“Schoon schip maken”

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Masterclass Scheepvaart
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Introduction

Need for Transport

Adam Smith (1776):

Growing

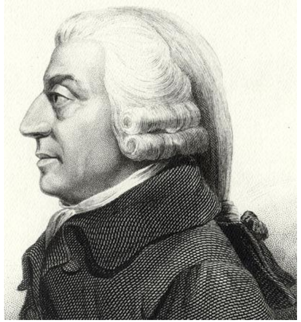
Distribution of Work + Trade = Wealth
+ Waste

Growing Demand

- Distributed Work >
- Productivity > Volume > Trade >
- **> Transport**
- Competition > innovation

Growing market share

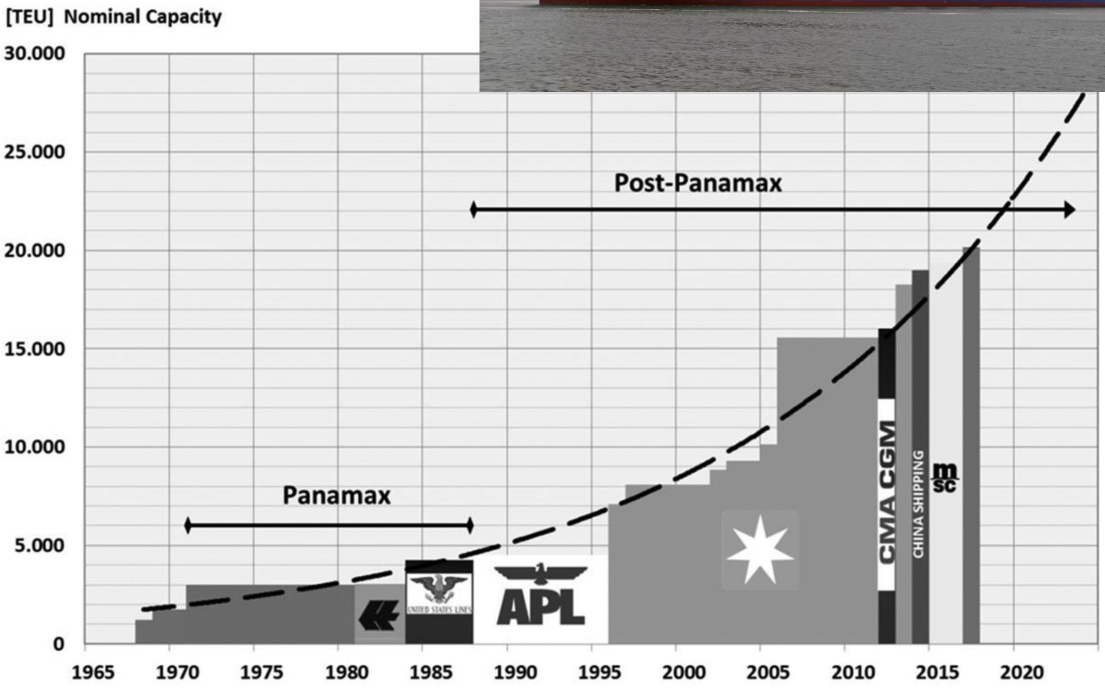
Reduced costs / more efficient



Cost-effectiveness

Economy of scale

2020: HMM Algeciras-class
23.964 TEU



1956: *SS Ideal X*
58 x 35’ containers

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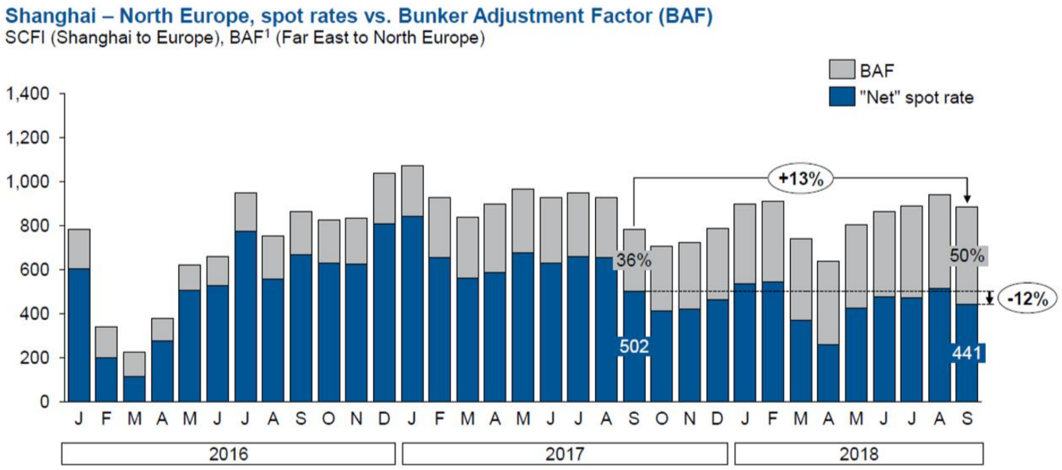
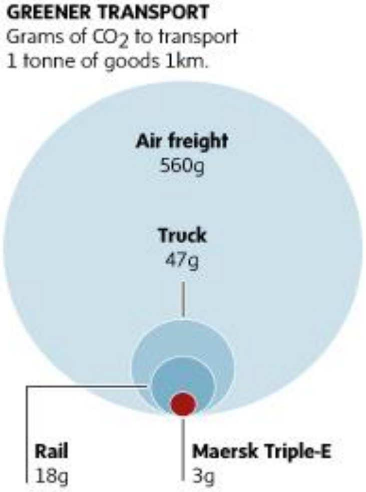
Cost-effectiveness

Economy of scale





L x B x H: 6,1 x 2,45, x 2,9 m

Shanghai – Rotterdam: Freight costs/TEU: $800,- to $1000,-

~6.000 pair of shoes / TEU :

> 0,13 – 0,17 $ct/shoe box of which ~50% is fuel costs

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April 2018: IMO CO_2-emissions Target

RESOLUTION MEPC.304(72)

INITIAL IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS

“On Friday April 13th, the IMO Marine Environment Protection Committee (MEPC) announced that member state delegates have agreed on a target to cut the shipping sector's overall CO_2 output by 50 percent by 2050, to begin emissions reductions as soon as possible, and to pursue efforts to phase out carbon emissions entirely. “

“The agreement includes a reference to bringing shipping in line with the Paris Climate Agreement's temperature goal, which seeks to limit global warming to "well below" two degrees Celsius.”

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Challenges for meeting the IMO ambitions

- Life expectation of ships is 20 to 25+ years > ships ordered tomorrow could still be in service in 2045. Need for retrofitting?
- On time availability of new cost-effective technologies to reduce GHG emissions
  - More efficient > less fuel/tonmile
  - Alternative “fuelled” drive systems producing less GHG > Zero-emissions; Many alternatives > What to choose?
- Effectiveness of regulating measures
  - Progress of IMO
  - Level playing field
  - Pricing (of environmental impact)
- Availability of stimulating measures (subsidies)

