The Future of Energy Transition in Ports

Transport Events

Rosie Atkins
Senior Engineer, WSP

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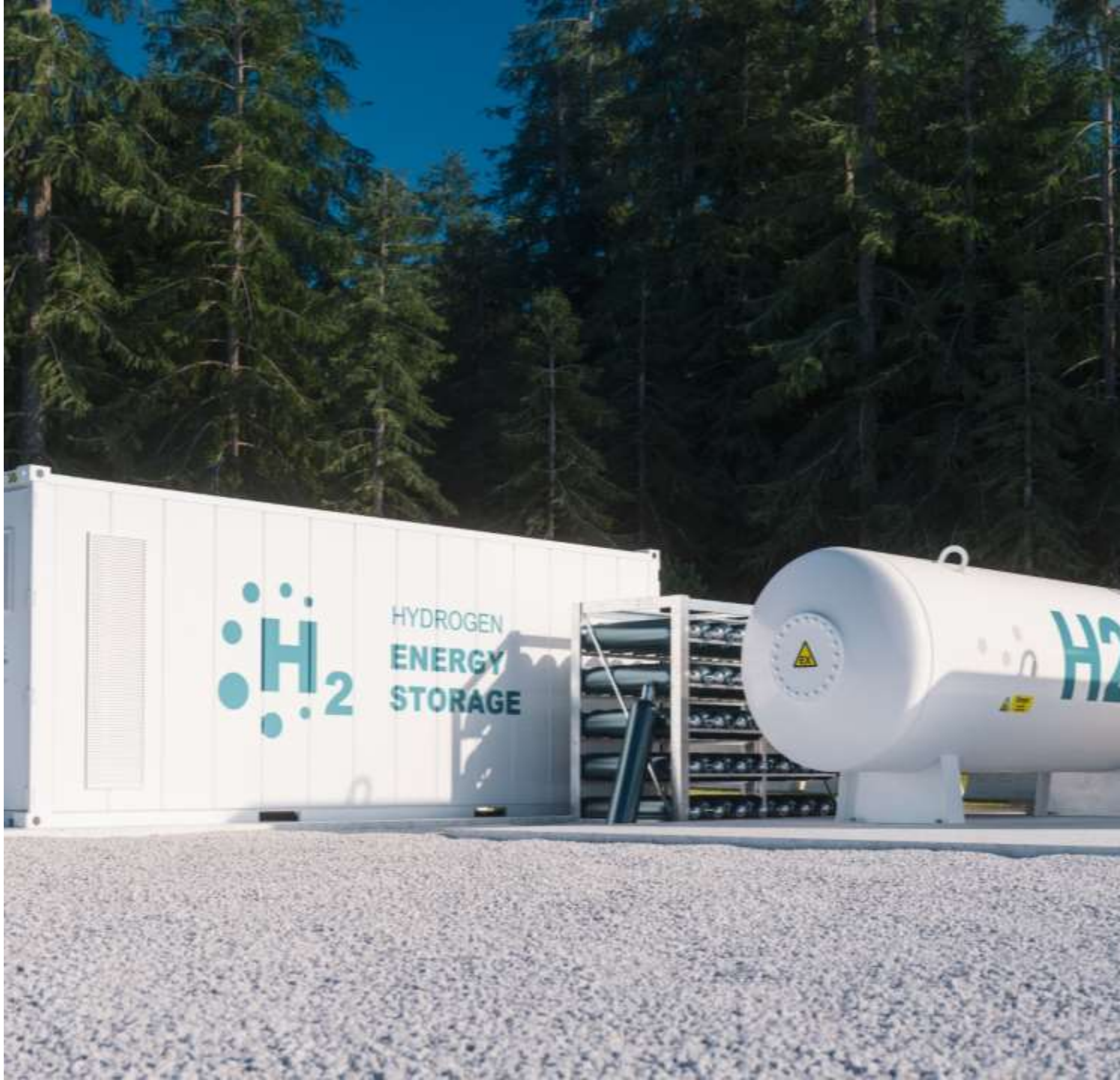
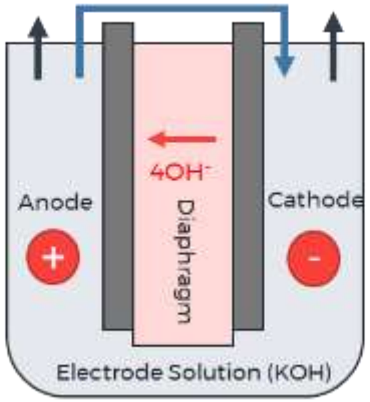
Hydrogen: Impacts

