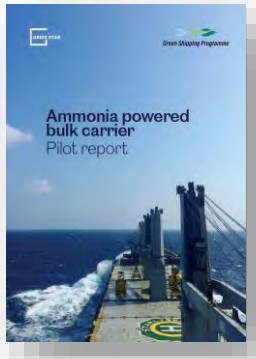
Ammonia powered bulk carrier

Ambition: To realize the first ocean going open hatch/bulk carrier to be powered by green ammonia – retrofit.

Joint project. ZESM has been invited in as partner.

Presentation of findings for ZESM ExCo May 11th
Trond Moengen,
ZESM Secretariat / Research Council of Norway



Leg 1: 4700Nm

Leg 3: 4915Nm

Leg 2: 4810Nm

Key question in the pre-study:
Is it sustainable to retrofit a ten-year-old ship to operate on green ammonia in a transatlantic trade right now? Is it technically feasible or financially sound? What do we need to make it sustainable?

Atle Sommer,
Managing Director,
Grieg Star

The pilot fits in perfectly with the ZESM ambitions, way of working - and action plan

Pillar	ID	Action	Fuel(s)	2022–2024	2024–2027	2027–2030
Pillar 1: Ships	2	Share knowledge from test pilot and demonstration projects (both new builds and retrofits)	● ● ● ●	✓	✓	

Ammonia powered bulk carrier pilot

● Ammonia ● Biofuels ● Hydrogen ● Methanol

S = Supporting stakeholders

Pillar	ID	Action	Fuel(s)	Timescale 2022–2024	Timescale 2024–2027	Timescale 2027–2030	Supporting Stakeholders: Maritime industry R&D	Government/ Regulators	Ship owners/ operators	Ports	Fuel producers & providers	Knowledge community
Cross pillar	1	Create a framework for knowledge sharing between zero-emission fuel vessel stakeholders with a Mission focus on 2030	● ● ● ●	✓			S	S				S
Pillar 1: Ships	2	Share knowledge from test pilot and demonstration projects (both new builds and retrofits)	● ● ● ●	✓	✓		S		S			S
	3	Share knowledge on information and best practices between ships owners, operators, and fuel suppliers	● ● ● ●	✓	✓	✓			S		S	
	4	Bring together relevant international players in order to accelerate demonstration and deployment of zero-emission fuel vessels and new ship technologies in green corridors, with a particular focus on obtaining experience in global supply chains	● ● ● ●	✓	✓	✓	S	S	S	S	S	S
	5	Showcase the possible support funds available for zero-emission fuel ship design from national, regional and global actors	● ● ● ●	✓	✓			S				S
Pillar 2: Fuels	6	Collect and share knowledge on performance of engines using methanol, ammonia, hydrogen, and advanced biofuels	● ● ● ●	✓	✓		S		S			S
	7	Develop and agree a methodology and framework for analyzing the impact of green shipping corridors	● ● ● ●	✓	✓			S	S	S	S	S
	8	Commercial testing and analysis to find the place on the value chain where there is willingness to pay extra for the use of renewable energy and green fuels, and where the willingness to pay is lowest	● ● ● ●	✓	✓			S	S	S	S	S
	9	Analyze the current and forecasted fuel demand at different ports to understand quantities needed for production scaling	● ● ● ●	✓	✓				S	S	S	S
	10	Develop and agree a methodology for performing well-to-wake life cycle analysis of marine fuels	● ● ● ●	✓							S	S
Pillar 3: Fueling infrastructure	11	Research and share barriers to community acceptance of ammonia, e.g. due to safety concerns	●		✓			S	S	S	S	S
	12	Develop global refueling plan and progress tracker covering key ports, including an overview of existing and planned infrastructure, refueling needs/demand, fuel capacity and availability, port development etc.	● ● ● ●	✓				S	S	S	S	S
	13	Identify ports and groups of ports for green corridor development	● ● ● ●	✓	✓			S	S	S	S	S
	14	Identify near term levers and policies to unlock fueling infrastructure investment	● ● ● ●	✓				S	S	S	S	S
	15	Create new business models and commercial strategies for zero-emission fuels	● ● ● ●	✓	✓			S	S	S	S	S
	16	Identify and track demand drivers for future fuels	● ● ● ●			✓		S	S	S	S	S
	17	Map existing refueling networks and demand for selected ports, including port support vehicles e.g. Container Handling Equipment	● ● ● ●	✓					S	S	S	S
	18	Identify opportunities to co-locate ammonia production and refueling infrastructure with other uses, e.g. cracking for power generation	●	✓						S	S	S

Main conclusion from pilot study – summarized

1 High retrofit investment costs

2 Lack of availability of competitively priced green ammonia

3 Unclear effects of regulatory frameworks

> The main barrier today is the combination of high retrofit investment costs, lack of availability of competitively priced green ammonia and unclear effects of regulatory frameworks.

