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Research on application of decision-making tool of LCA

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ABSTRACT

A LIME (Life-cycle Impact assessment Method based on Endpoint modeling) and JEPIX (Japan Environmental Policy Index) which are the environmental assessment methods recently developed in Japan are analyzed. Each method is constructed in an original target. They, however, have some common features. The cause of differences and common features are analyzed in this research. The analysis is done by using the example of applying LIME and JEPIX to the environmental impact assessment according to undertaking activities obtained from environmental report, environmental impact according to economic activity of the entire Japan, and individual product. Then, how the user should select the method is described in this research.

LIME and JEPIX could be used as decision making tool for effective policy target. It is better if these two methods are used at the same time. Environmental impacts calculated by LIME is an efficient policy target in a corresponding case to law achievement situation calculated by JEPIX. The integration of these two methods will balance the cost and environmental impacts on setting up a policy target. This research will be applied to develop an integration LCA method which can be used for decision making of the policy.

Keywords: Decision-making, LCIA, LIME, JEPIX

1. INTRODUCTION

Life cycle assessment (LCA) has been widely used in Japan. Two newly developed LCA methods, LIME and JEPIX has been introduced as an effort of Japanese scientists and industrial engineers to response to the wave of LCA application [1][2]. Even though these two methods have some common features, their differences on evaluation technique, and impact categories might confuse the practitioners, especially when using LCA results for decision making. The main difference is on the assessment approach. LIME is an end-point assessment method, while JEPIX is based on mid-point approach. The second is purpose of methods. LIME is a method to calculate the environmental load by input and output of material. It is developed for scientists and practitioners to understand the influence of each material on the environment based on scientific background. On the other hand, JEPIX is a method based on distant-to-target approach which is influenced by politics. The JEPIX is not a technique to calculate environmental burden based on scientific background. This research is to analyze the similarities and differences of these two LCA methods by two case-studies. In addition, a suggestion on how to select an appropriate method for decision making is proposed in the research.

2. METHODOLOGY

This study is mainly based on the statistical analysis of the two LCA methods using their impact categories to identify the similarities and differences. Eleven impact categories are global warming potential (GWP-CO2 equivalent), ozone depletion potential (ODP-CFC equivalent), dioxin, heavy metals, total nitrogen, total phosphorous, biological oxygen demand (BOD), chemical oxygen demand (COD) suspended particulate matter (SPM-25), nitrogen oxide (NOx), and sulphur dioxide (SO2).

In addition, final assessment results of JEPIX (eco-point) are used to compare with four safeguard subjects of LIME to analyze the correlation of these methods. The four safeguard subjects of LIME are human health (expressed in yen per DALY), social welfare (expressed in monetary value as Japanese yen per yen), biodiversity (expressed in yen per EINES), and primary production (expressed in yen per ton). Plastic is used as a case-study for this analysis. Another case-study on environmental impacts of a whole company using these two methods is carried out to analyze the environmental cost caused by its business activities.

3. RESULTS AND DISCUSSION

The first statistical analysis is to analyze the correlation of impact categories of LIME and JEPIX. Using eleven impact categories as indicated above, a similar trend in both methods is observed when arranging the methods according to magnitude of the impact as 1 kg of each environmental impact categories (respective substance equivalent). The most serious impact substance in both methods is dioxin. One kilogram of dioxin released would cost 300 million yens according to LIME method and 1x1012 eco-points (EIP) according to JEPIX method. Ozone depletion potential (CFC equivalent) is the second largest impact categories in both LIME and JEPIX methods (0.8 million yens and

