Environmental Performance and Eco-Efficiency of Using Biodiesel in Recreational Boats

A. M. Fet, Dr.Ing.

Dept. of Industrial Economics and Technology Management

Norwegian University of Science and Technology, Norway

P. L. Zhou, PhD

Dept. of Naval Architecture & Marine Engineering

Universities of Glasgow and Strathclyde, UK

ENSUS 2002, Newcastle, UK, December 17.2002

SYNOPSIS

Biodiesel has been widely used to fuel diesel engines for onshore vehicles, particularly, for agriculture machinery. It has been recognised as viable option for environmental protection and rational use of energy resources. Application of biodiesel for merchant ships' propulsion in a large scale has been seen a non-near future option due to lack of availability and supply chains of the fuel. However, powering recreational boats with biodiesel has shown a potential market under the driving force of marine environment protection. Incentives of using biodiesel on recreational boats are clean and environmental-friendly operations which is one of the essential features of recreational boats sector. In addition the property of bio-degradation of biodiesel makes it suitable for waterborne application. These have clearly demonstrated the benefits of environmental protection by using biodiesel on creational boats. However, its environmental performance and eco-efficiency need to be examined.

This paper presents current trends and requirements for reporting environmental performance in industry. It gives a brief introduction to the use of indicators, especially environmental performance indicators and eco-efficiency indicators and describes the methodology to be used to assess the environmental impact of use of different fuels, ie. biodiesel and fossil diesel, in recreation boats. Different weighting techniques are used to present and evaluate the environmental characteristics of the two fuels' application. With assistance of cost factors, the eco-efficiency is demonstrated.

INTRODUCTION

There are different types of reporting systems on environmental performance and eco-efficiency. Eco-efficiency reports inform about economic performance in addition to the environmental performance while sustainability reporting encompasses social, economic and environmental aspects, the "triple bottom line". Today, a move has been seen from traditional environmental reporting to eco-efficiency reporting and sustainability reporting.

Indicators are frequently used to report the environmental performance. Fig. 1 shows the three pillars in sustainable development as the corners in the triangle, and indicates reporting at different levels.

Organisations like the United Nation's Environment Program (UNEP), the World Business Council for Sustainable Development (WBCSD) and the Organisation for Economic Co-operation and Development (OECD) have a strong influence on the requirements set to such reporting [1]. One of the initiatives by UNEP is the Global Reporting Initiative (GRI). GRI was established in 1997 with the mission of

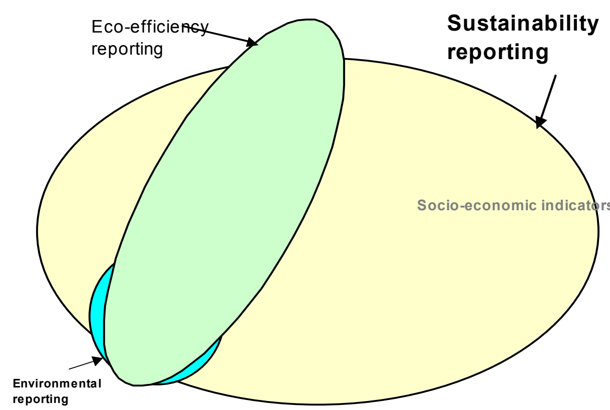

Fig. 1: Sustainability Reporting

developing globally applicable guidelines for reporting on economic, environmental, and social performance. The GRI's Sustainable Reporting Guidelines [2] represents the first global framework for comprehensive sustainability reporting. The latest version came in September 2002, which gives guidance to reporters on selecting generally applicable and organisation specific indicators, as well as integrated sustainability indicators. The development of eco-efficiency indicators is at the heart of the WBCSD's philosophy [3]. The word itself is a combination of economic and ecological efficiency. In order to compare with different systems, it is necessary to follow well known and standardises ways of reporting by means of a set of understood indicators.

METHODOLOGY

To decide upon the environmental performance, relevant data are needed. One way of collecting the data and selecting the most relevant indicators is to use the methodology described in the ISO 14031 code on "Environmental Performance Evaluation" [4]. The methodology is illustrated in Fig.2.