1 High retrofit investment costs

Estimated costs and Financial implications

- USD 22M retrofit cost (not including off-hire)
- OPEX increase approx. USD 200 000 (USD 550/day)
  - Maintenance
  - Specialised service engineers
  - Dry-doc cost for the main engine (spread out over the dry-dock period)
- In audition, sligtly reduced cargo intake

Capex elements	Million USD
Main engine	10
Fuel supply system	6
Storage tank	4
Shipyard work	2
Total estimated retrofit cost	**22**

35 MUSD

FINANCE AND ESG:

Retrofitting a vessel to run on green ammonia represents a significant investment, in the evaluated case >50% of the vessel's fair market value. Such an investment will depend on a stable regulatory framework supporting long-term functioning market mechanisms and continuous green ammonia availability to be viable.

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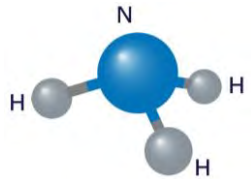
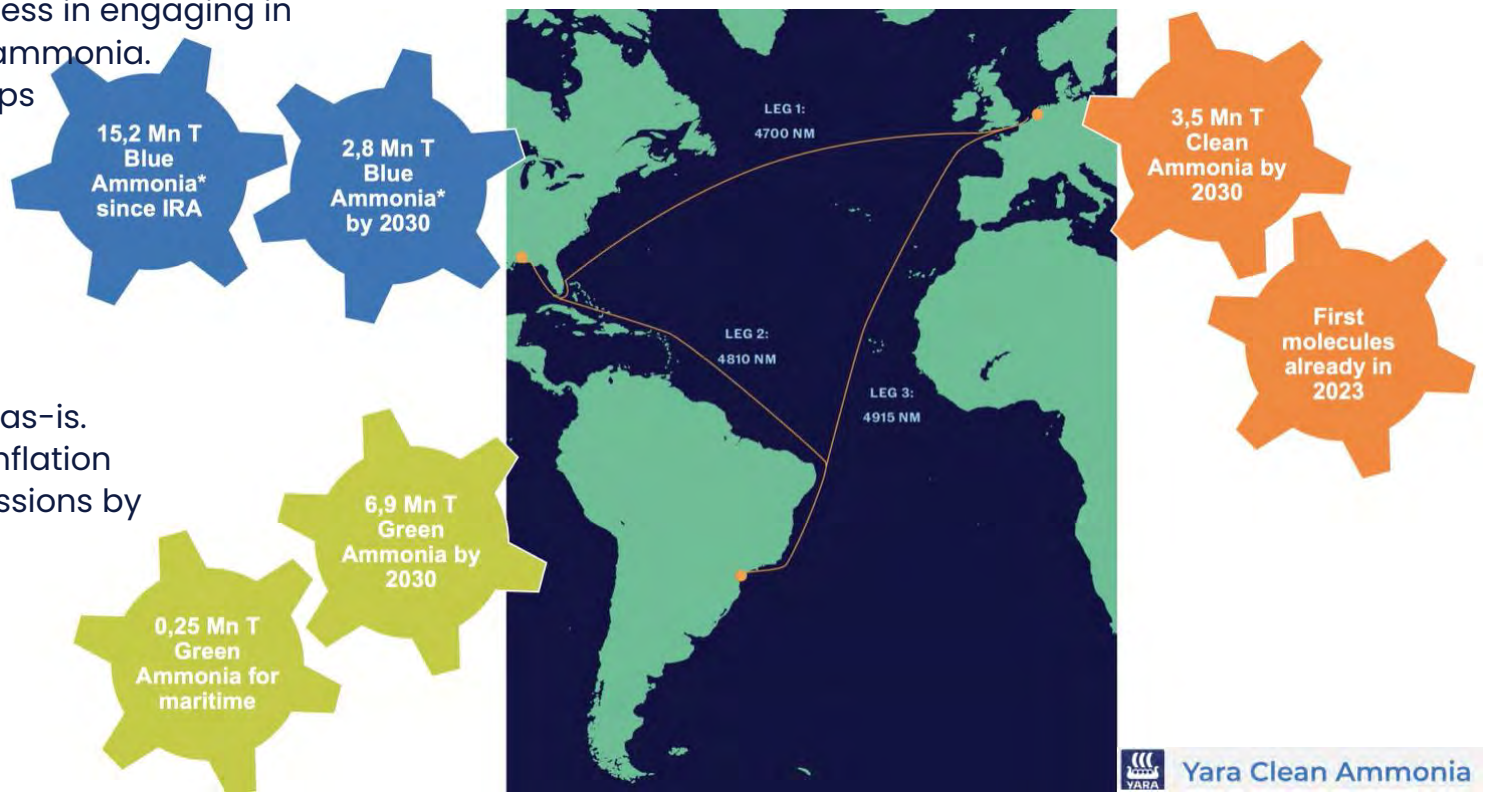
2 Lack of availability of competitively priced green ammonia



The outcome of the interviews shows a range in port-readiness levels across the continents.

