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

IVL Svenska Miljöinstitutet

Swedish ICT Viktoria

DTU

TØI Transportøkonomisk institutt, Stiftelsen Norsk senter for samferdselsforskning

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Nordic Energy Research
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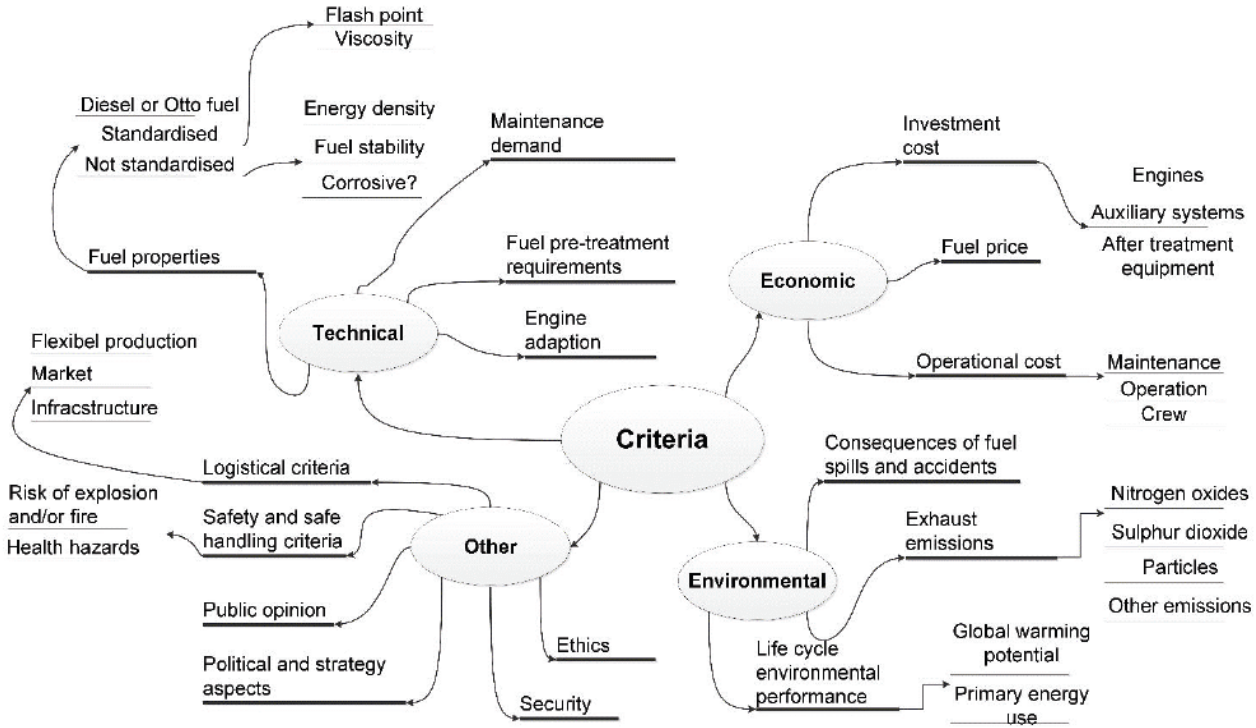
Possible marine fuels options

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

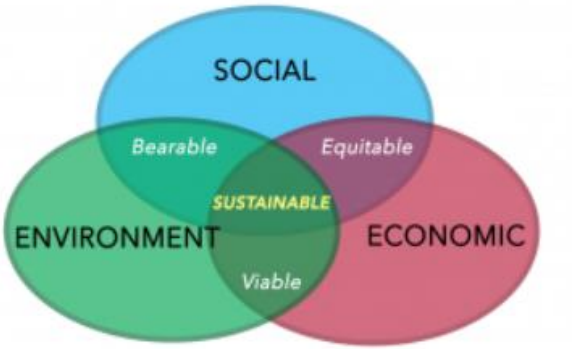
(Brynolf, 2014)

