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Comparative Assessment of Environmental Impacts Associated with the Decommissioning of Fixed offshore Platforms

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ABSTRACT

This paper presents the assessment of environmental impacts associated with the decommissioning of offshore fixed platforms, using two approaches of Life Cycle Assessment (LCA). Decommissioning is the process which the operator of an offshore oil or natural gas installation carries out when it is no longer needed for its current purpose. While there has been an increased environmental awareness in recent years, there is a lack in quantitative assessments approaches pertaining to environmental impacts due to offshore structures decommissioning in South East Asia. In this research, LCA is performed to quantify the environmental impacts in terms of energy consumption and gaseous emissions (CO2, SO2 and NOx) related to two decommissioning options, which are complete removal and conversion of a platform jacket to artificial reef (rigs to reef). The platform chosen for this study is a fixed jacket platform located in the shallow water region of Malaysia. The two tools employed in are Process-based LCA and Economic Input Output (EIO)-LCA method. The results showed that the impacts can be contradictory for the impact evaluation on the two decommissioning options using the different approaches. The probable reasons are deliberated in the conclusion section. The findings of this study may serve as a basic framework for future assessment of environmental impacts regarding offshore decommissioning activities in Malaysia.

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INTRODUCTION

In the upcoming years, the decommissioning activities especially in the Asian Pacific region will increase as a large number of the existing offshore structures approach the end of their productive live. The platform owners now face the challenging task of selecting the best decommissioning option while reducing the environmental impacts to cater to the increase in public interest. There are approximately 300 shallow water fixed offshore platforms in Malaysian waters and already 48% of it has exceeded the 25-year design life. In view of this trend, offshore decommissioning activity can be expected to rise in the near future. However, it should be noted that only a handful of offshore platforms have been decommissioned till date in Malaysia due to lack of regulatory framework, and weak decommissioning plans (Wan Abdullah Zawawi, N., 2012).

Environmental impacts from decommissioning process and the disposal of removed materials has become a major concern to the owners of the platforms. The major environmental impact from decommissioning appears in the form of gaseous emissions, especially carbon dioxide (CO2), which is the main culprit for global warming (Ngu Pei Jia, A., 2013). The estimated amount of CO2 of around 90,000 tons, released by the decommissioning process of an offshore platform in the North Sea, is comparable with the CO2 emissions from electricity consumption of 14,000 households in the United States in one year. In this study, Life cycle assessment (LCA) is used to estimate the environmental impacts from gaseous emission. The LCA tools utilised in this study are Process-based method and EIO-method. Process-based LCA can be used to identify the particular decommissioning activity that causes the greatest amount of total energy consumption and gaseous emission. On the other hand EIO-LCA eliminates two major issues of the Process-based method, i.e. the defined boundaries and circularity effects; while including the estimation of direct and indirect energy costs which gives a better overview of the environmental impacts of offshore decommissioning. Based on their respective strengths and

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limitations of both methods, the results evaluated will be compared and combined to get more reliable, representative and accurate outcomes.

LCA was performed on two decommissioning options, the complete removal of the platform from the operation site and re-use as an artificial reef, or also known as transforming rigs to reef. The results of these two methods are analysed to recommend the best LCA tool to perform environmental impact assessment for offshore decommissioning activity.

LCA Framework:

A typical LCA framework comprises of four phases, which are goal and scope definition, inventory analysis, impact assessment and interpretation of the results (Poremski, H.J., 1998). Figure 1 shows the flowchart describing the phases of LCA framework.

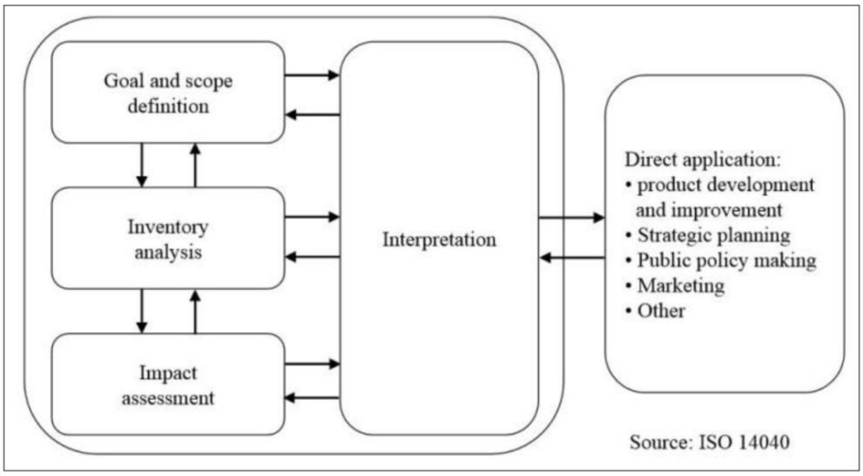

Fig. 1: LCA framework (American National Standards Institute, 1997).