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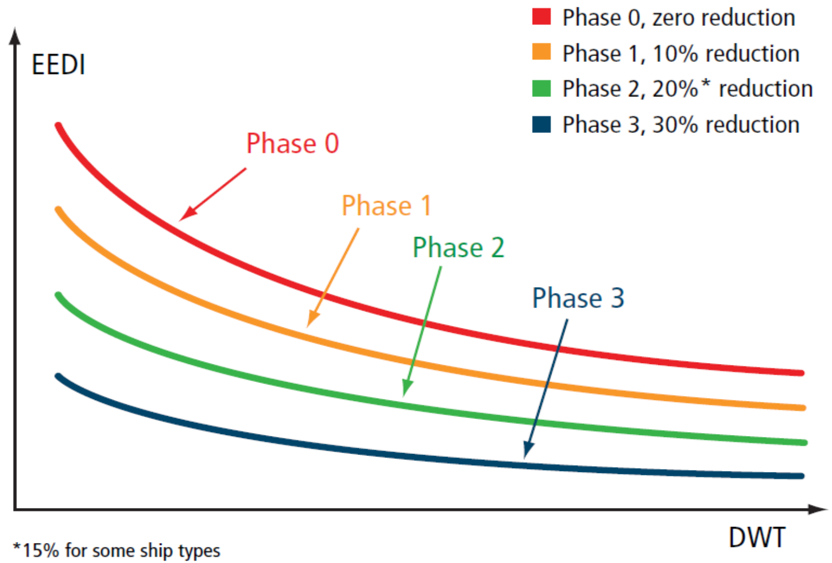
Energy Efficiency Design Index (EEDI)

Attained EEDI ≦ Required EEDI = (1-X/100) × Reference line value;

The **required EEDI** will be **reduced** by X **% each five years** based on the initial value (Phase 0) and depending on the vessel size.



More efficient – IMO regulation

EEDI – initial effect on the Design

$$EEDI = \frac{CO_2\ emission}{transport\ work} \sim \frac{C_1 \times P}{DWT \times V} = \frac{C_2 \times V^3}{DWT \times V} = \frac{C_2 \times V^2}{DWT}$$

$$R = c \times V^2$$

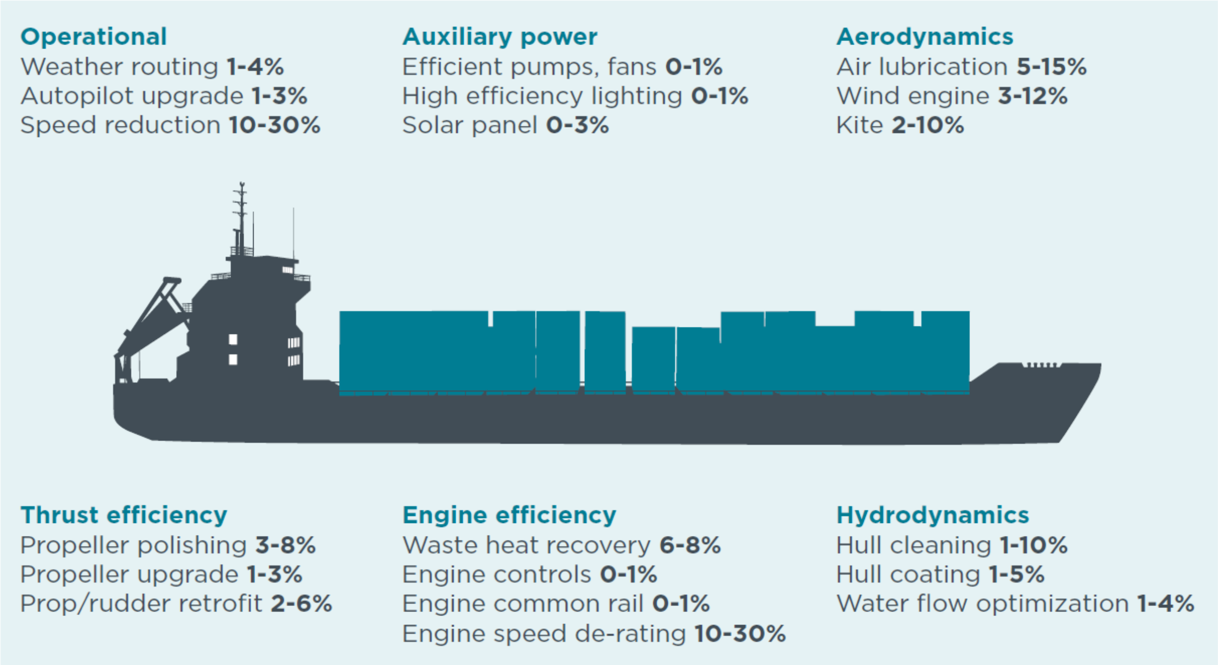
$$P = R \times V = c \times V^3$$

Speed has a large influence on EEDI

> Ships will be:
Larger and/or Slower

More efficient

Source: Wang & Lutsey 2013



- Only **reduces** fuel consumption and, therefore, emissions
- But also: efficiency improvements keep the demand going!

