



From wind and water to ammonia: Marine fuel and energy storage for a zero-emission future

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What is Ammonia?

- Compound of nitrogen and hydrogen (NH₃)
- Colourless gas with pungent smell
- Common in nature (e.g. nitrogenic waste of aquatic organisms)
- Important industrial product: Current global ammonia production is approx. 176 tons/year
- Used mainly as a fertilizer, but also in cleaning products (...)



Production pathways for Ammonia?

Brown/Grey Ammonia (current)

- Haber-Bosch-process: Involves catalytic reaction of hydrogen and nitrogen at high temperature and pressure
- Very energy intensive process, mainly because of the hydrogen, that is generated almost exclusively via steam reformation or fossil fuels

Blue Ammonia

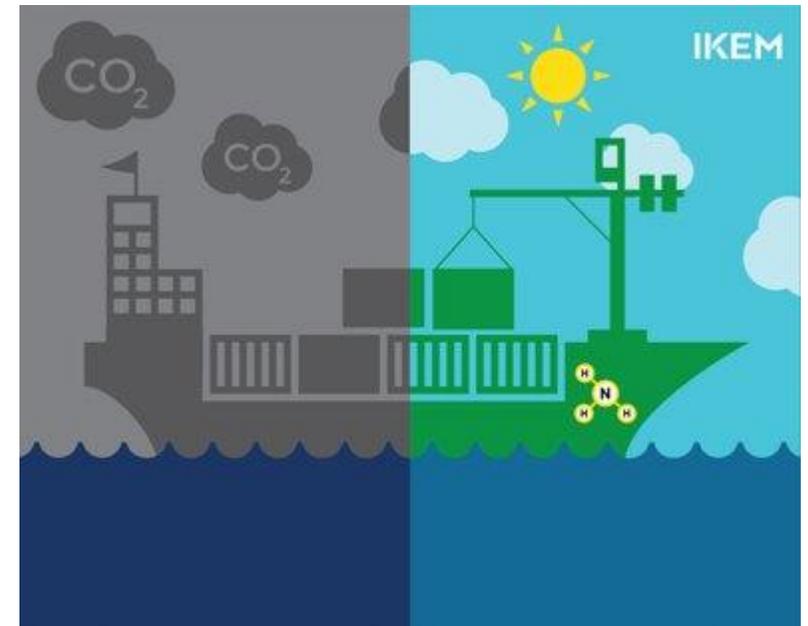
- Uses „blue“ hydrogen from steam methane reforming with carbon capture and storage (CCS)
- While up to 90% of carbon dioxide could be captured this way, upstream GHG emissions associated with natural gas extraction limit the reduction

Green Ammonia

- Haber-Bosch-Process is used powered by sustainable electricity (e.g. solar, wind)
- Hydrogen is produced through electrolysis
- Nitrogen is obtained directly from air using air separation
- Alternative to Haber-Bosch: electrolyser/fuel cell technology (is currently being developed)

Why Ammonia in Shipping?

- No carbon emissions when combusted
- Lower toxic emissions (SO₂, metals, polycyclic aromatic hydrocarbons)
- Can be used in engines and fuel cells
- Lower fire risk



Why Ammonia in Shipping instead of Hydrogen?



Relatively high energetic density as a liquid

- Possible to provide energy storage for ships for several weeks
- Liquid ammonia requires 46% less onboard storage compared to hydrogen

No requirement of cryogenic storage

- Both hydrogen and ammonia are stored in liquid form; While hydrogen requires cryogenic tanks maintained at $-253\text{ }^{\circ}\text{C}$, ammonia requires less cooling and can be stored at temperatures of around $-33\text{ }^{\circ}\text{C}$

Why Ammonia in Shipping instead of Hydrogen?