Process-based LCA is the most popular method amongst all LCA methods. There are several tools such as GaBi, Umberto or SimaPro existing in the market which are suitable for conducting this type of LCA. These tools provide data from previous researchers on the environmental impact of materials and processes which can be used by the user to form a system (Lehtinen, H., *et al*., 2011).

The other method is EIO-LCA, which utilises economic input-output tables and industry-level environmental data to construct a database of environmental impacts with reference to a selected economic value (Green Design Institute, 2013). The boundary problem of process phases LCA is solved as the EIO tables capture the interrelations of all economic sectors.

LCA Methodology:

The LCA methodology applied in this study includes four stages based on the ISO standard 14040.

First the assumptions and boundaries are set based on the available data and a published research using LCA analysis conducted for the decommissioning process of Heather Platform from the North Sea, used as a guidance in this study. The conversion factors for the quantification of energy consumption and gaseous emissions associated with the dismantling of platform components, material transportation and recycling based on unit fuel consumption per tonne, recorded by contractors based on their decommissioning experience, were obtained from the research done by Side *et al*. It has to be taken into account that gaseous emissions are particularly sensitive to combustion chamber conditions and vary according to engine age, maintenance and vessels loading.

The data incorporated into the online EIO-LCA model is compiled from surveys and forms submitted by industries to the government for national statistical purposes, which leads to uncertainties in sampling and incomplete data or estimates. The data implemented in the online model is based on the US 2002 Benchmark model. The EIO-LCA method is a linear model and represents impacts through the production of output by the sector based on an economic value (U.S. dollar values). Most of the EIO models represent the producer priced model which has the boundaries of "cradle to gate". This model estimates impacts from resource extraction all the way up to final assembly of the product as it leads to the factory gate (not including delivery). Apart from that, a purchaser priced model has the boundaries of "cradle to consumer”, which includes from resource extraction all the way up to purchase of the product. The appropriate economic input is the producer price with the transportation costs of shipping the product to the point of sale and a profit margin. For this study the purchase priced model is chosen, as the removed materials are returned onshore for recycling (Green Design Institute, 2010).

The first phase of LCA analysis is the goal and scope definition. For this assessment, the goal is conform to the objectives of this study, which require the identification and quantification of the environmental impacts associated with the decommissioning of fixed offshore platforms in Malaysia, and the proposal of relevant mitigation measures for environmental concerns arising with this process. As mentioned earlier, the scope is limited to two decommissioning options: the complete removal and re-use as an artificial reef. A small platform, Platform A, located in the shallow water of the South China Sea is selected as the case study for this project. The boundaries are set according to the assessment of total energy consumption and gaseous emissions for the decommissioning of the platform in the North Sea to ensure the consistency in data evaluation, that no energy is being counted twice.

The second stage, the life cycle inventory (LCI) includes data collection and calculation to estimate relevant inputs and output of the system. For this project the input is the energy consumption, whereas the outputs are the produced gaseous emissions. The four inventory parameters concerned in this paper are Carbon Dioxide (CO2), Nitrogen Oxides (NOx) and Sulphur Dioxide (SO2) and Equivalent Carbon Dioxide due to their significance in the contribution for emissions associated with offshore installations decommissioning. The LCA methods used in this project are Process Based- and EIO-LCA.

For the LCI in Process-based method, to estimate the total energy consumption and gaseous emissions associated with decommissioning of Platform A, the data were obtained by the paper about decommissioning of Heather Platform published by (Side, J.,), the BPEO Study and from documentation documents about the decommissioning process. It should be attended that the well plugging and abandonment (P&A) is not considered in this study. The scope is limited to the decommissioning of structural components: the topside, boat landing and jacket.