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Alternative fuels

Candidates for
Zero- emissions

Energy source	Fossil (without CCS)					Bio	Renewable[3]		
Fuel	HFO + scrubber	Low sulphur fuels	LNG	Methanol	LPG	HVO (Advanced biodiesel)	Ammonia	Hydrogen	Fully-electric
High priority parameters									
• Energy density	green	green	light green	light green	light green	green	yellow	orange	red
• Technological maturity	light green	light green	light green	yellow	yellow	green	orange	orange	yellow
• Local emissions	orange	orange	light green	light green	light green	orange	yellow	green	green
• GHG emissions	red	red	orange (2)	orange	orange	light green	green	green	green
• Energy cost	green	light green	green	yellow	light green	orange	red	red	red/yellow/green (4)
• Capital cost — Converter	light green	green	light green	light green	light green	green	light green	red	green
• Capital cost — Storage	green	green	yellow	light green	light green	green	light green	red	red
• Bunkering availability	green	green	light green	yellow	yellow	red	orange	red	orange
Commercial readiness (1)	green	green	green	light green	light green	yellow	orange	red	red/yellow/green (5)
Other key parameters									
• Flammability	green	green	green	light green	green	green	orange	red	green
• Toxicity	green	green	green	yellow	green	green	red	green	green
• Regulations and guidelines	green	green	green	light green	yellow	green	yellow	red	light green
• Global production capacity and locations	green	green	green	yellow	light green	orange	yellow	yellow	red

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Alternative fuels for Zero emissions

Most promising candidates

Only when produced from / recharged using renewables:

Hydrogen:

- Fits well with the anticipated energy transition to renewable power production on land.
- Highly flammable
- Low energy density

Ammonia:

- Carbon free energy carrier with higher density than hydrogen, requires SCR-reactor for NOx
- Technically feasible for deep sea.
- Highly toxic, high auto-ignition temperature

Fully electric (batteries):

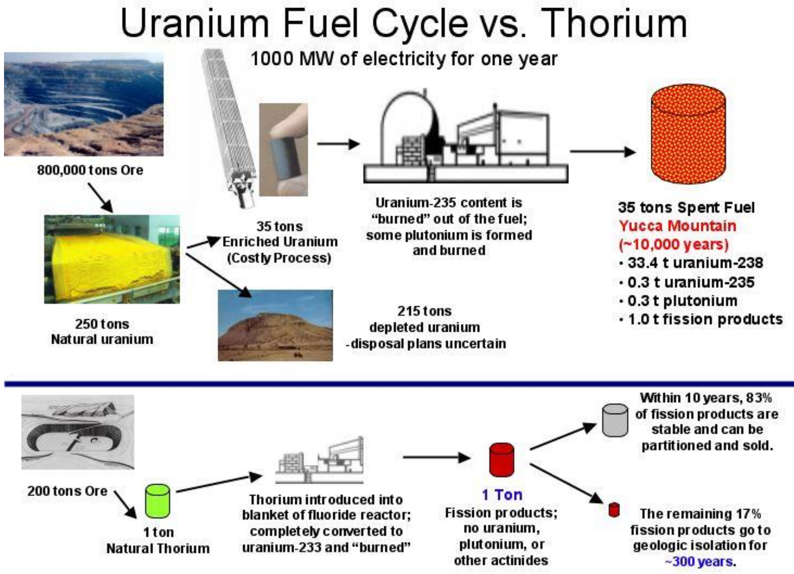
- Zero emissions when using electricity from renewable sources.
- Low energy density > only for short sailing distance.