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 multi-criteria 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

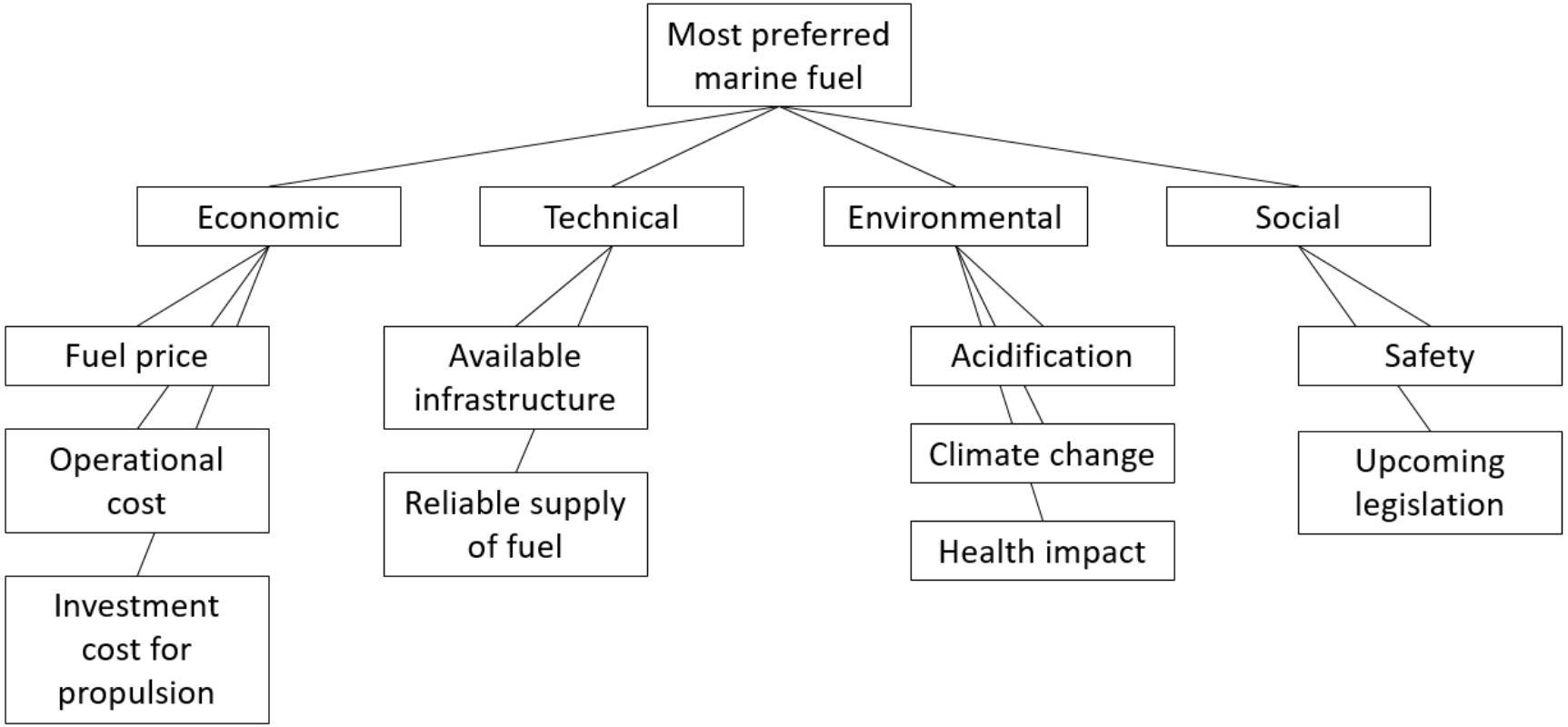
- Liquefied natural gas (LNG)
- Methanol produced from natural gas (NG-MeOH)
- Methanol produced from biomass (Bio-MeOH)
- Hydrogen produced from electrolysis by wind power (Elec-H2) with fuel cells