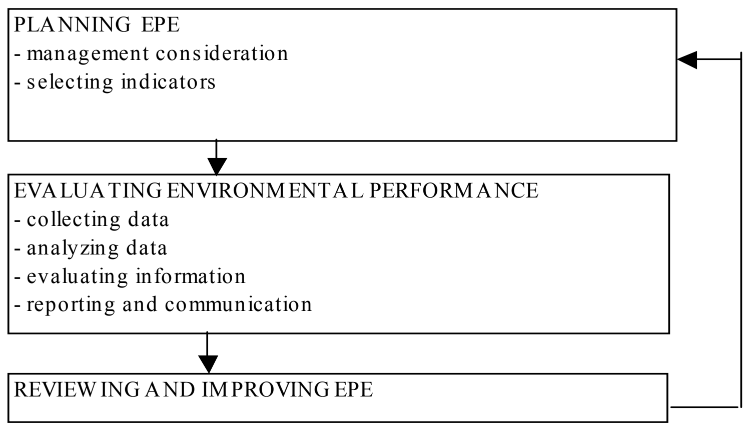

Fig 2: ISO 14031 methodology

To analyse the data and evaluate the information, that means to assess the environmental impact, the methodology recommended by ISO 14040 can be used [5]. The methodology consists of the main steps:

1. Goal and scope definition
2. Inventory
3. Impact assessment
4. Interpretation

In the step of impact assessment the following procedures are used:

3a: Classification; the step where the different substances are classified under the impact category they contribute to.

3b: Characterisation; the step in which the relative contribution of each substance within each category is calculated.

3c: Normalisation and evaluation; the step where the total contribution within each category is evaluated against the mean values in e.g. a country. Very often different weightings are used to compare the impact categories against each other.

To develop eco-efficiency measures, information on both the economic and the environmental performance is needed. By using the formula below the eco-efficiency can be calculated.

$$\textit{eco-efficiency} = \textit{product or service value per environmental influence} \quad (1)$$

Information concerning the entire life cycle is also required to allow an evaluation of different systems on the background of their environmental and economic benefits. However, in this study only the user-phase is concerned.

CASE STUDY

Data collection

A case study was conducted focusing on biodiesel (rapeseed oil) production and market in recreational boats in the UK [6]. Biodiesel has been considered as a environmentally-friendly fuel which offers advantages of cleaner emissions, less pollution, less toxic, biodegradable, less soot, less smoke, less odour, pleasant to handle, safety, high lubricity, smoother operation and complete combustion. These make biodiesel an attractive fuel for recreational boats where clean environment is more sensitive. In addition, the low solubility and high biodegradation rate of biodiesel is absolutely an advantage for the boating environment since accidental spills of fuel is sometime inevitable.

It was concluded [6] that the biodiesel production rate in the UK would be about 430,000 tonnes per year if all UK set aside land were used for growing rapeseed corps. Table I shows the results of a survey conducted with 50 boat clubs in the UK on boats number, type, operation time and power range.

Table I: Fuel consumption by different type of boats

Boat Type	Sailing Dinghy	Sailing Yacht	Motor Cruiser	Sport	Total
Fuel consumption (%)*	2.2	4.5	26.2	15.3	48.2

*Percentage of rapeseed oil production from the set aside land in the UK

This study will examine the environmental aspects regarding the life cycle of fossil fuel and biodiesel from fuel extraction/production to transport and combustion emissions.

Characterisation and normalisation of data

Table II presents the yearly emissions from the sailing yachts in the UK and other parameters required for the analysis. Column 5 shows the characterisation values. It indicates that the contribution of NOx emissions to acidification is only 70% of that of SO_2. Column 6 shows the normalisation factors. They are developed based on total emissions per year in UK. The yearly emissions are then divided on the normalisation factors. This makes the figures comparable, see the two last columns in the table.

Table II: Life cycle emissions of fuel from sailing yachts operation in UK [7.]