Alternative fuels for Zero emissions

Other candidates

Nuclear power:

- *USA: "nuclear is really the only solution that exists today that could be implemented relatively quickly."*
- *"if climate change accelerates, the negative connotations of nuclear will be secondary to global warming"*
- *Thorium as alternative for Uranium?*
- *Only as land-based solution?*

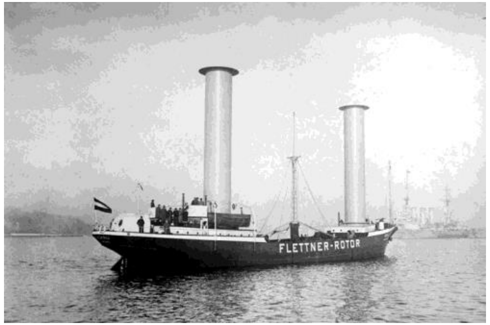


Alternative fuels for Zero emissions

Other candidates

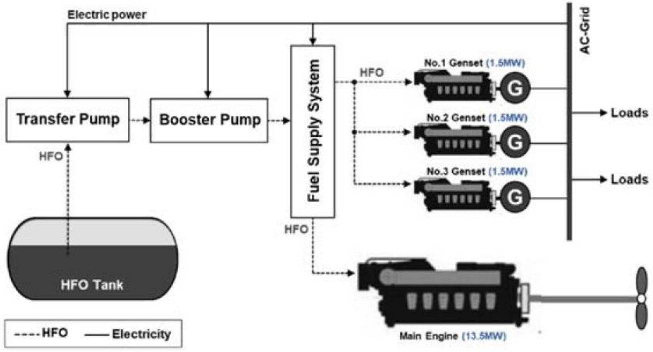
Wind Assisted Ship propulsion (WASP) (emission reduction!)

8 - 20% fuel savings
- Flettner Rotor: (1920) (2013 - E-Ship 1)
- Turbosail™: Alcyone (Cousteau 1973)
- Ventifoil (2020)
- Dyna Rig (Dykstra)

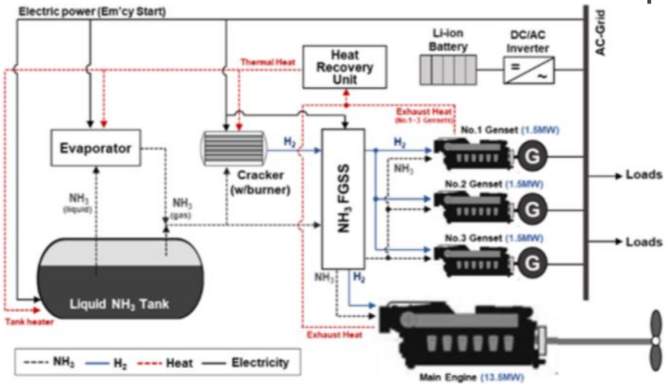


Alternative drive systems for Zero emissions

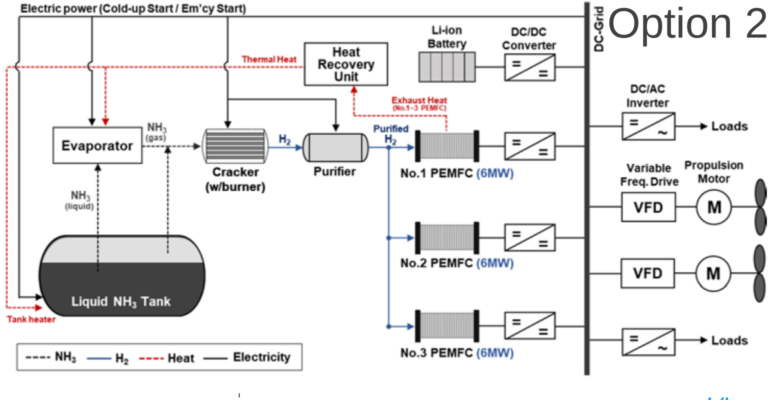
Ammonia fuelled systems



Option 1



Option 2



Ammonia (NH3) drive system:

