The Use of Carbon Composite for Commercial ferries - a case of radical Eco-innovation

based on the “Eco Island Ferry” Project
and S@il hybrid propulsion project

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My talk on carbon composite ferries

- The context (Denmark, cleantech, shipping)
- Technical issues
- Implementation (policy, business models)
- Innovation aspects
- Conclusions

The Context

http://www.worldatlas.com

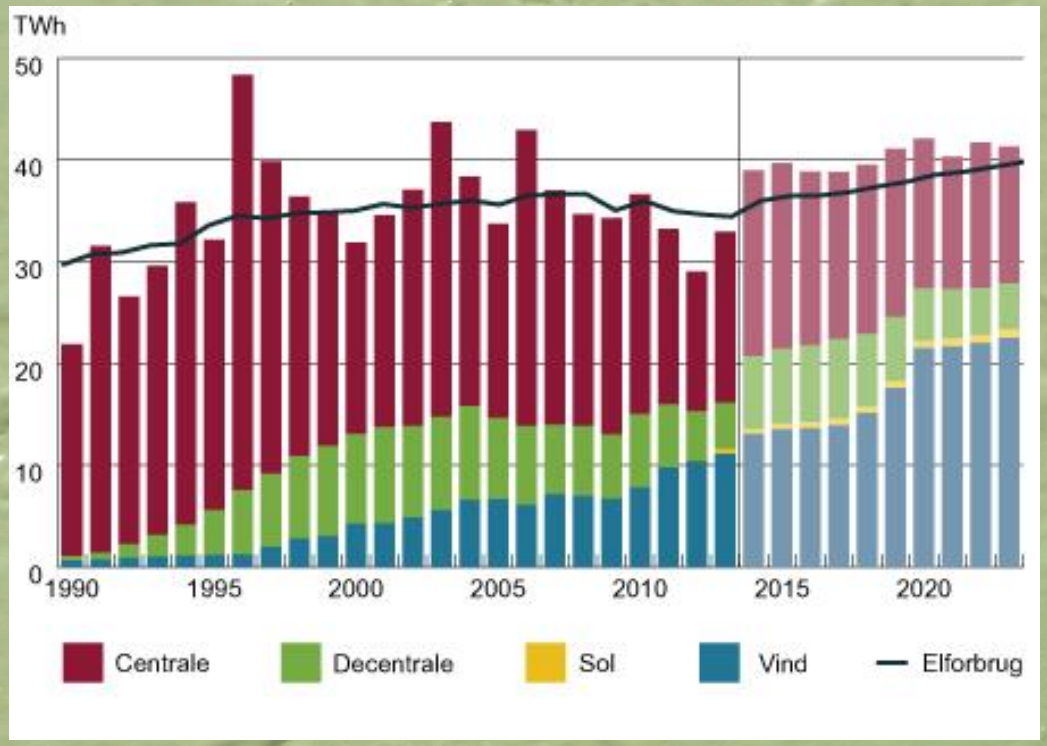
Data.un.org

5.6 Million people

43.000 km^2

Energy and waste situation in Denmark 2013

Electricity:

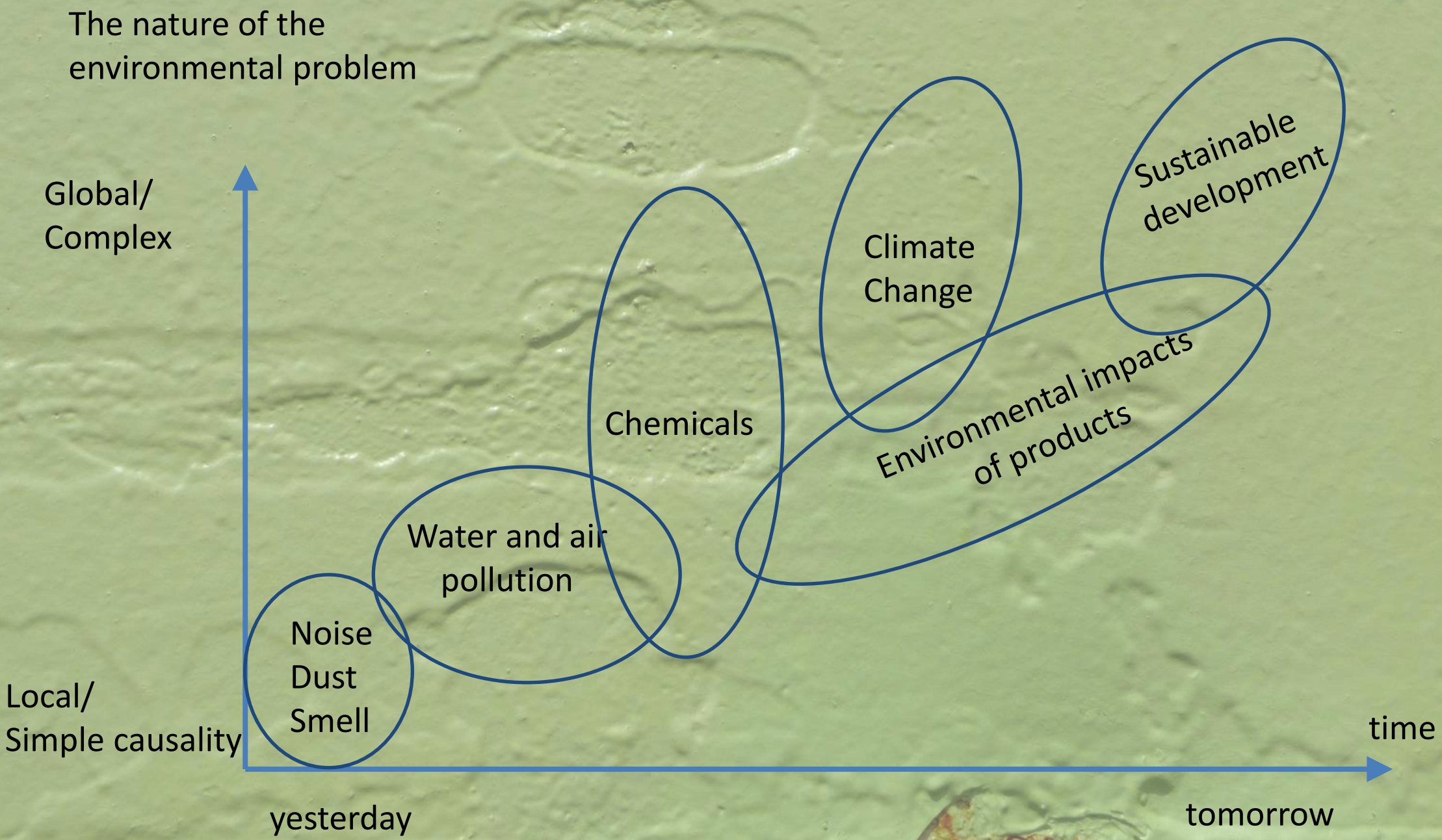


Energinet.dk

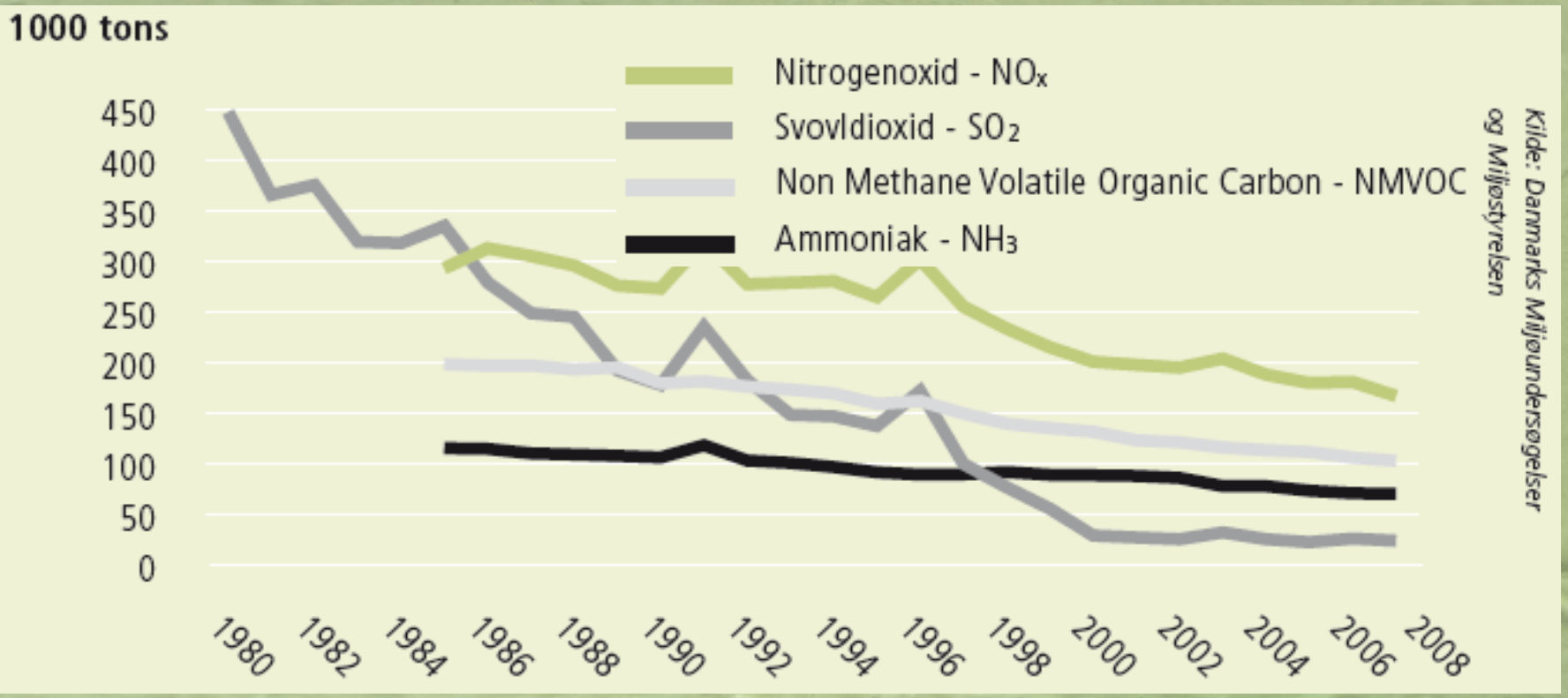
District heating covers more than 61% of space and water heating, mainly produced from combined heat and power plants.

Waste incineration account for approx 20 % per cent. Most municipal household waste is incinerated.

