

A Comparative Analysis of Six Life Cycle Impact Assessment Methodologies

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ABSTRACT

Four life cycle impact (LCIA) methodologies were utilized to quantify the environmental impacts of 10 energy system transportation gases. The inventory assessment results from GREET 1.5a were utilized for the following pollutant: were CO₂, CH₄, N₂O, CO, SO_x, NO_x, VOC and PM₁₀. Results showed that the greenhouse gases had the highest impact contribution. All LCIA methods agreed that hydrogen is the best fuel. Based on correlation analysis, FRED, EDIP and chemical exergy gave comparable results based on ranking while critical volumes, ecological footprint and LCA-NETS showed lower correlation. Correlation of these provides a means of reconciling the different methodologies for more comprehensive decision support.

I. INTRODUCTION

Life Cycle Assessment is a methodological framework for assessing the environmental impacts of products and processes from cradle to grave [1]. LCA phases include the following: goal and scope definition, inventory assessment, impact assessment and interpretation.

II. METHODOLOGY

2.1 Life Cycle Impact Assessment (LCIA)

Life cycle impact assessment involves the classification of emissions to appropriate impact categories. Impact categories include global warming, depletion of stratospheric ozone, eutrophication, acidification, photo-oxidant formation and many more.

2.2 Methods for LCIA

There are many existing LCIA methodologies, which differ upon the importance weights assigned to the impact categories considered

The six methodologies utilized are

1. Critical Volumes [2] – relative environmental impact is measured in reference to Philippine air quality limits.
2. Ecological Footprint [3] – translate the environmental impact based on the required area for sustaining the process considered. Area includes that needed for raw material extraction, energy provision, physical installations, staff support and waste dissipation in the ecosphere.
3. Environmental Design of Industrial Products (EDIP) [4] – The normalized total impact for category (j), NEP(j), is determined using:

$$NEP(j) = EP(j) (T \times ER(j))^{-1} \quad (1)$$

Where: EP(j) is the total impact for category

T is the projected service life in years of the product functional unit

ER(j) is the actual impact generated by the average person

4. Chemical Exergy

The general chemical exergy for equation for mixtures is shown in Equation 3 where x is the mole fraction, T is the temperature, R is the gas constant and e is the exergy value.

$$e^{ch} = \sum x_i e_i^{ch} + RT \sum x_i \ln x_i \quad (3)$$

III. RESULTS AND DISCUSSION

The results are shown below

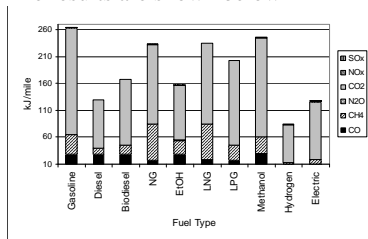


Figure 1 Critical Volumes

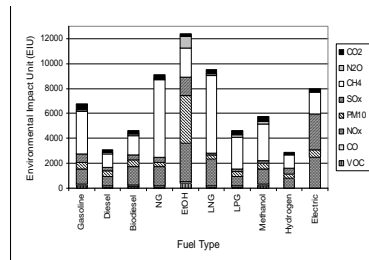


Figure 2 Chemical Exergy

Results show that hydrogen has the least environmental impact while ethanol and gasoline showed high pollution accounts. The greenhouse gases CO₂, N₂O and CH₄ had the highest contribution to the environmental impact.

	CV	EF	EDIP	FRED	EX	NETS
CV	1.000	0.271	0.325	0.362	0.590	0.670
EF	0.856	1.000	0.974	0.976	-0.032	0.340
EDIP	0.328	0.004	1.000	0.999	-0.021	0.300
FRED	0.300	-0.021	0.999	1.000	0.004	0.328
Exergy	0.340	-0.032	0.976	0.974	1.000	0.856
LCA-Nets	0.670	0.590	0.362	0.325	0.271	1.000

Table 1. LCIA Results Based on Rank

Correlation between methodologies are in Table 1. These results can be used for different life cycle case scenarios for more comprehensive decision support.

IV. CONCLUSION

- The comparative analysis revealed that the three greenhouse gases: CO₂, N₂O and CH₄ have the highest contributions in all methods presented among all fuel types.
- Hydrogen is the most environmentally benign fuel while gasoline is the worst fuel according to FRED, EDIP and exergy while critical volumes, ecological footprint and LCA-Nets calculations showed ethanol as the worst fuel.
- The analysis provides a way of comparing the different approaches to impact assessment for better and easier decision-making.
- Moreover, several conditions should be considered in the conduct of LCIA such as data availability, applicability of the method, time- and labor-intensity, simplicity of application and availability of software tools to be able to choose which among these LCIA methods should be used for a specific impact assessment of a product, process or service.

V. ACKNOWLEDGEMENT

This research was funded through De La Salle University-Manila's Ph.D. and M.S. Graduate Fellowship Program.

VI. REFERENCES

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