ASSESSMENT OF THE POSSIBILITIES FOR SELECTED ALTERNATIVE FUELS FOR THE MARITIME SECTOR

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ABSTRACT
There is still a lack of information on the possibilities for different alternative marine fuels. This study analyse the possibilities for selected alternative fuels for the maritime sector in 2030 by conducting a multi-criteria decision analysis. The method Analytic Hierarchy Process is used and the value and preferences of stakeholders from the shipping sector are considered. The study also includes a synthesis of knowledge on alternative marine fuels. Liquefied natural gas (LNG), natural gas and biomass based methanol (NG-MeOH, Bio-MeOH) as well as renewable energy based hydrogen are included. Ten different criteria spanning over economic, technical, environmental and social aspects are considered e.g., fuel price, operational cost, fuel supply, climate change, acidification and safety. As a common group the stakeholders put economic criteria highest, followed by social, environmental and technical criteria. The ranking of the fuels differs somewhat between the four different stakeholder groups. Renewable hydrogen followed by Bio-MeOH or LNG is the most preferred fuel for all groups and NG-MeOH the least preferred - except for the ship owners where LNG is most preferred. However, additional analyses are needed before any firm conclusions of the final fuel ranking can be made.

Keywords: Shipping, Marine fuels, Multi-criteria decision analysis, LNG, Methanol, Hydrogen

NOMENCLATURE

LNG	Liquefied natural gas
NG-MeOH	Methanol produced from natural gas
Bio-MeOH	Methanol produced from biomass
Elec-H2	Hydrogen produced from electrolysis by wind power with fuel cells
MCDA	Multi-criteria decision analysis

1. INTRODUCTION

There is a need to reduce the emissions from the shipping sector (Transport & Environment, 2017). For example, the European Commission's White Paper on strategies towards a competitive and resource efficient transport system, includes a target of a 40% cut in shipping CO_2-emissions below 2005 levels until 2050 (European Commission, 2011), and the international trade association for merchant shipowners, the International Chamber of Shipping, has set the industry goal of a 20% CO_2-reduction per tonne-km by 2020, and a 50% CO_2-reduction per tonne-km 2050 (ICS, 2014). There are technology and energy efficient measures available that decrease air pollution and greenhouse gas emissions, but to succeed with cutting total greenhouse gas emissions, energy efficient measures are not enough, there is also a need for low-emitting alternative fuels (Brynolf, Fridell, & Andersson, 2014). Alternative marine fuels refer to other fuels than the conventional marine fuels (such as heavy fuel oil and marine gas oil). There is a growing need for knowledge on alternative marine fuels, in particular since there is a range of different fuel options. The choice of fuel also requiress an analysis of a range of different factors as price, availability, technology maturity level, safety, environmental impact, policies etc.

This study analyse the possibilities for selected alternative fuels for the maritime sector in 2030 by conducting a multi-criteria decision analysis. The study includes a synthesis of knowledge on alternative marine fuels and an assessment of factors influencing the choice of marine fuel. Liquefied natural gas (LNG), natural gas and biomass based methanol (NG-MeOH, Bio-MeOH) as well as hydrogen produced from electrolysis by wind power with fuel cells (Elec-H2) are included.

2. METHOD

Multi-criteria decision analysis (MCDA) is a tool for managing complex decision problems. It aims to find an optimal solution, the most consensual solution, by taking into account all stakeholders' interests and preferences as well as practical information (Gamper, Thöni, & Week-Hannemann, 2006; Linkov & Moberg, 2012). The most commonly used MCDA-model in environmental science is the analytic hierarchy process (AHP) (Linkov & Moberg, 2012).

In the AHP method the alternatives (in this case the alternative fuel options and their potential impacts) are scored for each included criteria based on compiled information. The weights for the different criteria are then settled based on involvement of relevant stakeholders. In our case this means that the alternative marine fuels are ranked based on how they perform with respect to the selected criteria and the relative importance of the criteria settled by weighting based on the values and preferences of the involved stakeholders.

For this study ten different criteria spanning over economic, technical, environmental and social aspects were selected based on the result from a survey to relevant shipping stakeholders (Månsson, 2017). The included aspect/criteria under each sustainability perspective are listed in Table 1.

Table 1: The criteria included in the MCDA.

Economic	Technical	Environmental	Social
Investment cost for propulsion	Available infrastructure	Acidification	Safety
Operational cost	Reliable supply of fuel	Health impact	Upcoming legislation
Fuel price		Climate change	

A synthesis of knowledge on the selected alternative marine fuels where then performed with the focus on the ten selected criteria (Månsson, 2017). Following the AHP method the fuel options were scored based on this knowledge synthesis. At a workshop the involved shipping stakeholders were then asked to perform pairwise comparison of the included criteria following Saaty's fundamental scale of absolute numbers (Saaty, 2008). This means that the criteria are given weights based on how important they are. Thereafter the resulting weighting factors were combined with the fuel scoring. The final outcome is a ranking of the different fuel options. Since it with the AHP method is possible to consider differing views the stakeholders first performed their pairwise comparisons as individuals and then as representatives of some stakeholder groups.

For more detailed information about the methodology and the synthesis of knowledge for the different alternative fuel options the reader is referred to Månsson (2017).

3. RESULTS

In the scoring of the alternative fuels, LNG turned out best in terms of (i) fuel price and (ii) available infrastructure. NG-MeOH and Bio-MeOH turned out best in terms of (i) investment cost, (ii) operational cost, and (iii) safety. Elec-H2 turned out best in terms of (i) reliable supply of fuel, (ii) acidification, (iii) climate change, (iv) health impact, and (v) upcoming legislation. As one group based on the individual weightings the stakeholders valued economy most important followed by social aspects, environmental and last technical issues.

Based on the aggregation of the individual weightings the initial findings indicate the most preferred fuel is hydrogen (Elec-H2) followed by Bio-MeOH and LNG (between which it is a small difference). The ranking order of LNG and Bio-MeOH is sensitive to changes in criteria weights. For all the stakeholder groups tested at the workshop Elec-H2 (i.e., renewable hydrogen with fuel cells) followed by Bio-MeOH or LNG was indicated to be the most preferred fuel for all groups and NG-MeOH the least preferred with the exception of the ship owners where LNG seemed to be most preferred followed by NG-MeOH.

4. CONCLUSIONS

A synthesis of knowledge on impacts showed that locally produced electrolytic hydrogen from wind power has the largest environmental benefits, but is far more expensive than the other alternative marine fuels. The technical and social impacts of the alternative marine fuels are more subjective and depend on which assumptions that are made.

The stakeholders judging the importance of the criteria valued economic criteria the most, followed by social criteria, environmental criteria and technical criteria. The relative importance between the criteria is not that large however. This initial assessment indicates that the most preferred alternative marine fuel is electrolytic hydrogen. However, if electrolytic hydrogen is to be a future marine fuel, however, international collaboration and technology specific policies and subsidies are most likely needed and new infrastructure must be built.

Additional analyses with updated fuel assessment and the inclusion of more fuel options are needed before any firm conclusions of the most preferred marine fuel for different stakeholder groups in the future can be made.

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