Environmental challenges are changing (ashore)

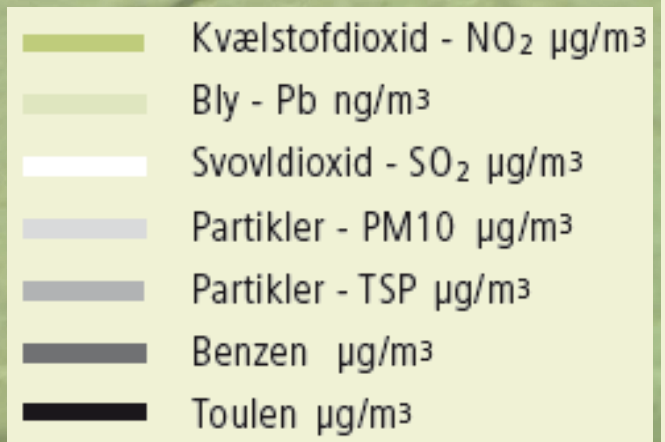


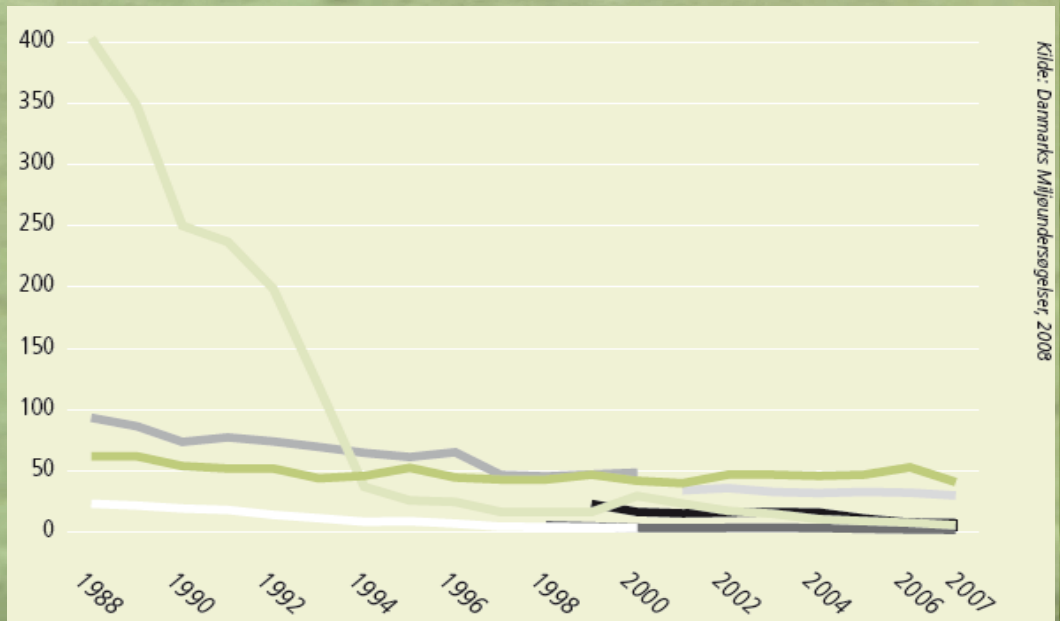
Is the environment benefiting of CleanTech?



Yes, emissions in Denmark are decreasing

…and yes, the air on Jagtvej in Copenhagen is getting cleaner

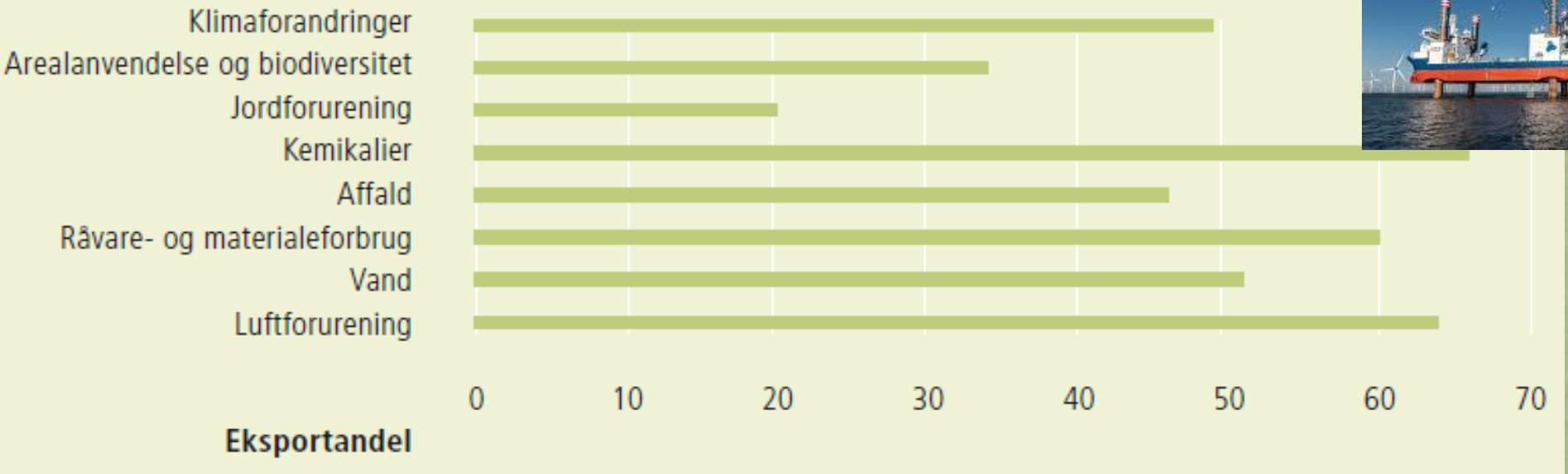




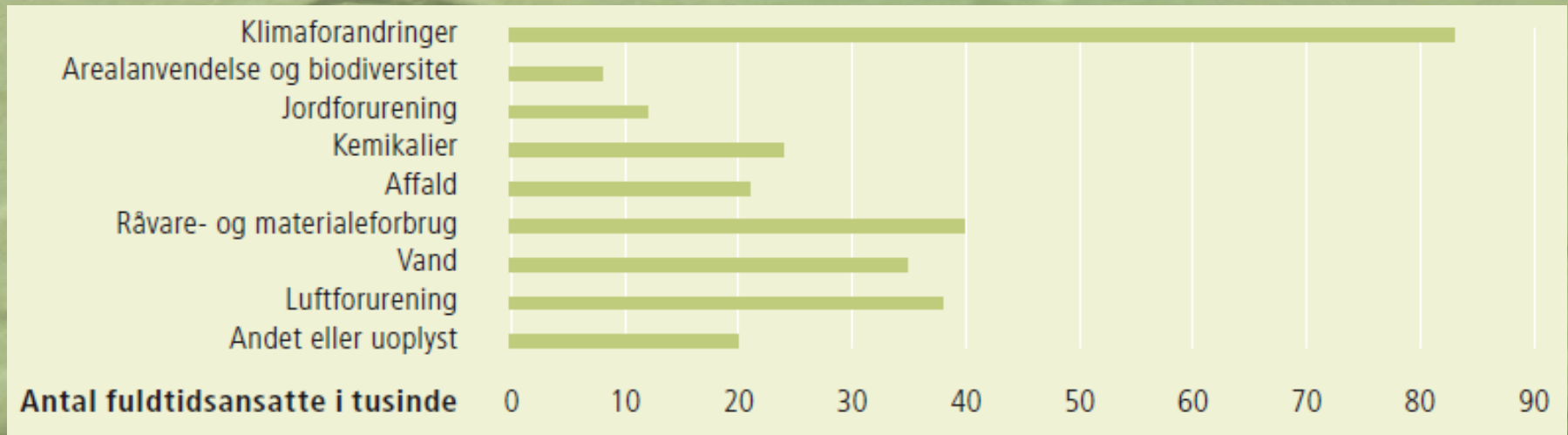
Source:
”Natur og Miljø 2009”
Danish EPA , 2010

Other CleanTech benefits for Denmark?