Hydrogen Economy Exploding *(Not literally)*

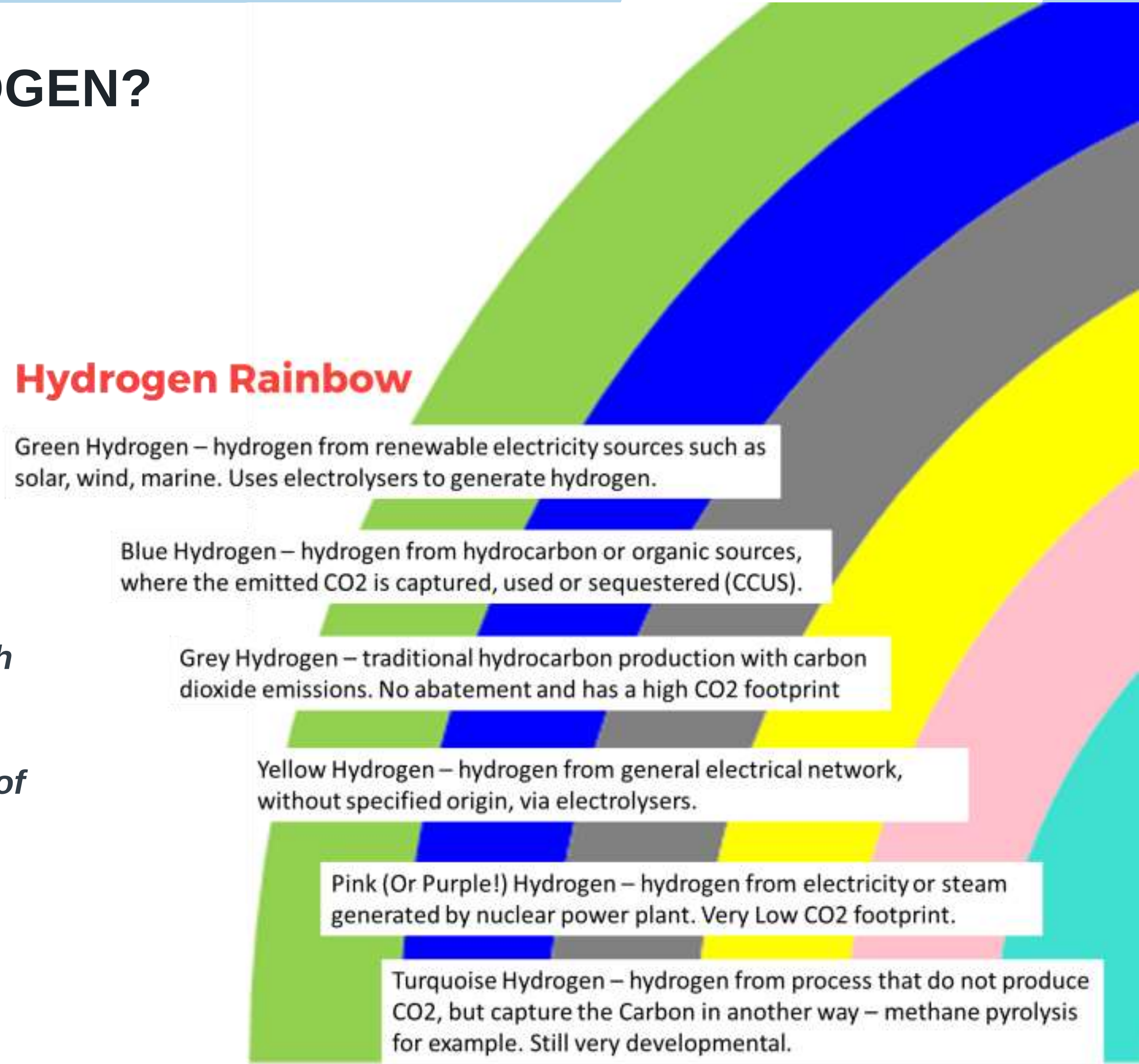


WHAT IS LOW CARBON HYDROGEN?



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.