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

Hierarchy tree



LNG ICE	NG-MeOH ICE	Bio-MeOH ICE	Elec-H2 FC

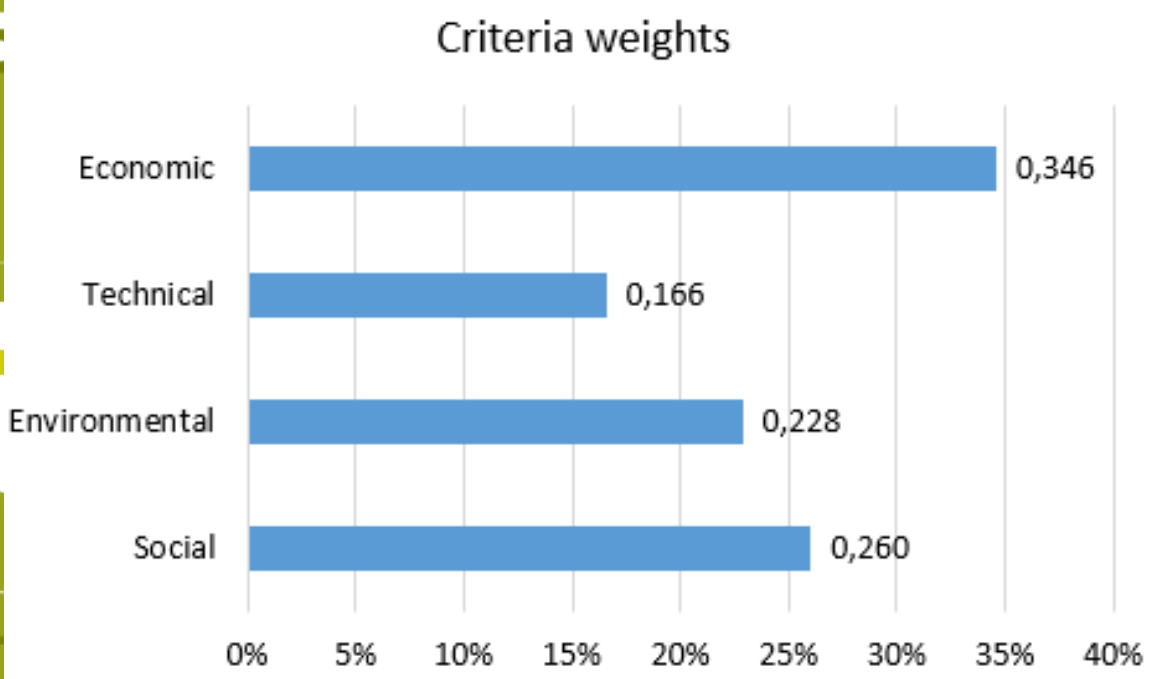
Multi-Criteria Decision Analysis

- 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

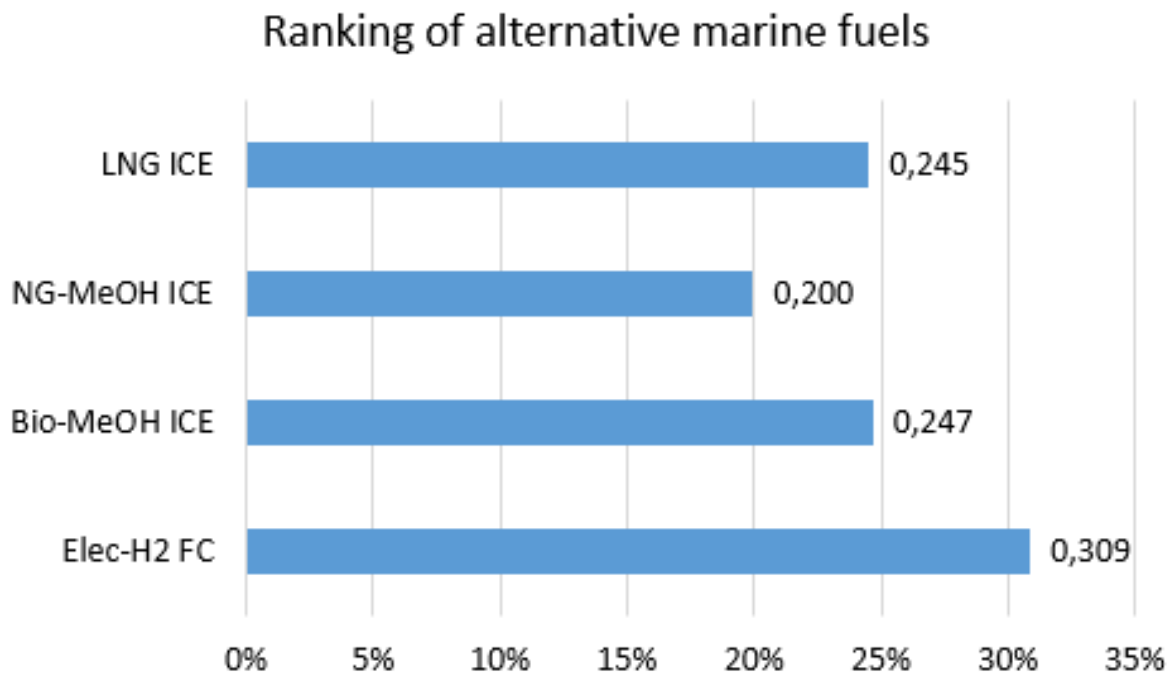