Big Business: approx. 50 Billion Euro turnover

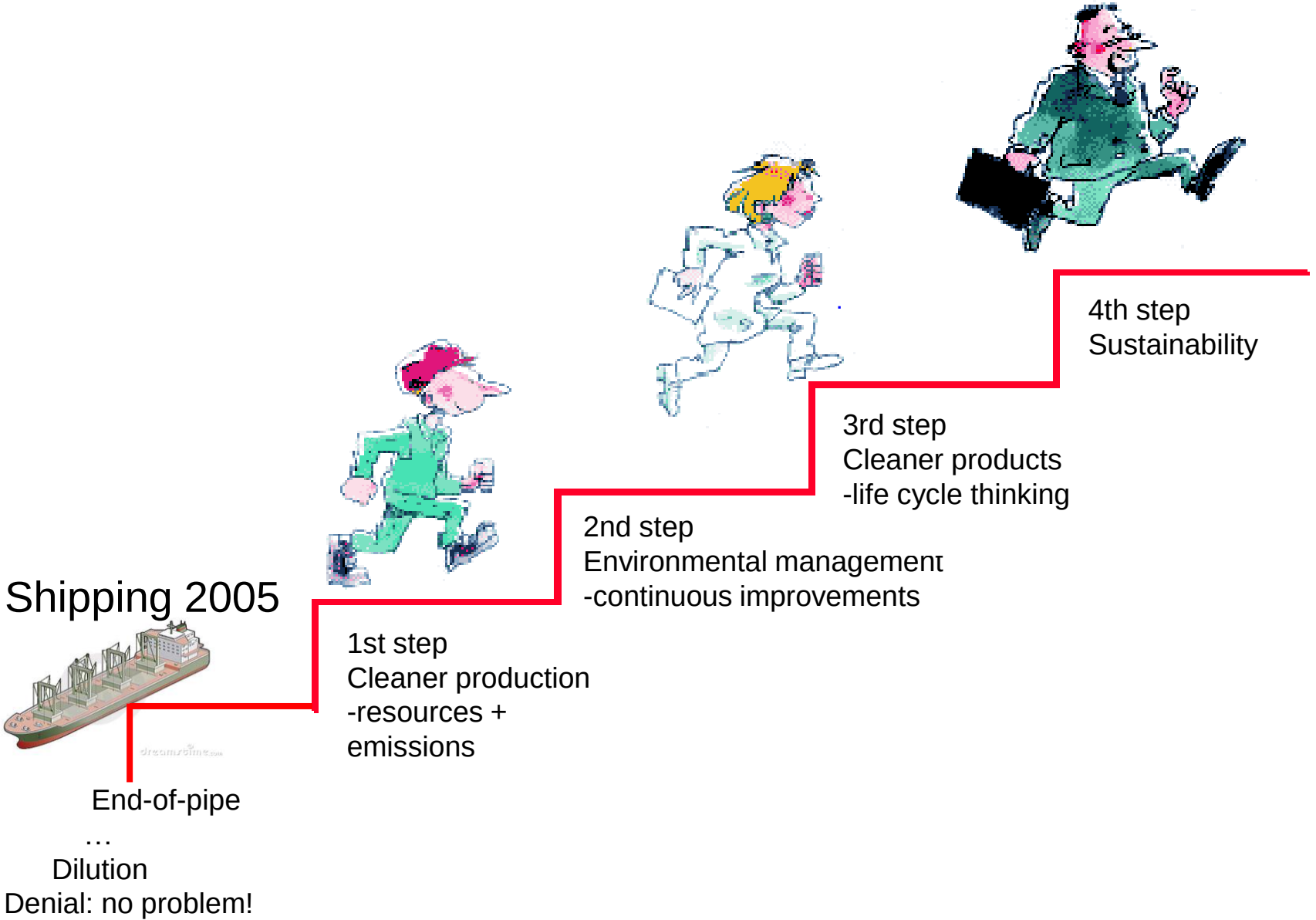


…and 120.000 employees in 720 companies

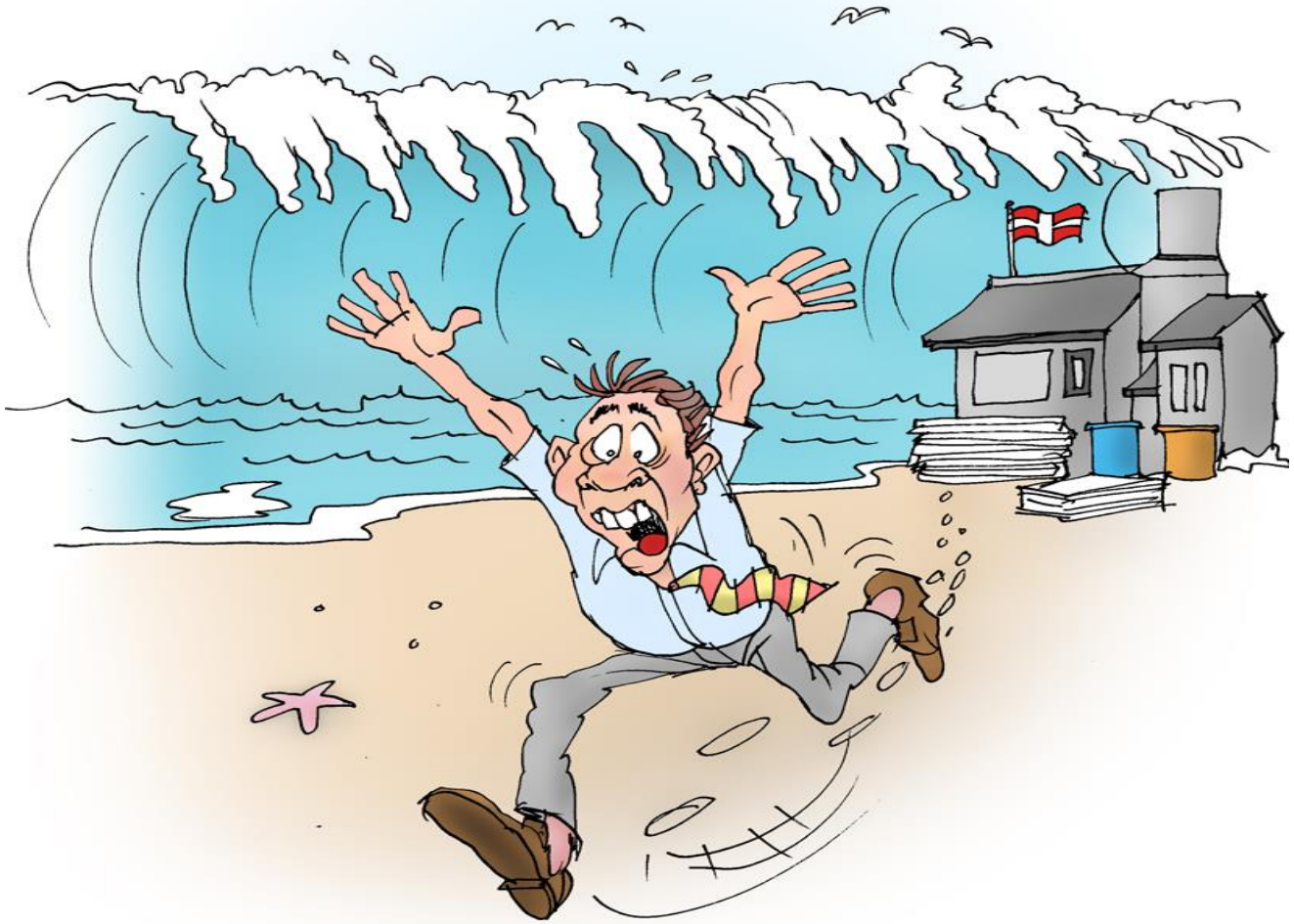


Source:
”Natur og Miljø 2009”
Danish EPA, 2010

Industry's preventive approaches to environmental challenges



A new wave is approaching: environmental regulation at sea



What does it consist of?

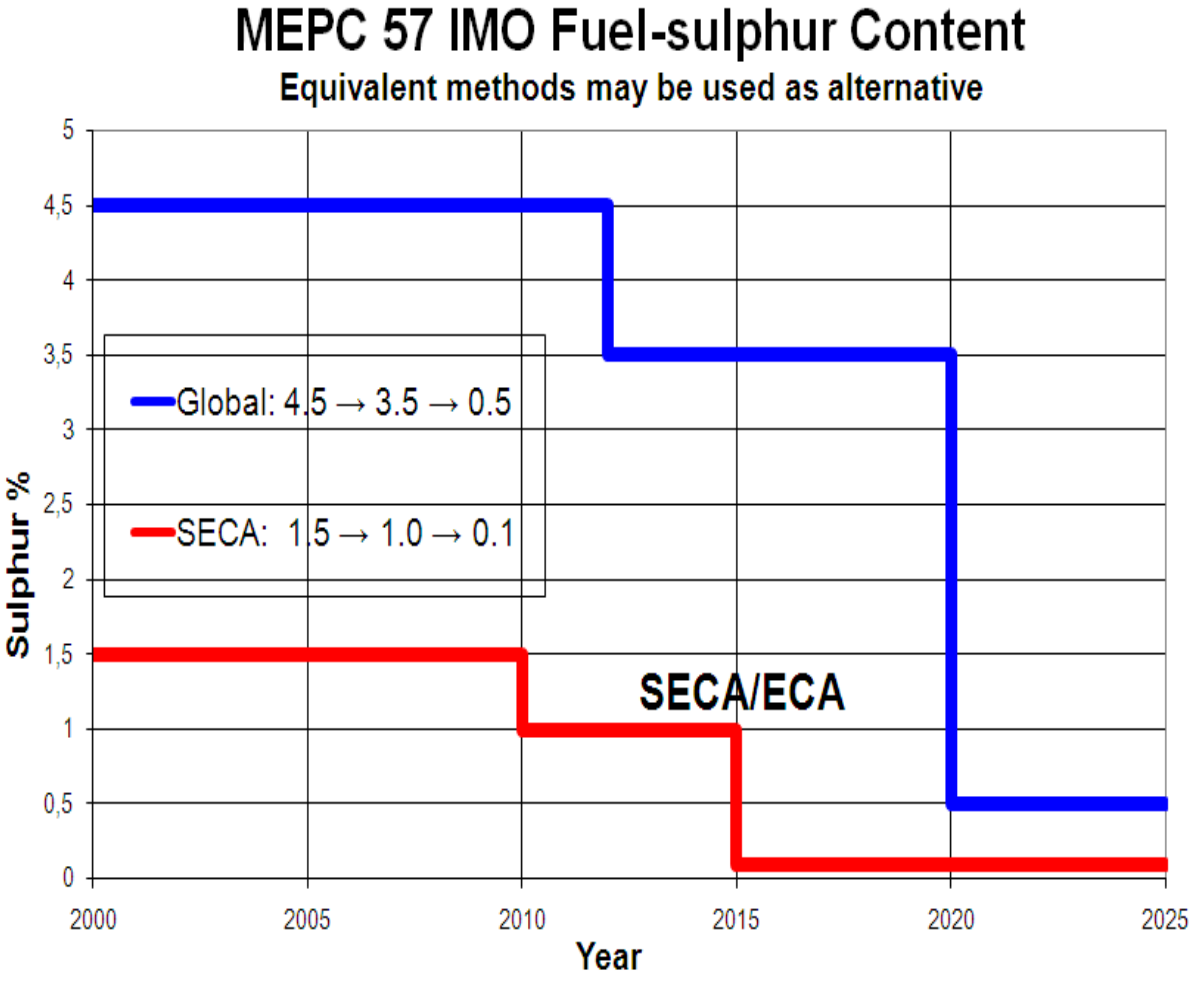
Legislation:

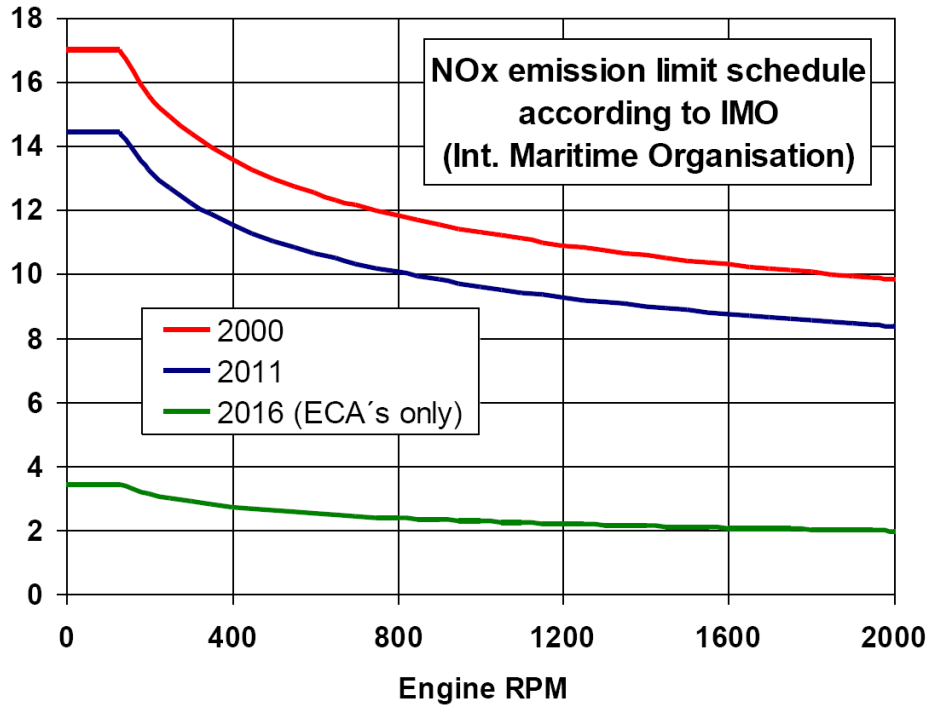
- MARPOL convention fra IMO
- new Annex VI (2008-11)
- EU's sulphur directive
- Californian legislation

Demand driven:

- Carbon footprint?
- Other aspects?