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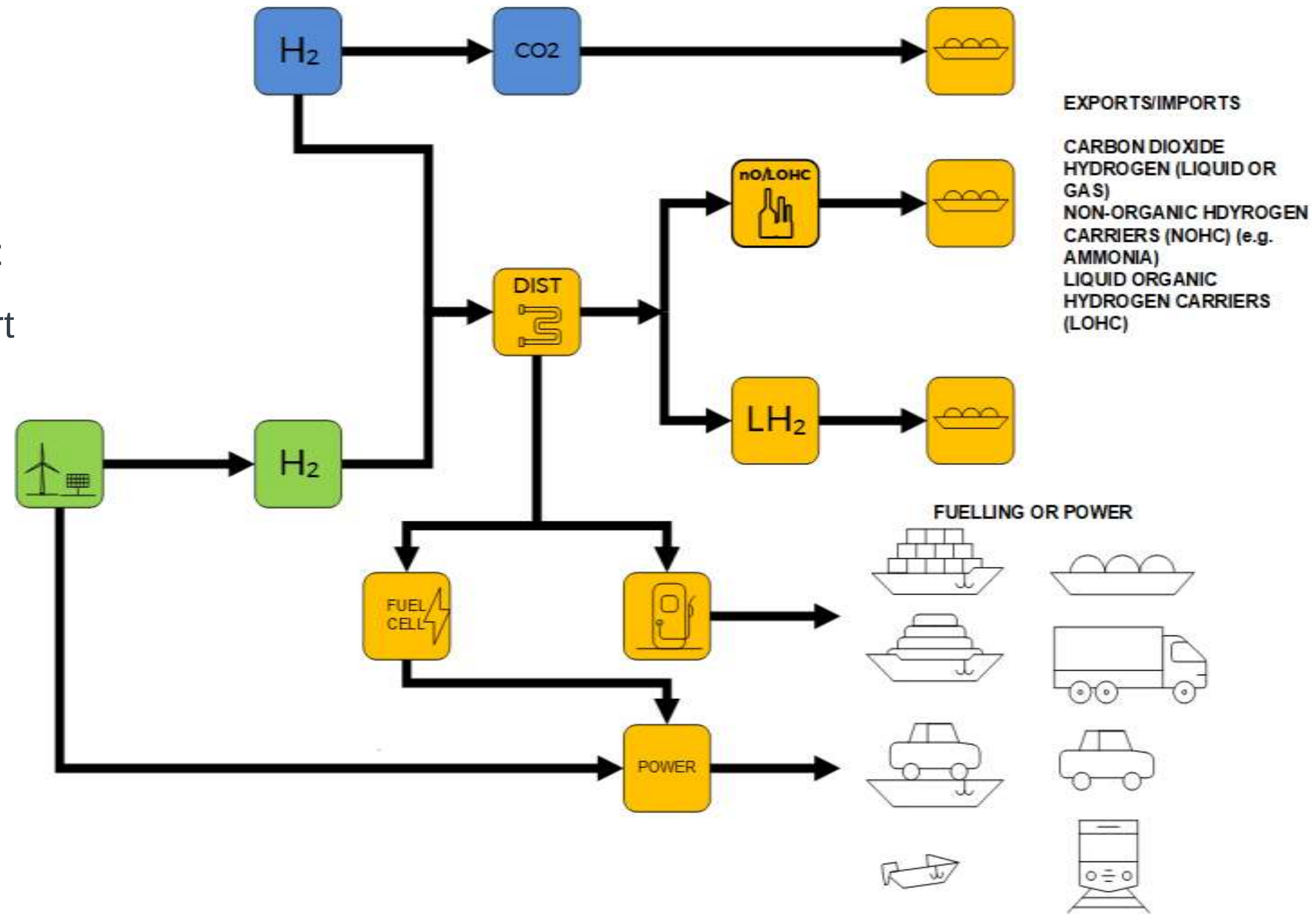
HYDROGEN AS A NEW ENERGY VECTOR

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



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HYDROGEN TRANSPORT & STORAGE: ENERGY DENSITY CHALLENGE

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

Transport / Storage Technology	Conditions	H2 density (kg/m^3)
Low pressure hydrogen	50 bar	3.95
High pressure hydrogen	20degC, 350 bar	23
Liquid hydrogen	- 253degC, atm. P	71
Liquid ammonia	- 33degC, atm. P	107
LOHC	Ambient cond.	54*