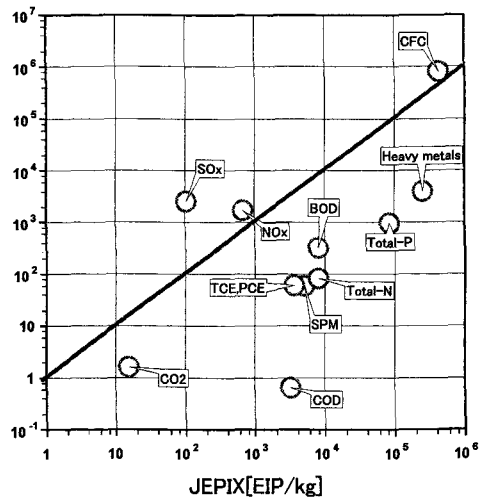

Figure 1. Correlation between LIME and JEPIX by eleven impact categories

3x106 EIPs). Global warming potential (CO2 equivalent) is the relatively insignificant impact categories compared to the others. One kilogram of CO2 equivalent released to the environment would cost 2 yen according to the LIME method, and account for 100 EIPs according to JEPIX method. A difference in significance of impact categories is on COD. In LIME method, one kilogram of COD released to water would cost 0.6 yen (ranked number 8 in the list of impact categories), while in JEPIX method, it would account for 2x104 EIPs (ranked number 11 in the list of impact categories).

Despite the similar trend of significance on impact categories, the statistical analysis indicates insignificant correlation between these two methods as shown in figure 1. This difference would cause tolerance in final results of the LIME and JEPIX methods. As a result, these LCA results would lead to different decisions in practice. A case-study on plastic clearly verifies this conclusion as described below.

A case-study on plastic uses 11 different thermo-plastics and biodegradable plastic. The life cycle inventory data of these 11 thermo-plastics were obtained from various sources including the Association of Plastics Manufacturers in Europe (APME) [3], Eco-leaf program [4], and Novamont company in Italy [5][6]. The life cycle inventory data of plastics obtained from APME is on the cradle-to-gate system, while the others are on the cradle-to-grave system. The final EIPs of 11 plastics are compared with safeguard subjects of LIME to analyze the correlation between these two methods. Results of analytical study show a strong correlation between human health safeguard subject of LIME and JEPIX eco-point with the R-square value of 0.952 (Figure 2). In addition, social welfare safeguard subject and JEPIX have a significant correlation with the R-square value of 0.806. Biodiversity and primary production safeguard subjects, however, showed relatively weak correlation with JEPIX results. There are three main reasons of the similarities and differences of the LIME and JEPIX. First of all, the human health issue is also a main concern of all interested parties including the Government, NGOs, academic institutions, and citizens. Therefore, either being based on the politics or interests of consumers, both methods should give priority on this common sense. Secondly, social welfare issue also has similar reasons of human health subject. This social property is to be reflected in the setting of a present target value in policy. Finally, a reason for the difference on biodiversity and primary production and JEPIX is on the consideration of influence on the eco-system of political issues. The political target on the environment hardly sees the damage on eco-system as one of the main priority. JEPIX is mainly based on the political target, thus it

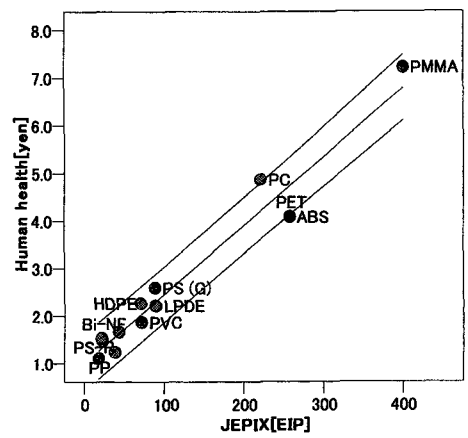

Figure 2. Correlation between JEPIX and safeguard subject-human health of LIME

Table 1. Inventory data on environmental substances and total sales of companies

Company name	Employee number	Sales (Billion ¥)	GHG [ton]	NOx [ton]	SO x [ton]	COD [ton]	BOD [ton]
Sharp	46,518	1,854	1,350,000	27	4	23	33.2
NEC	32,054	4,991	1,140,000	172	44	25	21
Fujitsu	40,483	5,255	1,349,000	1,940	483	377	545
Panasonic	267,196	7,299	3,283,000	1,520	278	951	1579
Sony	168,000	6,686	2,179,736	308	63	73	90
Hitachi	340,939	8,001	3,621,000	1,188	408	247	480
Mitsubishi	110,279	3,639	2,180,000	12	106	51	78

relatively less focus on these two issues. On the other hand, LIME is based on scientific background which equally considers the impact on biodiversity and primary production safeguard subjects.

