Economics of Sail Transport

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ENVIRONNEMENT
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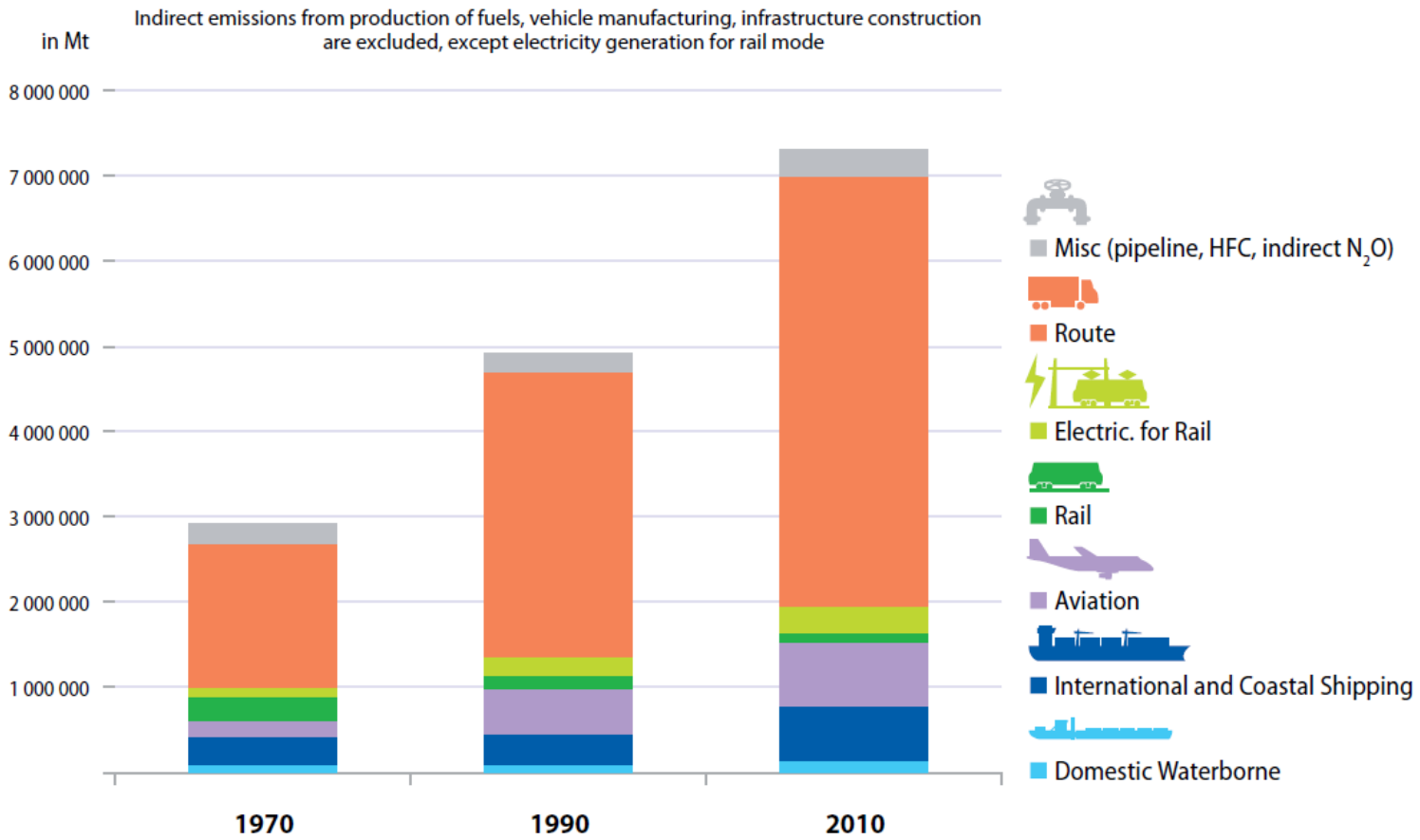
Transport is part of the problem but also of the solution

- Maritime transport is a key element of globalization
- It is also the most efficient way to transport goods in long distance
- But it is in total very dirty (soon the first source of sulfur in Europe) and threatened by oil instability and GHG emissions regulations

Direct GHG emissions by transport mode



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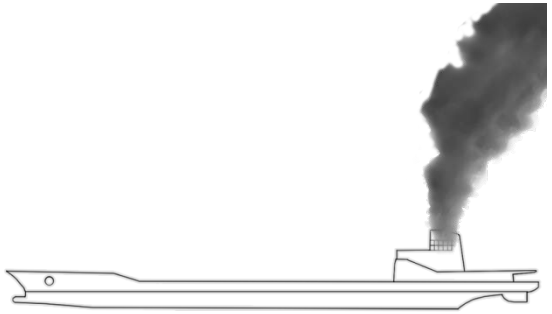
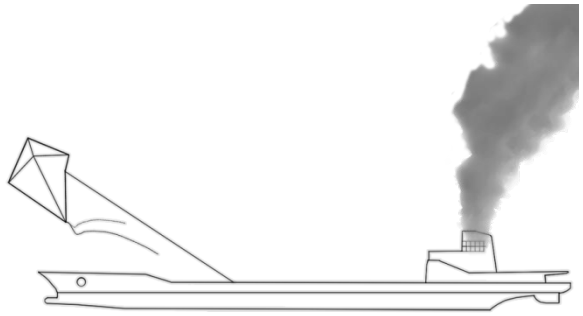
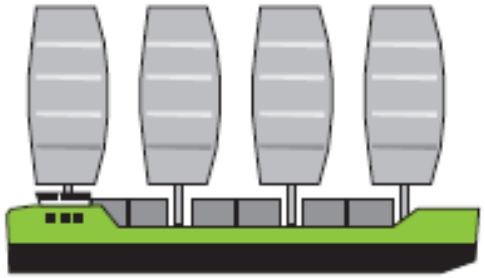
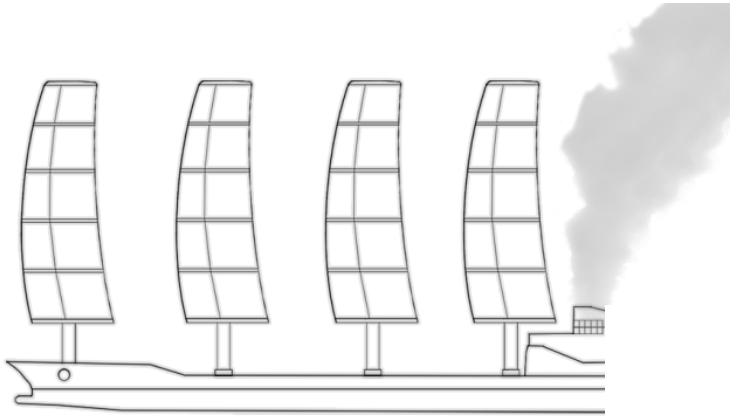


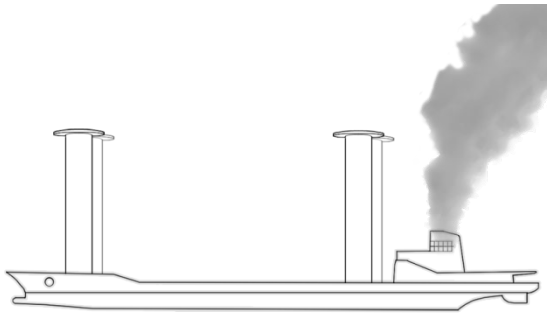
Fuel is the problem, but distillates and LNG (advocated by large players in the game) will be too… eventually

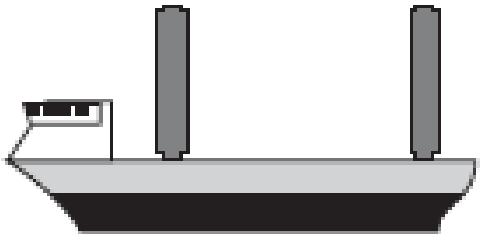
Shipping with sails combined with electric or biofuel propulsion :
multiple propositions now on the table,
even IPCC mentions sails in its latest report
AR5 + IRENA + Lloyds Register…











Drowning in technology…..

From Nikkels et Al., Dykstra Engineers

- Full automation of sails,
- New sail dispositions,
- Optimized hulls,
- New materials,
- Hybrid drive with electric component,
- Routing based on real time meteo + historical data