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HYDROGEN & AMMONIA FUELED SHIPS

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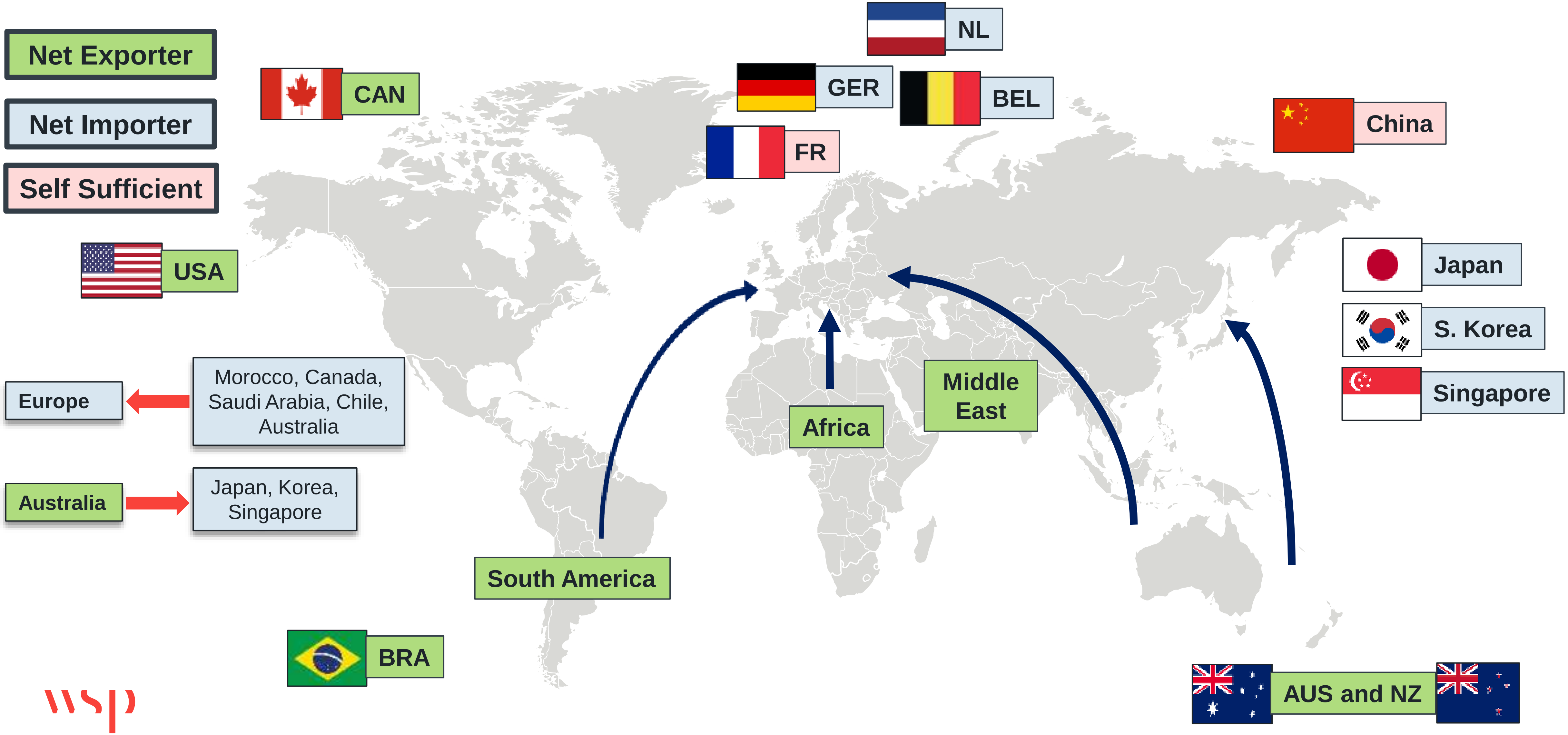
- **Hydrogen ships are** early stage with only a select number of operational ships
- **Ammonia ships** entering design stage – beneficial over hydrogen in terms of energy density
- Ship propulsion will be via **fuel cell** or **internal combustion engine**

ShipFC Viking Energy, Norway
Ammonia

Statkraft and Skagerak Energi, Norway
Hydrogen

Norled Hydra ferries, Norway
LH2 and CH2

HYDROGEN IMPORT-EXPORT MARKET



Carbon Capture & Storage

Ship Transport

CCS IN ENERGY TRANSITION

Carbon Capture and Storage involves the capture of CO_2 from large point sources (such as power and industrial emitters), and transporting it to be injected into underground formations, storing CO_2 permanently.

