BOWE2H Baltic Offshore Wind Energy to Hydrogen

Interreg Baltic Sea Region

Co-funded by the European Union

IKEM

Non-profit think tank

Mission: Work towards and accelerate the global energy transition

IKEM‘s departments

- Energy law
- Mobility
- Research Academy
- Climate & Innovation

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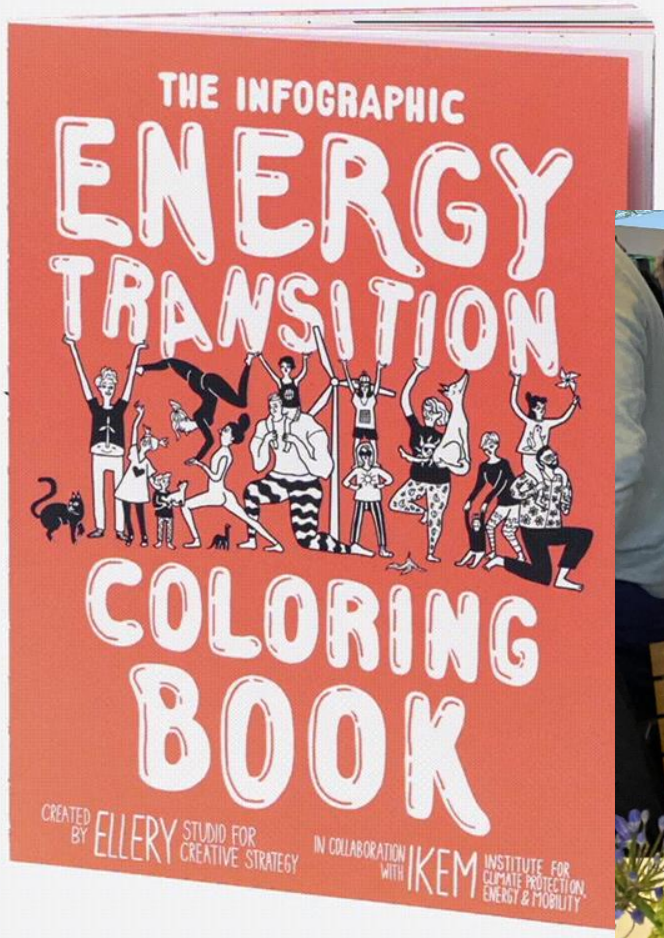

THE INFOGRAPHIC
ENERGY TRANSITION
COLORING BOOK
CREATED BY ELLERY STUDIO FOR CREATIVE STRATEGY
IN COLLABORATION WITH IKEM INSTITUTE FOR CLIMATE PROTECTION, ENERGY & MOBILITY


THE INFOGRAPHIC
ENERGY TRANSITION
COLORING BOOK


Gender Equality:
ALL ABOARD!
EQT THE GENDER EQUALITY HANDBOOK
EQT
THE GENDER EQUALITY TOOLKIT
For working women and friends
A playful peer-to-peer learning experience
EQT arms you with the tools you need to call out gender bias and make this world a little more fair – and a lot more fun – for everyone!
WITH A CARD GAME, HANDBOOK AND POSTER
EQT
Gender Equality Toolkit
for Working Women and Friends
Women making waves:
A HISTORY OF FEMALE EMPOWERMENT
HERE TO SERVE
CLAP BACK
CLAP
CLAP
BOXED OUT
MEVSPLAINER
A WHOLE LATTE BS
facts
facts
MIC DROP

GREEN AMMONIA: A NEW SUSTAINABLE FUEL SETS SAIL

STATUS QUO

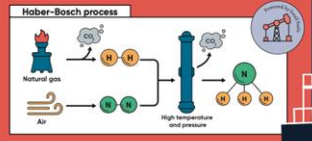
WHAT'S ALL THIS AMMONIA MANIA?

The search for green energy has never been more urgent. And while we are all getting used to hydrogen popping up in policy targets and news headlines, ammonia is the apparent new kid on the block. In reality, ammonia has been around for over a century, just not as fuel – almost 90% of ammonia today is used as fertiliser, the rest for cleaning and chemical processes. But could **green ammonia be the sustainable fuel of the future?**

88% OF AMMONIA TODAY IS USED AS FERTILISER

MEET THE MOLECULE

Ammonia, chemical formula NH_3, is a simple molecule built from one nitrogen atom and three hydrogen atoms. Liquid ammonia is therefore an excellent source of hydrogen, containing **50% more hydrogen by volume than pure liquid hydrogen** (a molecule of hydrogen has just two hydrogen atoms). Ammonia is normally produced through the Haber-Bosch process, which is energy intensive and currently powered by fossil fuels, thus contributing significantly to global greenhouse gas emissions.