Etc…

Main control panel

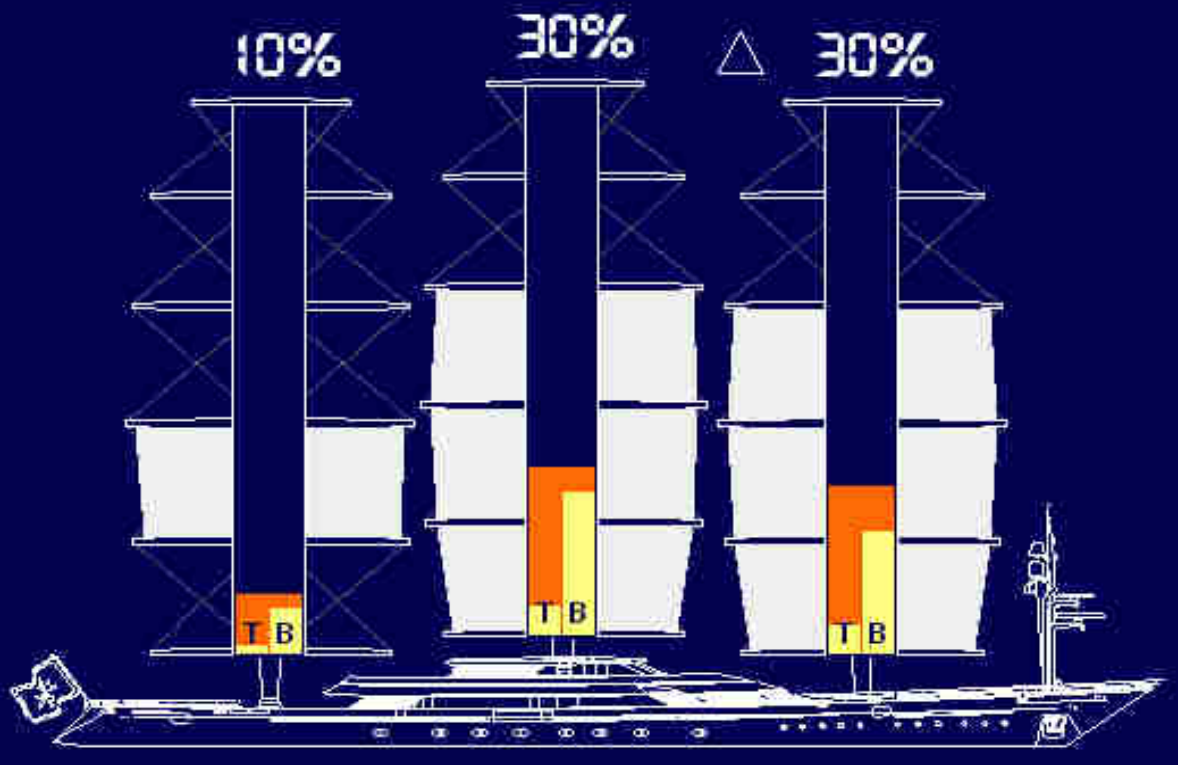
Alarm time	Message

FIBRE OPTIC STRUCTURAL MONITORING

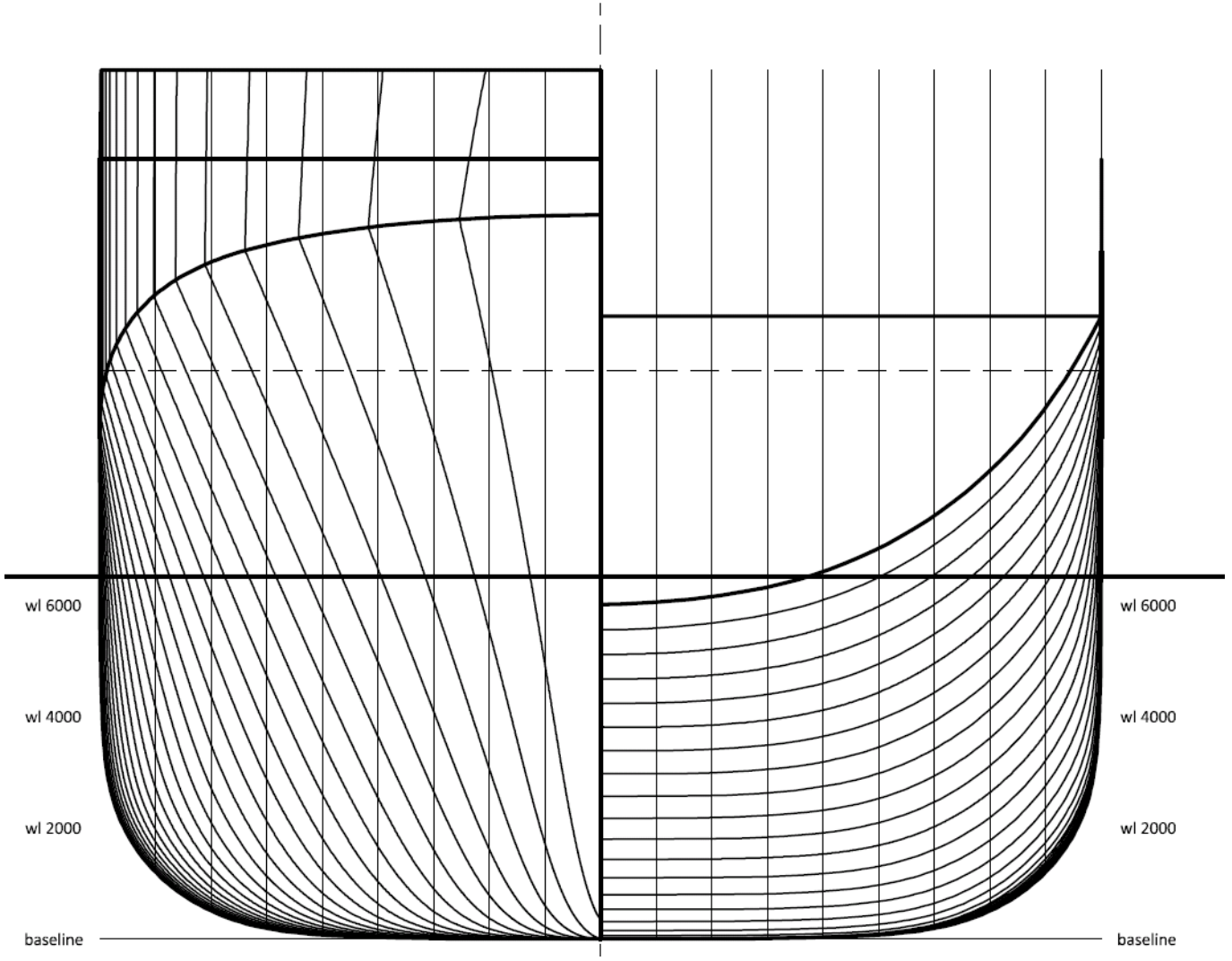
MENU

ALARMS DETAIL

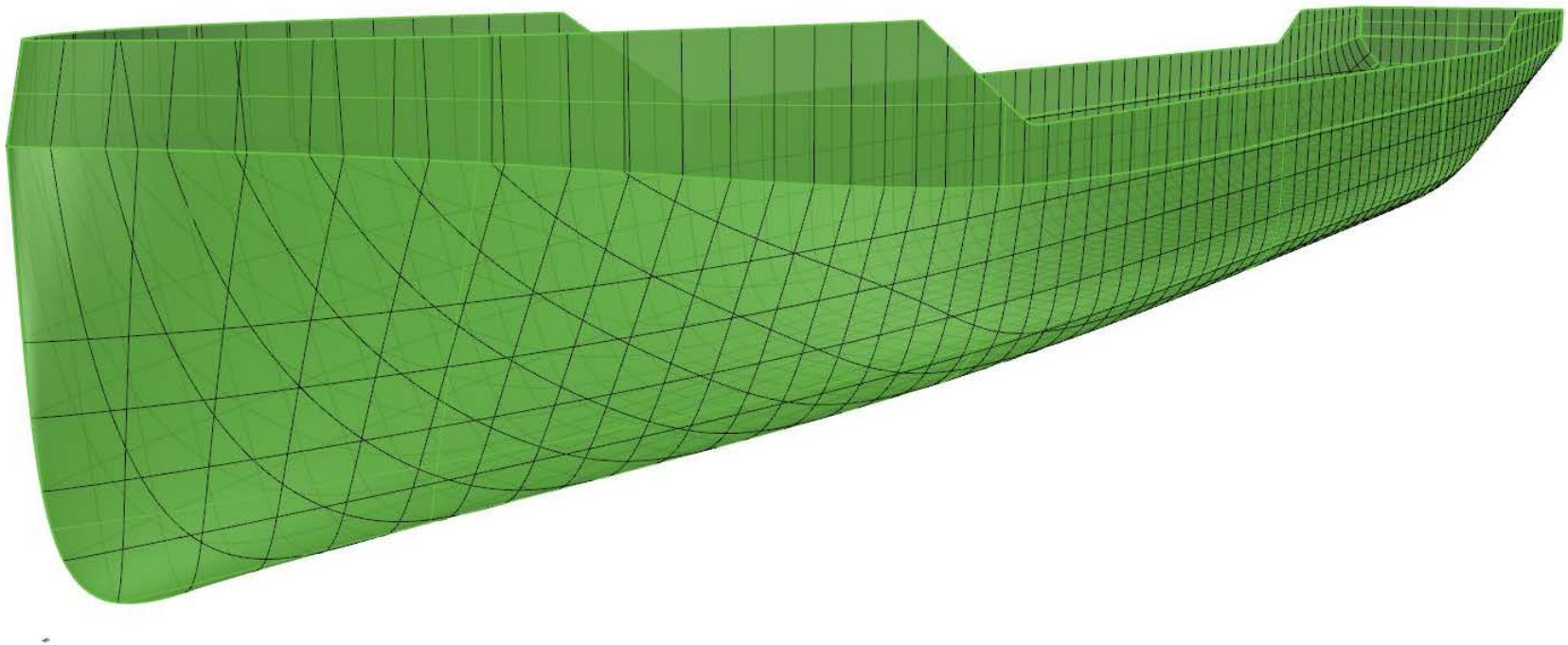
	MIZZEN	MAIN	FORE	COMBINED
DRIVING FORCE %	24	7	15	47
HEELING MOMENT %	9	8	19	37
DF / HM	100	55	51	32



Body plan


wl 6000
wl 4000
wl 2000
baseline
wl 6000
wl 4000
wl 2000
baseline

Hull lines



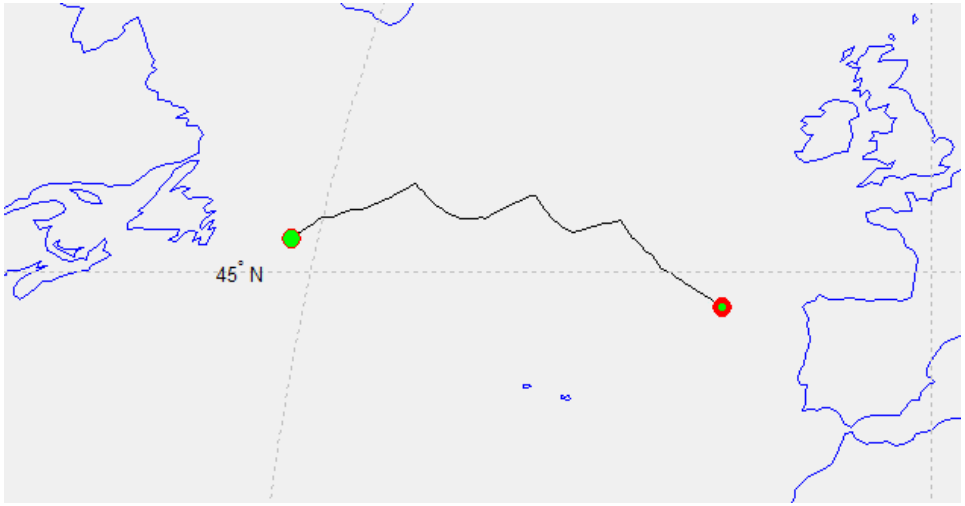
Weather routing definition

Weather conditions

- Wind
- Waves
- Current

Optimize

- Course, engine use
- Time, fuel consumption



routingGUI

Ship

Load ship

Max TWS (kts) 50

Max wave height (m) 10

Power steps 6

Power - +

Rotation rate (% max) 80

Power (kW) 1771.