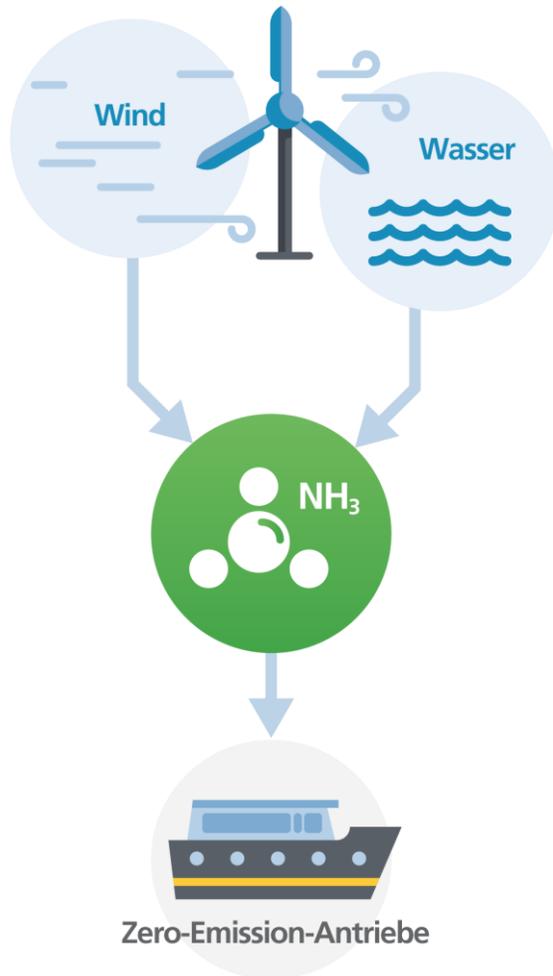
Existing global infrastructure

- Because of demand of the fertilizer industry, Ammonia is exported around the world and can be seen as a well understood, globally traded commodity which has been transported by international vessels for years
- An existing supply chain means existing expertise and to a certain degree, existing regulatory frameworks

Flexibility

- Can be used without complicated onboard processing in internal combustion engines and future fuel cells

Innovation Field Ammonia-based Energy Technologies



- Seasonal production of ammonia from **air and water**
- Decentralized production from **renewable energy**
- Utilisation in **zero-emission-drives** for maritime mobility
- Technical solutions for ammonia **logistic and infrastructure**

