Prospects for renewable marine fuels

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Shift Sustainable Horizons in Future Transport

www.nordicenergy.org/flagship/project-shift/

Shift will inform smarter Nordic transport and energy policy

- By developing and applying tools that integrate modal shifts, fuel options, business models and consumer behaviour into scenario modelling and in-depth analysis



Nordic Energy Research Nordic Council of Ministers

Possible marine fuels options

45'

| Diesel-quality fuels | Heavy fuel oil (HFO) Low sulphur HFO (<1 wt. % S) Low sulphur distillate fuels (<0.1 wt. % S) Vegetable oils Hydrotreated vegetable oil (HVO) Pyrolysis oil Biodiesel Biomass-to-liquid (BTL)/synthetic biodiesel Gas-to-liquid (GTL)/synthetic diesel (Fischer-Tropsch) | |
|-------------------------|--|----|
| Gases | Liquefied natural gas (LNG) Liquefied biogas (LBG) Dimethyl ether (DME) Liquefied petroleum gas (LPG) Hydrogen/hydrogen with carbon capture and storage (CCS) | |
| Alcohols | Methanol Ethanol Buthanol OBATE-fuel | |
| Solid fuels | Uranium Coal Wood | |
| | Electricity | (B |

(Brynolf, 2014)

Background

 Choice of fuel warrants an analysis of a range of different factors as price, availability, technology maturity level, safety, environmental impact, policies etc.



Initial results from a Multi-criteria Decision Analysis of Alternative Fuels for the Maritime Sector



Overall aim

- To assess the prospect of renewable fuels in the shipping sector by conducting a multicriteria decision analysis of selected alternative fuels with a panel of shipping sector related stakeholders.
- The multi-criteria decision analysis model Analytic Hierarchy Process is used.
- Time perspective 2030

Objectives

- What are the relative economic, technical, environmental and social impacts of the selected alternative marine fuels?
- What are the relative importance of different criteria in the selection of alternative marine fuels according to stakeholders?
- What alternative marine fuel is most preferable considering the stakeholders' preferences?

Included marine fuels

- Liquefied natural gas (LNG)
- Methanol produced from natural gas (NG-MeOH)
- Methanol produced from biomass (Bio-MeOH)
- Hydrogen produced from electrolysis by wind power (Elec-H2) with fuel cells

10 criteria (Economic, technical, environmental and social)

Multi-Criteria Decision Analysis

- MCDA is a tool for managing complex decision problems
- Score alternatives and weight the criteria
- The alternative marine fuels are ranked based on how they perform with respect to the selected criteria and the relative importance of the criteria
- Possible to consider differing views





Multi-Criteria Decision Analysis

- Pairwise comparisons
- Alternatives are scored based on how they perform with regard to a specific sub-criteria
- Criteria are given weights based on how important they are
- Results in ranking
- Intensities from 1-9 are used

Scoring of Alternative Marine Fuels

- LNG best in: Fuel price, Available infrastructure
- NG-MeOH best in: Investment cost, Operational cost, Safety
- Bio-MeOH best in: Investment cost, Operational cost, Safety
- Elec-H2 best in: Reliable supply of fuel, Acidification, Climate change, Health impact, Upcoming legislation



3 Relative Importance of Criteria for Joint Stakeholder Scoring



Most important subcriteria (for each group of criteria) are:

- Fuel price
 - Reliable supply of fuel
 - Climate change
 - Upcoming legislation

Ranking Order of Alternative Marine Fuels for Joint Stakeholder Scoring



The ranking order of LNG and Bio-MeOH is sensitive to changes in criteria weights and perspectives used in scoring

Most "preferred" fuel: Hydrogen followed by bio-methanol and LNG (equally preferred)

Fictional Authority and Ship-owner Weights

Authority role-play criteria weights



Shipowner role-play criteria weights



Fictional Authority and Ship-owner Ranking Orders

Authority role-play ranking of alternative marine fuels



Most "preferred" fuel: Hydrogen followed by bio-methanol

Shipowner role-play ranking of alternative marine fuels



Most "preferred" fuel: LNG followed by NGmethanol

Fictional Authority and Ship-owner Ranking Orders

Authority role-play ranking of alternative marine fuels







Result for fuel and engine manufacturer: H2 or H2/LNG, LNG, bioMeOH, fossil MeOH

Stakeholders

- Stena Line
- Wallenius Marine
- Wärtsilä
- Preem
- Swedish Maritime Administration
- Swedish Transport Administration
- Energigas
- SSPA
- Environmental analysis Vehicles and Fuels
- Gothenburg University
- Chalmers University of Technology
- IVL Swedish Environmental Research Institute

Discussion

The results depend on:

- The alternative marine fuels included (aim to include more biomass based options)
- Selected criteria
- Perspectives used in scoring (will be improved)
- Mix of stakeholders
- More sensitivity analyses

Result may change





Contact

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Thank you!