Fuel cons. (ton/h) 0.384

Weather data

Open GRIB | Multiple GRIB

GRIB start date 2007 12 31 0

View weather

Colors: Wind speed | Arrows show: Nothing

Time set/max (h) 0 180 << >>

Routing output

Route time (h) | Average leg time (h)

Fuel cons. (ton) | Max. course diff. (deg)

Distance (nm) | Calculation time (s)

Max. course difference from GC course (deg)

Show route << >> All | Save all

Numerical

Nx 30 | Aspect ratio 0.6 | Nr 15

Ny 51 | Course range 140

Start / end

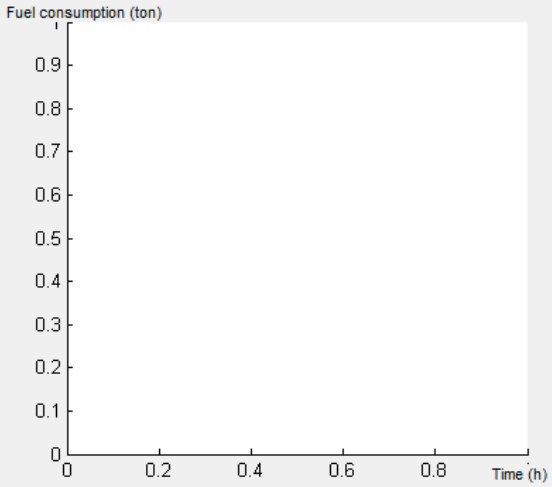
	Start	End	Zoom
Latitude	45	45	20
Longitude	-15	-45	

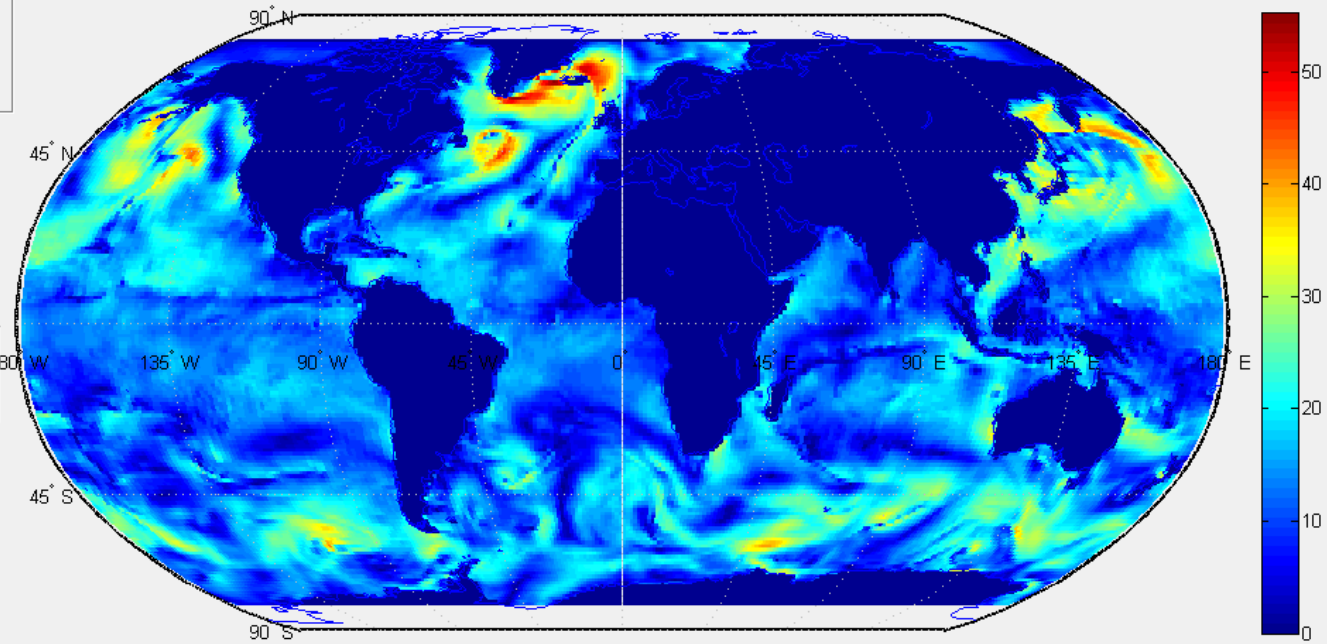
Draw grid

Routing

Start time 0 | Maximum end 357 | Routing mode: Combined (Nr) | Waves | Current

Fuel cons. (ton) 1000 | Do it





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Open GRIB | Multiple GRIB

GRIB start date 2007 12 31 0

View weather

Colors: Nothing | Arrows show: Nothing

Time set/max (h) 0 180 << >>

Routing output

Route time (h) | Average leg time (h)

Fuel cons. (ton) | Max. course diff. (deg)

Distance (nm) | Calculation time (s)

Max. course difference from GC course (deg)

Show route << >> All Save all

Numerical

Nx 30 Aspect ratio 0.5 Nr 15

Ny 51 Course range 140

Start / end

	Start	End	Zoom
Latitude	40	47	35
Longitude	-10	-53	

Draw grid

Routing

Time: Start 0, Maximum end 180, Routing mode: Combined (Nr)

Fuel cons. (ton) 1000

Do it

Waves

Current

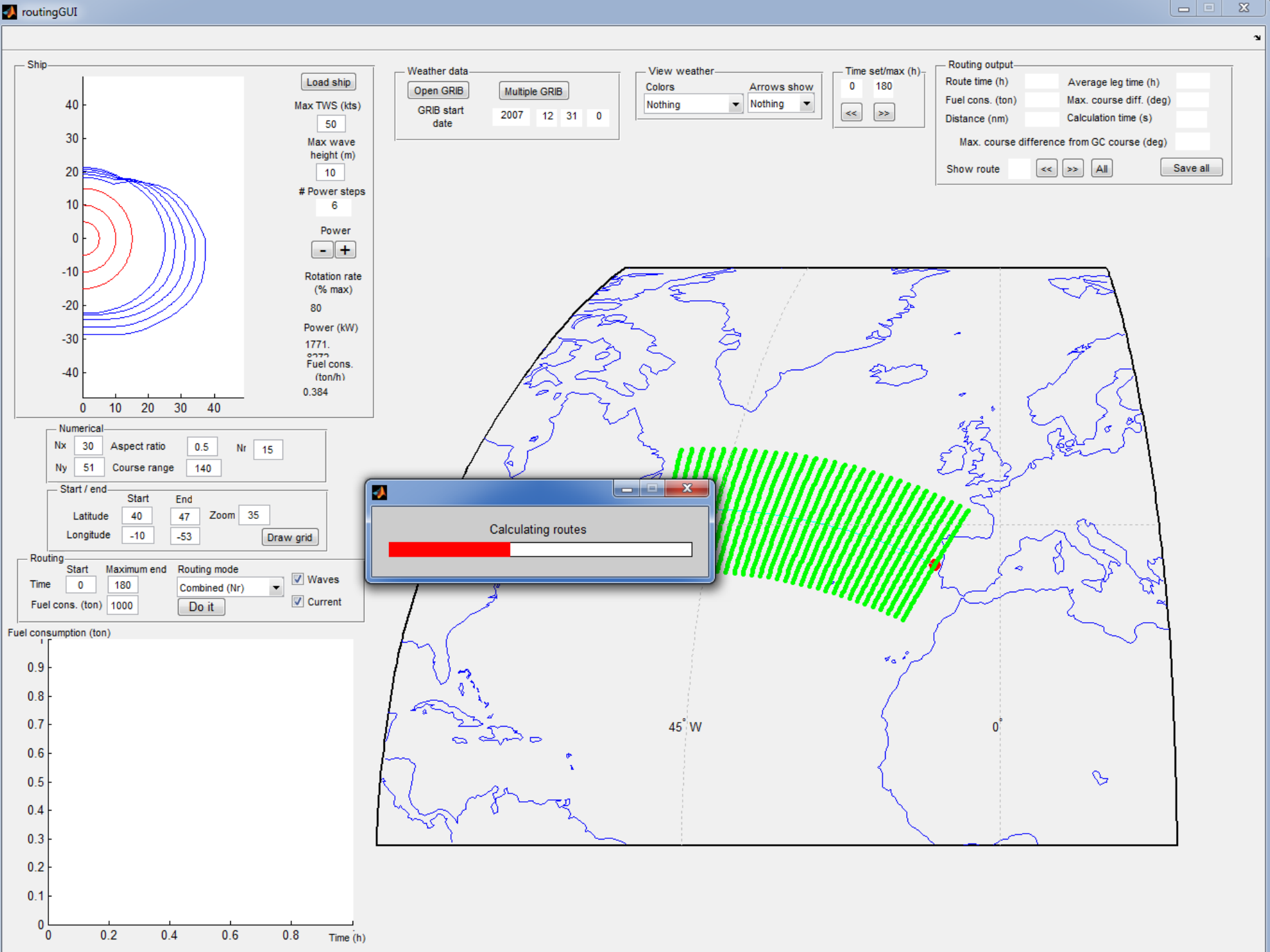
Fuel consumption (ton)

Time (h)

45° N

45° W

0°


routingGUI
Ship
Load ship
Max TWS (kts)
50
Max wave height (m)
10
Power steps
6
Power
-
+
Rotation rate (% max)
80
Power (kW)
1771.
Fuel cons. (ton/h)
0.384
Weather data
Open GRIB
Multiple GRIB
GRIB start date
2007 12 31 0
View weather
Colors
Nothing
Arrows show
Nothing
Time set/max (h)
0 180
<< >>
Routing output
Route time (h)
Average leg time (h)
Fuel cons. (ton)
Max. course diff. (deg)
Distance (nm)
Calculation time (s)
Max. course difference from GC course (deg)
Show route
<< >> All
Save all
Numerical
Nx 30
Aspect ratio 0.5
Nr 15
Ny 51
Course range 140
Start / end
Start
End
Latitude 40 47
Zoom 35
Longitude -10 -53
Draw grid
Routing
Start
Maximum end
Routing mode
Time 0 180
Combined (Nr)
Waves
Current
Fuel cons. (ton) 1000
Do it
Calculating routes
Fuel consumption (ton)
Time (h)
45° W
0°

routingGUI

Ship

Load ship

Max TWS (kts) 50

Max wave height (m) 10

Power steps 6

Power - +

Rotation rate (% max) 80

Power (kW) 1771.

