Hydrogen: Impacts

Hydrogen Economy Exploding (Not literally)
WHAT IS LOW CARBON HYDROGEN?

Provides a cross-sector opportunity to replace high emitting fuels with low carbon hydrogen, thus reducing the resulting carbon emissions.

The hydrogen production processes have a range of greenhouse gas impacts with Green and Blue the most developed low carbon solutions.
HYDROGEN AS A NEW ENERGY VECTOR

Port Opportunities:
- Hydrogen / ammonia fuelling for ships
- Export / import of hydrogen / derivatives
- Hydrogen fuel cell port vehicles / equipment
- Hydrogen refuelling station for local transport

- Infrastructure impacts
  - Bulk commodities & storage
  - Distribution
  - Loading arms
In order to store and transport hydrogen, it must be compressed or converted to a storage medium with an increased energy density in comparison to low pressure gaseous hydrogen. This is especially important for onwards transport of hydrogen via ship export.

**Ammonia**
+ Established distribution system and technology
+ Energy vector in own right
- Highly toxic

**Liquid Hydrogen**
+ No requirement for high pressure storage
- Energy intensive process and high operating costs

**Liquid Organic Hydrogen Carriers**
+ In liquid state at broad temperature range
- Not deployed at commercial scale

<table>
<thead>
<tr>
<th>Transport / Storage Technology</th>
<th>Conditions</th>
<th>H2 density (kg/m³)</th>
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</thead>
<tbody>
<tr>
<td>Low pressure hydrogen</td>
<td>50 bar</td>
<td>3.95</td>
</tr>
<tr>
<td>High pressure hydrogen</td>
<td>20degC, 350 bar</td>
<td>23</td>
</tr>
<tr>
<td>Liquid hydrogen</td>
<td>- 253degC, atm. P</td>
<td>71</td>
</tr>
<tr>
<td>Liquid ammonia</td>
<td>- 33degC, atm. P</td>
<td>107</td>
</tr>
<tr>
<td>LOHC</td>
<td>Ambient cond.</td>
<td>54*</td>
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Hydrogen ships are early stage with only a select number of operational ships.

Ammonia ships entering design stage – beneficial over hydrogen in terms of energy density.

Ship propulsion will be via fuel cell or internal combustion engine.
HYDROGEN IMPORT-EXPORT MARKET

Net Exporter

Net Importer

Self Sufficient

Europe

Morocco, Canada, Saudi Arabia, Chile, Australia

Australia

Japan, Korea, Singapore

South America

BRA

Middle East

Africa

BEL

GER

FR

NL

USA

Can

China

Japan

S. Korea

Singapore

AUS and NZ

USA

Europe

Australia

South America

BRA

Middle East

Africa

BEL

GER

FR

NL

USA

Can

China

Japan

S. Korea

Singapore

AUS and NZ
CO₂ Transport

- Via pipeline (large-scale)
- Via truck / rail (small-scale)
- Via Ship (small-scale)
  - CO₂ shipping established at a small-scale for use in the food and beverage industry
  - Typical current ship capacity = 1000m³ / 1060t CO₂
  - Potential future ship capacities = 10,000 – 50,000t CO₂

Requirement for Ship Transport

- To connect CO₂ capture clusters without access to underground storage
- Can gather CO₂ from several locations to facilitate deployment of numerous clusters
- Increasing scale of T&S solutions, reducing cost

Approaches

A) Delivered to onshore facility with CO₂ pipeline out to offshore storage site (well understood)
B) Direct offshore injection in CO₂ offshore storage site (not proven)

Barriers and Challenges

- Cross-border legislation and regulation
- Not undertaken as large-scale required
- Must meet constraints of ports (ship draft, berth, storage)

Nippon Gases 1770t CO₂ Vessel
**TYPICAL CO₂ SHIPPING SUPPLY CHAIN**

**Export Terminal**
- Liquefaction
- Buffer Storage
- Cryogenic Loading Arm
- LCO₂ Carrier

- CO₂ liquefied to improve storage density
- Buffer storage – between ship loading
- CO₂ loaded into carrier using cryogenic LA

**Import Terminal**
- Unloading & Storage
- Gasification
- Unloading onshore at port
- For CO₂ to reach reservoir conditions
- Permanently stored in reservoir

**Offshore pipeline**
- UG Storage
CROSS-BORDER CO2 TRANSPORT NETWORKS

- **Dartagnan**
  Multi-Model Hub – Dunkirk

- **Porthos & ARAMIS**
  Rotterdam, Antwerp, North Sea

- **Northern Lights**
  (Most developed) - Norway

- **Poland EU CCS Interconnector**
  Multi-modal Hub – Poland

**North Sea** at the centre of CCUS deployment in Europe

**Storage capacity** potentially 300 Giga-tonnes

East Coast Cluster
UK
ENERGY TRANSITION OUTLOOK

Carbon Dioxide and Hydrogen

- Ports are impacted by net zero
  - Shipping and maritime sector needs to hit net zero targets
  - Critical to delivery of low carbon solutions worldwide as well as everything we do now
  - New markets may arise for both import and export

- Ports are essential in facilitating the energy transition – need to be able to:
  - Facilitate new infrastructure
  - Handle increased load
  - Accommodate new gas networks
  - Access green / low carbon electricity
Thank you
SPARE SLIDES
Hydrogen backed to be a part of Belgium’s future energy economy. The Port of Antwerp has to be part of green hydrogen import value chain in Belgium by the end of the decade (2030).

The Port of Rotterdam is working with Iceland’s national energy company to explore the possibilities for importing clean hydrogen. Plans for green hydrogen produced in Portugal to be shipped to Rotterdam.

Germany have made agreements to develop low-carbon hydrogen projects in Morocco, Canada, Saudi Arabia and Chile.

Japan aims to build the first full-scale hydrogen supply chain by 2030.

Singapore and South Korea are likely to be hydrogen importers also.

Net Exporters

- Access to ample affordable renewable energy
- Access to ample natural gas and CCS infrastructure
- Existing trade links with port terminals

Globally, hydrogen import and export hubs are likely to develop as dependent on territorial decarbonisation pathways and ability to produce large volumes of low carbon hydrogen.
Employees
Worldwide
49,900

Canada
8,000

UK & Ireland
8,200

Nordics
6,080

Central & South America
3,200

Continental Europe
1,340

Asia
3,275

Middle East & India
3,585

Africa
450

Australia & New Zealand
5,525
IMPACTS AT PORTS

Changes to fuelling, moving away from hydrocarbons to sustainable, hydrogen based or decarbonised fuels

For Hydrogen or Hydrogen carriers

➢ Decarbonise fuels
➢ Export potential from green energy areas to users that are decarbonising
➢ Infrastructure changes
  ➢ Bulk commodities/storage – space and energy requirements
  ➢ Distribution
  ➢ Loading
➢ Green/decarbonised fuel – port services, port transport, cargo transport, local transport