Relative Importance of Criteria for Joint Stakeholder Scoring



Most important sub-criteria (for each group of criteria) are:

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

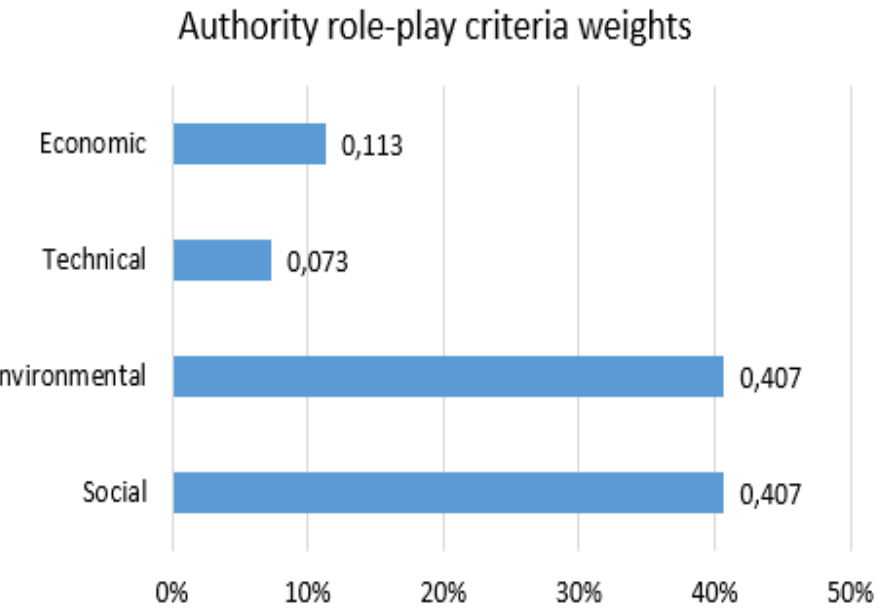
Ranking Order of Alternative Marine Fuels for Joint Stakeholder Scoring

