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The potential of ammonia as marine fuel – an initial assessment

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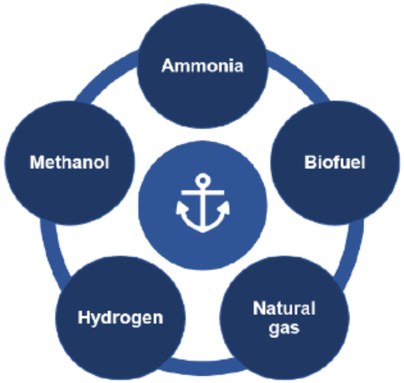
Background

- IMO target of 50% GHG reduction in 2050
- Range of alternative fuel options, with different pros and cons

Why assessing ammonia?

- Ammonia is a liquid carbon-free fuel that can be produced from renewable energy sources
- Can be used in fuel cells or in combustion engines
- Contribute with knowledge on fuel options that are discussed internationally but not used yet.



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Aim

- To assess the potential of ammonia as a fuel for shipping compared to other alternative marine fuels

How? Literature review and comparison with other alternative marine fuels using a multi-criteria decision assessment approach.

On-going pre-study funded via Lighthouse industry programme Sustainable Shipping (Swedish Transport Administration)

Ammonia

- Main Production method: Haber Bosch:
  $3 H_2 + N_2 \rightarrow 2 NH_3$ (400-500 ° C, 150-300 bar)

(H_2: from steam methane reforming and N_2 from air separation unit)

- Other potential production methods (e.g., H_2 from electrolysis)
- 80% of current global ammonia production used in fertiliser industry

Advantages

- Potentially no CO_2 emissions (no tailpipe)
- Traded on a global scale - handling experience and existing infrastructure
- Potentially less competition from other transport sectors, not based on limited resources
- No need for cryogenic storage which is needed for liquid hydrogen and LNG
- Ammonia has higher energy density than liquid hydrogen, less costly to transport
- Maybe possible to upgrade existing dual-fuel engines to operate on ammonia
- No SOx-emissions

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Challenges

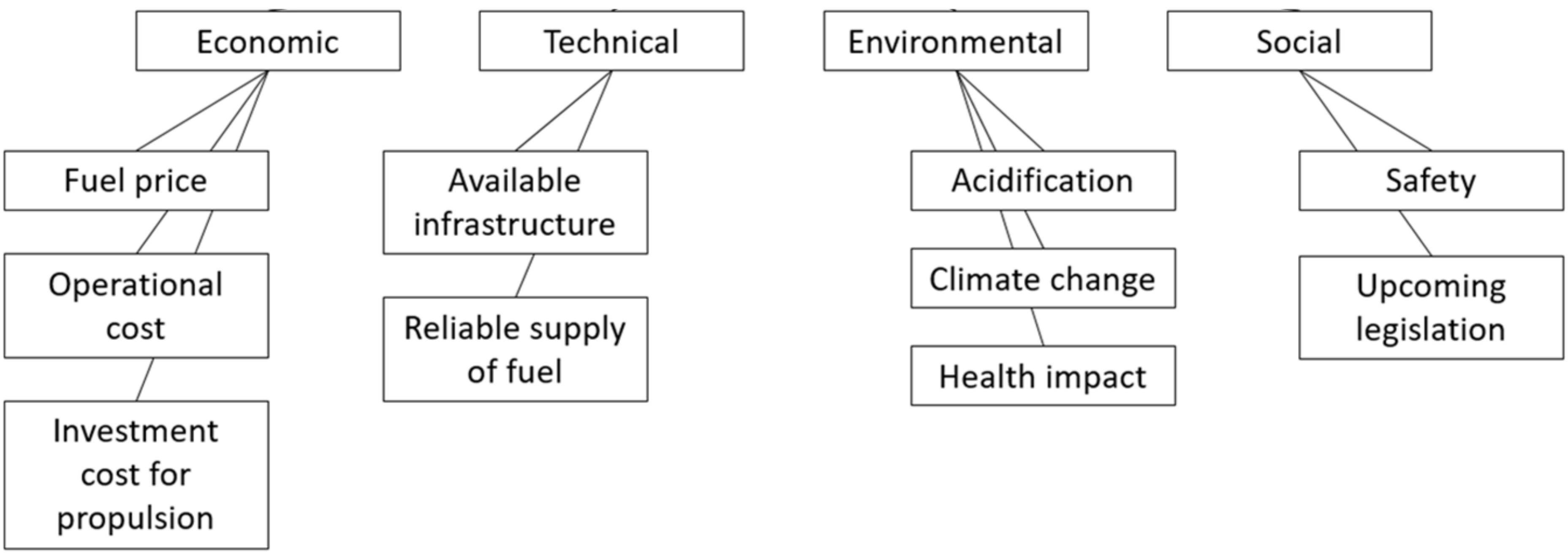
- Ammonia currently mainly produced from fossil resources -> contribute to CO2 emissions in LCA perspective -> Large-scale renewable production of ammonia needed!
- Lack of tests in marine applications
- Toxic and corrosive
- Lack of regulations when used as a fuel
- Future cost incl fuel cells (relative to other fuel options)
- NOx emission, potential need of SCR technology (ICE)
- Storage space compared to fossil fuels
- Competition with fertilizer industry may effect food prices

