

## 2. A Method of Evaluating Corporate Environmental Performance using non-Disclosure Emission Penalty Factor

This study proposes an evaluation method of environmental performance which realizes inter-company comparisons. This method employs an integrative technique of environmental loads which translates the emission amounts of two or more environmental load substances, to a single measurement. When existing integrative technique is considered in terms of external evaluation, these techniques assume that all of the necessary data for calculations are disclosed by companies. However, today's disclosure level is not sufficient for the evaluation to work properly.

This method imposes estimated emissions including penalties for those companies with undisclosed emission data. The penalty is calculated for each substance using a non-disclosure emission penalty factor. This enables external evaluation with the current disclosure level, and provides incentives to the companies that disclose emission data.

In addition, this method defines the organizational boundaries and business scope of emission data, and compensates each company's size in its industry. Therefore, it can compare companies of different type and of different industry.

Key words : environmental evaluation, environmental performance, integrative technique of environmental burden, JEPIX, environmental management, environmental report

### 1. Introduction

#### 1.1 Cooperate Environmental Efforts

In corporate activities, reduction of environmental loads has become an important issue. Accordingly, there is tremendous effort made to disclose corporate emission data in environmental reports.

The intentions of those efforts are to comply with government environmental policy such as CO<sub>2</sub> reduction, to deal with the environmental issues the business partners or clients concerns, and to boost cooperate image enhancement.

According to a questionnaire survey conducted by the Japanese Ministry of Environment [1] in fiscal year 2003, 38.7% of the companies listed published environmental reports. In the investigation in 2005, 47.0% of the companies listed made reports, so it can be pointed out that the ratio of enterprises making environmental reports is increasing.

#### 1.2 Significance in Evaluation Methods of Environmental Performance

This study pays an attention to the evaluation methods of environmental performance, which stimulates

corporate activities for reducing environmental loads and development of comprehensive environment-conscious management. Such methods are employed for in-company administration use and for out-company use by stakeholders.

The former methods vary according to the purpose of each company [2]. They are used for measuring ecological effect, and prioritizing and controlling environmental activities [3]. This elevates the level of administrations to improve corporate activities for reducing environmental loads and development of comprehensive environment-conscious management.

The later activates inter-company comparison of environmental performance and leads to competitive effect in corporate environmental efforts through the use of government, consumers, or eco-fund. This research focuses on the method not only for the in-company use but also for the out-company use. It enables the evaluation by the external stakeholders

### **1.3 Characteristics of the Method**

#### **1.3.1 Existing Methods**

##### **(1) Single Score Method - JEPIX and LIME**

Integrative technique converts emission data of multiple substances to a single-score environmental indicator. JEPIX (Environmental Policy Priorities Index for Japan) assesses the distance to target – the environmental policy versus actual environmental situation based on the mass flow data [4] in order to obtain the per-emission weighted factor of environmental load for each substance. JEPIX identifies twelve categories of environmental aspect and per-emission environmental load of each substance in virtual unit EIP (Environmental Impact Point).

LIME [5] is an impact assessment method based on the end-point modeling. It assesses damages, which are caused by environmental load, to the end points such as human health, biological diversity and social asset. Social cost per emission of each substance is estimated and total damage cost for environmental load is calculated in monetary unit.

In order to employ those methods for external evaluation of companies, all of the emission data should be disclosed.

##### **(2) Sustainable Management Rating**

There are three major categories - management, environment and society – for evaluating company in Sustainable Management Rating [6]. A category consists of about eight subcategories. For each subcategory, company is evaluated and scored to assess sustainable management of corporate activities in a comprehensive manner. Since this is just a numeric conversion of qualitative aspect of each category, evaluations results are often subjective and ambiguous.

##### **(3) Environmental Accounting Guideline**

This is a framework, which is provided by Japan Ministry of the Environment, for supporting corporate effort in environmental accounting. Cost of environmental conservation and its economic effect are

measured in monetary unit or in physical quantity [7]. Although it is a method of integrating and evaluating environmental and financial data, calculation of the economic effect tends to be arbitrary.

### **1.3.2 Purposes**

This study proposes an evaluation method of environmental performance which realizes inter-company comparisons. This method employs an integrative technique of environmental loads, which translates the emission amounts of two or more environmental load substances, to a single measurement.