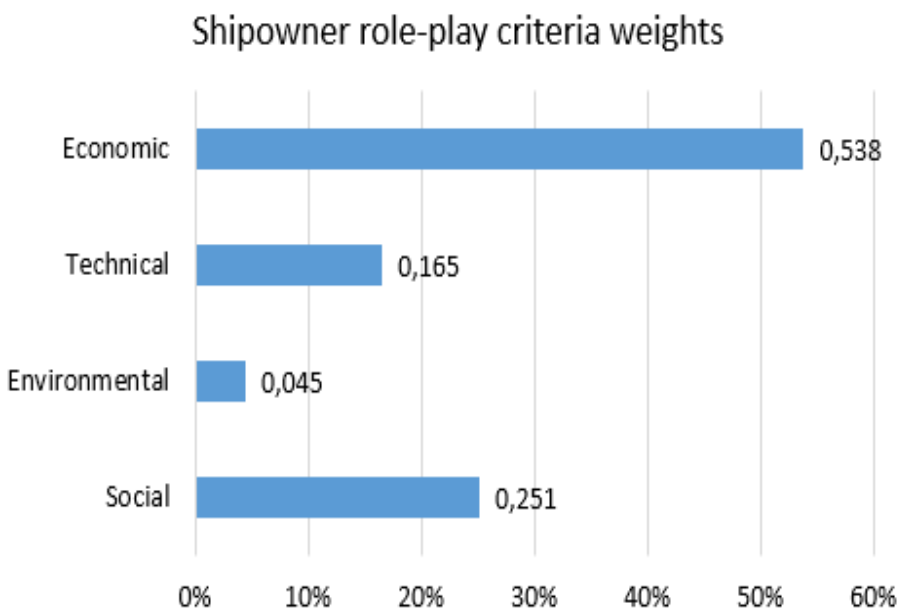


The ranking order of LNG and Bio-MeOH is sensitive to changes in criteria weights and perspectives used in scoring

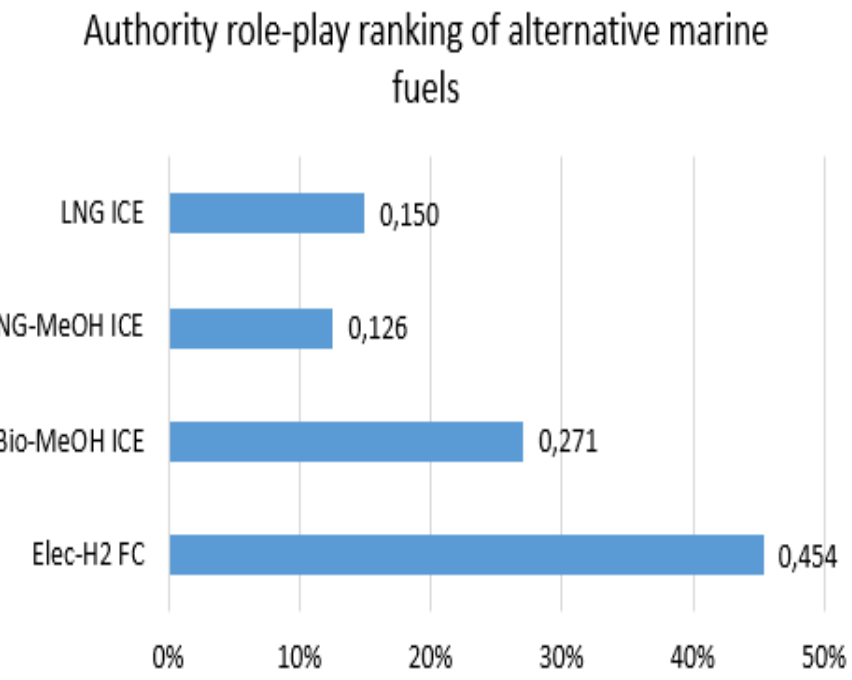
Most “preferred” fuel: Hydrogen followed by bio-methanol and LNG (equally preferred)