- Option 1: Combustion engines
  - H2 for ignition (from NH3)

- *Option 2: Fuel cells*
  - *NH3 > H2 for PEM-Fuel cells*
    or
  - *NH3 for SO-Fuel Cells*

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Alternative drive systems for Zero emissions

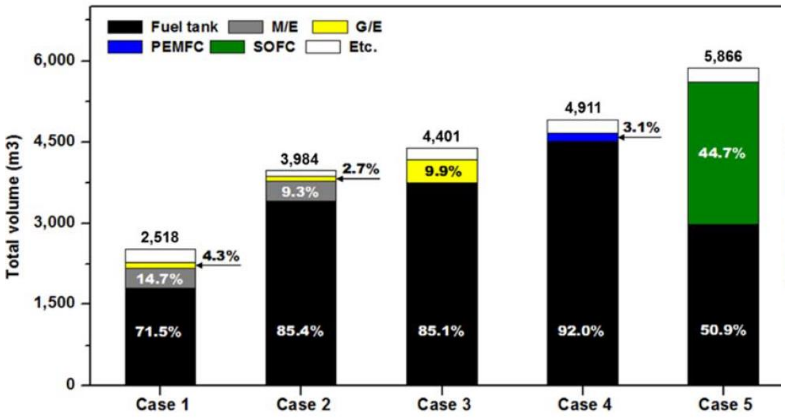
Ammonia fuelled systems

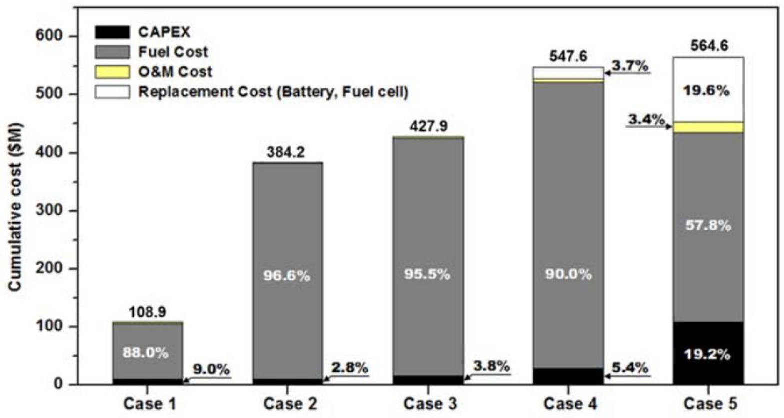
Journal of Marine Science and Engineering

Article

A Preliminary Study on an Alternative Ship Propulsion System Fueled by Ammonia: Environmental and Economic Assessments

Reference ship: 2500 TEU container ship





HFO **NH3 engines** **NH3 Fuel Cells**

-38 -49 -62 -87 TEU

100% -1,5% -2% -2,5% -3,5%

HFO **NH3 engines** **NH3 Fuel Cells**

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Alternative drive systems for Zero emissions

Hydrogen fuelled systems

Hydrogen (H2) storage:

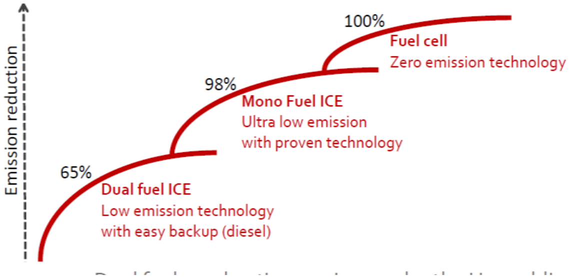
- Compressed Gas Hydrogen (CGH)
- Cryogenic Liquid Hydrogen (CLH)
- Solid hydride (metal, sodium borohydride)