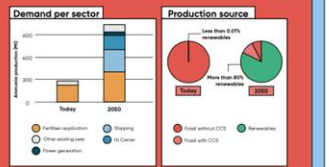


A RISING TIDE FOR GREEN AMMONIA

About **183 million tonnes** of ammonia are produced in the world every year, and annual **demand is set to rise to 688 million tonnes by 2050.** This increase in demand is mainly due to a whole new market opening up: the energy sector! Clean energy is in high demand, and especially hard-to-decarbonise sectors such as heavy transport and shipping are in dire need of sustainable fuel alternatives, like green ammonia. Green ammonia is produced with renewables, meaning the Haber-Bosch process is powered by wind or solar energy, instead of fossil fuels. And that is the plan: **By 2050, 80% of ammonia is projected to be produced with renewable energy – up from just 0.01% today!**

183 million tonnes of liquid ammonia could fill more than **100,000** OLYMPIC SWIMMING POOLS (66 million tonnes of ammonia is almost four times as much)!

PROJECTED DEMAND AND PRODUCTION OF AMMONIA BY 2050



FUEL COMPARISON

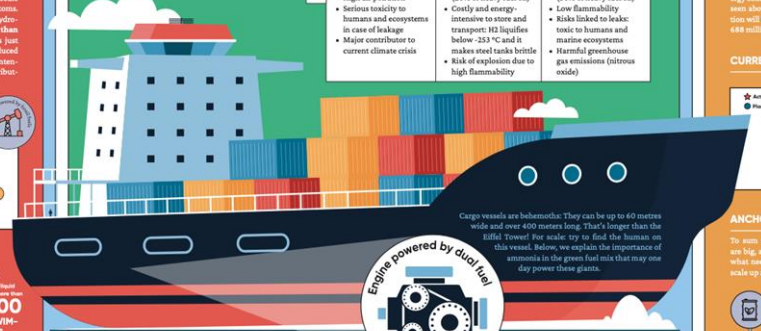
FOSSIL FUELS? TIME TO ABANDON SHIP

The shipping industry accounts for three per cent of global greenhouse gas emissions. It is largely powered by heavy fuel oils (HFO), the world's dirtiest, most polluting fuel. A green alternative is urgently needed: a fuel with high energy density and low emissions. The main options currently on the table are hydrogen and ammonia – both can be produced with renewable energy and offer up to ten times the energy density of a lithium-ion battery. Each of these fuels has its pros and cons, as shown in this table.

	HEAVY FUEL OIL	HYDROGEN	AMMONIA
Pros	• Very high energy density • Easy to handle and transport (liquid at room temperature and atmospheric pressure) • Excellent combustion properties	• Can be produced with renewables • Releases no GHG emissions when used • Very little toxicity in case of leaks • Excellent combustion properties	• Can be produced with renewables • Reasonable energy density (50% higher than liquid hydrogen) • Liquifies below -33 °C
Cons	• High GHG emissions • High air pollution • Serious toxicity to humans and ecosystems in case of leakage • Major contributor to current climate crisis	• Very low energy density (20% of heavy fuel oil) • Costly and energy-intensive to store and transport: H2 liquifies below -253 °C and it makes steel tanks brittle • Risk of explosion due to high flammability	• Low energy density (30% of heavy fuel oil) • Low flammability • Risks linked to leaks: toxic to humans and marine ecosystems • Harmful greenhouse gas emissions (nitrous oxide)

94% GHG emission reduction compared to HFO

29x cheaper to store ammonia than hydrogen



Cargo vessels are behemoths: They can be up to 60 metres wide and over 400 meters long. That's longer than the Eiffel Tower! For scale: try to find the human on this vessel. Below, we explain the importance of ammonia in the green fuel mix that may one day power these giants.

FUEL UTILISATION

DUAL FUEL: THE BEST OF BOTH WORLDS

We've seen that both ammonia and hydrogen have their own drawbacks that can make them challenging to use. A dual-fuel engine could be the answer, using a fuel mix that combines the high energy density of ammonia with the easy combustion of hydrogen. Ammonia is mixed with a small amount of hydrogen, which is produced on site by converting (or 'cracking') part of the ammonia into pure hydrogen. This dual fuel is burnt in the combustion engine and voilà! Propulsion!