For the ease of data evaluation in Process-based LCA, the decommissioning process is divided into several discrete aspects, consisting of marine vessel utilisation, platform dismantling, platform materials recycling, platform materials left at sea and transportation onshore.

The cost input data to perform LCA analysis, using the EIO online model are the estimated cost for complete removal, which is total up to RM 27,187,304.25 (US$ 8,860,386.14). As for the conversion to an artificial reef is no suitable cost information available, the author assumed the cost to be 35% of the costs for complete removal based on comparisons of costs published by (Twachtman Snyder and Byrd, Inc., 2000) for decommissioning the platforms Hidalgo, Gail and Harmony in the Gulf of Mexico. Hence, the costs for the conversion to an artificial reef are assumed to be RM 9,515,556.49, thus US$ 3,101,135.15.

The third phase is the life cycle impact assessment (LCIA) which involves the evaluation of the significance of potential environmental impacts based on the results obtained by the previous stage. After the inventory data is classified into their respective impact category the data is modelled within those categories and finally prioritised and weighted. The impact categories applicable in this conducted LCA are global warming (CO2 and equivalent CO2) and acidification (SO2 and NOx) (Scientific Applications International Corporation, 2006).

The last stage, the life cycle interpretation includes the combination and interpretation of the findings from the inventory analysis and impact assessment. During the final stage of this study, the decommissioning activity, which has the greatest contribution to total energy consumption and gaseous emissions, may be identified and the more appropriate decommissioning option could be suggested based on the results. Furthermore the quantitative outcomes provided by the different LCA tools can be compared with each other. Additionally relevant mitigation measures for environmental concerns, that arises in connection with the decommissioning of fixed offshore platforms could be suggested and recommendations be given.

RESULTS AND DISCUSSION

Process Based LCA:

Table 1 and Figure 2 present the quantitative environmental impact assessment performed, using Process-based LCA in EXCEL for the decommissioning methods considered in this study. The environmental impacts are quantified in terms of total energy consumption and gaseous emissions.

Table 1: Results and percentage difference between complete removal and conversion to artificial reef of Platform A in terms of energy consumption and gaseous emissions using Process-based LCA

Variable	Complete Removal	Artificial Reef	Difference [%]
Energy Consumption [GJ]	37,105	38,151	2.74
SO2 Emissions [kg]	36,409	36,802	1.07
NOx Emissions [kg]	36,372	36,759	1.05
CO2 Emissions [kg]	2,535,263	2,649,652	4.32
Equivalent CO2 Emissions [kg]	1,539,531	1,555,829	1.05
Overall CO2 Emissions [kg]	4,074,794	4,205,481	3.11

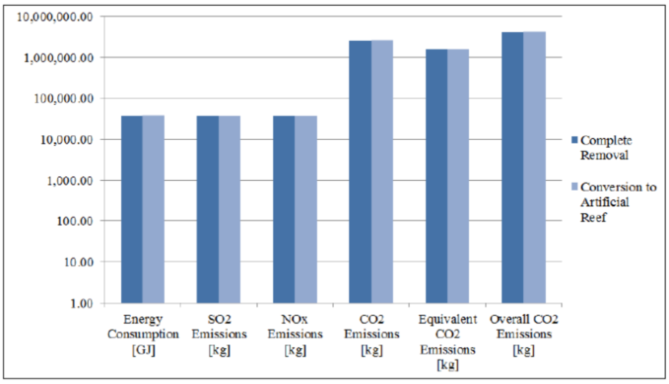

Fig. 2: Comparison between total energy consumption and gaseous emissions depending on decommissioning option for Platform A.

The energy consumption in the case of conversion to an artificial reef is 2.74% higher than performing complete removal. This increase in energy consumption can be related to the transportation of topside to onshore facilities for recycling, which results in greater marine vessel utilisation than in the case of complete removal.

However, the values for total energy consumption and gaseous emissions do not vary widely.

The greatest contributor to the overall CO_2 emission for complete removal (99%) and for conversion to an artificial reef (97%) is the marine vessel utilisation. The CO_2 emissions produced by recycling and transportation to onshore facilities are insignificant (less than 1%). For the option of rig to reef, the platform jacket is left at sea thus does not involve recycling and transportation to onshore facilities. The materials left at sea contribute to the overall CO_2 emissions and energy consumption because it is assumed that the steel, which is left at sea, has to be re-produced from ore which requires great amount of energy and further contribute to gaseous emissions.