Extra material

G3

Participants



Participants

Intensities for scoring and weighting

| Intensity of importance | Definition | Explanation |
|---|---------------------------|---|
| 1 | Equal importance | Two elements contribute equally to the objective |
| 3 | Moderate importance | Experience or judgement slightly favour one element over another |
| 5 | Strong importance | Experience or judgement strongly favour one element over another |
| 7 | Very strong importance | One element is favoured very strongly over another |
| 9 | Extreme importance | The evidence favouring one element over another is of the highest possible order of affirmation |
| 2, 4, 6, and 8 can be used when the difference is less pronounced than the above explanations | | |

Saaty's table: The fundamental Scale for Pairwise Comparisons (Saaty, 2008)

A complete and correct pairwise comparison matrix

| | (Economic) | (Technical) | (Environm ental) | (Social) |
|-------------------|------------|-------------|---------------------|----------|
| Economic | 0 1 | 0 5 | 3 | 4 |
| Technical | 1/5 | 1 | 1/3 | 1/2 |
| Environm ental | 0 1/3 | 3 | 1 | 2 |
| Social | 1/4 | 2 | 1/2 | 1 |

Note: The method includes a consistency check to make sure the scores are consistent. Being consistent means that if **Economic** is strongly favoured over (Technical), and slightly favoured over (Environmental), it follows that **Environmental** must be slightly favoured over (Technical).



Economic impacts

Table 4.1: Impact matrix for included economic criteria

| Alternatives | Investment cost [kEuro [*] /Ship] | Operational cost [Euro [*] /MWh] | Fuel price [Euro [*] /GJ] | |
|--|--|--|---|--|
| LNG ICE NG-MeOH ICE Bio-MeOH ICE Elec-H ₂ FC | 124 800 ^a 117 500 ^a 117 500 ^a 206 200 ^a | 3.90-4.40 ^b 3.25-3.50 ^b 3.25-3.50 ^b Slightly higher ^c | ${f 8^{ m d}}{17^{ m e}}{28^{ m f}}{52^{ m g}}$ | |



Technical impacts

Table 4.2: Impact matrix for included technical criteria

| Alternatives | Available infrastructure | Reliable supply of fuel |
|--|-------------------------------|---|
| LNG ICE NG-MeOH ICE Bio-MeOH ICE Elec-H ₂ FC | + ^a c e g | $\begin{array}{c}b\\d\\ -f\\ ++h \end{array}$ |
| | | |



Environmental impacts

Table 4.3: Impact matrix for included environmental criteria

| Alternatives | Acidification potential | GWP ₁₀₀ | DALY |
|------------------------|-------------------------------|-----------------------------|-------------------------|
| | [mole H ⁺ eq/t km] | [g CO ₂ eq/t km] | [yr/t km] |
| LNG ICE | 0.05^{a} | 0.9^{a} | 4.2×10^{-9} b |
| NG-MeOH ICE | 0.10^{a} | 1.1^{a} | 10.4 $\times 10^{-9}$ b |
| Bio-MeOH ICE | 0.15^{a} | 0.2^{a} | 13.3 $\times 10^{-9}$ b |
| Elec-H ₂ FC | 0^{c} | 0^{c} | 0 ^c |



Social impacts

Table 4.4: Impact matrix for included social criteria

| Alternatives | Safety | Upcoming legislation |
|--|--|--|
| LNG ICE NG-MeOH ICE Bio-MeOH ICE Elec-H ₂ FC | $\begin{array}{l} +^{\mathrm{a,b}} \\ + + ^{\mathrm{a,c}} \\ + + ^{\mathrm{a,c}} \\ - ^{\mathrm{d,f}} \end{array}$ | $\begin{array}{c} -^{\mathrm{f}} \\^{\mathrm{f}} \\ ++^{\mathrm{f}} \\ +++^{\mathrm{g}} \end{array}$ |

Referensgrupp knyts till projektet

- Följande aktörer har hittills visat intresse för att delta:
 - Stena Line
 - Laurin Maritime,
 - Sjöfartsverket,
 - Västra Götalandsregionen,
 - Preem,
 - Trafikverket,
 - Energimyndigheten
 - Miljöanalys Fordon och bränslen
 - Vill ni vara med? Varmt välkomna!