CO_2 Transport

- Via pipeline (large-scale)
- Via truck / rail (small-scale)
- **Via Ship (small-scale)**
- CO_2 shipping established at a small-scale for use in the food and beverage industry
- Typical current ship capacity = 1000m^3 / 1060t CO_2
- Potential future ship capacities = 10,000 – 50,000t CO_2

Nippon Gases 1770t CO2 Vessel

Requirement for Ship Transport

- To connect CO_2 capture clusters without access to underground storage
- Can gather CO_2 from several locations to facilitate deployment of numerous clusters
- Increasing scale of T&S solutions, reducing cost

Approaches

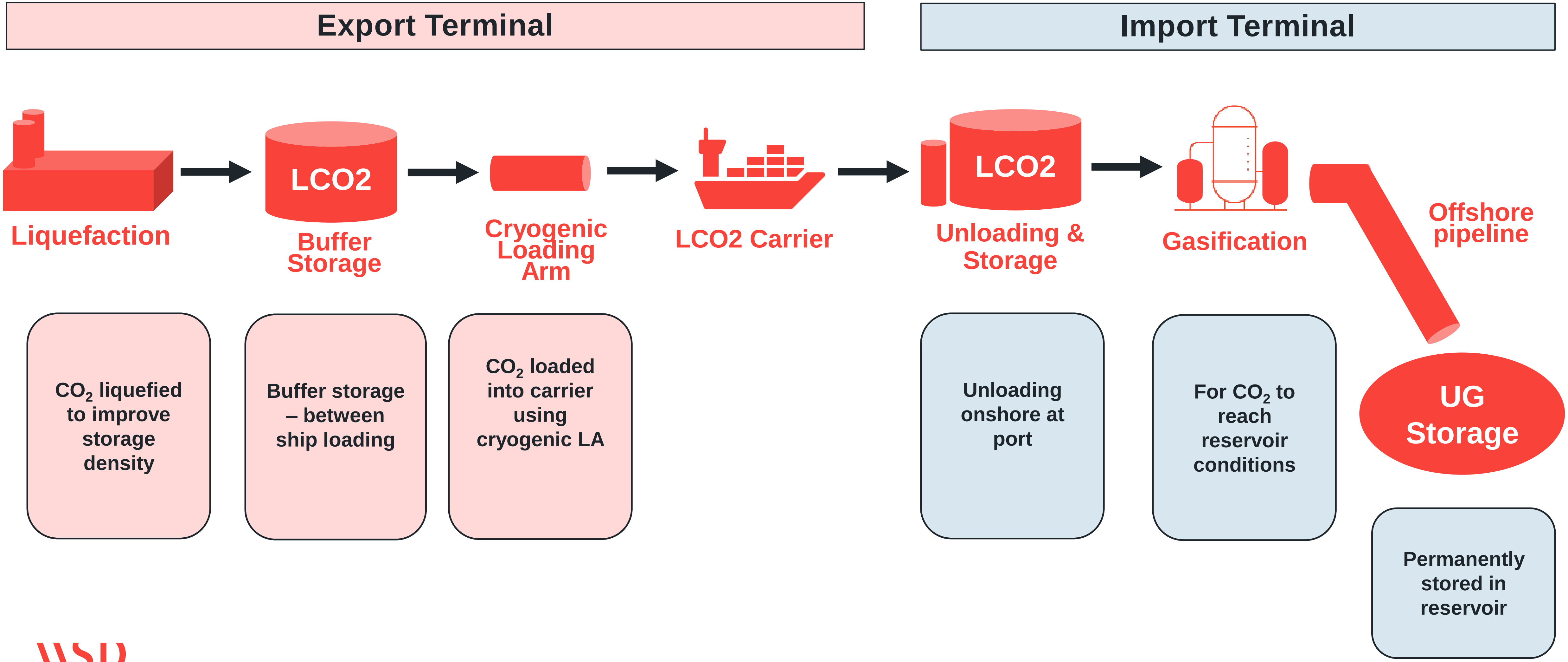
A) Delivered to onshore facility with CO_2 pipeline out to offshore storage site (well understood)

B) Direct offshore injection in CO_2 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)