Beside a case-study on plastics, environmental impact assessment at company level using the LIME and JEPIX was carried out. Seven big Japanese companies including Sharp, NEC, Fujitsu, Panasonics, Sony, Hitachi and Mitsubishi are used for this case-study. Five environmental impact substances including greenhouse gases, NOx, SOx, COD, and BOD are investigated based on the annual environmental reports in 2003 produced by these companies. Data on the companies' profit is obtained from Standard & Poor Consultant Company (Table 1).

The LCA results of both LIME and JEPIX are almost similar. Figure 3 illustrated the environmental cost caused by companies' business activities in 2002 fiscal year. The figure clearly indicates that Panasonics and Hitachi companies created largest environmental cost and impacts among the seven companies. Sony and Mitsubishi follow as the second group to cause significant environmental impact in terms of monetary and eco-point to society and eco-system. NEC and Sharp cause relatively less impact on environment and society. These results tell us the true about the external cost of several billion yen per year borne by our society for enterprises to run their business. Similarly, the eco-points using JEPIX help company to identify their priority level of reducing environmental impacts.

In addition, further analysis indicates that environmental cost per 10,000 yen of company profit varies by company (Figure 4). A ten thousand yen profits gained by Sharp would cost almost three times more on environment and society than that of NEC and about two times more than that of Sony. Similarly, a ten thousand yen profits gained by Mitsubishi Company would cost about double on environment and society than that of Sony. Results of analysis show that our society has to bear several thousand yens for each ten thousand yen profits gained by the companies. Furthermore, the study finds that using results of LIME or JEPIX methods alone for decision making is not enough to lead to the right direction. The environmental cost per 10,000 yen profits is able to reflect the true cost on the environment and society.

Despite these facts, LIME and JEPIX could be used as decision making tool for effective policy target. It is better if these two methods are used at the same time. Environmental impacts calculated by LIME is an efficient policy target in a corresponding case to law achievement situation calculated by JEPIX. The integration of these two methods will balance the cost and environmental impacts on setting up a policy target (Figure 5).

Nevertheless, the LIME and JEPIX methods are needed to be improved before they can be used as a decision making tool. First of all, the reliability of the conjoint analysis and damage function integration in LIME method has to be strengthened. In addition, a question is how to verify the result of external cost in LIME is needed to be answered scientifically. Secondly, for the JEPIX method, no weighting analysis among impact categories has been carried out. The

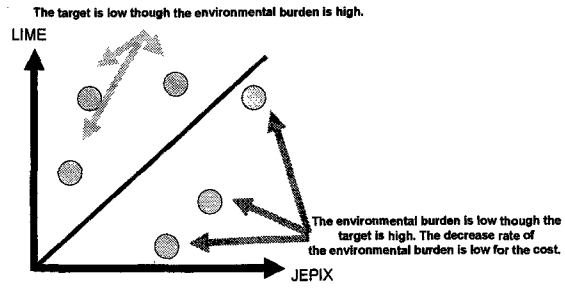

Figure 5. Model to integrate LIME and JEPIX for policy making decision

weighting factors for each impact categories are important because one eco-point caused by CO2 emission is not equal to one eco-point caused by the CFC emission. Thirdly, sensitivity analysis for JEPIX method is needed. The reliability of JEPIX results is influenced by the accuracy of Japanese actual flow data. Finally, JEPIX method has not considered the impact of resource consumption especially on the depletion of non-renewable resource.