SOx and NOx Emissions are regulated by the International Maritime Organisation (IMO)





Environmental improvement options in shipping

Optimal operation (weather routes, lean, reduced speed, maintenance)

Technical changes

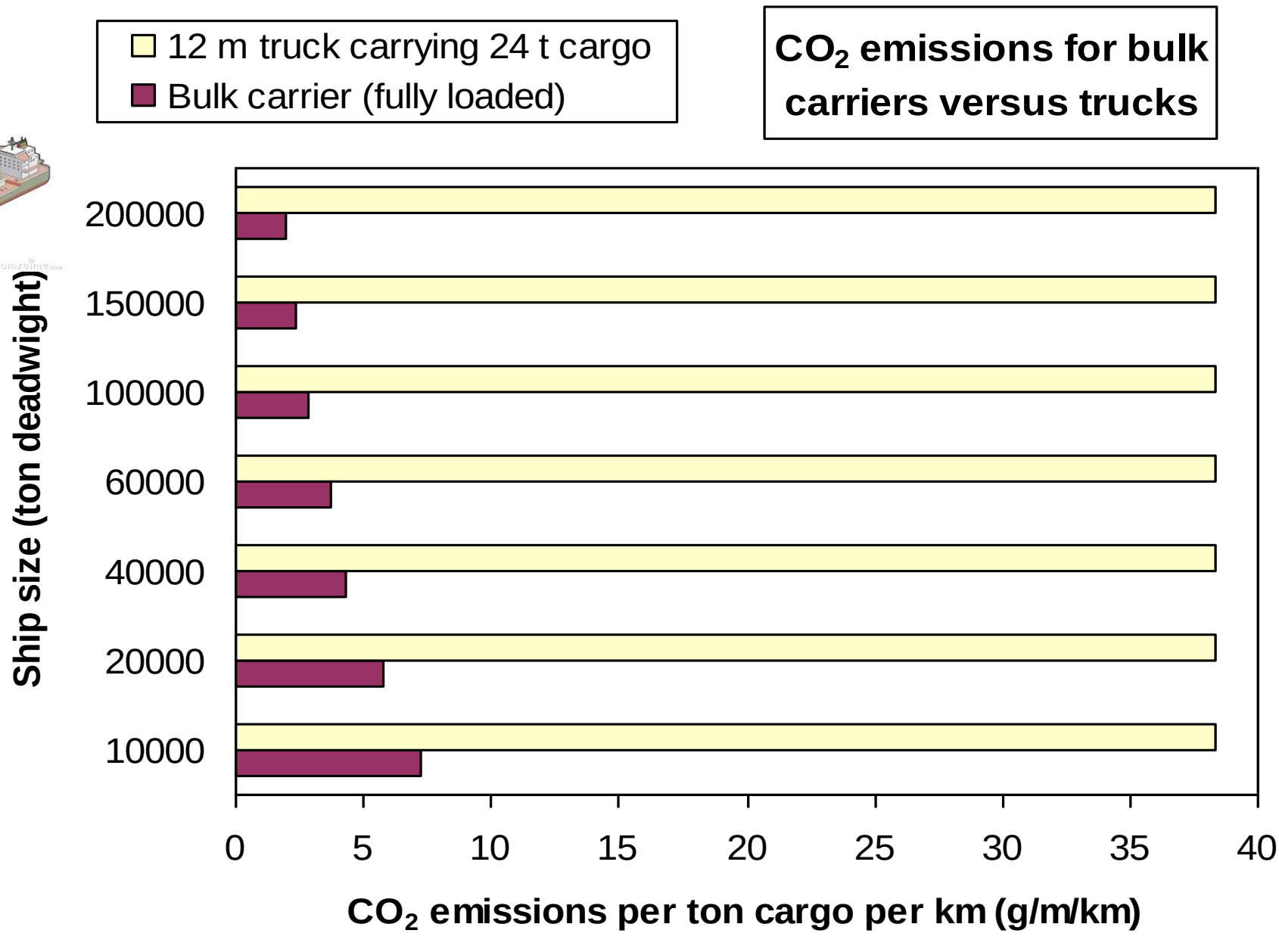
- New design (propulsion, hull, bulb, lightweight, surfaces, fins)
- Add-on (micro bubles, Scrubbers, catalysts, EGR, Ballast water treatment

Cleaner fuels

- Low sulphur fuels (diesel)
- Gas (LNG)
- Biofuels…?
- Electric and hybrid systems

On-shore power supply

CO_2 emission for ships and trucks



Conclusions from DMU (2010)

In 2007, the average contribution of shipping to air pollution in Denmark was:

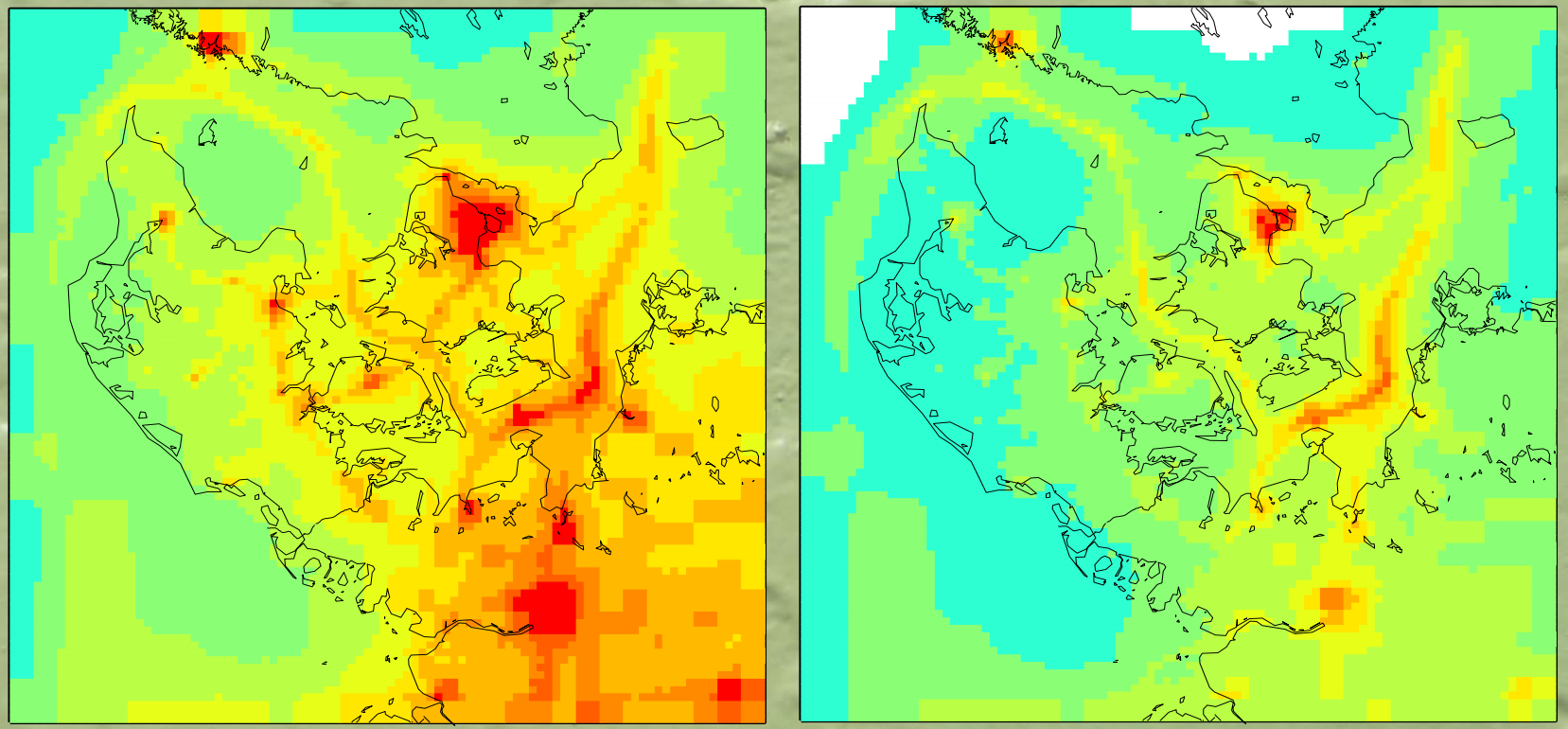
- SO_2 33%
- NO_2 21 %
- mPM2.5 18 %
- PM2.5 9%

- CO_2 globally: 2,7 % (IMO, 2009)

Scenario calculations show significant reductions when IMO's sulphur criteria are implemented in 2020.

For NO_2 and PM2.5 the calculated effect is smaller.

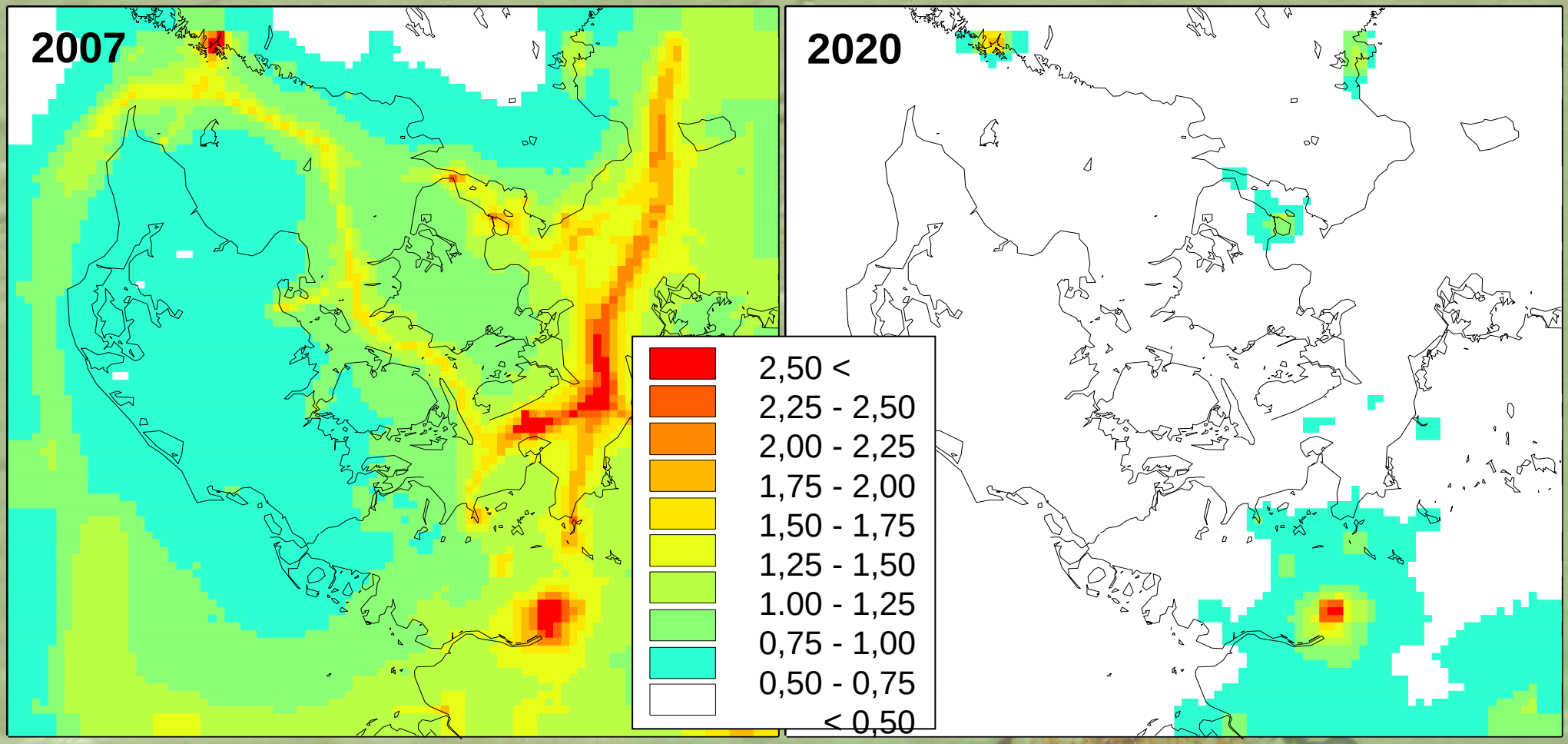
NOx reductions: not very shipping related