- **European** ports
  - achieve the highest score on the port readiness level, compared to Brazilian and American ports.
  - They show a clear focus on sustainability, and concrete goals on how they are working towards limiting their CO2 emission.
  - Though none of the ports have indicated ammonia volumes,
- **Brazilian** ports
  - score medium in terms of port readiness level.
  - not as active as European ports but show an eagerness in engaging in projects and initiatives within green hydrogen and ammonia.
  - Some of the Brazilian ports have formed partner-ships with European ports,
- **American** ports
  - score lowest on port-readiness level.
  - The ports have included sustainability in their strategy, but target this in different ways.
  - Some ports have begun preparing for a green transition, while others are still focusing on business as-is.
  - This will, however, most likely change now with the Inflation Reduction Act of 2022, aiming to reduce carbon emissions by
  - 40% within 2030 by providing subsidies to the green
  - hydrogen production.



2 Lack of availability of competitively priced green ammonia

The team have interviewed several 11 ports in Europe, USA, and Brazil focusing on strategies, plans - and supply today

Europe

Port of Rotterdam

Port of Hamburg

Port of Antwerp-Bruges

Port of Brake

Strategy & Targets

- Support use of renewable energy to maintain and expand the ports and strives to use energy-saving and lower-emission alternatives
- Aim to reduce emission by 25% within 2025 compared to levels of emission in 2017
- Actions to reach goal by improving the energy efficiency and promoting renewable energy, i.e., by using alternative fuels
- Sustainability strategy to cover 4 areas with long-term goals
- Green hydrogen network planned

Facts

- Multifunctional specialty port with a leading position for agricultural products and cellulose
- 2 100 ship calls/year
- 6.2 million MT Breakbulk, grain, lumber, iron
- Rail connection to Europe
- Hydrogen strategy in port but initially for land-based installations. No ammonia volumes indicated

Projects & Initiatives

- DUAL ports; Developing Low carbon Utilities, Abilities and potential of regional entrepreneurial Ports, an initiative to decarbonize ports and reduce environmental footprint. Current efforts include LED lighting, sediment treatment and appointing Green Port Officers.
- WASh2Emden; Northern Germany has, at times, surplus energy from wind turbines. This cannot be stored in sufficient quantities, which causes turbines to be turned off the grid. This initiative examines opportunities for turning the electricity into green hydrogen for utilization in the port
- Identifying possibilities for distribution and storage of hydrogen
- Memorandum of understanding (MOU) signed with Bellerdune Port Authority (Canada) to collaborate on energy and manufacturing sectors, with a particular focus on production, shipment and storage of cleaner fuels – green ammonia, hydrogen, biomass and natural gas.

Brazil

Port of Pecém

Port of Itaqui

Port of Santos

Porto of Açu

Strategy & Targets

- Aim to make Açu a platform of sustainable business development focusing on the low carbon economy, in which sustainable fuels are included
- Monitors GHG emissions with the objective to know and quantify their profile of emissions and direct actions of mitigation
- Have begun development of a decarbonization plan to define emission reduction targets for their operations
- Established guidelines to ensure focus of sustainability in their activities
- Environmental Ship Index Associate & winner of the World Ports Sustainability Award
- Interested in joining the GSP feasibility study

Facts

- 3rd largest in iron ore terminal & 2nd cargo handling. Largest offshore support base in the world
- 2.4 GW of renewable energy in the pipeline, 30% of Brazilian oil export and largest thermal power complex in Latin America
- 28.9 mill. tonnes/year solid and liquid bulk, general cargo, iron ore and oil
- Infrastructure and multipurpose terminals in place. Largest offshore supply base
- Ammonia/hydrogen strategy, but no ammonia volumes in port indicated

Projects & Initiatives

- The port is studying the financial feasibility of producing green hydrogen and production of green ammonia from hydrogen (200,000t of ammonia/year in the initial phases of implementation in 2026-2027)
- Port of Antwerp have a partnership with Port of Açu fostering the Brazilian market trade of more than 7.4mill. tonnes in cargo between Brazil and the Port of Antwerp
- Porto do Açu has engaged with several clients interested in developing green hydrogen for local green ammonia production
- Gás Natural Açu (GNA) and the port will invest 1 billion EUR in developing energy infrastructure at the port
- Shell have signed a MoU with the port to develop a 10MW green hydrogen generation pilot plant in 2025, with potential to reach 100 MW
- Fortescue Future Industries Pty Ltd and the port have signed a MoU to perform a s study for installing a green hydrogen plant of 300 MW, potentially reaching 250 000 MT green ammonia/year
- VAST, a company from Prumo's group responsible for crude oil double banking operations, is developing a liquid terminal and has ammonia fuel as part of the future developments planned. VAST will also be responsible for the licensing process for ammonia operation.