Fuel cons. (ton/h) 0.384

Weather data

Open GRIB | Multiple GRIB

GRIB start date 2007 12 31 0

View weather

Colors: Nothing | Arrows show: Nothing

Time set/max (h) 0 180 << >>

Routing output

Route time (h) | Average leg time (h) 2.1

Fuel cons. (ton) | Max. course diff. (deg) 16.4

Distance (nm) | Calculation time (s) 117

Max. course difference from GC course (deg) 66

Show route All << >> All | Save all

Numerical

Nx 30 | Aspect ratio 0.5 | Nr 15

Ny 51 | Course range 140

Start / end

	Start	End	Zoom
Latitude	40	47	35
Longitude	-10	-53	

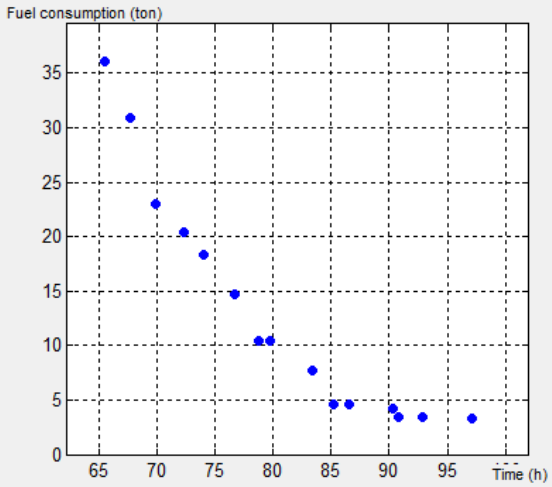
Draw grid

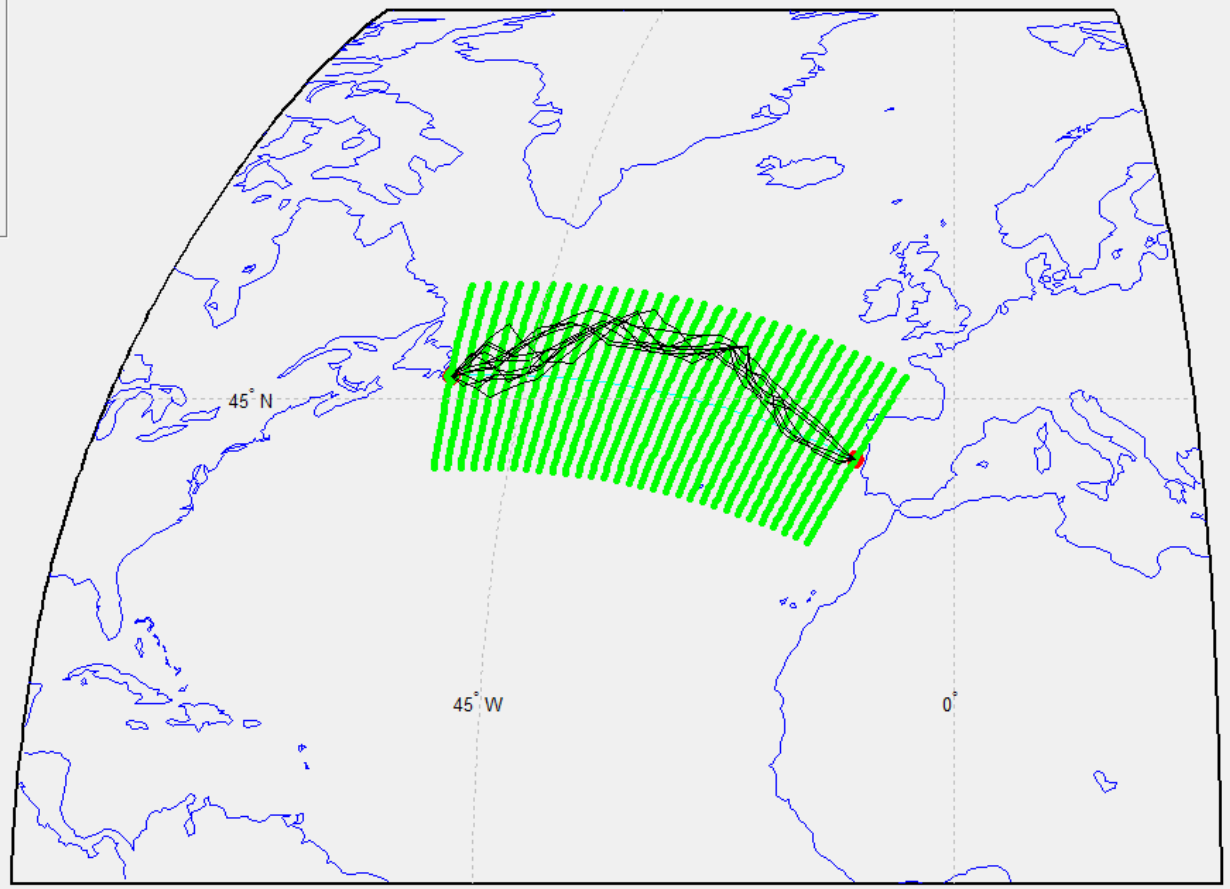
Routing

Time: Start 0 | Maximum end 180 | Routing mode: Combined (Nr)

Fuel cons. (ton) 1000 | Do it

Waves | Current





routingGUI

Ship

Load ship

Max TWS (kts) 50

Max wave height (m) 10

Power steps 6

Power - +

Rotation rate (% max) 80

Power (kW) 1771.

Fuel cons. (ton/h) 0.384

Weather data

Open GRIB | Multiple GRIB

GRIB start date 2007 12 31 0

View weather

Colors: Nothing | Arrows show: Nothing

Time set/max (h) 0 180 << >>

Routing output

Route time (h)	65.54	Average leg time (h)	2.1
Fuel cons. (ton)	36.04	Max. course diff. (deg)	16.4
Distance (nm)	2057	Calculation time (s)	117
Max. course difference from GC course (deg)			66

Show route 1 << >> All Save all

Numerical

Nx 30 Aspect ratio 0.5 Nr 15

Ny 51 Course range 140

Start / end

	Start	End	Zoom
Latitude	40	47	35
Longitude	-10	-53	

Draw grid

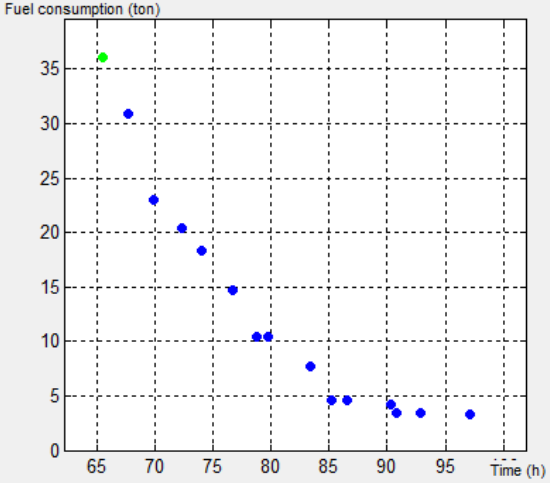
Routing

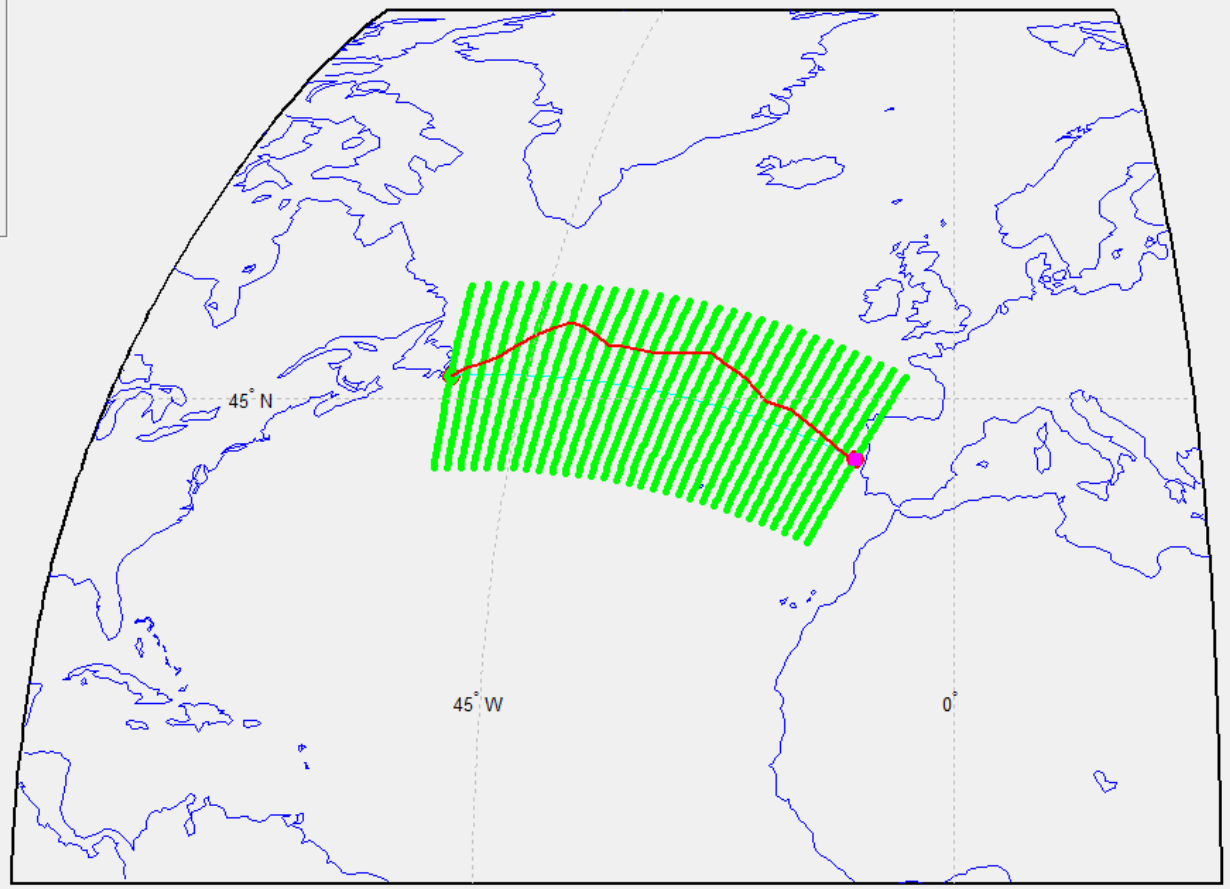
Time: Start 0, Maximum end 180, Routing mode: Combined (Nr)

Fuel cons. (ton) 1000 Do it

Waves Current

Fuel consumption (ton)





routingGUI

Ship

Load ship

Max TWS (kts) 50

Max wave height (m) 10

Power steps 6

Power - +

Rotation rate (% max) 80

Power (kW) 1771.