Impact category	Substances	Fuelled by Fos-D* (kg/year) [8]	Fuelled by Bio-D (kg/year) [8]	Charac-terisa-tion	Norma-lisation factors [9]	Normalised values fossil diesel	Normalised values biodiesel
Climate change	CO_2	1.4×10^8	3.4×10^7	1	4.16×10^{11}	3.46×10^{-4}	8.17×10^{-5}
Acidification	SO_X	1.5×10^5	2.9×10^4	1,0	1.62×10^9		
	NO_X	6.2×10^5	8.2×10^5	0,7	1.75×10^9	3.40×10^{-4}	3.45×10^{-4}
Local air pollution	Particulars / soot	5.2×10^5	3.1×10^5	1	0.44×10^9	1.28×10^{-3}	8.26×10^{-4}
	CO	4.8×10^5	5.8×10^5	1	4.76×10^9		
Photo oxidant formation	NMVOC	2.9×10^5	1.5×10^5	1	1.96×10^9	1.48×10^{-4}	7.66×10^{-5}
Eutrophi-cation	NO_X	6.2×10^5	8.2×10^5	1	1.75×10^9	3.54×10^{-4}	4.68×10^{-4}

* Fos-D represents fossil diesel fuel; Bio-D represents biodiesel.

Emissions of CO could also be included in the impact category of photo oxidant formation, but its contribution is insignificant after characterisation [8]. Other impacts categories, e.g. ozone layer depletion, and other substances in the selected impact categories are not included due to lack of reliable data. The chosen impact categories and substances are however sufficient to illustrate the method. From the state of the art knowledge in environmental performance study, it is safe to assume that the missing emission substances have little effect on the total results as presented in Fig.3. However, this is an area that needs further investigations.

Fig.3 shows the characterised and normalised environmental profile from sailing yachts in the UK fuelled by fossil diesel and biodiesel based on the figures in Table II. The results show that the use of biodiesel offers a better result within each impact category except for eutrophication, while the difference in acidification is insignificant. The adverse effect of eutrophication and acidification is due to the higher level of NO_X emissions of biodiesel. There is clearly an advantage in the contribution to climate change by using biodiesel (76.4 percent reduction), photo oxidant formation (48.2 percent reduction) and local air pollution (35.5 percent reduction).

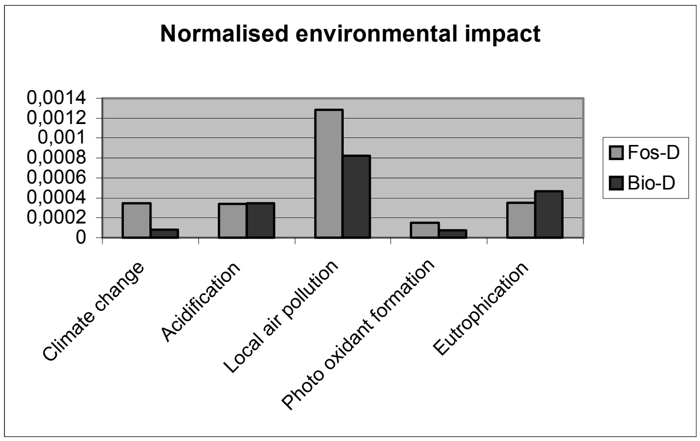

Fig.3: Characterised and normalised inventory results

Weight factors

Eight factors and valuation techniques are used for comparing the relative importance of different environmental impact categories, or to derive at a single index for comparison of the environmental performance of alternative systems when a decision with conflicting environmental targets is to be taken. In this study this is demonstrated by two different ways, weighted against political goals for improvement or weighting set by an expert panel. The highest number represents the most important category, see Table III. The normalised values in Table II are weighted and presented in Fig.4 and Fig.5.