Marine fuels to compare

- Renewable **Ammonia** in fuel cells (FC) and internal combustion engines (ICE) (Elec-NH3)
- Natural gas based **Ammonia** in FCs and ICEs (NG-NH3)
- Liquefied natural gas (**LNG**),
- Liquefied biogas (**LBG**),
- Biomass and Natural gas based **Methanol** (Bio-MeOH + NG-MeOH)
- **Hydrogen** for fuel cells produced from (i) natural gas (NG-H2)or (ii) electrolysis based on renewable electricity (Elec-H2)
- Hydrotreated vegetable oil (**HVO**)

Choice of fuel depend on a range of factors e.g., price, availability, safety, environmental impact

Included criteria:



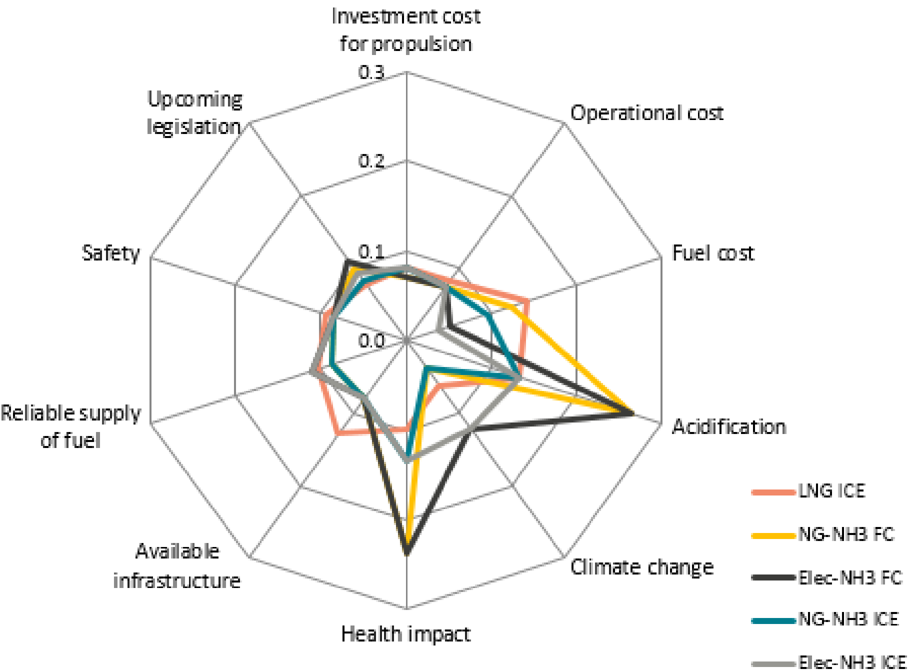
Multi-criteria assessment

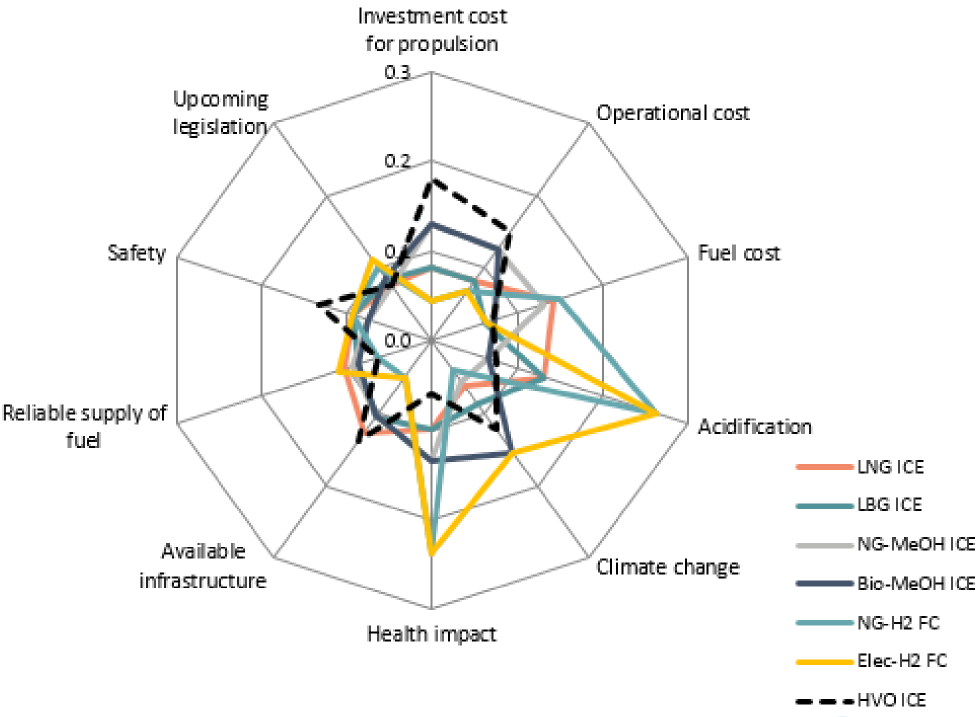
- Fuel options scored based on how they perform for each sub-criteria based on available info (e.g., climate change impact, operational cost)