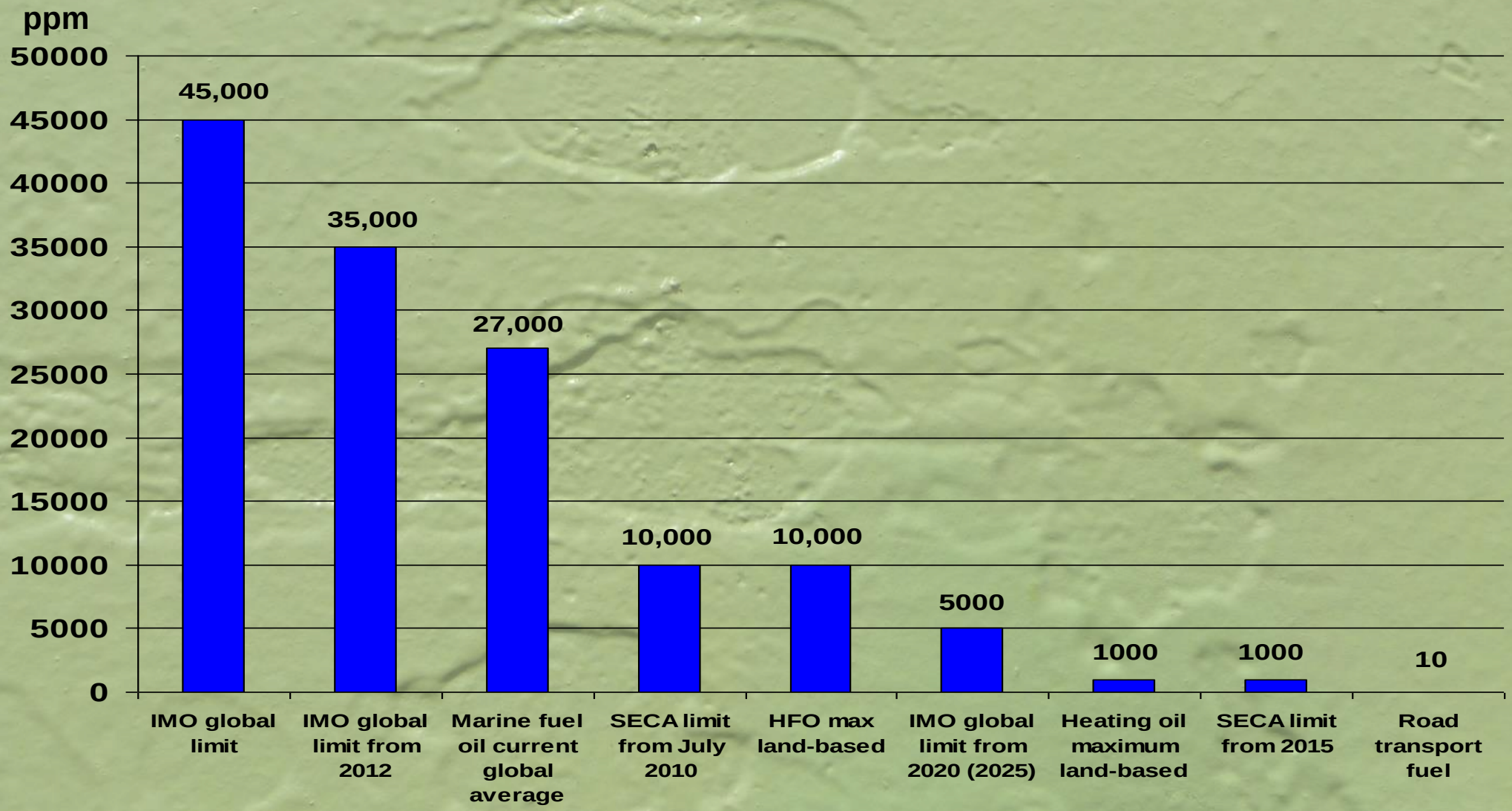
Figur 6 Beregnede koncentrationer af NO_2 i µg/m³. Til venstre er vist situationen i 2007, til højre situationen i 2020. Der sker NÆSTEN INGEN ÆNDRING (ed.:HR) i udslippet af NO_x fra skibstrafik mellem de to tidspunkter, mens der er markante reduktioner for landbaserede kilder.

Model calculation for 2007 and 2020

Concentration of SO_2, $\mu g/m^3$



Sulphur contents in different fuels



Christer Ågren, 28-11-2010

Aim of the Eco Island Ferry project

The idea is:

To work out a basis for comparing two small passenger ferries built of either carbon composites or steel.

- life cycle costs
- environmental impact

To inspire shipowners and naval architects to consider modern materials for ship building when fuel consumption and environmental impact have high priority

Support from The Danish Maritime Fund and Västra Götaland Region

Timeline for the Eco Island Ferry Project

May 2011
Application from 8 partners (DK+SE)

Dec. 2010

1st MARKIS Conference: Th
Danish compar
meet Swedish
Experts

June 2010: Three small Danish companies share a common interest for small composite ferries

2011: Funding from:

Götaland Region
Maritime Fund
participants
n. Res. Inst. of Sweden

arts

What if similar advanced techniques were applied to ensure environmental improvements in mainstream segments?

As if environmental impacts matter

(Lead user innovation made possible by the navy and luxury superyachts)

Not a commercial project

- No ferry actually constructed (the reference ferry *was* in operation)
- All materials and analyses are publicly available
- Maximum dissimination of results and publicity

The real anticipated outcome:

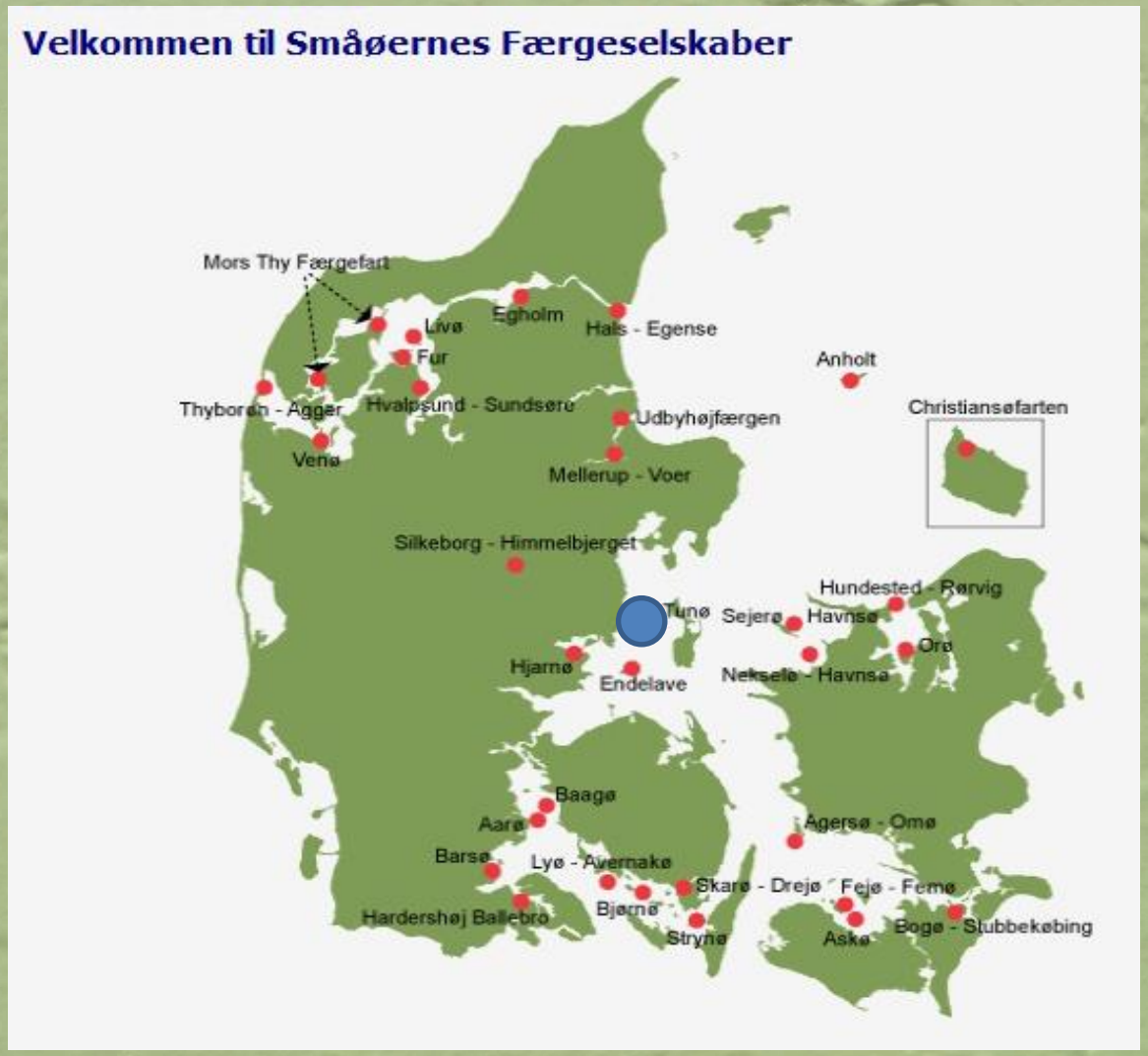
- Change of perspective among shipowners and authorities
- Competence building in industry
- Capacity building in Danish and Swedish maritime authorities
- The basis for a follow-up commercial project (= real ferries)

Market Research

What does the market look like in different nearby countries?

- Number of vessels?
- Age?
- Size?
- Business models/costs?
- Ferry landing?
- Operational hours per day?

The Markets: Denmark



- 70 ferries (incl back-up)
- 10 recent newbuilds
- Still, 30 are more than 25 years old (average age: 44)
- Business model?