Fuel cons. (ton/h) 0.384

Weather data

Open GRIB | Multiple GRIB

GRIB start date 2007 12 31 0

View weather

Colors: Nothing | Arrows show: Nothing

Time set/max (h) 0 180 << >>

Routing output

Route time (h)	76.72	Average leg time (h)	2.1
Fuel cons. (ton)	14.68	Max. course diff. (deg)	16.4
Distance (nm)	2153	Calculation time (s)	117
Max. course difference from GC course (deg)			66

Show route 6 << >> All Save all

Numerical

Nx 30 Aspect ratio 0.5 Nr 15

Ny 51 Course range 140

Start / end

	Start	End	Zoom
Latitude	40	47	35
Longitude	-10	-53	

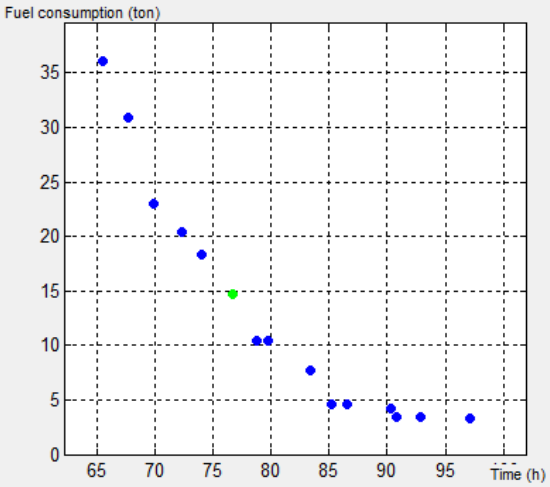
Draw grid

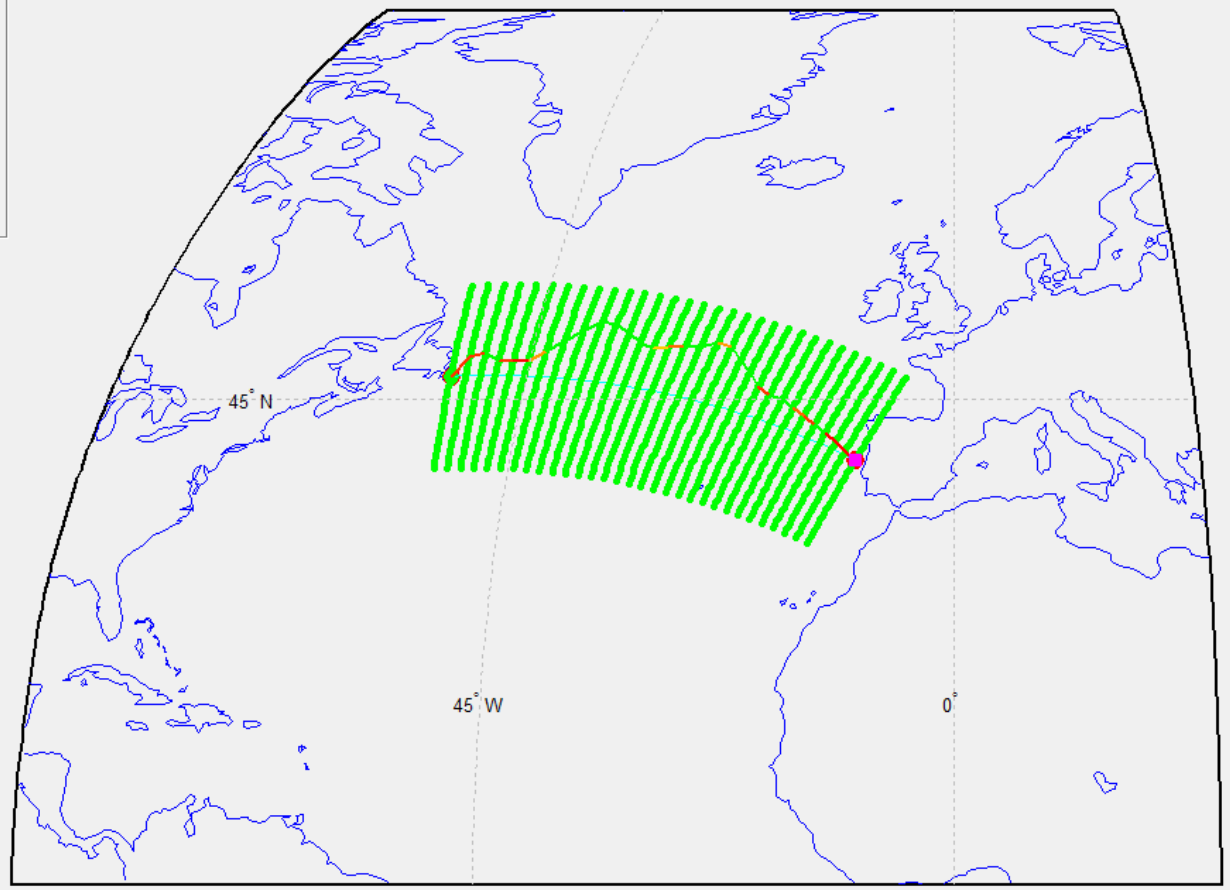
Routing

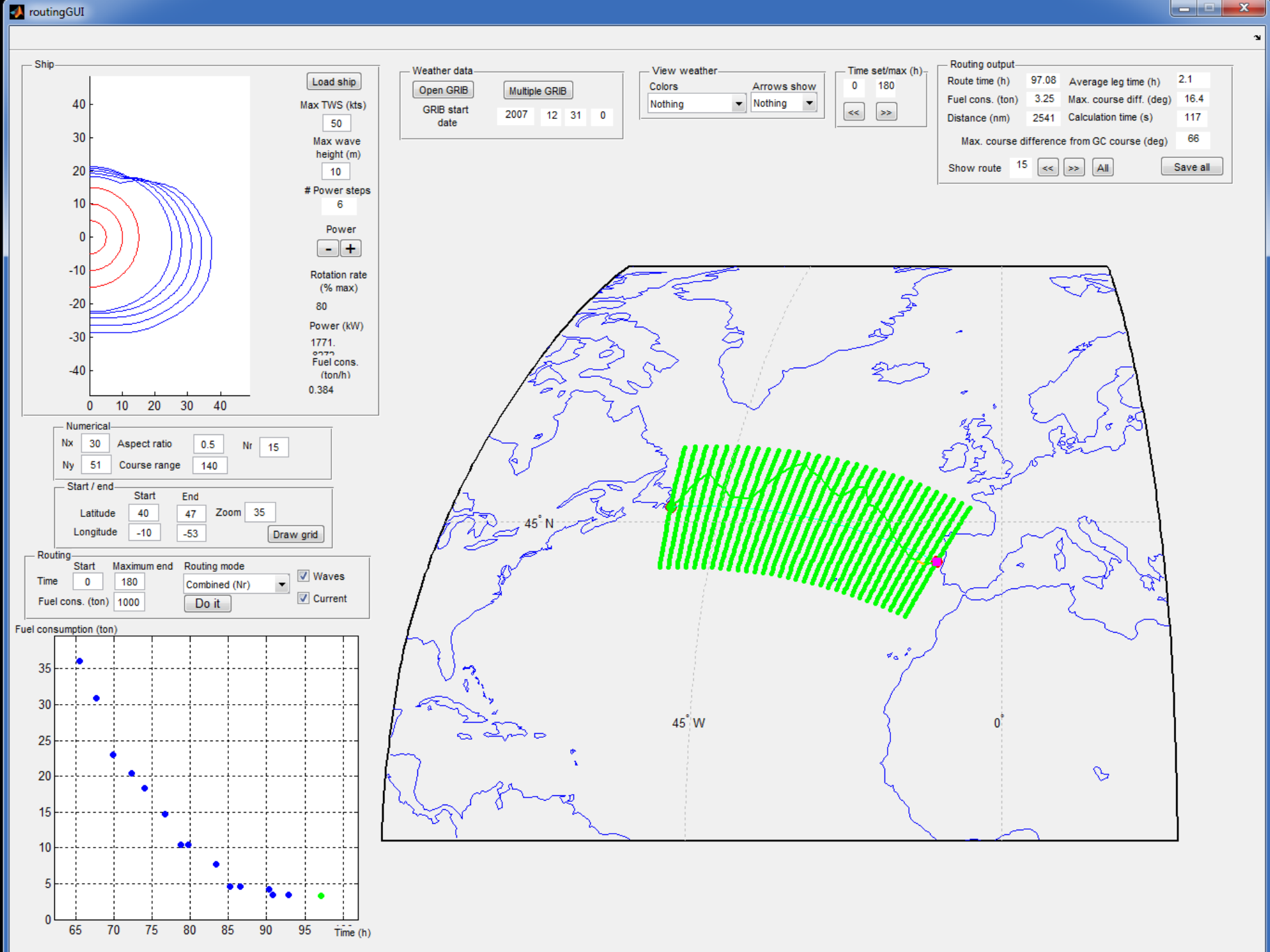
Time: Start 0, Maximum end 180, Routing mode: Combined (Nr)