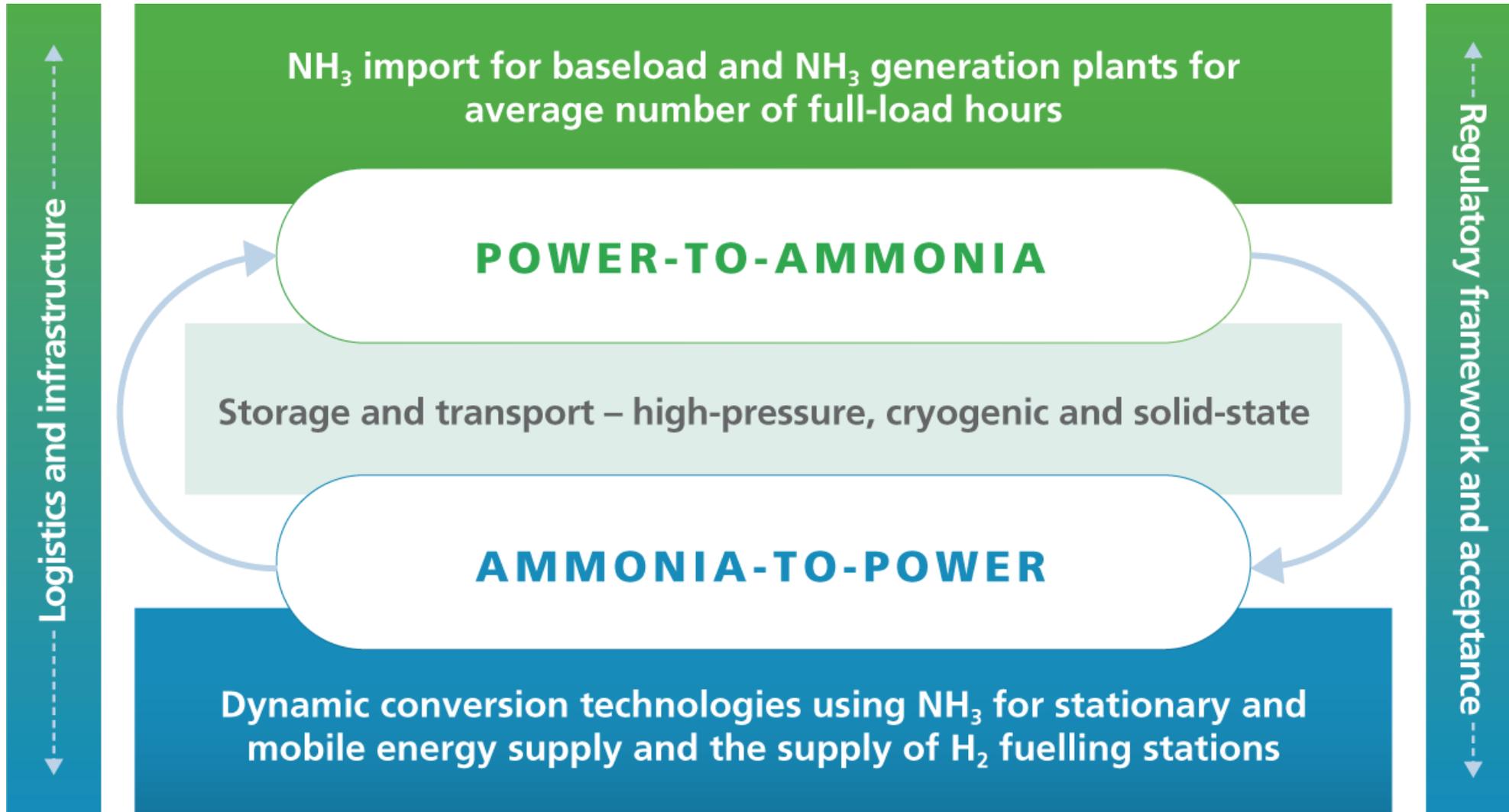
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2 Leitprojekt
TransHyDE

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Ammonia Eco System Development



Power-to-Ammonia

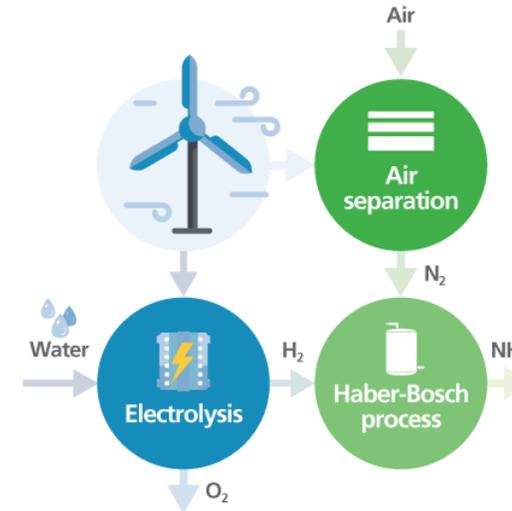


CAMPFIRE develops green ammonia plants for next generation:

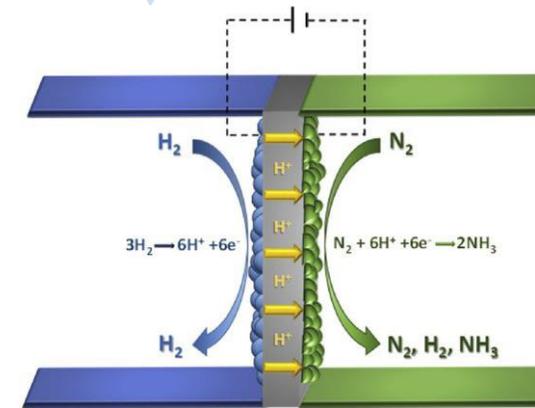
- advanced micro-Haber Bosch reactors and catalysts at reduced costs
- medium-load ammonia plants
- flexible and fast load changes
- seasonal and regional storage of renewable energy