Tunø Ferry – existing and new

Reference ship: Tunø-ferry

- EC directive, D-class
- Construction material: Steel
- 200 Passengers & 6 Cars
- approx. 30 meters
- 9,5 knots
- Displacement **340 T**
- Installed engine power: **2 X 294 kW**

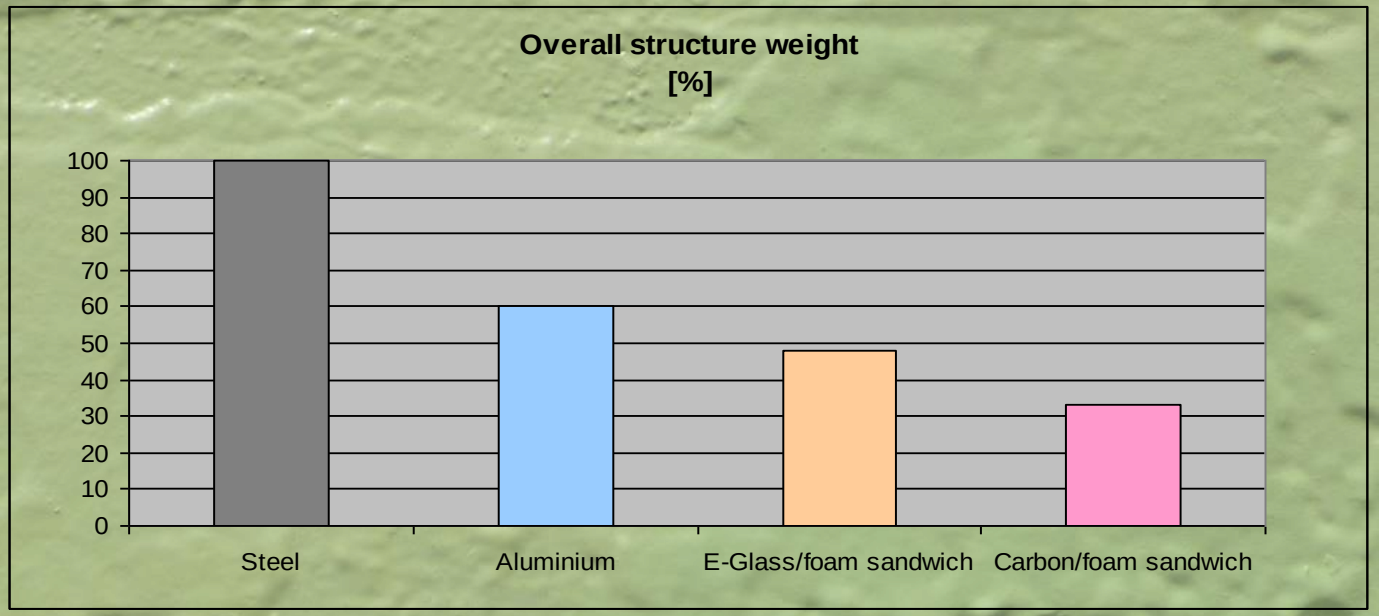
The Challenger…

Replacement for the Tunø-ferry

- EC directive? D-class, SOLAS
- Construction material: FRP (Carbon comp.)
- 200 Passengers & 6 Cars
- approx. 30 meters
- 9,5 knots
- Displacement **120 T**
- Expected engine power: **2 x 110 kW**

Structure weight

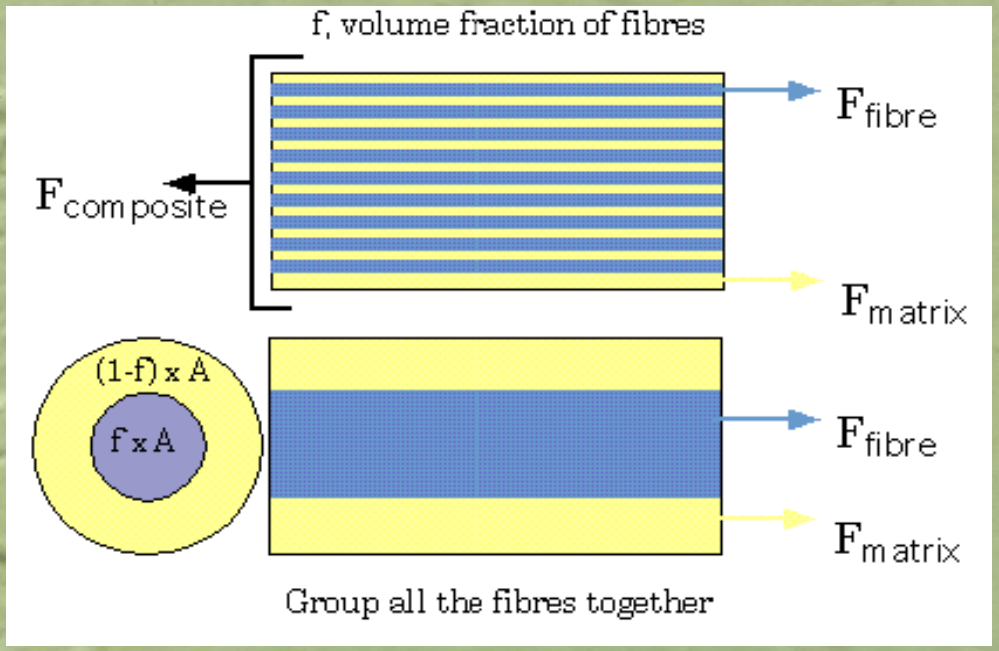
Overall structure weight	[%]	[%]
Steel	100	
Aluminium	67 -	56
E-Glass/foam sandwich	52 -	43
Carbon/foam sandwich	37 -	31



Slide by Niels Hjørnet

What is composite?

A mixture of resin and fibres



Slide by Niels Hjørnet

Comparison

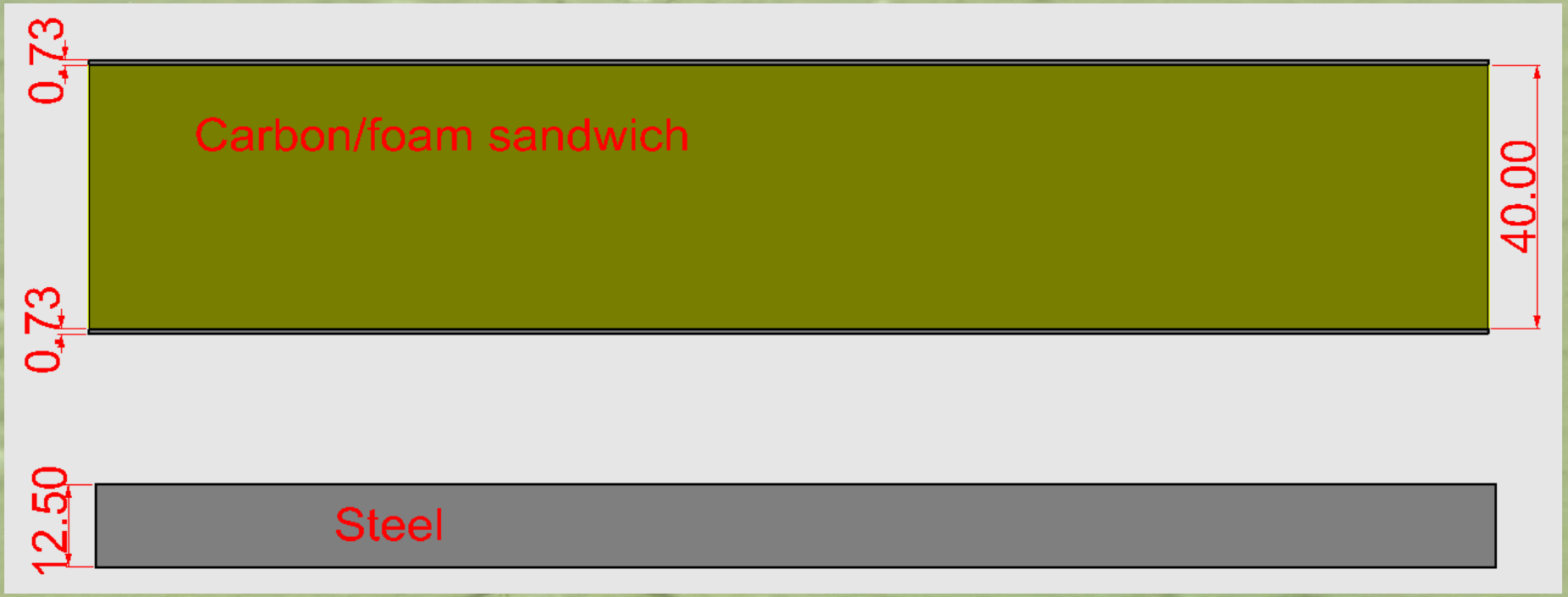
Steel - carbon

Material properties	E-modulus [GPa]	Tensile/yield strength [MPa]	Density [kg/m³]	**Specific strength [kNm/kg]**
Steel	210	355	7850	**45**
Carbon T300/Epoxy	57	540	1418	**381**