Pros
- Hydrogen enables easy combustion
- The hydrogen can be cracked from ammonia on site
- Faster and more complete combustion already at 5% hydrogen by weight added
- Even less emissions than from pure ammonia combustion
- Existing maritime internal combustion engines can be retrofitted to be dual fuel compatible

Cons
- Additional conversion step needed to produce pure hydrogen for addition to the fuel
- Mitigating measures needed to eliminate remaining emissions

WHAT ABOUT FUEL CELLS?

Fuel cells use pure ammonia or hydrogen at higher energy efficiencies than internal combustion engines (ICE). This technology is still in early development stage for shipping applications.

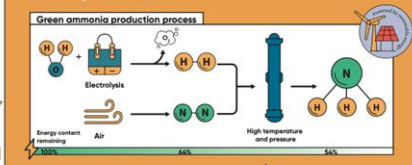
KEELING OVER EMISSIONS

Green ammonia is CO_2 free, but still causes some emissions, and leakages could happen. These can be mitigated with the right precautions. The possible emissions are:
- Nitrous oxide (N_2O) is a potent greenhouse gas, with 300 times the atmospheric warming capacity of carbon dioxide! Mixing ammonia with hydrogen and optimising the combustion process cuts down these harmful emissions.
- Nitrogen oxides (NO_x) affect the ozone layer and cause smog. They can be filtered out at the exhaust and neutralised.
- Ammonia itself is dangerous if it leaks into the environment. This can be prevented with careful storage construction, like double tank walls.

FUTURE CHALLENGES

ALL ABOARD FOR GREEN AMMONIA!

Ammonia boasts many benefits! It produces no carbon dioxide emissions, can be produced with renewable electricity, can be used in fuel cells and combustion engines, has a higher energy density than batteries or hydrogen, and existing infrastructure can process and transport it.
So, how do we get more of the stuff?



MORE RENEWABLES, PLEASE!

Producing more green ammonia will require more green power – a lot more, given that a great deal of energy content gets lost in the conversion process, as we've seen above. How much more renewable power production will be needed for our green ammonia ambitions of 688 million tonnes per year?

To power the production of 2050 goal of 566 million tonnes of green ammonia, we'd need **A SOLAR FARM ALMOST TWICE THE SURFACE OF BELGIUM!**

CURRENT AND PLANNED GREEN AMMONIA PLANTS

Right now, there is only one green ammonia production plant in the world, located in Cusco, Peru. There are more green ammonia plants in the pipeline, but the combined production capacity only adds up to 71 million tonnes per year. More investment and concrete plans are needed to bring this green fuel to the forefront!

ANCHOR AWEIGH!

To sum up, the benefits of green ammonia are big, and the (climate) stakes are high. So, what needs to happen for green ammonia to scale up and the market to take off?

POLICY
We need a political commitment to green ammonia, accompanied with clear targets and supporting regulatory mechanisms such as green certification and incentives to create a stable investment climate.

TECHNOLOGY & INFRASTRUCTURE
From ports to bunkering stations, infrastructure for the production, transport and storage of ammonia must be increased and adapted for its deployment as a fuel.

RENEWABLE ENERGY
Renewables will need to expand greatly to produce enough green ammonia. This means boosting domestic renewable capacity, and building international partnerships!

INTERNATIONAL COLLABORATION
We need a common international standard to enable a global green ammonia market. The International Maritime Organisation, already set to approve ammonia as a shipping fuel in 2023, is well placed to lead this process.

EMPLOYMENT
The socio-economic benefits of green fuels are enormous: 30 million jobs will be created in the broader hydrogen market by 2050! R&D, innovation and training are key to tap into these benefits.

COSTS AND CARBON PRICING
To accelerate investments in green ammonia, there must be a level playing field: let's start with phasing out fossil fuel subsidies and introducing an effective carbon price!

CATCH THE WAVE!

Ammonia – in the form of fertiliser – already helps feed the world today. Soon, it will have another essential task: to counter climate change as a sustainable fuel. Renewable ammonia is not the only green alternative to fossil fuels, but it is one of the most promising approaches to powering the climate-neutral economy of tomorrow. We must act now: at current levels of emissions, we have until 2030 before the Paris Agreement goals become impossible to achieve. Green ammonia may not be a silver bullet – but it's certainly a shot worth taking.