Table III: Political weight factors and weight factors expressed by experts [10]

Impact Category	Weight factor, political goals	Weight factors, Expert panels
Climate change	1	19
Ozone depletion	1	12
Acidification	1,5	4
Photo oxidant formation	1,8	5
Local air pollution	1,5	4
Eutrophication	2	7

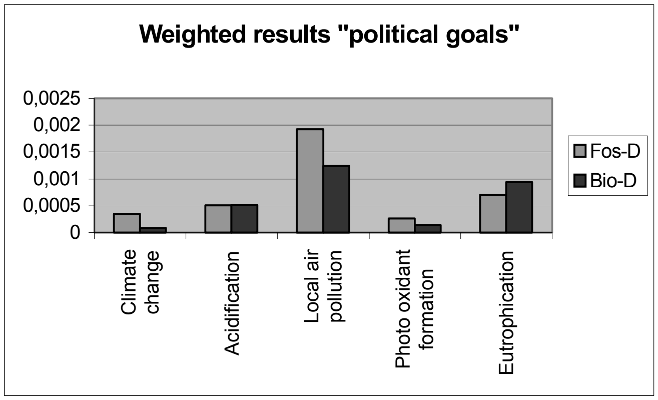

Fig. 4: Weighted results based on political targets.

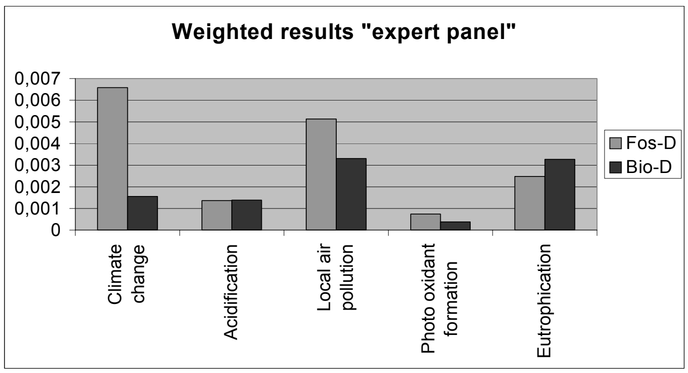

Fig.5: Weighted results based on expert procedures.

Eco-efficiency

In order to calculate the eco-efficiency, it is necessary to evaluate the economic values created by sailing activity (see equation (1)). However, it is difficult to obtain values/incomes on recreational activities, and one way to deal with this is to measure the value as the inverse of costs based on the fuel prices and yearly costs shown in Table IV and Table V.

Table IV: Fuel prices in the UK[11, 12]

	Production	Retail profit	Tax	VAT	Retail price
Bio-D from used oil (pence)	40,48	3,00	25,82	11,60	**80,90**
Bio-D from fresh seeds (pence)	55,48	3,00	25,82	14,75	**99,05**
Fos-D (pence)	17,48	3,00	45,82	11,60	**77,90**
Red Diesel (pence)	17,48	9,00	3,13	5,18	**34,79**

Table V: Fuel cost per year by sail yacht [11]. Sensitivity study on fuel costs[13]

	A*	B	C	**D**
Bio-D	40632	90.2	874	**32032156**
Red Diesel	40632	34.79	852	**12043764**
Fos-D	40632	77,9	852	**26967783**
Bio-D, no tax	40632	50,56	874	**17955053**

*A = fuel consumption (t/y)
B = average fuel cost pence per litre
C= density of fuel (kg/m^3)
D = total fuel cost per year (GBP/y)

The environmental influence can be expressed by the impact categories as shown in Table II. The eco-efficiency of sailing yachts in UK on a yearly basis could then be calculated by:

Eco-efficiency =(1/ yearly costs) / environmental impact (2)

The values in Table V are used when the eco-efficiency figures are calculated. The results from the different scenarios are presented in Fig.6. They show that biodiesel with no tax has the best eco-efficiency for the impact categories climate change and photo oxidant formation For acidification normal priced biodiesel has the worst eco-efficiency. This is due to NOx-emissions. However, for other impact categories, fossil diesel shows a good eco-efficiency. For red diesel the environmental performance of fossil diesel is used, which is partly incorrect. By comparing Fig. 3 and Fig.6, the influence of costs on the eco-efficiency can be derived. However, the use of cost-factors is just for the purpose of demonstrating the method. Other pricing mechanisms and taxation systems could be included here. This is a subject for further studies.