CAMPFIRE develops Solid State Ammonia Synthesis (SSAS)

- efficient production at small scale and at long service life
- water steam can be used directly
- challenge: ammonia decomposition at $T > 450^{\circ}\text{C}$ process temperature must be reduced



Flow guidance element



Membran-Electrode-Assembly



SSAS Teststand

Ammonia-to-Power



CAMPFIRE develops green ammonia energy generation devices:
cracker, fuel cells and ICE engines and new power generation concepts
for:

- maritime propulsion systems
- stationary applications (CHP)
- construction machines

(also see HiPowAR www.hipowar.eu)



Green Cruising



Zero-emission inland vessel



Ammonia cracker for
back-conversion
to hydrogen



Oxygen permeation
membranes



ICE gas engine with for operation on ammonia & hydrogen



containerized engine power unit

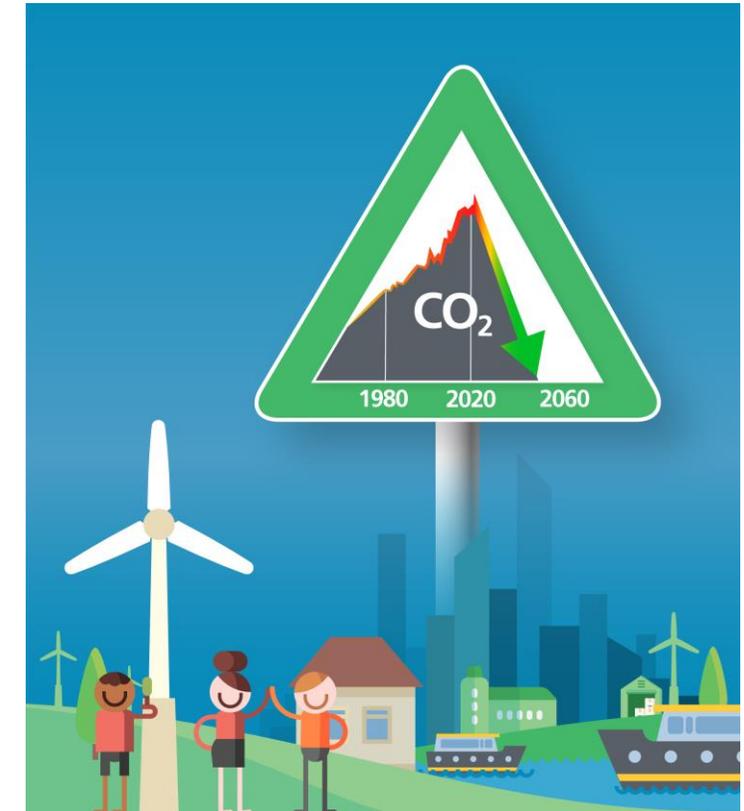


Our vision: Green Ammonia Technologies for the global hydrogen energy economy

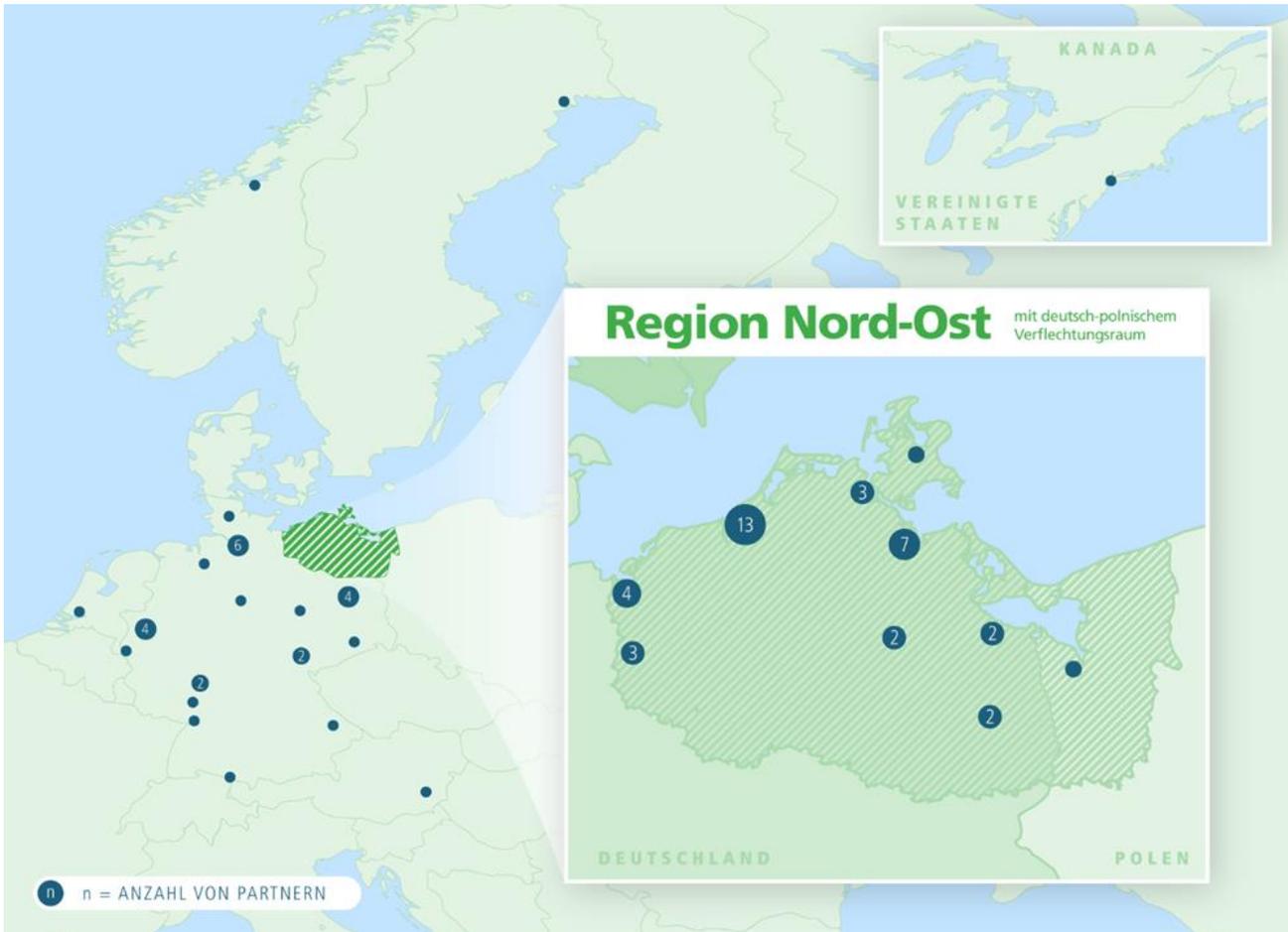


Green ammonia technologies as key to addressing societal challenges of the future:

- Regional value creation of renewable energy
- Economic storage and transport of hydrogen
- Decarbonisation of shipping



CAMPFIRE Partner Alliance



The CAMPFIRE Alliance has 71 partners with focus in Mecklenburg-Vorpommern and Northern Brandenburg (Region North-East):