SO_2 and NO_x are the main constituents in acid rain, which is also hazardous to the environment. The amount of SO_2 and NO_x emissions by complete removal and conversion to an artificial reef are varies about 1% in difference. The activity which mostly contributes to these gaseous emissions is the utilisation of marine vessel during decommissioning, followed by material recycling for the case of complete removal. The conversion of Platform A to an artificial reef produces less SO_2 and NO_x as compared to the material recycling but produces higher CO_2 emissions due to greater usage of marine vessels, and the emissions produced during the steel production to replace the amount of steel left at sea.

Based on the results obtained by Process-based LCA, it is evident that marine vessel utilisation is the major factor for the energy consumption and the quantity of CO_2, NO_x and SO_2 emissions followed by far by material recycling and the steel production considered for the amount of steel which is left at sea in order to create an artificial reef. From this point it can be concluded, minimising the utilisation of marine vessel will result in the overall reduction on environmental impacts during offshore decommissioning. Process-based LCA shows that the conversion to an artificial reef results in greater impact on environment, which contradicts the popular believe where this option is generally considered to be environmental friendly and beneficial to the marine environment.

For the complete removal option, although greater amount of steel is recovered for recycling purposes, it does not sufficiently compensate the energy consumption and gaseous emission as a result of marine vessel utilisation and the steel re-production.

EIO-LCA:

The total energy consumption and gaseous emissions for complete removal and conversion to an artificial reef of the stated case study are calculated by referring to the standard unit economic value of one million US dollar implemented in the purchaser price model for support activities for oil and gas operations provided by the Green Design Institute's online tool on www.eiolca.net. Table 2 and Figure 3 present the comparison between energy consumption and gaseous emission using EIO-LCA approach.

On the basis of the obtained results and as consequence of the applied calculation model with dependence of the respective option costs, it is straightforward, that complete removal requires about 65 % more energy and releases about 65 % more harmful gaseous emissions. In contrast to Process-based LCA, in this analysis conversion to an artificial reef is the more appropriate decommissioning option in terms of energy consumption and gaseous emissions due to lower cost assumed based on empirical estimations which consider the re-use as an artificial reef as more cost-effective.

Table 2: Results of complete removal and conversion to artificial reef of Platform A in terms of energy consumption and gaseous emissions using EIO-LCA.

Variable	Standard Unit (1 million US Dollar)	Complete Removal (8.86 million US Dollar)	Conversion to an Artificial Reef (3.10 million US Dollar)
Total Energy Consumption [GJ]	7790	69,022.41	24,157.84
SO2 Emissions [kg]	1890	16,746.13	5,861.15
NOx Emissions [kg]	6330	56,086.24	19,630.19
Overall CO2 Emissions [kg]	650000	5,759,250.99	2,015,737.85

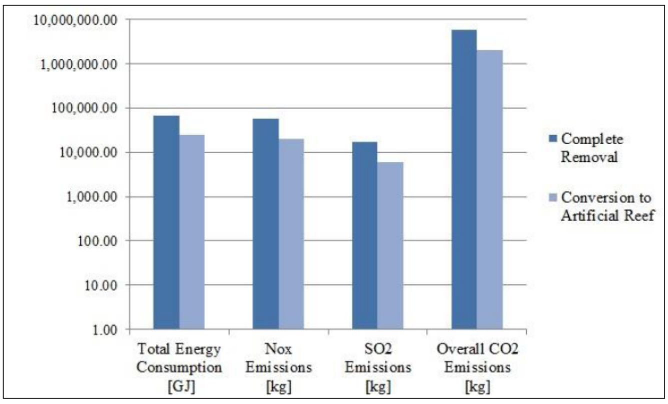

Fig. 3: Comparison between energy consumption and gaseous emissions depending on decommissioning option for Platform A.