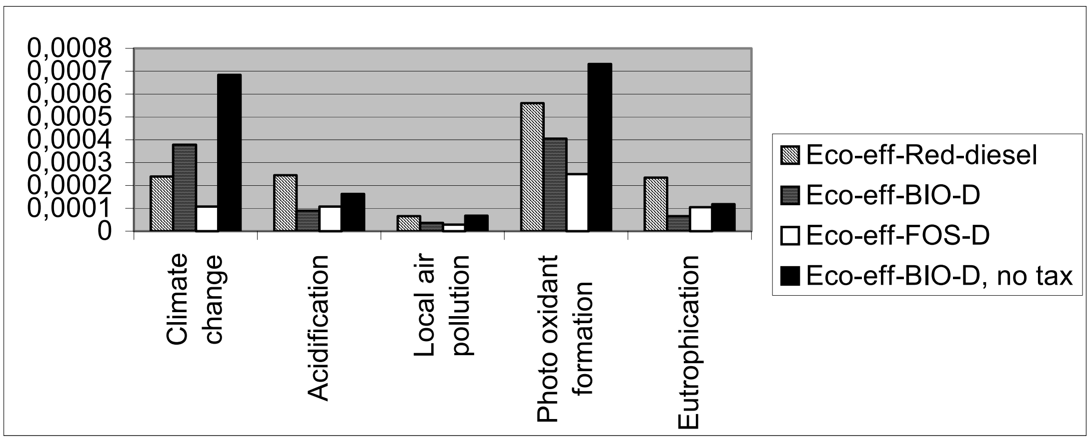

Fig.6: Eco-efficiency for different alternatives, see Table V**.**

CONCLUSIONS AND FUTURE CHALLENGES

The presentation has shown how to combine cost information and environmental impact information into eco-efficiency measures. The figures show the values of eco-efficiency indicators for each impact category. Such indicators can be used in eco-efficiency reporting, see Fig 1. There exist studies on how to add the different impact categories into one single score [14], which means that it could be possible to present the eco-efficiency for each fuel type and case by an aggregated eco-efficiency indicator. However, this requires weighting models between the different impact categories. This is a subject for further studies.

REFERENCES:

1. OECD, "Policies to enhance sustainable development", OECD 2001.
2. GRI, "Sustainable Reporting Guidelines on Economic, Environmental, and Social Performance", June 2000, see www.globalreporting.org
3. WBCSD, "Measuring eco-efficiency, a guide to reporting company performance", Verfaille, H.A., Bidwell, R., June 2000.
4. ISO 14031, "Environmental Performance Evaluation", the international standardisation organisation, 1998.

5. ISO 14040, “Life Cycle Analysis – general framework”, ”, the international standardisation organisation, 1996.
6. K Fet, “The Use of Biodiesel in Recreational Boats”, Final Year Project for BEng in Marine Technology, the University of Newcastle upon Tyne, May 2000.
7. P L Zhou, A M Fet, O Michelsen, K Fet, “A feasibility study of using biodiesel in recreational boats in the UK”, submitted to the Journal of Engineering for the Maritime Environment, May 2002.
8. MZ Hauschild, H Wenzel, “Fotokemisk ozondannelse som vurderingskriterium ved miljøvurdering af produkter”, in M Hauschild (ed.), “Baggrund for miljøvurdering af produkter”, Miljøstyrelsen og Dansk Industri, København, 1996 (in Danish)
9. Stationery Office, July 2000, ISBN 011 5154973
10. Fet, A. M., Michelsen, O., Johnsen, T., Sørgård, E., “Environmental performance of transport –A comparative study.” Norwegian University of Science and Technology – IOT, NTNU, Norway, 2000.
11. Author's conversation with Mr. TL De Winne, British Association for Bio Fuels and Oils (BABFO), May 2002.
12. BABSO report,http://www.biodiesel.co.uk
13. "Digest of United Kingdom Energy Statistics 2000", Department of Trade and Industry, London.
14. Saling, P., Kicherer, A., Dittrich-Krämer, B., Wittlinger, R., Zombik, W., Schmidt, I., Schrott, W. and Schmidt, S. 2002. Eco-efficiency analysis by BASF: The method. *Int. J. LCA* 7(4): 203-218