Slide by Niels Hjørnet

Comparison

Steel – carbon/foam sandwich

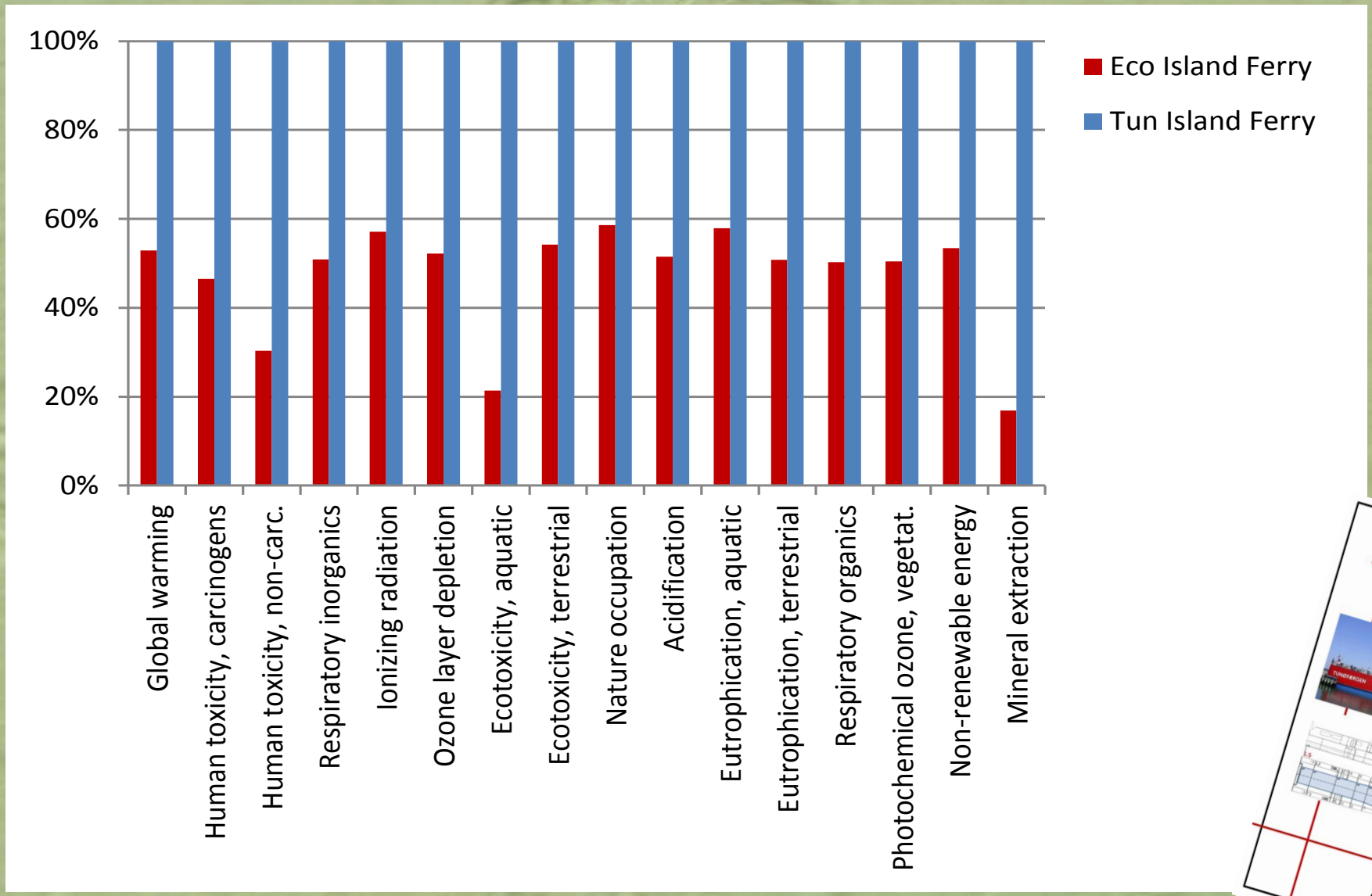


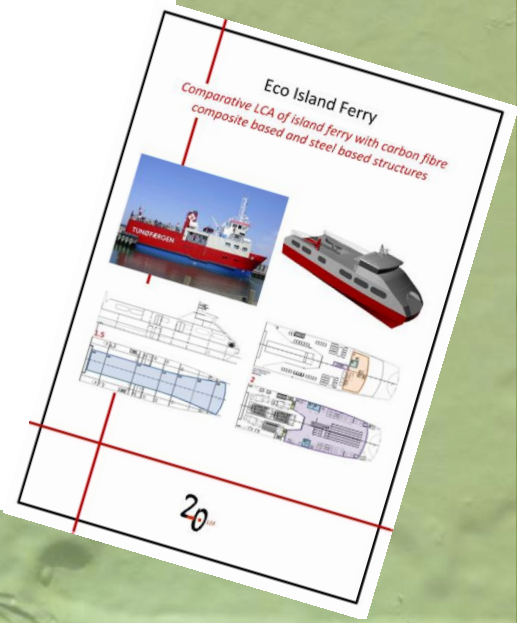
Same stiffness: EI = 3.431 * 10^4 Nm^2/m

Weight:	Sandwich	**5.5 kg/m²**
	Steel	**98.2 kg/m²**

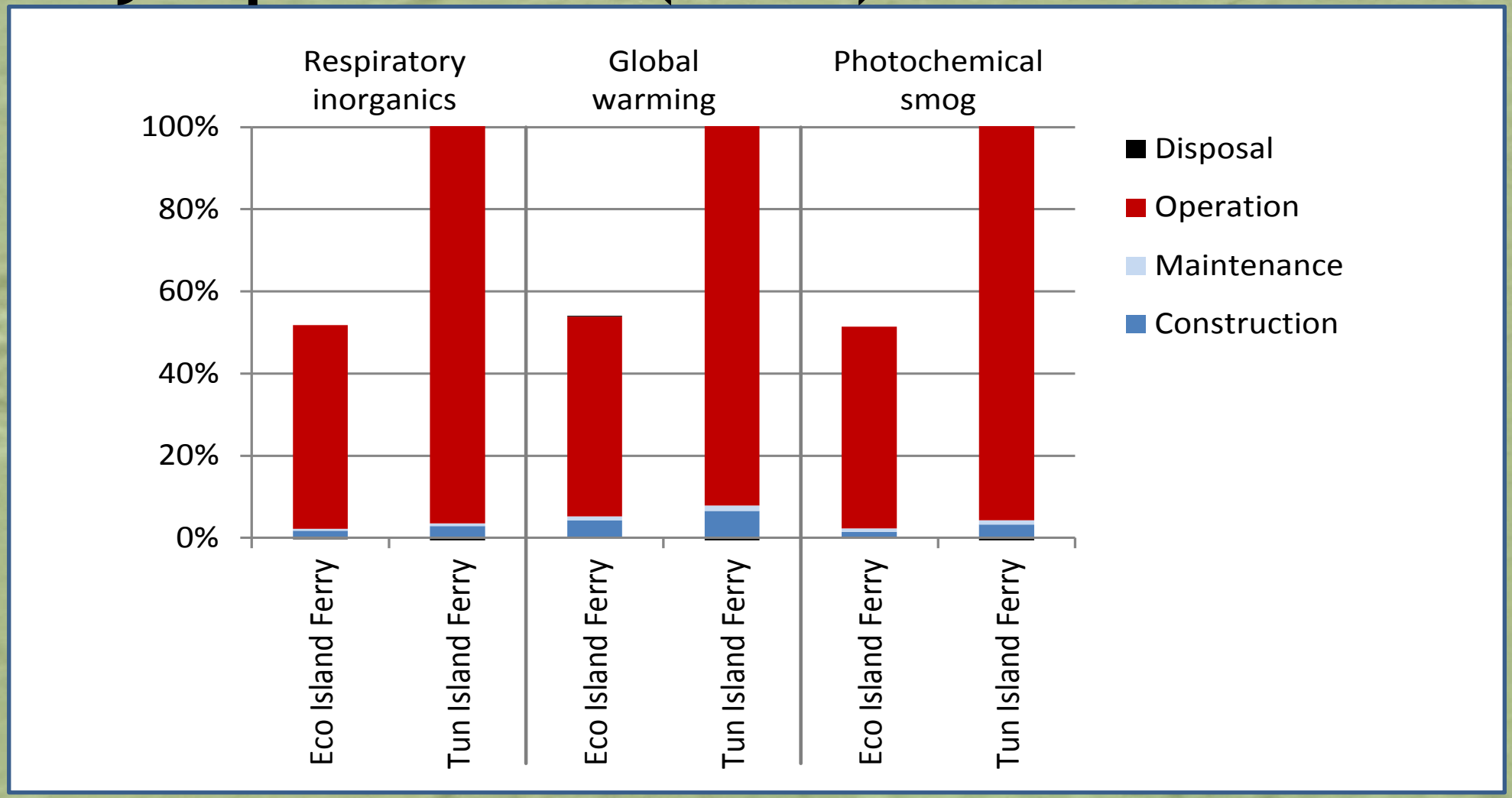
Slide by Niels Hjørnet

Results: Environment

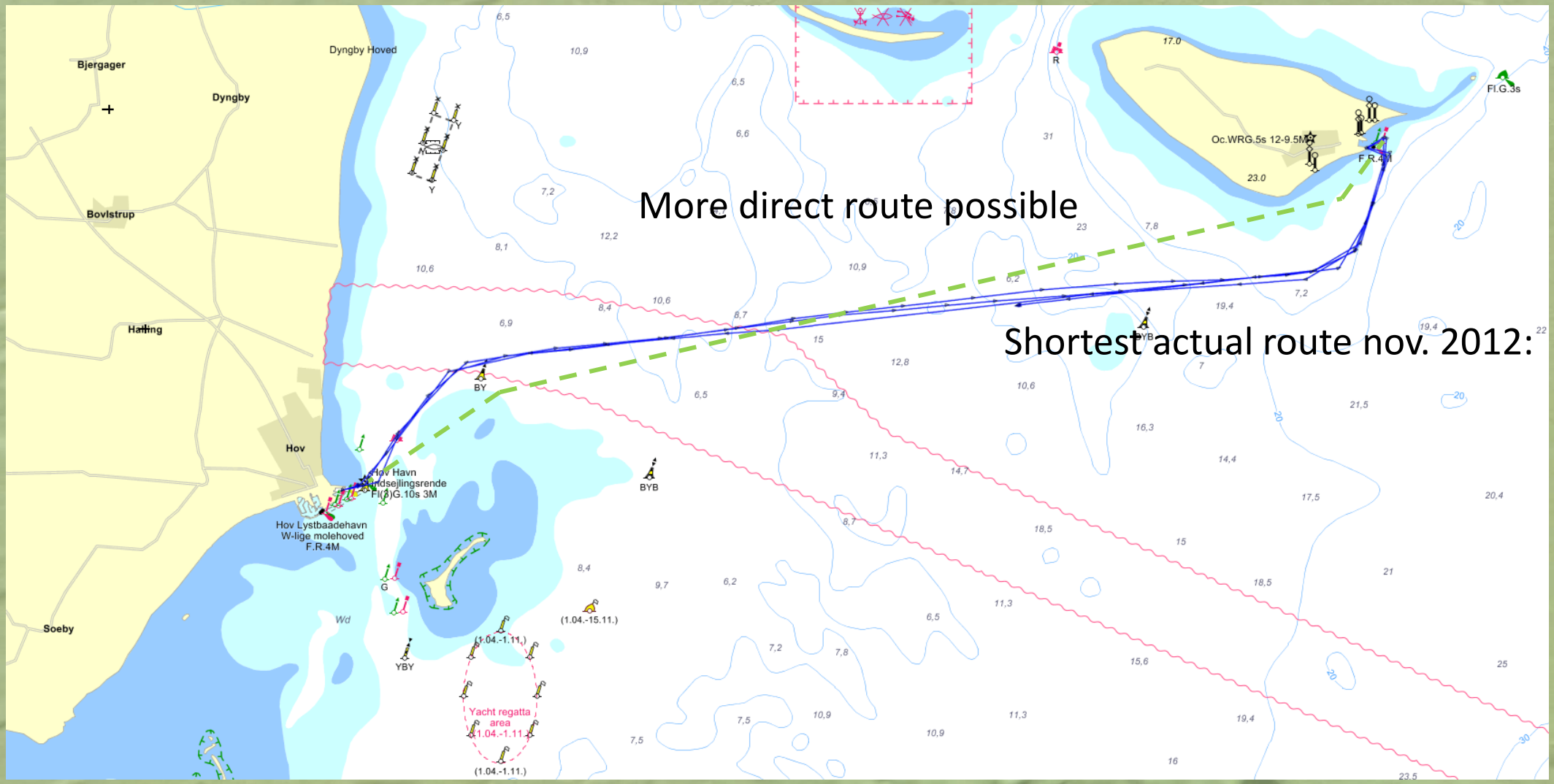




Ferry operation (fuel) is the reason



Lower draft (1.4 m) saves 3,2 nautical miles a day and 5 min on each trip



Results Payback: Break-even after 8.6 years use

Assumptions:

- 3 % increase on fuel price (also shown for 0%, 5% and 10%)
- 4 hours daily operation = 2 return trips
- Salaries not included! (considered equal)
- 4 % interest rate
- 2.1% inflation rate