Comparison of Results From Process Based- And EIO-LCA:

In this study, by conducting the two different LCA methods, the Process-based method and EIO-LCA method, the outcome is found to be different. Based on the results from Process-based LCA, complete removal of the platform located in the Malaysian shallow water is the better decommissioning method in terms of energy consumption and gaseous emissions. On the other hand by performing EIO-LCA, conversion to an artificial reef requires less energy and produces less harmful gaseous emissions. Besides, the difference between the values estimated using the EIO online model are much higher corresponding to the assumed cost difference of 65% between complete removal and conversion to an artificial reef. However, the differences between the numerous results obtained by establishing Process-based method just vary in the range of 1.05 %and 4.32 %. For this LCA analysis assumptions were made in terms of vessel utilisation and travel distances due to lack in available information. The higher amount of vessel utilisation and greater travel distances due to material transport both to the artificial reef site and to the selected fabrication yard for further recycling purposes lead to the higher energy consumption and discharge of gaseous emissions compared to complete removal. Otherwise the results for complete removal and the conversion to an artificial reef correspond in the identification of the decommissioning activity contributing the most to the investigated issues, which is in both cases the vessel utilisation.

Several factors were identified to be the causing the difference in results obtained from both LCA approaches. Among those are the different perspectives of the LCA tools, the difference in the input data assumed, which are the estimated cost for each decommissioning option and vessel utilisation, travel distances, conversion factors as well as the quantity of materials for recycling, left at sea and transported onshore respectively.

Recommendations:

Process-based LCA proves that the conversion to an artificial reef is not by default the better decommissioning option. More research needs to be executed to investigate the benefits, side effects and environmental impacts caused by this decommissioning option depending on the platform size, location, surrounding conditions as well as the effects of monitoring and maintenance issues.

For the future implementation of LCA in the evaluation of environmental impacts associated with decommissioning of offshore structures, it is recommended to have a complete set of detailed and relevant data such as platform characteristics, structural data, travel distances and vessel utilisation for conducting LCA analysis and to minimise the assumptions applied in this study. The uncertainty and sensitivity analysis could be carried out, if a complete set of reliable and relevant data is available for implementation.

Conclusion:

In conclusion, by conducting the Process-based and EIO-LCA method in quantifying the environmental impacts, the outcome is totally different. Using the former, complete removal is the better decommissioning option in terms of energy consumption and gaseous emissions (CO2, SO2 and NOx). On the other hand by performing EIO-LCA conversion to an artificial reef requires less energy and produces less harmful gaseous emissions. The availability of input data and assumptions made due to that plus the different concepts of the tools could lead to the opposing outcome.

In this study, the use of Process-based method for the assessment of the energy consumption and the gaseous emissions related to the decommissioning of Platform A is concluded as the better LCA tool. The conclusion is made based on the understanding that there are several stages of the decommissioning process implemented and the activity which has the greatest contribution to environmental impact can be identified. Although a lot of assumptions were necessary due to limitation in data availability, the results should be much more accurate than the results provided by EIO-method. The findings from this paper could serve as a basic framework to be used in the near future to assess the environmental impacts associated with offshore decommissioning activities in Malaysia by using LCA analysis.

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REFERENCES

American National Standards Institute, 1997. "ISO International Standard: Environmental management - Life cycle assessment - Principles and Framework.

Green Design Institute, 2010."Assumptions, Uncertainty, and other Considerations with the EIO-LCA Method," 2010. [Online]. Available: http://www.eiolca.net/Method/assumptions-and-uncertainty.html. [Accessed 15 October 2013].

Green Design Institute, 2013. "Limitations of the EIO-LCA Method and Models," [Online]. Available: http://www.eiolca.net/Method/Limitations.html. [Accessed 14 June 2013].

Lehtinen, H., *et al*., 2011. "A Review of LCA Methods and Tools and their Suitability for SMEs," Europe Innova.

Ngu Pei Jia, A., 2013. CA for Offshore Installations Decommissioning: Environmental Impact Assessment," Universiti Teknologi Petronas.

Poremski, H.J., 1998. "Life Cycle Assessment - Development Planning through Decommissioning," Offshore Technology Conference held in Houston, Texas: OTC 8788.

Scientific Applications International Corporation, 2006. "Life Cycle Assessment: Principles and Practice.

Side, J., S. Kerr and R. Gamblin, "An Estimation of the Energy Consumption and Gaseous Emissions Associated with Heather Platform Decommissioning Options," SPE 37858 European Environmental.

Twachtman Snyder and Byrd, Inc., 2000. "State of the Art of Removing Large Platforms Located in Deep Water (Final Report)," Houston, Texas.

Wan Abdullah Zawawi, N., M. Liew and K. Na, 2012. "Decommissioning of Offshore Platform: A Suitable Framework," Science & Engineering Research, Sabah, Malaysia.