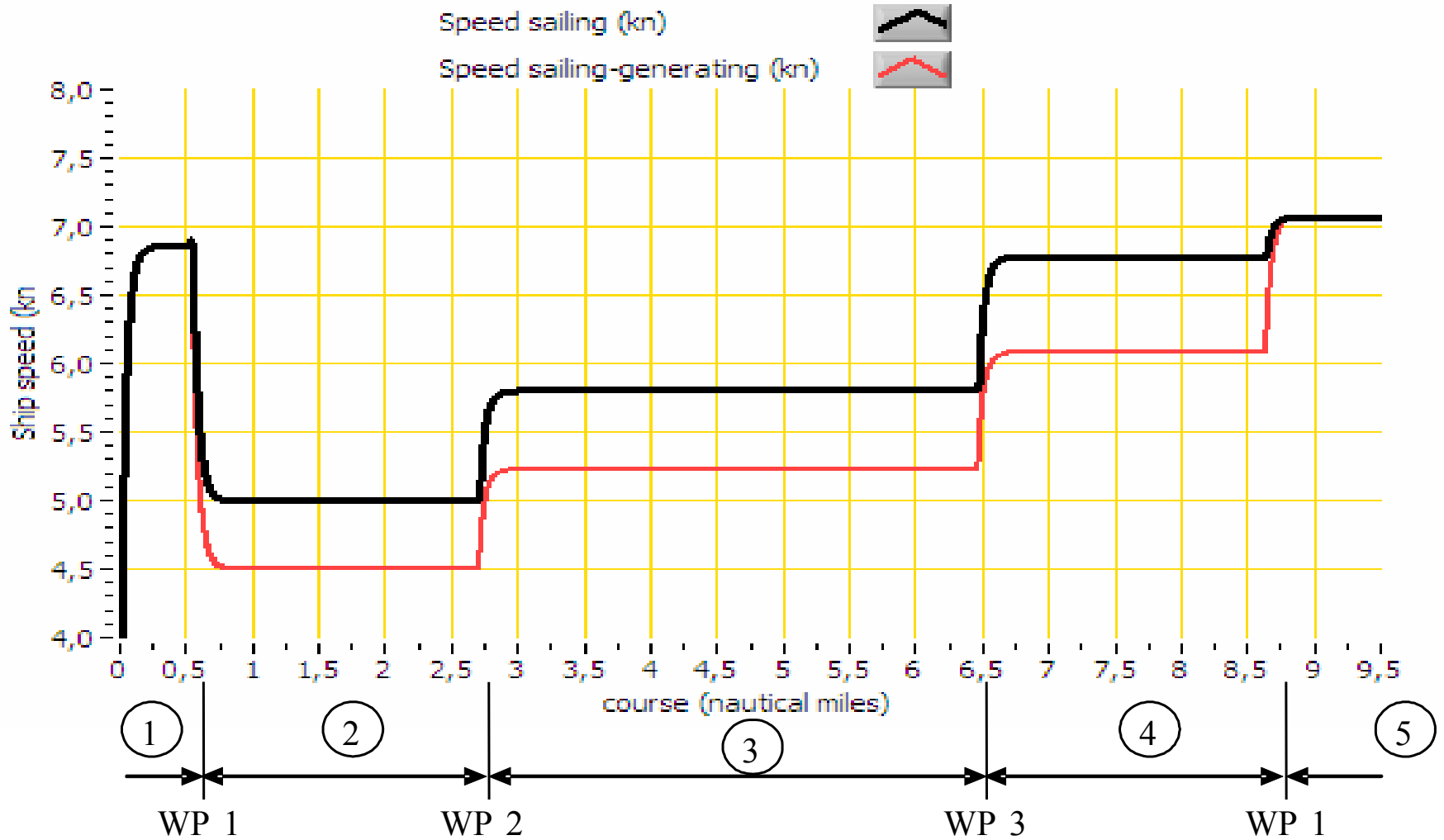
Results

Simulation results of ship speed sailing with and without generation



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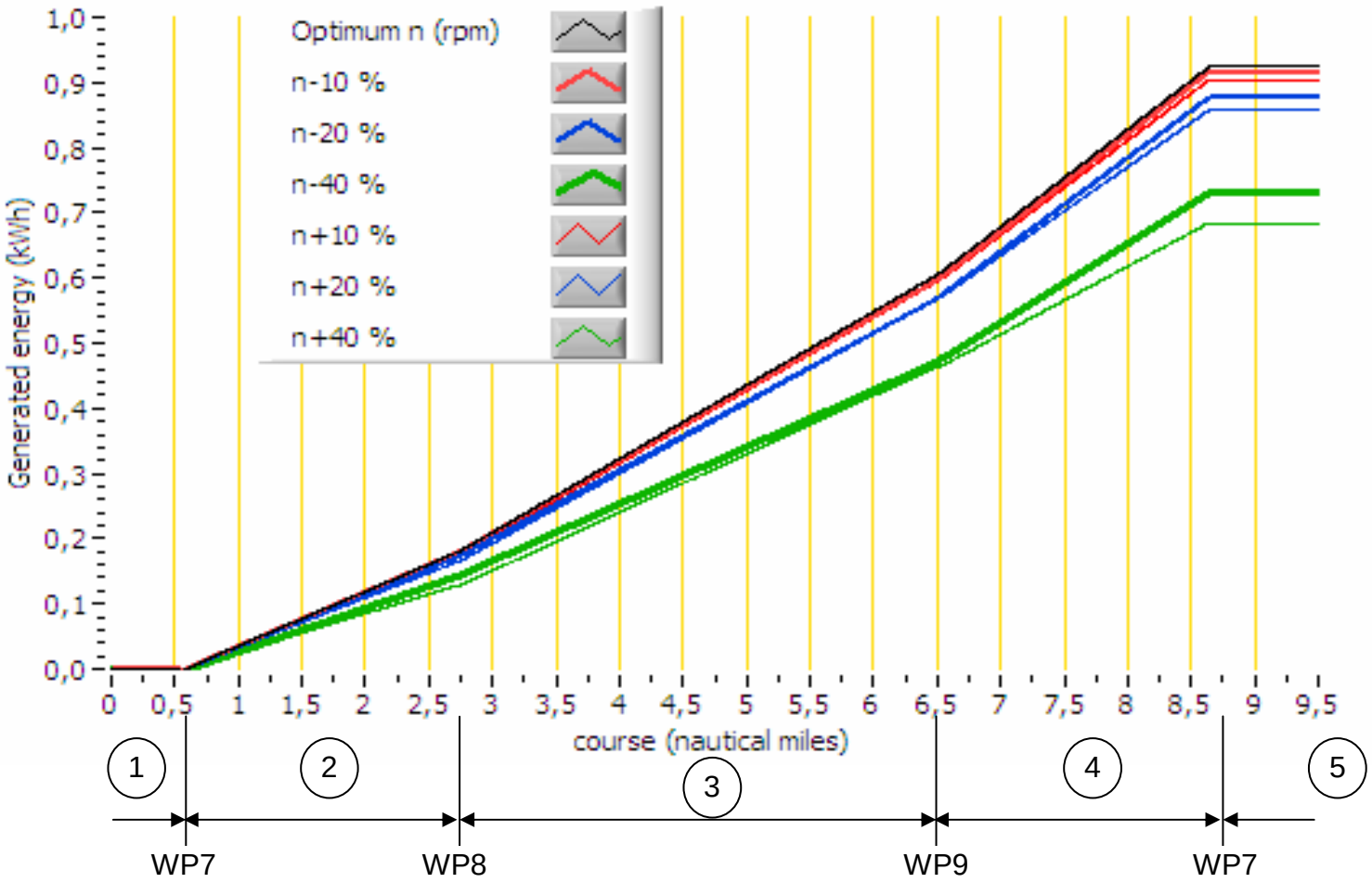
Results

Generated energy (kWh) sailing between WP7-WP8-WP9-WP7 for different propeller speed set points.



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Conclusion

1. The available power to use in energy generation is significant and useful to energy generation, incremented in longer tracks sailing under sail exclusively. This power was highly dependent of the propeller rpm operation set point. An advanced control algorithm is necessary to maximize energy generation.

2. The ship speed variations due energy generation were not significant.

3. Presented energy recovery strategy, helps to reduce hybrid sailboat fuel consumption and emissions, without compromise navigation speed and can be used in “Vehicle to grid” (V2G) operations.

4. The positive results obtained from these simulations will be continued capturing navigational data by means of instrumentation already installed on board training ship “Saltillo”. Tests at sea are going to be carried out on 2010.


QUESTIONS ????