USA

Port of Mobile

Port of Savannah

Port of Houston

Strategy & Targets

- Goal to become carbon neutral by 2050
- Developed a 5-year strategic plan, which included implementing an innovative environmental leadership strategy and support sustainable growth among others
- 72 ongoing activities related to environment, social, safety, and governance, and 27 new initiatives
- They are in business to develop alternative fuels, both for inland consumption and for maritime end-users
- Aim to grow their storage capacity for green ammonia but the total amount of storage is not yet known

Facts

- Largest Gulf Coast container port, 7th ranked U.S. container port by total TEUs
- Largest petrochemical complex in the nation and 2nd largest in the world
- 10 000 vessels & 200 000 barges transits annually
- 44.5 million tonnes in 2021
- Ample truck, rail and air connections. No bunkering of ammonia, but could pivot quickly
- Hydrogen strategy, whereas grey ammonia availability **of 30k MT**

Projects & Initiatives

- Sustainability partnerships, alternative fuels such as H2, development of future terminal, and implementing green shipping corridors are part of the ports action plan towards reaching carbon neutrality by 2050
- Initiatives included in the action plan include supporting industry partners to facilitate alternative fuel bunkering and infrastructure, such as LPG/LNG, Ammonia, Methanol, and Hydrogen
- The first greenfield terminal development in the port, a waterborne ammonia terminal, is now fully operational
- Conducting a feasibility study where they will investigate scaling challenges of hydrogen production, review policy and regulations, identify potential hydrogen users, evaluate resources and infrastructure, and help create a strategic plan for policymakers

3 Unclear effects of regulatory frameworks

We have a significant **chicken-and-egg** challenge:

Green ammonia production is **awaiting visibility on offtake volumes** from shipping.

Simultaneously the **shipping industry depends on known availability** to facilitate the required modification. External funding mechanisms are crucial to create momentum for deepsea application of green ammonia.

"Retrofitting a vessel to run on green ammonia represents a significant investment, in the evaluated case >50% of the vessel's fair market value. Such an investment will depend on a stable regulatory framework supporting long-term functioning market mechanisms and continuous green ammonia availability to be viable"

How to use the results in further ZESM work?

First follow up:

At the request of Grieg and the partners in the pilot, ZESM organized the 19th of April a workshop looking into on of the barriers identifies in the pilot study: The challenges on the availability of ammonia in US ports

The aim of the workshop:

- To improve the understanding of what it takes to realize ammonia as fuel in shipping and bring the Grieg Pilot one step closer to realization;
- to understand the US drivers that affect port strategies;
- to understand the effects of US local and national regulatory shipping emission reductions; and
- to map any US parallels to EU ETS

Results:

- Successful workshop
- 28 participants, mostly from relevant US authorities and stakeholders

Program

GMT+2	ET		
1600 – 1620	**10:00 – 10:20**	**Part 1 - Introduction – setting the scene**	
5 min		Welcome and introduction	*Trond Moengen*, ZESM
10 min		Main results and conclusions from the pilot – focusing on availability of ammonia	*Torleif Frimannslund*, VP Technology and Decarbonization, Grieg Star
5 min		Questions and comments	All
1620 - 1700	**10:20 – 11:00**	**Part 2 – Ammonia as maritime fuel – US perspectives**	
10 min		Ammonia as maritime fuel – Overall US policies, barriers and possibilities	Joshua Messner Technology Manager, US Department of Energy
15 min		Port of Savannah – Plans for ammonia ship-to-ship bunkering	Taiki Iijima, Sumitomo Corporation of America
15 min		Discussion, comments and reflections	All
1700 - 1730	**11:00 – 11:30**	**Part 3 – Ammonia as maritime fuel – European perspectives**	
15 min		Examples from ongoing pilot project: Ammonia bunkering in Florø	*Andre Risholm, CEO* Azane Fuel Solutions
5 min		Ammonia as maritime fuel – considerations from regulatory authorities	*Celin Tonheim, Chief Engineer* NDCP - Norwegian Directorate for Civil Protection
10 min		Discussion – learnings	All
1730 - 1800	**11:30 - 12:00**	**Part 4 – The way forward – recommendations**	
10 min		US regulations developing – how to align and learn by cooperation	Discussions – all
10 min		Improving ammonia availability in the Gulf – How should the Grieg project proceed?	Discussions – all
5 min		Closing	*Trond Moengen*, ZESM

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Roadmap and Action plan

● Ammonia ● Biofuels ● Hydrogen ● Methanol

S = Supporting stakeholders

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