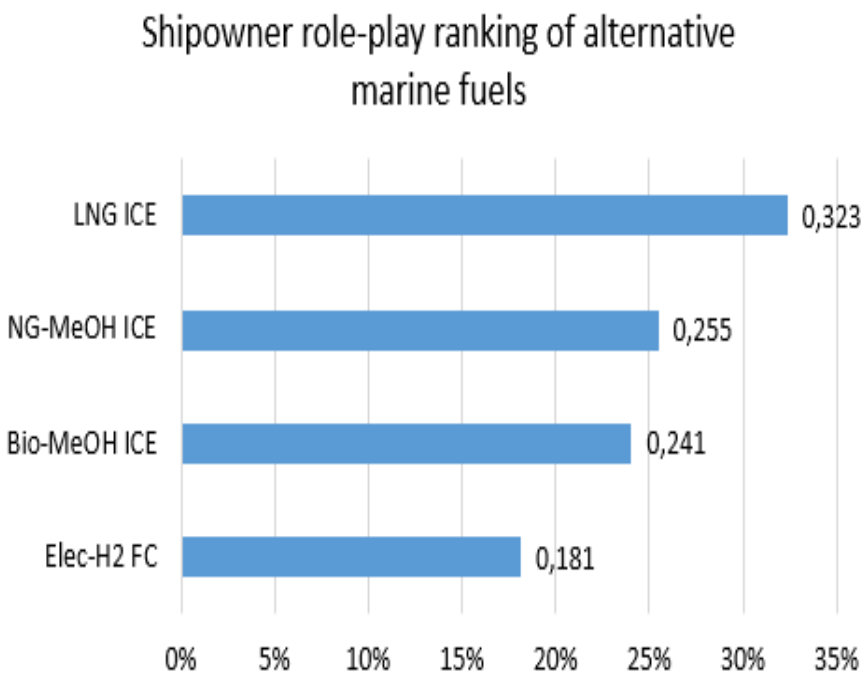
Fictional Authority and Ship-owner Weights