TYPICAL CO_2 SHIPPING SUPPLY CHAIN



CROSS-BORDER CO2 TRANSPORT NETWORKS

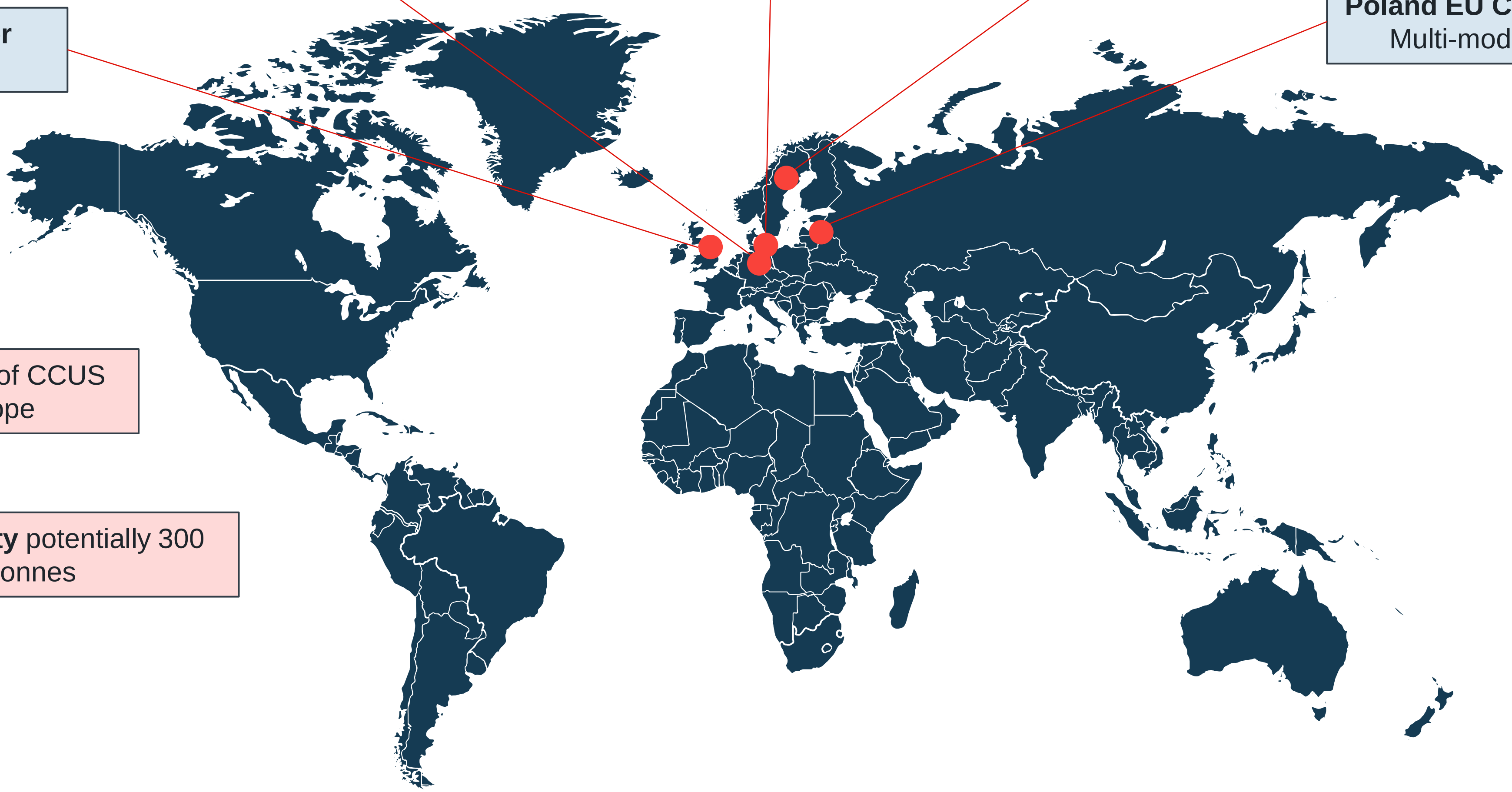
Dartagnan
Multi-Model Hub – Dunkirk

Porthos & ARAMIS
Rotterdam, Antwerp, North Sea

Northern Lights
(Most developed) - Norway

Poland EU CCS Interconnector
Multi-modal Hub – Poland

East Coast Cluster
UK



North Sea at the centre of CCUS deployment in Europe

Storage capacity potentially 300 Giga-tonnes

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 faciliating 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