Although the conventional qualitative methods enable to evaluate not only corporate activities for reducing emission of substance but also those in whole spectrum of environmental management, subjective and ambiguous aspect of the evaluation result may be problematic. Using numerical data disclosed in environmental report, this method implements external evaluation of companies in a quantitative way.

In this study, proposed method is applied to the automobile industry and the precise machinery industry using EcoFactor in JEPIX as an integrative technique. Comparison with other evaluation methods is also presented.

## 2. Method of Calculating Presumed Emission

### 2.1 Overview of non-Disclosure Emission Penalty Method

Not only in the area of environment, there is a tendency for companies not to disclose inconvenient data [8]. This method calculates a single-score environmental loads even if some emission data of substance is not disclosed (NOTE(1)). Presumed emission including penalty is applied in a uniform way for non-disclosing companies. Concept of this method is illustrated in Figure 1. For a given substance  $M_j$  with environmental impact, a group of companies are divided into disclosing companies and non-disclosing companies. Next, the largest emission in the disclosing companies is defined as the standard emission of the group and presumed emission is calculated by multiplying non-disclosure emission penalty factor  $\alpha_{M_j}$  with the standard emission. The presumed emission is used for complementing the undisclosed emission data of the non-disclosing group. Then, single score integrated method will be applied.

In this method, it is assumed companies to be evaluated belong to the same industry. Difference of industry or industry-dependent emission trend should be taken into account in order to obtain reasonable presumed emission.

It should be noted that non-disclosure emission penalty factor  $\alpha_{M_j}$  is set to larger than 1.0. This results that undisclosed emission is evaluated worse than the worst emission of disclosing companies, and provides the non-disclosing companies with the incentives of disclosure. The factor  $\alpha_{M_j}$  varies depending on the disclosure rate in the group and the variance of emissions in the disclosing company group. Calculation process of the factor is explained in 2.2.4

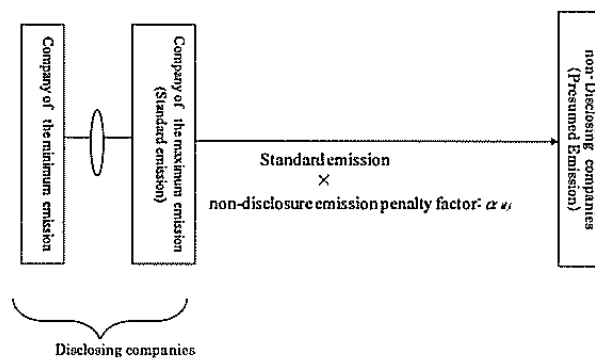


Figure 1 Estimation of non-Disclosed Emission

## 2.2 Details of the Proposed Method

### 2.2.1 Definitions of Symbols

Number of companies to be evaluated:  $NC$

Companies to be evaluated in the same industry group:  $C_i (i = 1, 2, \dots, NC)$

- Substance with environmental impact:  $M_j$  ( $j = 1, 2, \dots, m$ )
- Number of the companies disclosing emission data of  $M_j$ :  $NC_{M_j}^{OP}$
- Emission of the substance  $M_j$  by company  $C_i$ :  $ES_{1M_j}^{C_i}$
- Boundary-aligned  $ES_{1M_j}^{C_i}$ :  $ES_{2M_j}^{C_i}$
- Domestic boundary-alignment ratio of  $C_i$ :  $BS_1^{C_i}$
- Global boundary-alignment ratio of  $C_i$ :  $BS_2^{C_i}$
- Global consolidated sales amount of  $C_i$ :  $S_1^{C_i}$
- Domestic consolidated sales amount of  $C_i$ :  $S_2^{C_i}$
- Individual sales amount of  $C_i$ :  $S_3^{C_i}$
- Non-Disclosure Emission Penalty Factor of  $M_j$ :  $\alpha_{M_j}$
- Max  $\alpha$* : Upper bound of  $\alpha_{M_j}$
- Min  $\alpha$* : Lower bound of  $\alpha_{M_j}$
- Presumed Emission of substance  $M_j$ :  $P_{M_j}$
- Set of companies belonging to the standard group of  $M_j$  emission:  $D_1^{M_j}$
- Number of the companies belonging to  $D_1^{M_j}$ :  $ND_1^{M_j}$
- Average emission of  $M_j$  in  $D_1^{M_j}$ :  $ED_1^{M_j}$
- Set of companies belonging to the superior group of  $M_j$  emission:  $D_2^{M_j}$
- Number of the companies belonging to  $D_2^{M_j}$ :  $ND_2^{M_j}$
- Average emission of  $M_j$  in  $D_2^{M_j}$ :  $ED_2^{M_j}$
- Disclosure rate of  $M_j$ :  $R_{M_j}^{OP}$
- Disclosure coefficient:  $\alpha_{M_j}^{OP}$
- Evaluation coefficient of standard emission of  $M_j$ :  $\alpha_{M_j}^{BASE}$
- Evaluation value of standard emission  $M_j$ :  $EV_{M_j}$
- Point of technology ownership ratio of  $M_j$ :  $EVP_1^{M_j}$
- Technology ownership ratio of  $M_j$ :  $R_{M_j}^{D2}$
- Point of technology gap rate of  $M_j$ :  $EVP_2^{M_j}$
- Technology gap rate of  $M_j$ :  $TG_{M_j}$
- Ecofactor of  $M_j$ :  $EF_{M_j}$
- Total emission of  $C_i$  in single score method:  $EI_{C_i}$