Fuel cons. (ton) 1000 Do it

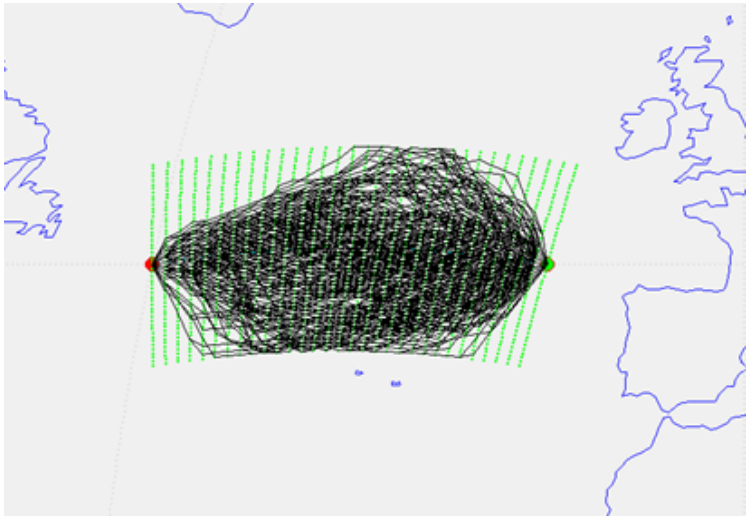
Waves Current

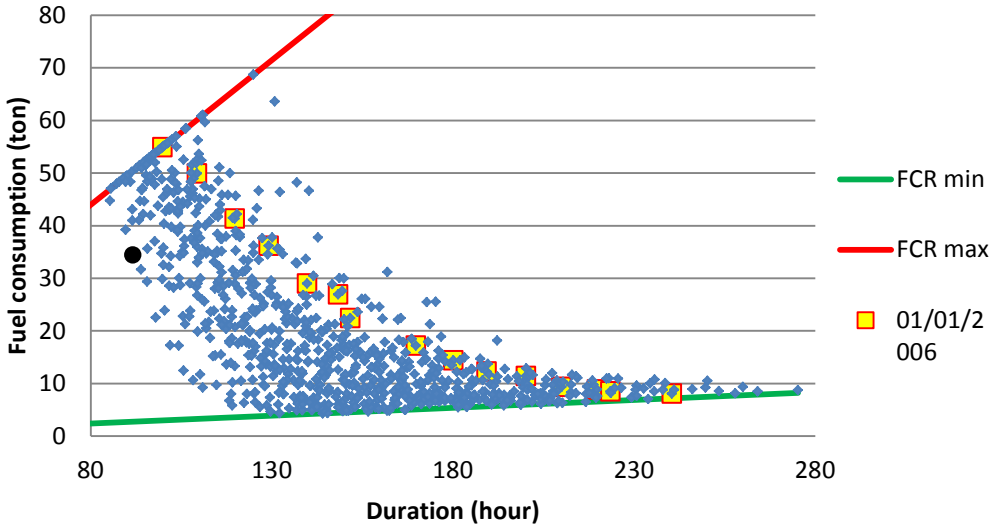


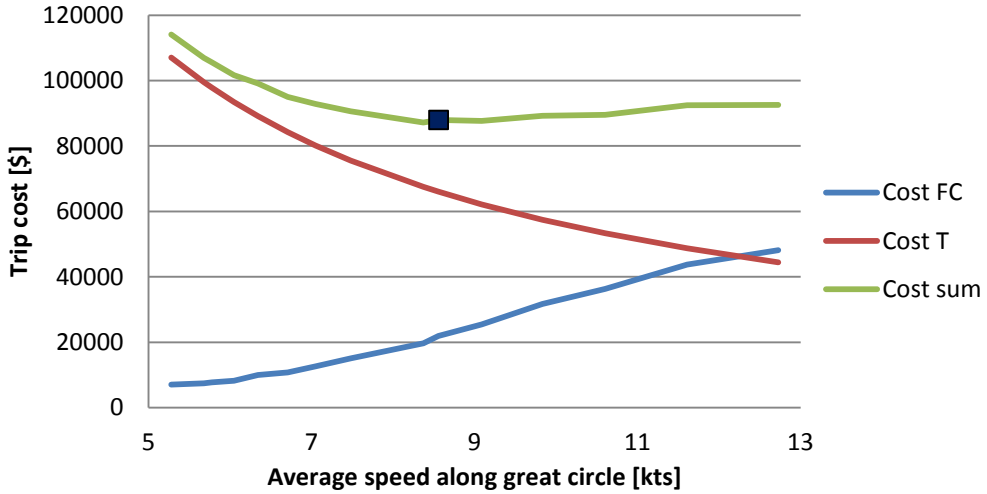



routingGUI
Ship
Load ship
Max TWS (kts)
50
Max wave height (m)
10
Power steps
6
Power
-
+
Rotation rate (% max)
80
Power (kW)
1771.
Fuel cons. (ton/h)
0.384
Weather data
Open GRIB
Multiple GRIB
GRIB start date
2007 12 31 0
View weather
Colors
Nothing
Arrows show
Nothing
Time set/max (h)
0 180
<< >>
Routing output
Route time (h) 97.08
Average leg time (h) 2.1
Fuel cons. (ton) 3.25
Max. course diff. (deg) 16.4
Distance (nm) 2541
Calculation time (s) 117
Max. course difference from GC course (deg) 66
Show route 15 << >> All
Save all
Numerical
Nx 30
Aspect ratio 0.5
Nr 15
Ny 51
Course range 140
Start / end
Start
End
Latitude 40 47
Zoom 35
Longitude -10 -53
Draw grid
Routing
Start
Maximum end
Routing mode
Time 0 180
Combined (Nr)
Waves
Current
Fuel cons. (ton) 1000
Do it
Fuel consumption (ton)
Time (h)
45° N
45° W
0°