4. CONCLUSION

In conclusion, the research has tried to statistically analyze the similarities and differences of the LIME and JEPIX methods. The differences would lead to different direction of the policy. The integration of these two methods is needed to increase the reliability on decision of policy. In order to reduce the cost load of our society, LIME method has to further develop for a better eco-efficiency method. Furthermore, by comparing the LIME and JEPIX methods, reducing environmental impacts on the whole society in order to realize the environmental regulation targets. In the near future, the study will attempt to develop an integration LCA method which can be used for decision making of the policy.

Acknowledgement

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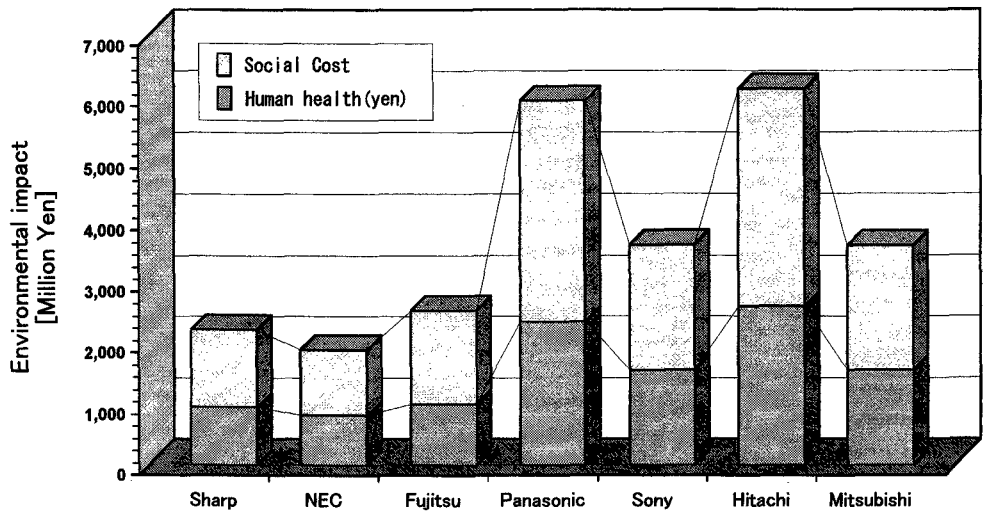

Figure 3. Environmental cost caused by companies' business activity to society per year using LIME method

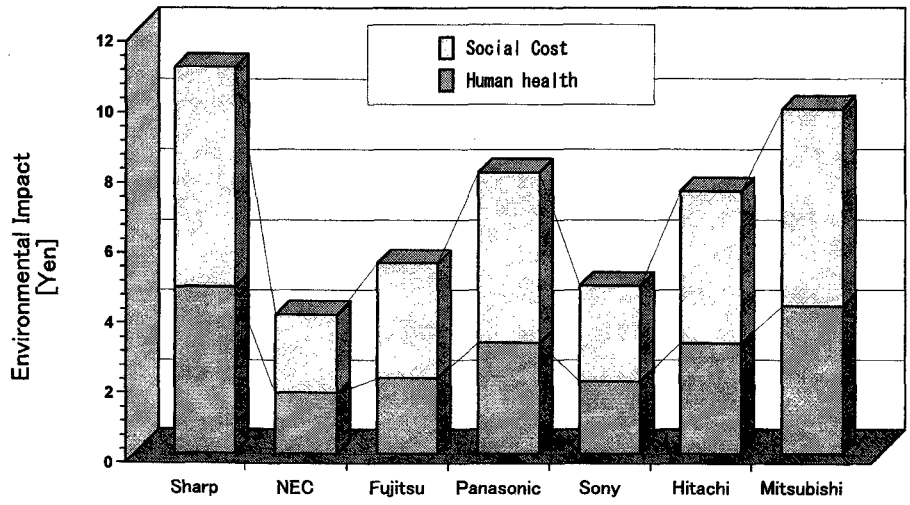

Figure 4. Environmental cost for 10,000 yen profit of company