Drive system:

- Internal combustion engine (ICE)
    - Duel fuel > mono fuel
    - NOx emissions > SCR needed

- Fuel Cells

    - Size 1-1,5MW > multiple stacks



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Fuel cells

Nedstack 1MW PEMFC
Size: 2 x TEU

- Electric propulsion
- Modular, standard energy units (Fuel cells)
- “containerized” engine room

Advantages:

- low to zero noise, higher efficiency at part load (!),
- No single point of failure, solid state tech: low maintenance (cost), high reliability and graceful degradation when in modules and stacks.
- Promising technology for autonomous ships.

Challenge:

- Cost (1000+ k€/kW for PEM, expected to decrease with start of serial production),
- Lifetime (state of the art 20.000+ hours).

Conclusion

Ship owners – what to do next?

- Actual IMO-measures for short-, mid- and long-term still not clear
- CO_2-discussion is developing fast (societal pressure)
- Global market > strong competition > small margins

- New regulating measures at regional level can be expected
  - What will EU and/or USA do?

  > **Growing uncertainty**

- What to decide?
  - Many options available now or underway / under development
    - Apply now or modify later?
    - Economic life expectation?

  > **Growing complexity in decision making**


Artist's impression of TSHD concept developed for the EU Research Project JOULES: autonomous, hybrid-electric, fuel cell-driven dredging vessel

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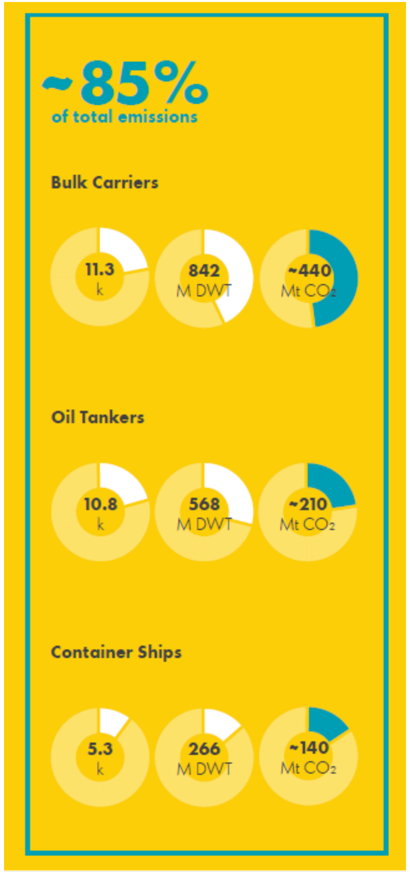
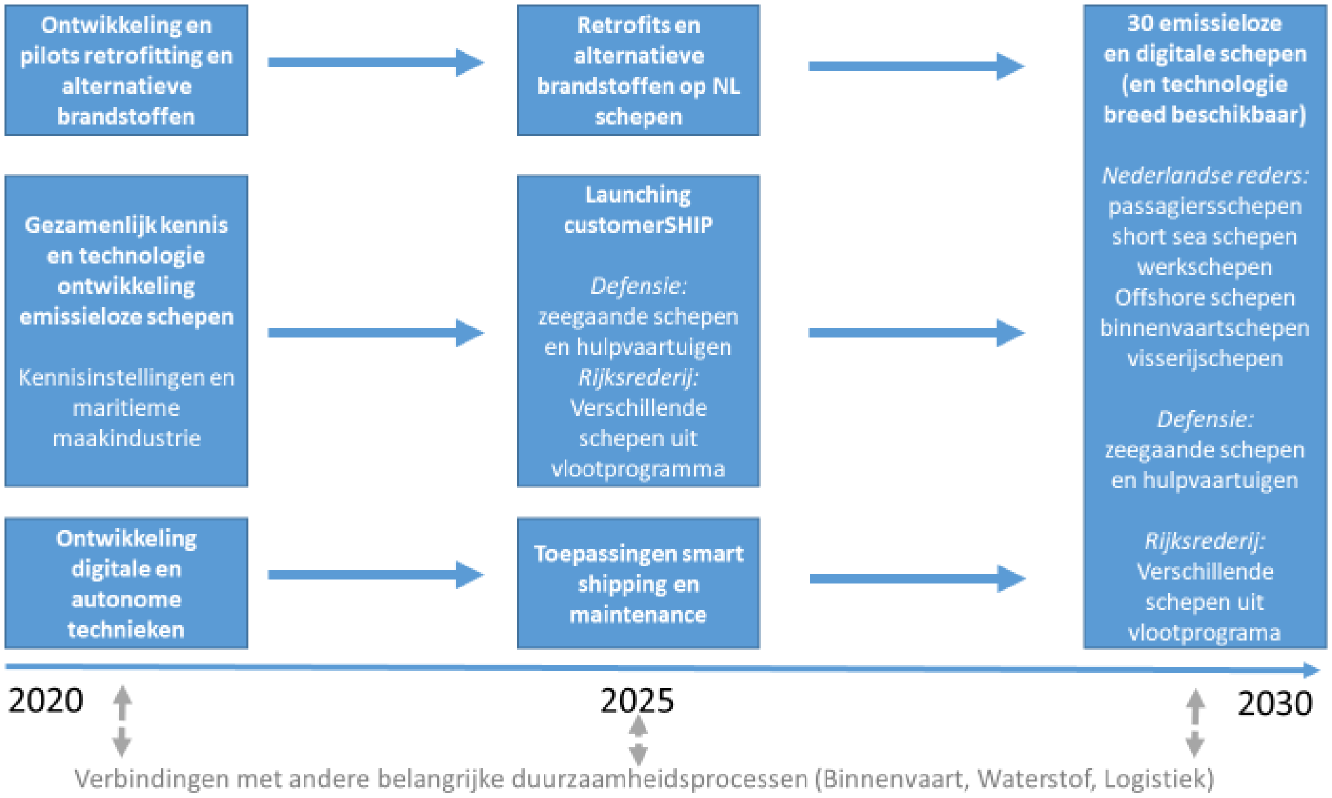
Why should we do it?