- Criteria/Sub-critera given weights based on how important they are, relative importance (based on individual (joint) and stakeholder group preferences: *Authority, Ship-owner, Fuel producer and Engine manufacturer*)
- Ranking: What alternative marine fuel is most preferable considering the stakeholders' preferences?

Criteria impacts – fuel scoring

Sub-criterion	Elec-NH_3 ICE	NG-NH_3 ICE	Elec-NH_3 FC	NG-NH_3 FC	LNG ICE
Investment cost [kUSD/kW]	5100	5100	5300	5300	5100
Operational cost [USD/MWh]	10	10	10	10	9
Fuel cost [USD/kW]	259.75	79.50	173.17	53.00	41.03
Available infrastructure	1.8	1.8	1.8	1.8	2.9
Reliable supply of fuel	2.8	2.2	2.8	2.2	2.6
GWP_{100} [g CO_2-eq./MJ_{fuel}]	30	140 (116-158)	30	140 (116-158)	80 (78-93)
Acidification potential [mole H^+-eq./MJ_{fuel}]	8.4e-5	8.4e-5	0	0	8.4e-5
Health impact [mg PM_{10}/MJ_{fuel}]	0.22 (0.0-0.43)	0.22 (0.0-0.43)	0	0	0.40 (0.37-0.43)
Safety	2.3	2.3	2.3	2.3	2.5
Upcoming legislation	3.3	2.9	3.9	3.5	2.8

