Hydrogen as seen from a shipping company

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A wise man said it like this:

«The farther backward you can look, the farther forward you are likely to see»

Sir Winston S. Churchill, 1874 - 1965
Our first non-emission vessel; Mathilde (1861 – 1880)
Our first polluter; steamship Talabot (1887 – 1905)
From wind to coal

- Investment cost
- Availability of coal
- Crew; number and competence
- Technical complexity
- Cargo capacity

+ Speed
+ Regularity (year round)
+ Safety
+ Flexibility
+ Income

Enabled by technology, driven by economy, short sea first, took 50+ years
From coal to oil

- Availability of oil
  Bunkering systems

+ Crew; number and health
  Cargo capacity
  Endurance
  Bunkering procedures

Enabled by technology, driven by economy, short sea first, took 30+ years
In 2005 we launched our vision for 2025, the Orcelle; a zero emission car carrier
We participate in developing next generation vessels
The SeaShuttle project; a semi-autonomous container feeder with compressed hydrogen and fuel cells

Funded by the Norwegian Government
We initiated design of the first LH2 bunker vessel; BV Tomorrow

LH2 Cargo capacity: 9 000 m³
500 tons
Example of today’s emission challenges in shipping

- 130 vessels
- 1,600,000 tons of fuel
- 800,000,000 USD
- 5,000,000 tons of CO2
- 6,500 tons of NOx
- 40,000 tons of SOx
- ?? tons of PM

All figures are rough estimates for illustration only
What is global climate related, and what is local pollution?

Green, blue or grey hydrogen?
«Well to Wake», or «Tank to Propeller»?
<table>
<thead>
<tr>
<th>Fuel cell installations</th>
<th>IMO</th>
<th>挪威船舶集群</th>
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</table>
| • No Regulations existing | • No Rules existing  
| • Development ongoing, but process slow. | • Will follow IMO pathway  
| • IGF code Part A require Alternative Design Approach to be followed (i.e. IMO MSC.1/1455) |  
| | | launched Jan 1st 2018. This is prescriptive rules with detailed req’s. |
World production and use of Hydrogen (~70 mill. tons/y)

Production sources

- Natural Gas: 48%
- Oil: 30%
- Coal: 18%
- Electrolysis: 4%

Use: 90% in process industry

- Ammonia: 55%
- Raffinery: 25%
- Methanol: 10%
- Other: 10%

Main challenge: CO2 emissions
Ammonia; NH3, another way of handling hydrogen

Processed from hydrogen and nitrogen

To be stored and transported liquid when
- cooled to minus 33 C or
- compressed to 9 bars

A commodity well known as cargo

May be used in combustion engines:
emits no CO2, but NOx (to be removed by SCR)

BUT: What does the Chief say?
Liquid Organic Hydrogen Carrier; LOHC
New technology under development

Hydrogenation; Chemical Bonding H2 to organic liquid

Transport/Storage/Bunkering

Dehydrogenation Separating H2 from organic liquid

Return liquid for reuse

Fuel Cell

Combustion engine or Turbine

Electricity/Propulsion

To be handled like oil in tanks, pumps and pipes
Carries 57 kgs H2 per m3

We consider these 4 hydrogen fuels as our options
No solution fits all, and we may still find new ones

<table>
<thead>
<tr>
<th>Compressed; CH₂</th>
<th>Liquid; LH₂</th>
<th>Ammonia; NH₃</th>
<th>LOHC</th>
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<tbody>
<tr>
<td>Ferries and high speed craft</td>
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<td>Short and deep sea cargo vessels</td>
<td>Short sea cargo vessels in fixed routes</td>
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<td>Short sea cargo vessels</td>
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<td>Offshore vessels</td>
<td>Retrofit in general</td>
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<td>Offshore vessels</td>
<td>Cruise vessels</td>
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Common challenges in all hydrogen valuechains: Overall energy efficiency <25%!!
Some considerations on way forward

To authorities:

Do not specify technologies, but set realistic goals and requirements to emissions

Be predictable in regulatory matters

Help forerunners in risk mitigation (funding, research, long term contracts)

This is a volume game; accept grey hydrogen to get moving

To technology providers:

Think wide in your choice of solutions

Be open on all your pros and cons and challenges
From oil to hydrogen?

- Investment cost
- Cargo capacity / Endurance
- Crew; competence
- Availability and price of fuel
- Safety issues
- Bunkering systems

+ Environmental impact
+ Less maintenance (?)
+ Cleaner on board

To be enabled by technology, must be driven by economy, short sea first, will take 10 years?
Good luck to us all!

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