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SPARE SLIDES

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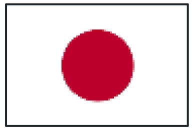
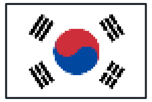
GLOBAL PICTURE: HYDROGEN

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

Net Importers

	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

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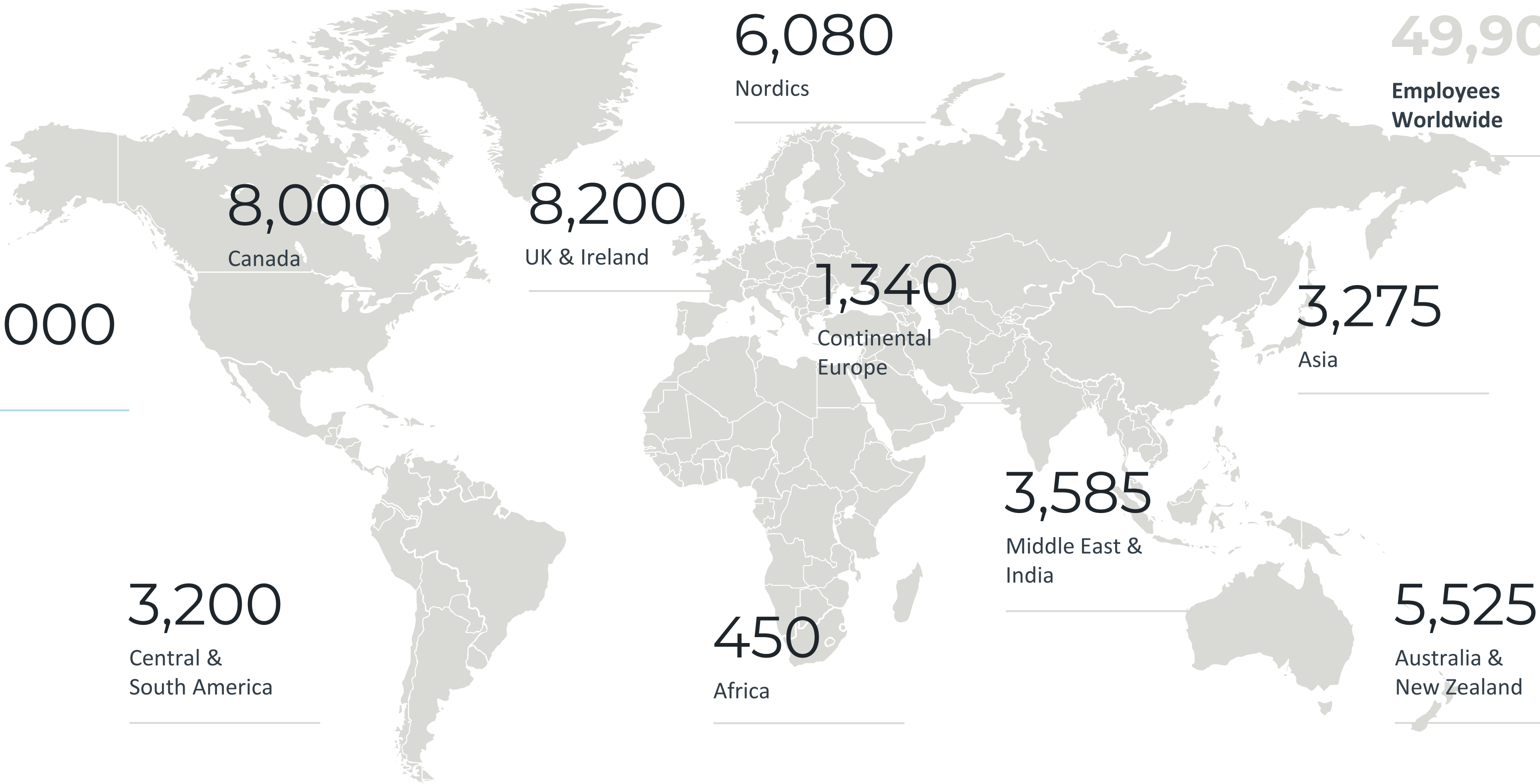

IMPACTS AT PORTS

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**