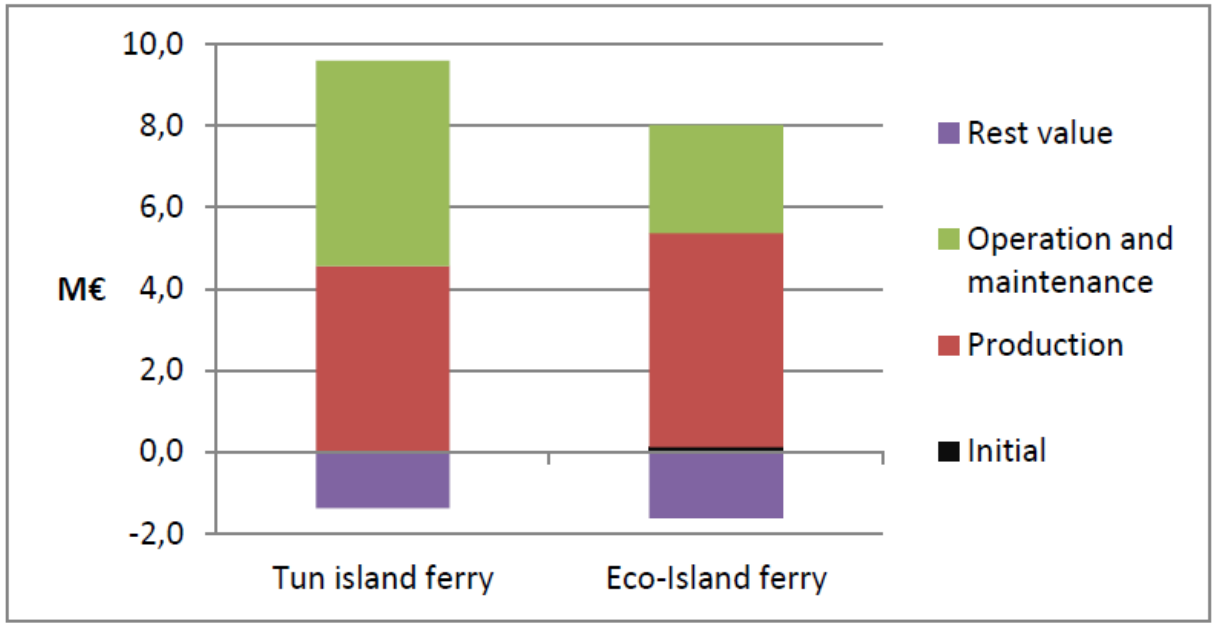


Figure 6 Contribution from different phases in the life cycle cost, presented at current price

Life Cycle Costs and break-even

Highly sensitive to operational hours:

Trips per day	Operation Break-even
1 (2 hours daily use)	12.1 yrs
2 (4 hours daily use as today)	8.6 yrs
3 (6 hours daily use)	6.5 yrs
4 (8 hours daily use)	5.3 yrs

Results:Identified institutional barriers

1. Considering Life Cycle Costs in public tendering
2. New green business models to finance extra investment
3. Allowing ferries in carbon composites – in a more simple way
    1. ~~Eu Ferry directive requirement: *”Steel or similar”*~~
    2. National approval for specific route- cheap but export difficulties
    3. SOLAS requirement ”risk analysis based approval” (rule 17). For unrestricted use (expensive)
    4. High speed Code – extra manning (expensive)

Four planned outputs from Øko-Ø:

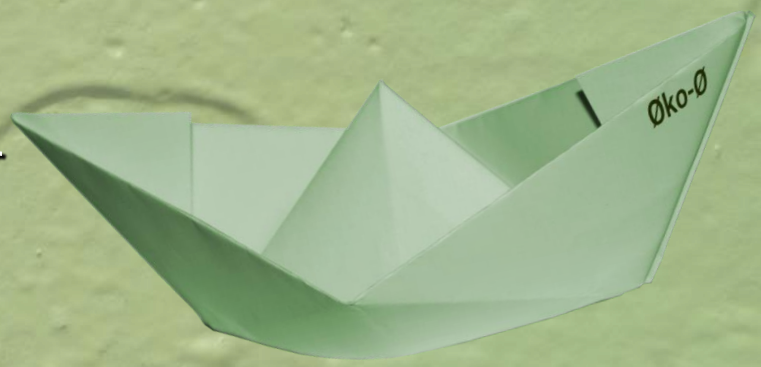
√ 1. A general arrangement, scantling, propulsion calculation, specification for a carbon composite ferry.

√ 2. Life Cycle Cost analysis. Assessing total cost of ownership and pay-back time for extra initial costs (design and construction)

√ 3. Life Cycle Assessment – mapping environmental inputs and outputs throughout the whole life time of the ferry and an assessment of the environmental impacts of these.

√ 4. ”Rule 17 analysis”. Which alternative constructions and arrangements are necessary to get approval for a small displacement lightweight composite ferry?

= No real ferry, only paper



Triple helix innovation

Authorities

Søfartsstyrelsen

Västra Götaland Region

Sv. Transportstyrelsen

Erhvervshus Nord

Research

2.-0 LCA consultants

SP Technical Research

Aalborg University

Danish Yachts

Niels Hjørnet Yacht Design

Coriolis AB

Kockums AB

Private industry

Three enthusiastic innovators and how they learned

Jens Otto Sørensen, Danish Yacths

sailed submarines

learned modular design for navy

Mats Hjortberg, Coriolis AB

Composites and tender problems

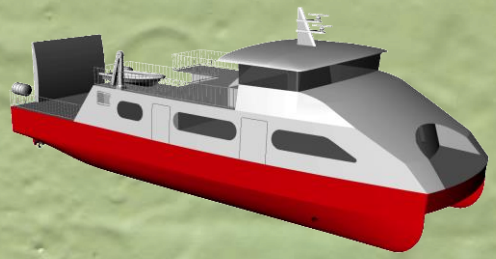
Niels Hjørnet,

”homebaker” of racing boats:

”Leave ashore what you won’t need”

How can Odder Municipality save 263.345 kg CO_2 on transportation each year?

Alternative 1:



Alternative 2:

+

Shift all cars to hybrid: Exchange public cars Fiat Panda Dual 1.2 dynamic (127 g CO_2/km) with Yaris hybrids (78 g CO_2/km)

183 X

The future: More than just paper

-Interest
-Presentations
-Teaching
-Press
-Serious meetings
-EU ferry directive revision
-Izmir Municipality:

Let’s have 15 of those (starting 2014)

Özata.com

Waves can be used positively

…but you must know
where and when
they are coming

Are new wave-causing impacts approaching?

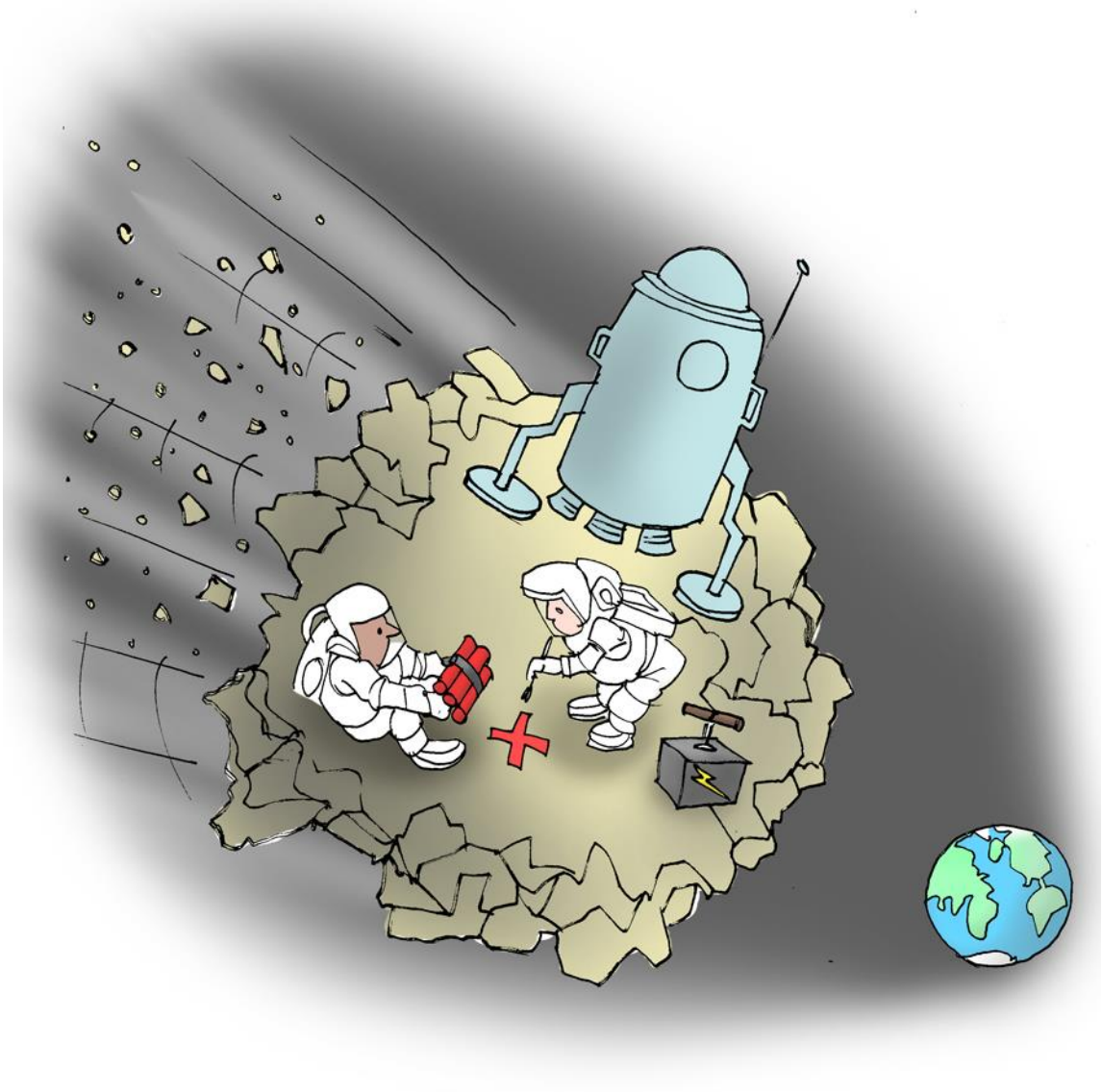
”Observatory” Research, Industry and authorities

MARKIS (DK, N, S)

Network, facilitating triple helix

How can the wave creation be influenced?

- Knowledge
- Interests
- Power
- Technology and solutions
- Network



Key points

Anticipate upcoming env regulation! – and influence it

Shipping is different:

- Global competition
- Instruments and enforcement
- Marked-based efforts?

Solutions exist

Institutional Implemetation barriers

References and Contact:

Mosgaard, M., Riisgaard, H., & Kerndrup, S. (2014). Light Island Ferries in Scandinavia: A Case of Radical Eco-innovation. In *Eco-Innovation and the Development of Business Models* (pp. 275-295). Springer International Publishing.

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Smith, J.H. and Watson J (2013) Eco Island Ferry – Comparative LCA of island ferry with carbon fibre composite and steel based structures. 2.-0 Lca Consultants Aalborg

More info on www:

Eco-island.dk

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Your questions