- 51 industry partners
- 5 international partners
- 20 research institutes

Aiming at development of a green ammonia ecosystem

23 collaborative projects, supported by funding over 55 Mio €



Green Ammonia Infrastructure and Legal Framework



Logistic and infrastructure

Flexible, on-shore and ship-to-ship ammonia fueling station

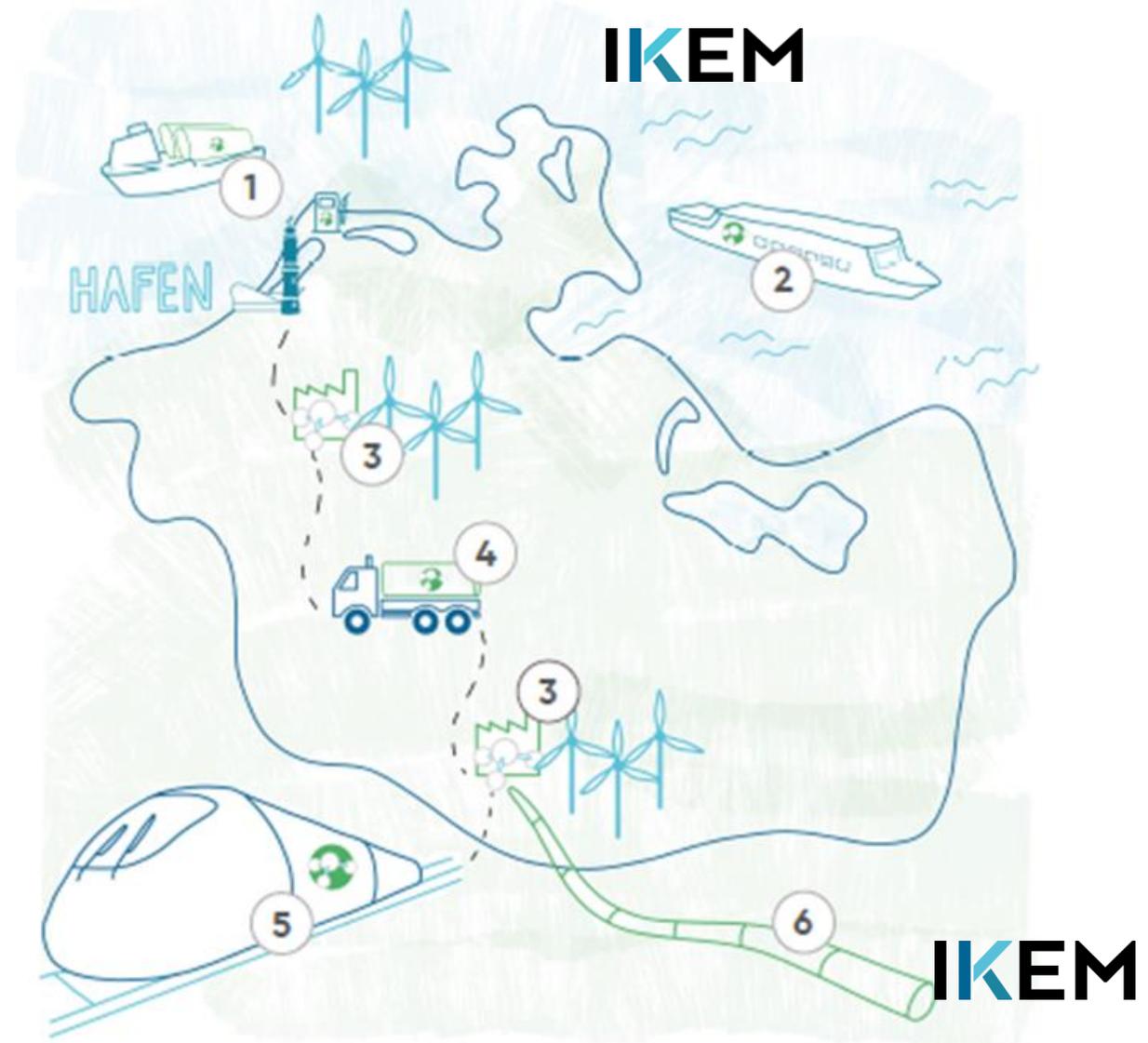
Ammonia-to-hydrogen fueling stations

Ammonia-CHP 1 MW power stations



Legal framework and acceptance

Standardization and certification



Thank you for your attention!



CAMPFIRE | END



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