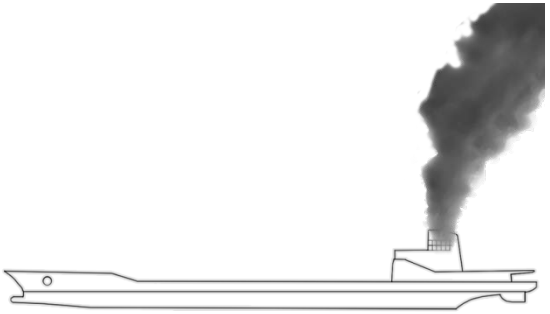
Results routing with weather archive

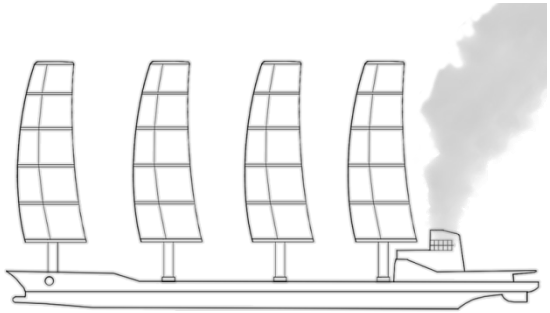


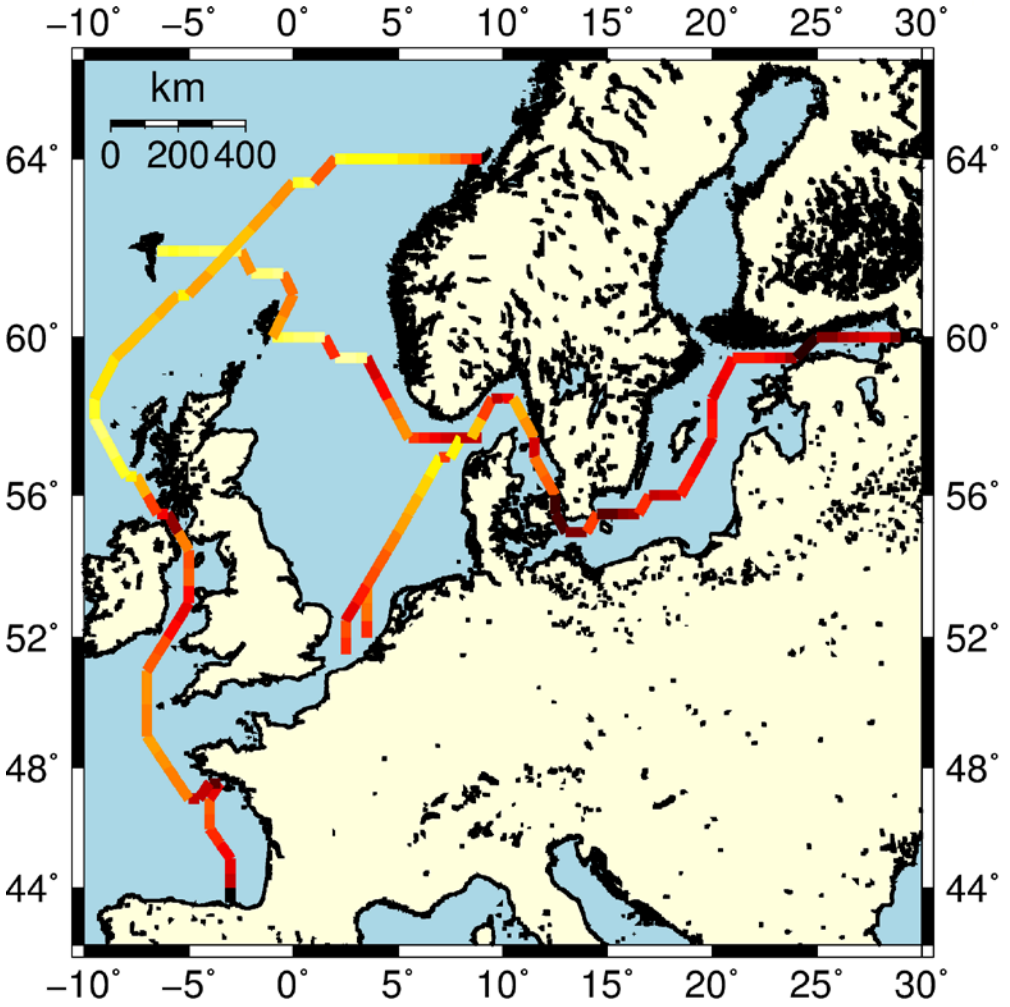




Performance can thus be predicted



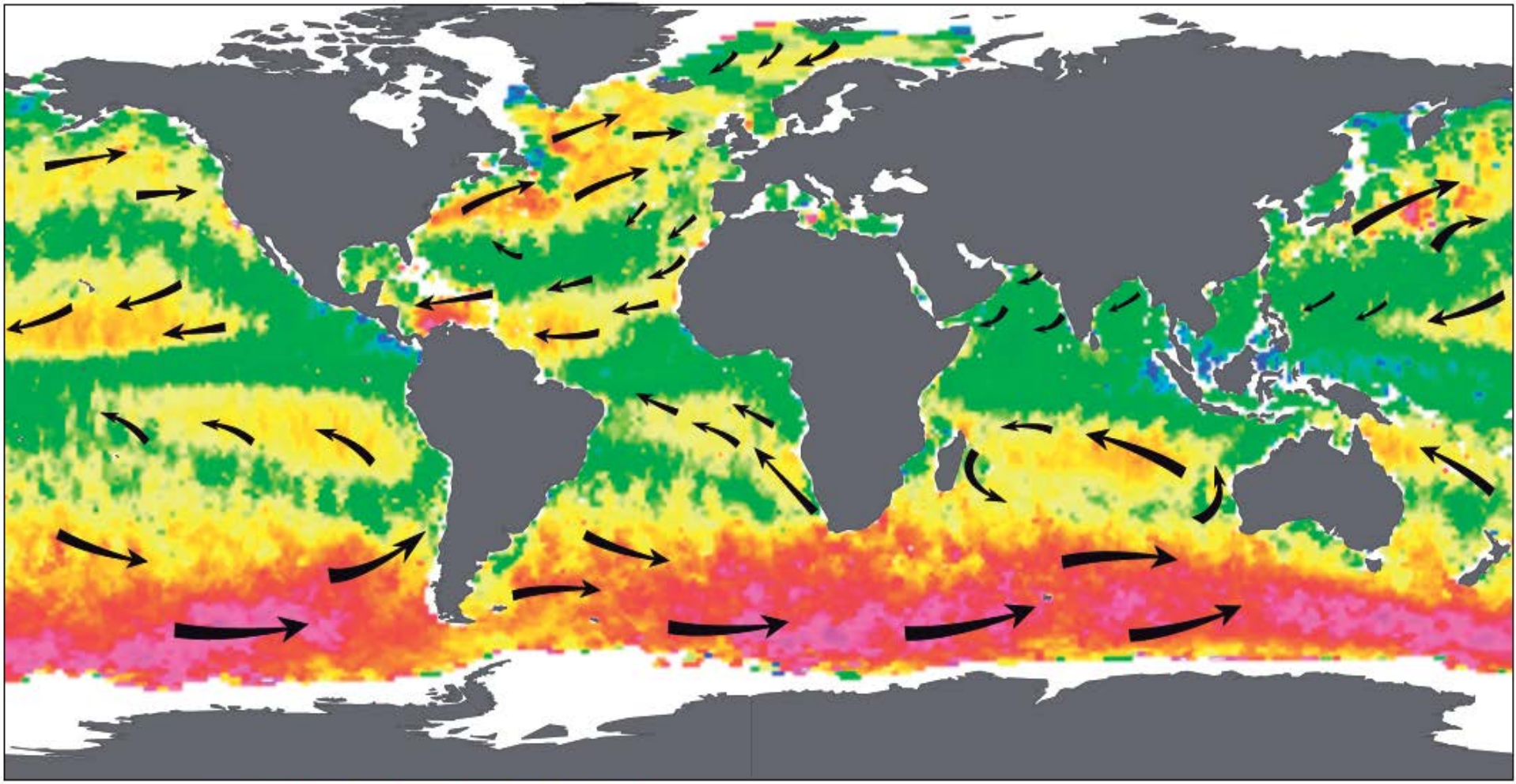




European Union

The European Regional Development Fund

The prevailing winds above world oceans



Wind speed in m/s

N/D 0 3 5 7 9 10 15 18

Source : NASA, Aquarius mission. Wind speed, average of the first quarter 2014. Coastline from GSHHG / NOAA.

Realized by AJOD

The Interreg IVB North Sea Region Programme

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The European Regional Development Fund

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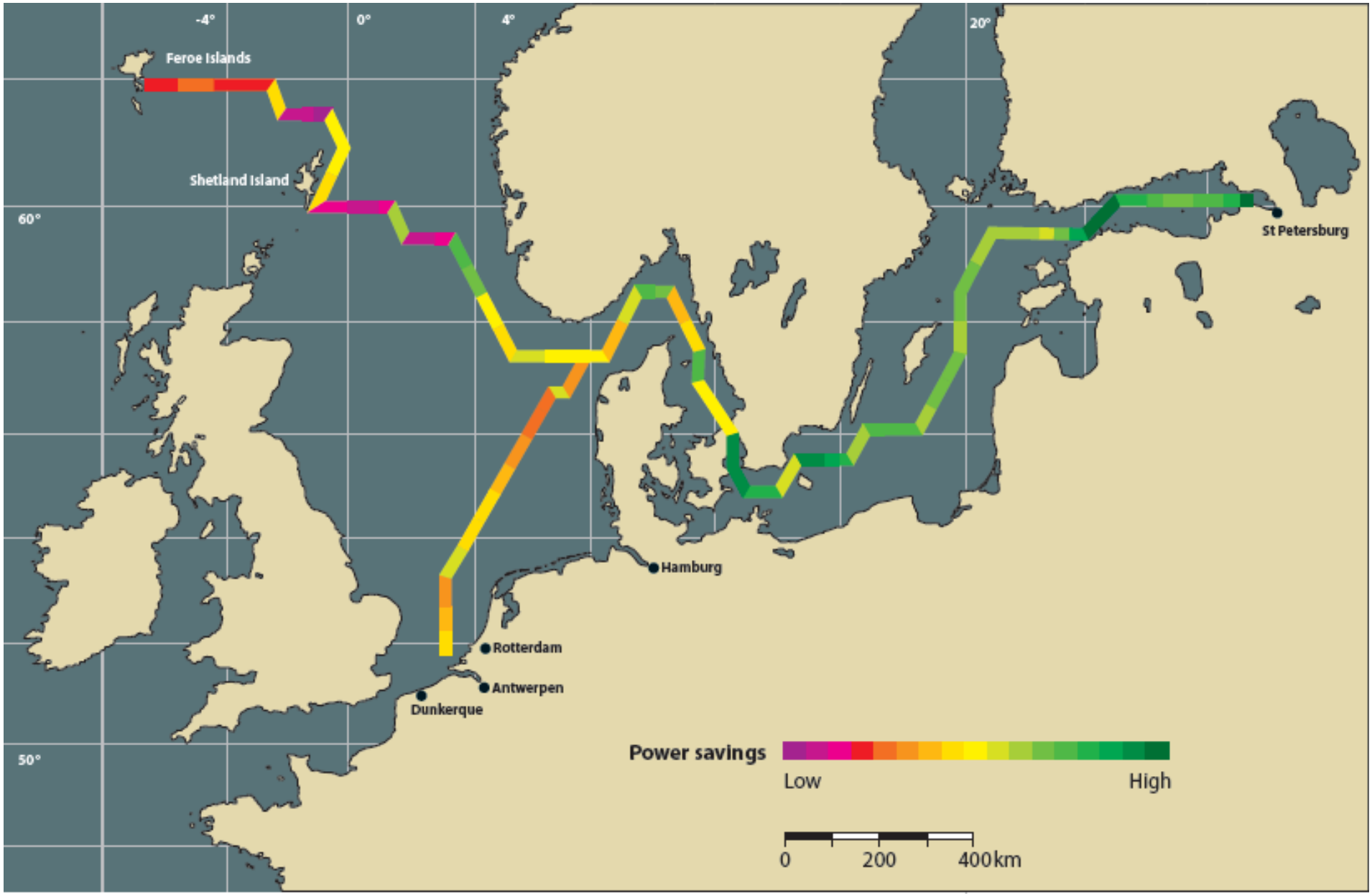
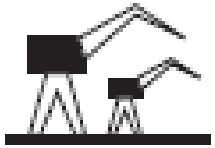

-4°
0°
4°
20°
Feroe Islands
Shetland Island
60°
St Petersburg
Hamburg
Rotterdam
Antwerpen
Dunkerque
50°
Power savings
Low
High
0
200
400km