Fictional Authority and Ship-owner Ranking Orders

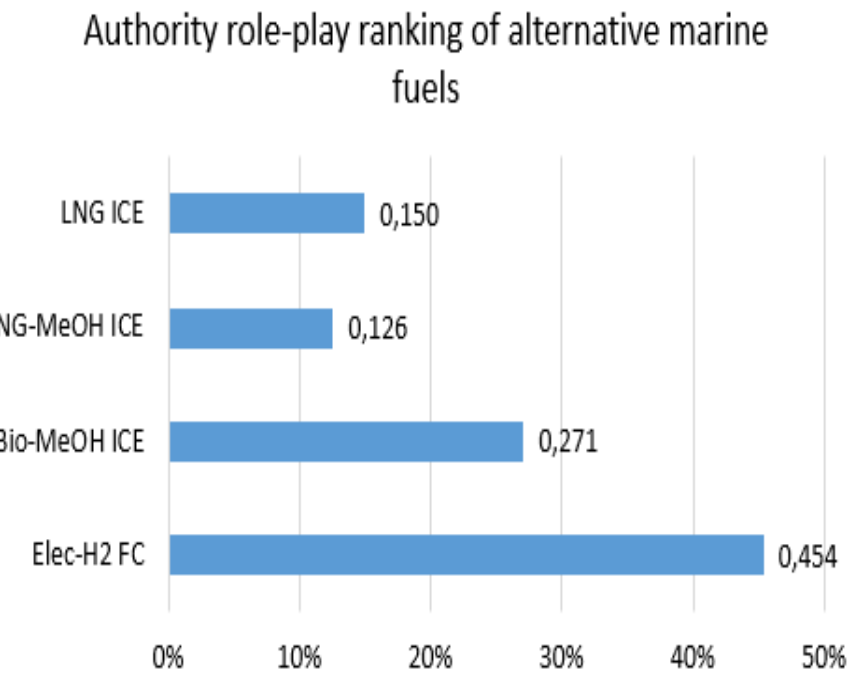


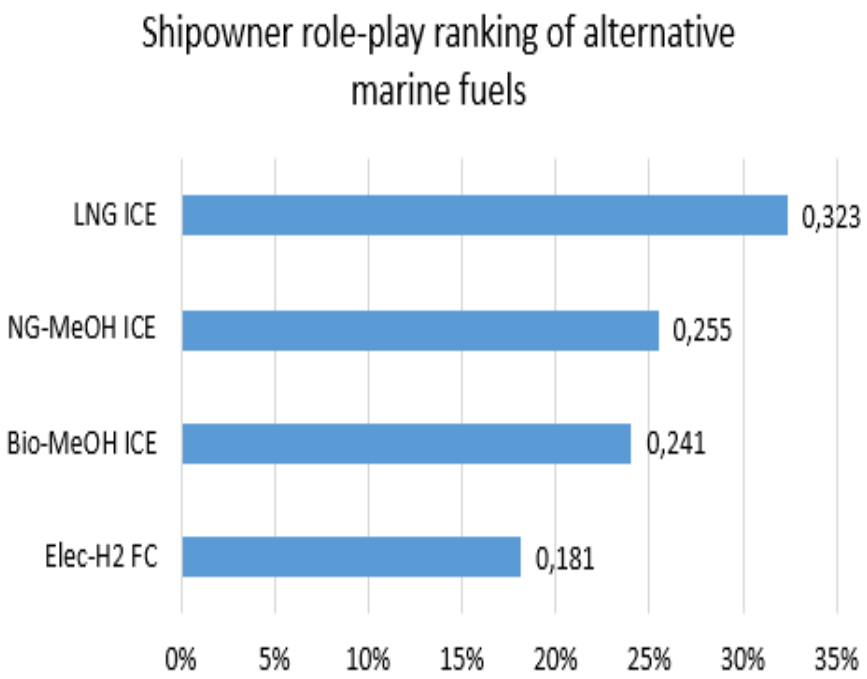


Most “preferred” fuel: Hydrogen followed by bio-methanol

Most “preferred” fuel: LNG followed by NG-methanol

Fictional Authority and Ship-owner Ranking Orders





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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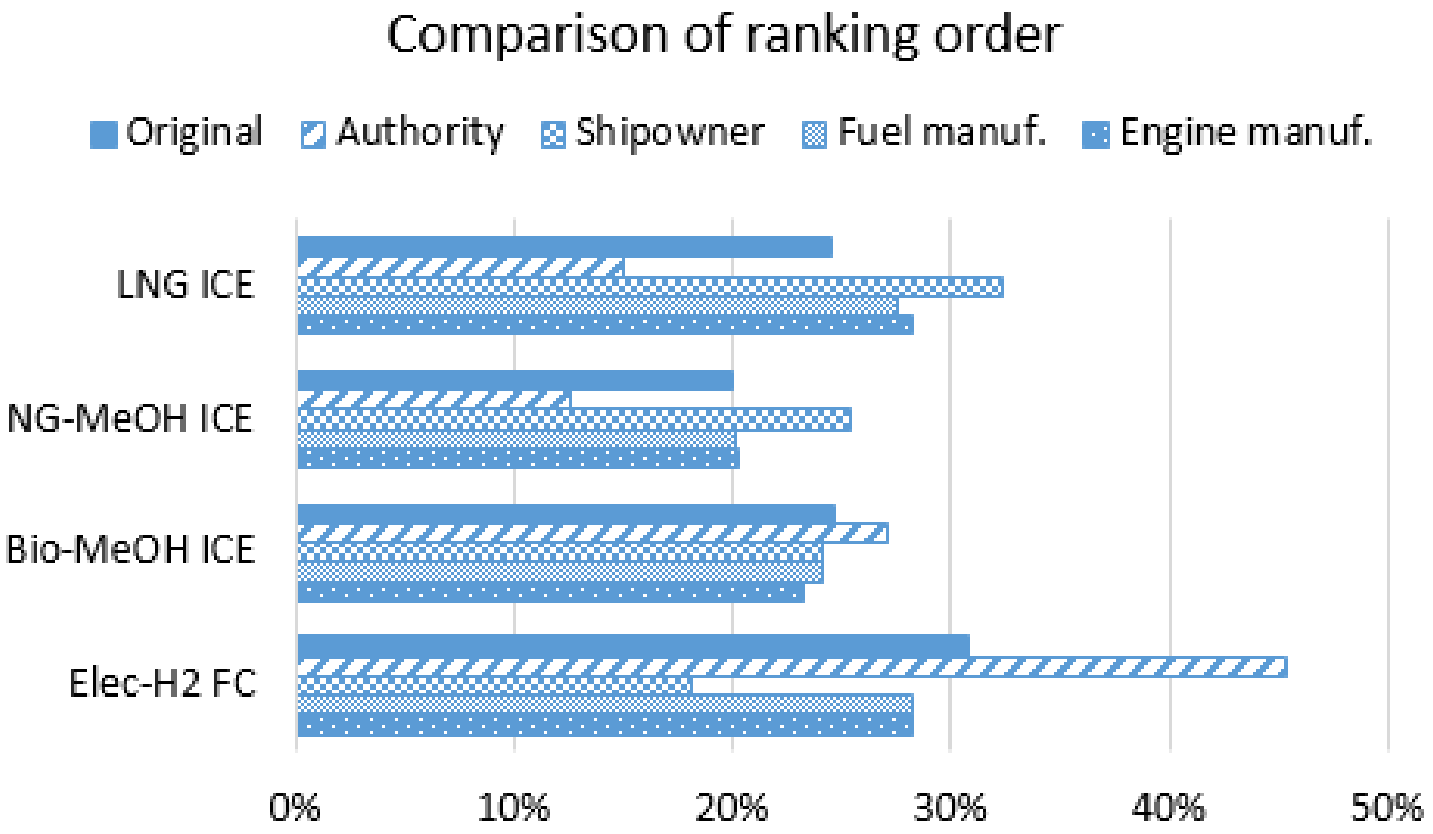
Thank you!

Extra material



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)	(Environmental)	(Social)
Economic	1	5	3	4
Technical	1/5	1	1/3	1/2
Environmental	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	124 800[a]	3.90-4.40[b]	8[d]
NG-MeOH ICE	117 500[a]	3.25-3.50[b]	17[e]
Bio-MeOH ICE	117 500[a]	3.25-3.50[b]	28[f]
Elec-H_2 FC	206 200[a]	*Slightly higher*[c]	52[g]

Technical impacts

Table 4.2: Impact matrix for included technical criteria

Alternatives	*Available infrastructure*	*Reliable supply of fuel*
LNG ICE	$+^{a}$	$---^{b}$
NG-MeOH ICE	$-^{c}$	$---^{d}$
Bio-MeOH ICE	$--^{e}$	$-^{f}$
Elec-H_2 FC	$---^{g}$	$++^{h}$

Environmental impacts

Table 4.3: Impact matrix for included environmental criteria

Alternatives	*Acidification potential* [mole H^+ eq/t km]	GWP_{100} [g CO_2eq/t km]	*DALY* [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]	10.4×10^{-9}[b]
Bio-MeOH ICE	0.15[a]	0.2[a]	13.3×10^{-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	$+^{a,b}$	$-^{f}$
NG-MeOH ICE	$++^{a,c}$	$--^{f}$
Bio-MeOH ICE	$++^{a,c}$	$++^{f}$
Elec-H_2 FC	$-^{d,f}$	$+++^{g}$

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!