- Total emissions of shipping are determined, to a large extent, by the expected long term growth of the world economy (and population)
  - manufacturing by robots > levelling "labour" costs?
  - Additive manufacturing (3D-printing)?
  - Circular economy?
  - "Europe first" / effects of Covid-19?
- Shipping industry now is responsible for (only) 2,7% of the global CO2 emissions.
- Global Problem that can only be solved at international level?
- Impact of measures at national level small!
- New business opportunities for our Industry



What can we do?

2050 Masterplan Emissieloze Maritieme Sector



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Conclusion

- Most promising candidates for Zero-emission shipping:
  - Hydrogen + Internal combustion engines and/or Fuel cells
    - Storage options: Gas, Liquid or solid?
  - Ammonia + Internal combustion engines and/or Fuel cells
  - Al electric using batteries: Short distances
  - Wind assisted Ship Propulsion (additional to reduce expensive fuel)

- Ship design solutions for ‘provisions for”
  - Flexible designs

- Stimulating governmental measures:
  - Research & development
  - Subsidies to cover extra costs & risks
  - Launching customer

- Regulating measures at EU-level

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Back up

Project call organisation	Project Name
NML MIIP	AmmoniaDrive, FCMAR, Biofuel Mar, Incentives for Green Shipping
Joint Industry Projects	Green Maritime Methanol
NWO	GasDrive (LNG), Perspectiefvoorstel AmmoniaDrive
Horizon 2020	Nautilus (LNG + SO Fuel Cell)
EU Interreg	H2SHIPS, ISHY
EU Partnership Waterborne	Next Presentation

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