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Credits: Lead researcher – Mareike Knoll | Creative direction – Odilia Stabost | Concept – Anika Nicolaus Ponder | Design and illustrations – Odilia Stabost, Anna-Louisa Dogley, Julie Hertal | Copy-writing – Dimir Bellzheus Avdić | Funcraft – Kate Miller

Sources: Status Quo: Hatfield, 2020; Seo et al., 2021; Aziz et al., 2020; Robert, 2018; Rouwenhorst et al., 2022; NCBI, 2022. Fuel comparison and utilisation: Faber et al., 2020; McKee et al., 2014; Valera-Medina et al., 2018; Comer, 2019; Campos et al., 2021; DeCicio et al., 2018; Dincer, 2012; Cinelvi et al., 2012; Aziz et al., 2020; Lindstad et al., 2021; Kim et al., 2015; Bartlow, 2012; Stockstad et al., 2022; Ravishankara et al., 2009; Galluccl, 2021; Future challenges: Hasik et al., 2020; Rouwenhorst et al., 2022; Zincir, 2022; Salmon et al., 2021; Nayak-Luke et al., 2020; Hydrogen Taskforce, 2020; Bartels, 2008.
Assumptions: Olympic swimming pool size: L 50m, W 25m, D 2m, liquid NH3: 0.68 kg/L. Renewable ammonia production: 10 MWh per tonne. 980 MWh/ha per year: average yield for solar field in Germany. Storage comparison over a six-month period.

CAMPFIRE

Our green ammonia infographic explainer poster

Federal Ministry of Education and Research

Towards 2050!

The EU has been at the forefront of climate policy, pledging to reduce emissions by 80%-95% by 2050. At least 15% interconnection among national electricity markets and 50% energy from renewable sources by 2030 are the major targets pursued by the EU's Energy Union. By fostering the integration of electricity markets and encouraging further deployment of renewable offshore wind energy, a meshed grid has a central role to play on the way to tomorrow's sustainable energy system!

About

The Baltic InteGrid project investigated the possibility to establish a meshed offshore grid in the Baltic Sea - an ingenious way to connect offshore wind farms and electricity markets. Extensive interdisciplinary research has shown that a meshed grid would provide substantial socio-economic benefits to the region, and could be a key component in an integrated, sustainable energy system for 2050. The Baltic InteGrid was funded by the European Union and Interreg Baltic Sea Region. All research results are available on www.baltic-integrid.eu.

1 - Policy and regulation

A meshed grid would offer considerable socio-economic benefits to the Baltic Sea Region. It would, however, be contingent on regulatory drivers to reduce complexity and set incentives for developers. For starters:

- National policy makers should set offshore wind energy targets (and update them regularly!) as well as simple permitting procedures with one-stop-shops to create a stable environment that welcomes offshore wind investors.
- The encouragement of public participation at all planning stages could boost acceptance and bring value to communities!
- Offshore wind energy expansion can benefit from the 'super-shallow approach', which keeps the cost of grid connection with the TSOs rather than wind farm developers, reducing the latter's risk and costs.
- The complexity of multilateral offshore grid projects must be reduced. To this end, EU policy makers could develop a transparent CBCA methodology to distribute costs between the TSOs involved.
- EU policy makers can decrease transaction costs for investors by developing a regulatory framework for meshed grids. An alternative to such an EU-wide approach is for the EU to offer targeted assistance, financial or expertise-based, to specific regions or projects.
- EU policy makers should provide legal definitions for the components of a meshed offshore grid and set rules for its operation.
- The development of a meshed offshore grid requires close cross-border cooperation. The EU could facilitate this by offering a roadstock and by encouraging national governments to form a supranational body that could operate a meshed offshore grid.

2 - Regional value

A meshed grid would offer regional added value and create new jobs in the service and maintenance market. Thanks to its great port infrastructure and skilled labour, the Baltic Sea Region could become a leader in the installation and maintenance of offshore wind farms and grid components!

3 - A wind of change!

Offshore wind energy is expected to develop rapidly and on a large scale in the Baltic Sea Region, growing from 2.1 GW of installed capacity in 2018 to a 9 GW by 2030 and up to 35 GW by 2050!

4 - Costs coming down!

The Baltic Sea Region has great offshore wind potential thanks to strong winds, shallow waters, short distances to shore and low tidal fluctuations. In fact, the levelised cost of energy in the south-western Baltic is forecast to be as low as 63 €/MWh by 2030!

5 - Planning for the future

Meshed offshore grids have a cross-border scope. For this reason, maritime spatial planning in the Baltic Sea requires trans-sectoral transnational cooperation. Moreover, the long-term needs of the region must be reflected in maritime spatial plans by considering the needs of strategic sectors, like energy and the environment.

6 - The march of technology

Offshore wind technology has experienced a rapid fall in costs over the past decade, with the first subsidy-free tender submitted in 2017. Cost decreases are also expected for HVDC technology as well as for floating foundations for offshore wind farms, meaning future farms can be built in greater water depths. Finally, optimising the layout of sea cables can allow for costs to be reduced even more!