Then, mixing costs and hypothesis

Fuel

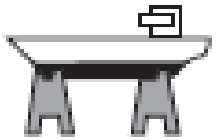


Frais de port

Temps au port

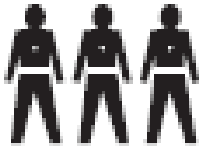
Management

Insurance



Dry-dock

Opérating costs



Crew costs

Repair & maintenance

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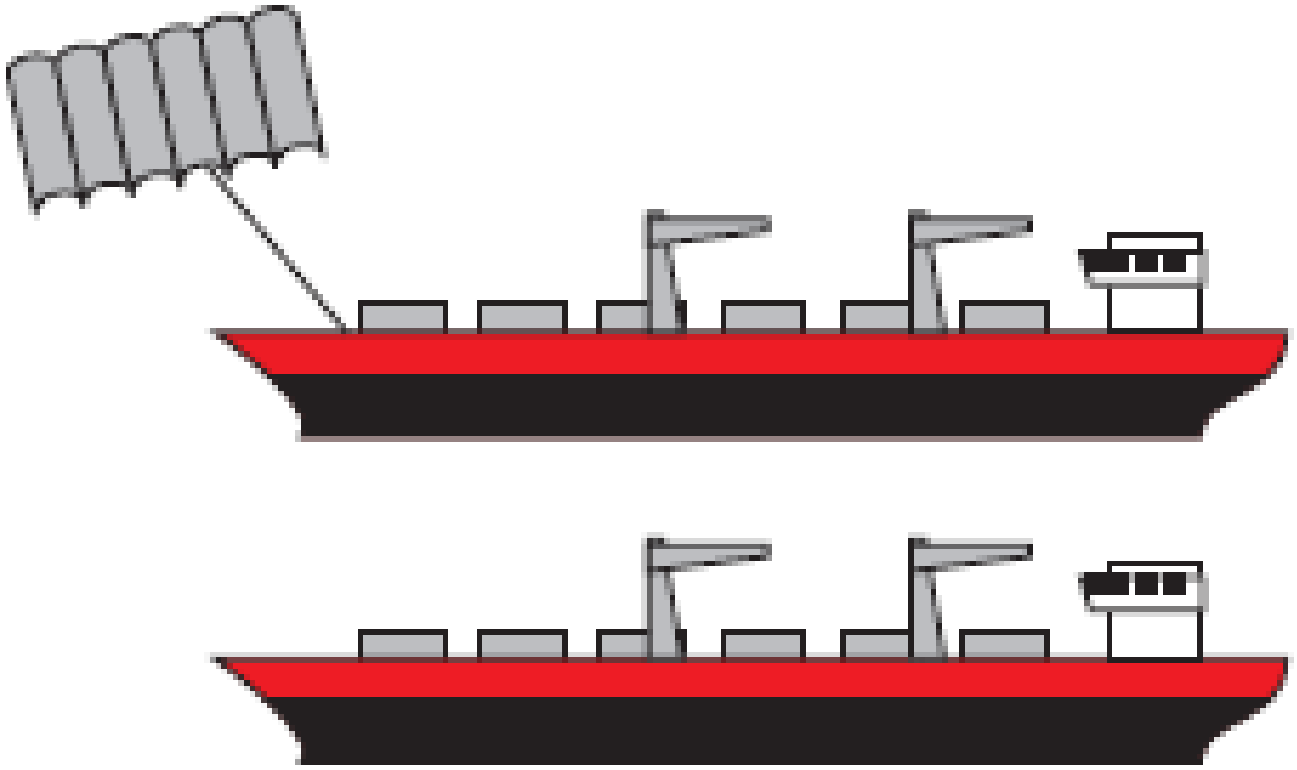
Example : Importance of auxilliaries for alternative energy

Type of ship	Power rating ratio A/E to M/E
Liquid bulk ships	0,3
Dry bulk carriers	0,3
Container	0,25
General Cargo	0,23
Ro Ro Cargo	0,24
Passenger	0,16
Fishing	0,39
Other	0,35
Tugs	0,1

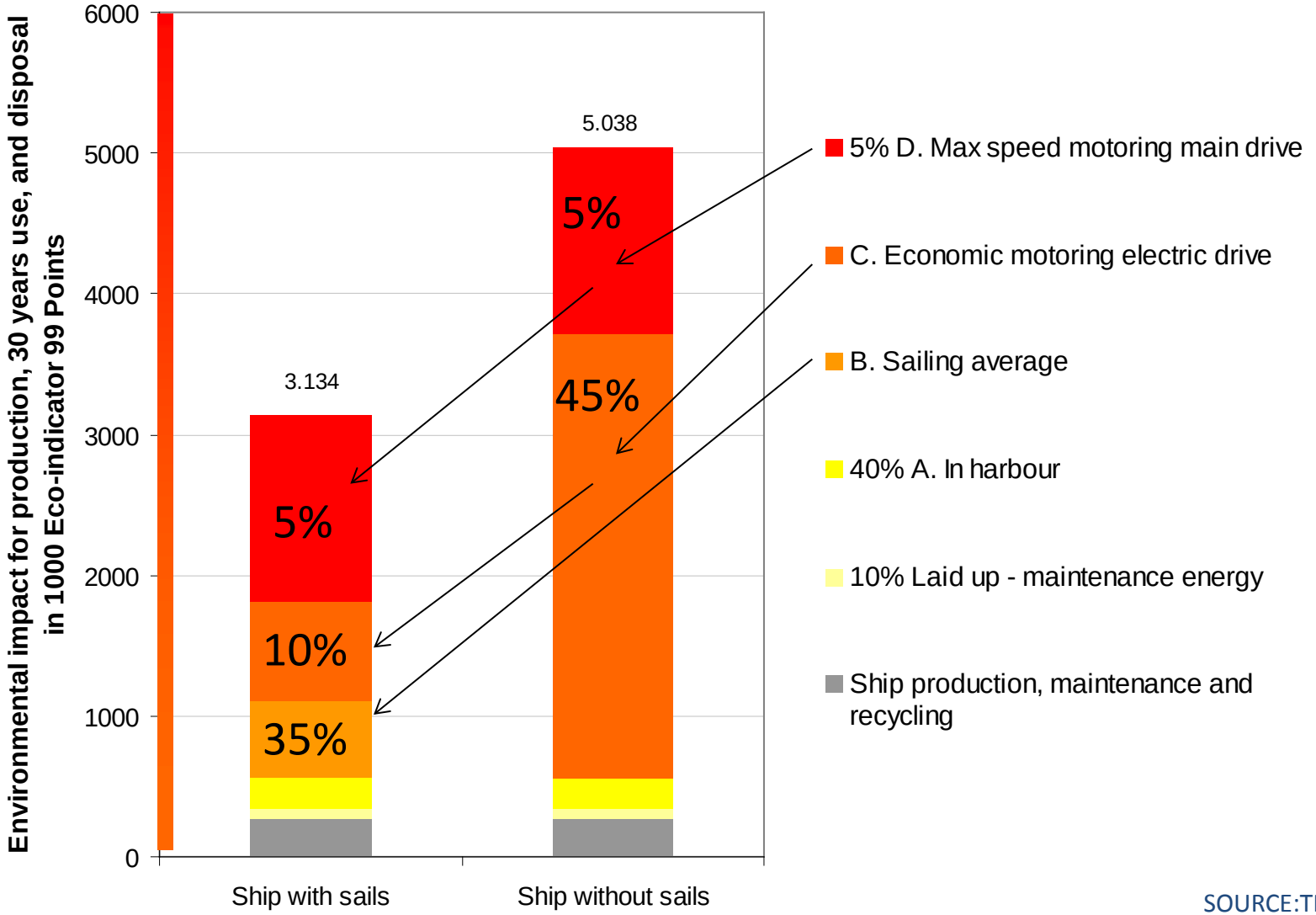
Compare similar situations with scenarios



Typical comparison show possible economic use of sails

	Unit	MDO	MDO wind	IFO	IFO wind
Total investment	Million €	5,79 🏆	6,76	5,95	6,92
Present value of future earnings	Million €	0,64	1,35	3,54	3,76 🏆
Payback period	Years	16,71	15,32	9,46 🏆	10,49
Internal Rate of return	%	9%	10%	14% 🏆	13%
Average haulage cost	€/ton of cargo	101	98	90	89 🏆
Average freight earned	€/ton of cargo	103	103	103	103

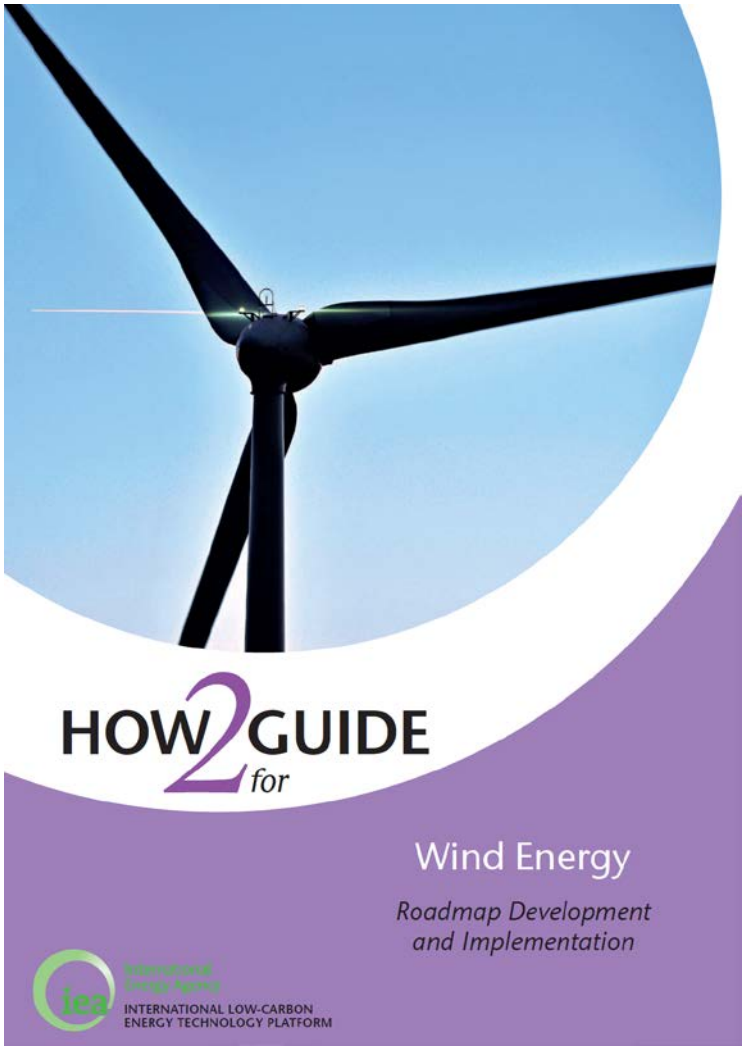
LIFE CYCLE ANALYSIS MOTOR SAILOR OR MOTOR SHIP



SOURCE:TNO

Barriers Remaining

- Many barriers remain (Argyros D et al. 2014, Nuttal P. et al. Smith T.et al), IRENA (2015), LR (2015), etc.
- Risk of the first mover.
- The main barrier remains the split incentive between owners and users
- Regulatory landscape:
  - EU new rules for shipping (MRV)
  - IMO MEPC May 2015



sail

Roadmap : Taking stock of the success of others. Example of wind

The Interreg IVB North Sea Region Programme

provinsje fryslân
provincie fryslân

European Union

The European Regional Development Fund

www.nsrsail.eu

Relevant history of wind into Sail development

- Technology subsidies focused on large, technology (and military) oriented firms. Money was generally wasted.
- Belief that you have a “technology winner” is illusory even when your preferred techno has edge. Learning curve tramps technology superiority.
- Data had to be shared, implementation progressive with many players, so that banks and insurance firms could join the pack
- A huge boost came from the Kyoto Protocol Mechanisms (over half of all wind in China!) and public rates in Germany (with climate rationale)

Thank you. Antoine Bonduelle

Readings : IRENA , Loyds Register's, SAIL publications

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