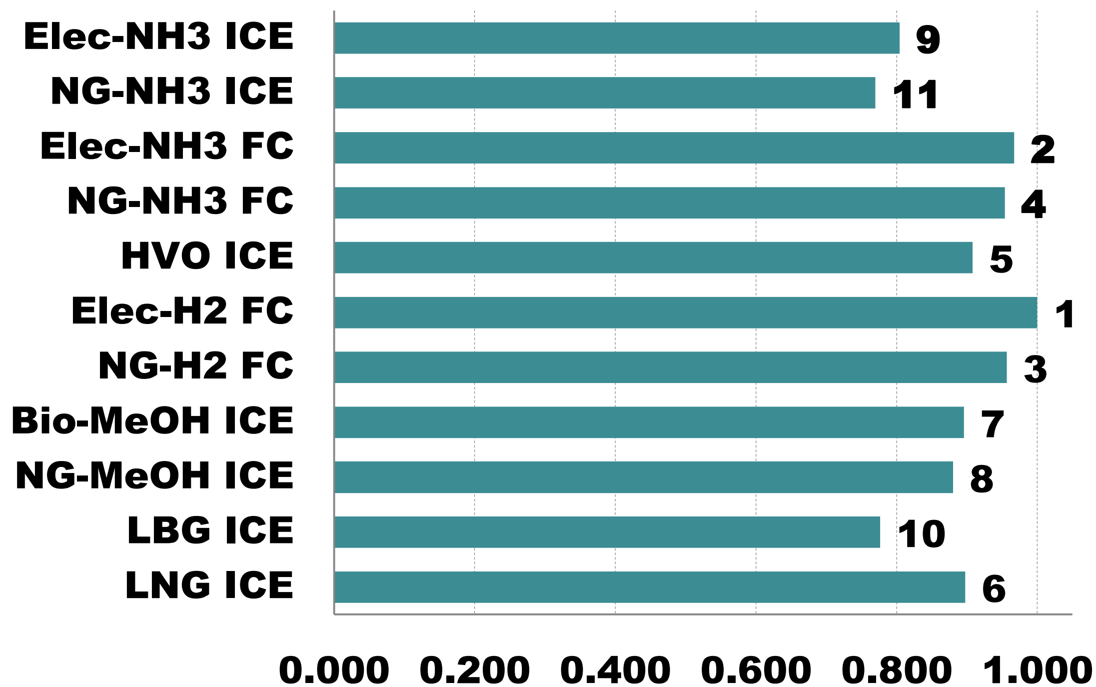
Scoring of Alternative Marine Fuels





Preliminary base case joint ranking

- Ammonia in fuel cells turns out better than ammonia in internal combustion engines
- Initial assessment indicates that ammonia might be as interesting as hydrogen and biomass-based marine fuels (also the case for other stakeholder groups)



See: Lövdahl, J., Magnusson, M., 2019. Evaluation of Ammonia as a Potential Marine Fuel - Modelling and assessment of alternative marine fuels … Master thesis. Chalmers University of technology.

Finally

- Further assessments needed in order to draw firm conclusions about the potential of ammonia
- Policy initiatives are needed to promote the introduction of renewable marine fuels.

- Danish assessment of climate-neutral shipping in 2050: “*Regarding fuels, from a socio-economic cost perspective, hydrogen, methanol and ammonia are the most compatible, though due to high uncertainties regarding future cost developments and safety requirements (especially with ammonia), there is no clear winner*.” (ben Brahim et al., 2019)

THANK YOU!

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Involved actors

- Stena Line
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- Wärtsilä
- Preem
- Swedish Maritime Administration
- Swedish Transport Administration
- Energigas Sverige
- SSPA (Maritime research Institute)
- Swedish Energy Agency
- Region Västra Götaland
- Göteborg University