7 - All hands on deck!

A meshed offshore grid would show the sea with many other users, some of which have been around for centuries. Natural protection zones, shipping lanes, military areas, cables, gas pipelines, fishing and tourism must all be included in stakeholder consultations at an early stage of development to avoid future conflicts and acceptance problems.

8 - Happy as a clam

The Baltic Sea is the youngest sea on our planet, and its brackish waters are home to a unique ecosystem of fish, seals, porpoises, crabs, mussels, benthos, birds and many more! The careful application of environmental assessments will ensure that a meshed offshore grid does not impact this rich marine life.

9 - Save some space

The Baltic Sea is a very densely used maritime space! A meshed grid offers a real benefit in this sense, by combining radial and interconnector cable infrastructure, it needs fewer transformer stations, landfall points and subsea cables, thereby taking up less space.

10 - Costs and benefits

Assuming a moderate to high expansion of offshore wind in the Baltic Sea in the coming decades, cost-benefit analyses have demonstrated that a meshed offshore grid will be the most efficient way to connect wind farms and countries. Financial savings, local job creation, increased system stability, increased market integration, lower electricity prices and a green energy supply ... a meshed grid has a lot to offer!

11 - Starting the BOG

The pre-feasibility studies of the Baltic Offshore Grid show that the development of a meshed grid will start in the South Baltic, where planned offshore wind development aligns well with interconnector needs. Considering the long lead times of offshore wind and grid infrastructure projects, the coordination process in the South should start as soon as possible, before business as usual developments lock the area into an inefficient grid infrastructure!

12 - Better together

The Baltic InteGrid built a strong stakeholder network, uniting hundreds of experts around the topic of offshore wind and meshed grids at workshops and conferences. This exchange must continue to keep the momentum and interest in the topic of meshed offshore grids! To that end, our conference platform, the Baltic Offshore Grid Forum, will go on beyond the project lifetime and bring regional stakeholders together for years to come.

Baltic InteGrid
Baltic Offshore Grid Forum
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
Interreg
Baltic Sea Region

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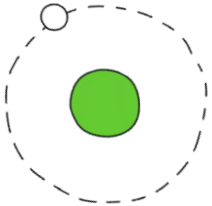
Project partners

1. IKEM - Institute for Climate protection, Energy and Mobility
2. Latvian Association for Local and Regional Governments
3. Polish Wind Energy Association
4. German Offshore Wind Energy Foundation
5. Energy Agency of Southern Sweden
6. Lithuanian Energy Agency

Mission

To foster a transnational green, integrated energy system in the Baltic Sea region, with offshore wind and green hydrogen at its core.



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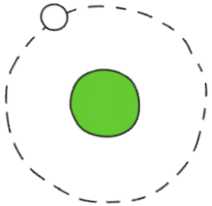

Infographic OWE & H_2 roadmap

Infographic report outlining policy, grid, and planning towards transnational OWE and green H_2 development (2024)

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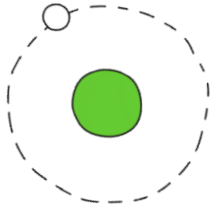

Infographic OWE & H_2 roadmap

Infographic report outlining policy, grid, and planning towards regional OWE and green H_2 development (2024)

Events & network

Four real-life and two online events to foster exchange and build a regional OWE and H2 network (ongoing)

BOWE2H Baltic Offshore Wind Energy to Hydrogen

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BOWE2H event timeline

Kick-off event (digital)

Overview of OWE and H2 in the BSR, national insights, BEMIP vision, policy, grid perspective, green H2 and green fuels.

BOWE2H Baltic Offshore Wind Energy to Hydrogen

Interreg Baltic Sea Region

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Infographic OWE & H2 roadmap

Meta-study (2023)

OWE and H_2 in the BSR, transnational developments

Infographic OWE & H2 roadmap

Meta-study (2023)

OWE and H_2 in the BSR, transnational developments

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STEP2

Interviews & **co-creative workshops** on challenges and solutions (2023/2024)

Infographic OWE & H2 roadmap

Meta-study (2023)

OWE and H_2 in the BSR, transnational developments

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Interviews & **co-creative workshops** on challenges and solutions (2023/2024)

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STEP 3

Infographic roadmap to regional OWE & H2 (2024)

Timeline

- **Metastudy:**

  April 2023
- **Events, workshops and interviews:**

  Ongoing til summer 2024
- **Infographic roadmap:**

  Summer 2024


Thank you!
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