## 2.2.2 Adjusting Organizational Boundary and Business Process

### (1) Organizational Boundary and Business Process Range

Boundary is the organizational scope within which emission data is summed up. SMRI (Sustainable Management Rating Institute) classifies the boundary into “individual”, “major consolidated”, “most consolidated”, and “all consolidated” [6]. Complying with the method, three kinds of classes on basis of financial accounting - “domestic individual”, “domestic consolidated”, and “global consolidated” – are employed. This is also because emission data is often classified on a basis of domestic and global geometry.

Although the scope of consolidation is different for each company, that difference is not considered in this study. It is impossible to judge if “consolidated” means “major consolidated” or “all consolidated” in environmental report of the company. Since corporate boundaries are not necessarily unified in the current environmental reports, the maximum emission after each boundary is aligned is set to the standard emission.

Business process constitutes different kinds of boundaries for each company. Range of business process such as production area and logistics area is the scope in which emission data is collected and summed up. Without those ranges unified, results of the comparison among companies are not fair.

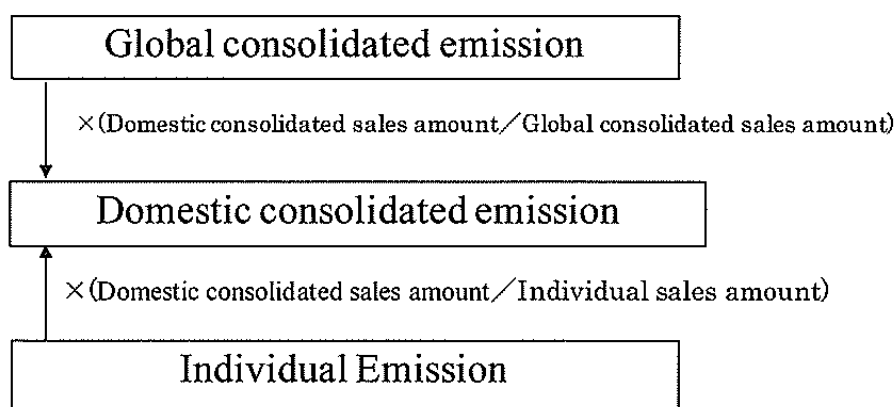
## (2) Procedure of the Alignment

Firstly, emission data for each substance should be collected from environmental report. In this data collection process, each organizational boundary and business process range should be as same as possible. If impossible for some emission data, then the following alignment procedure should be applied.

### 1) Procedure of Boundary Alignment

In this study, domestic consolidate is set as boundary because Ecofactor in JEPIX is used. JEPIX is calculated based on the Japanese environmental policy. Geographical segmentation is set to “domestic”. Segmentation of financial accounting is “domestic consolidated”, which is the most extensive segmentation. Domestic consolidated emission data is collected as much as possible.

When only domestic individual or global consolidate emission data is available, boundary of each emission is translated to the domestic consolidated emission. This process is illustrated in Figure 1. Correction value for alignment is defined as the ration of post-alignment sales amount to pre-alignment sales amount. Boundary aligned is obtained by emission data in the environmental report multiplied with the correction value for alignment (NOTE (2)).



**Figure 2 Alignment of Organizational Boundary**

When emission data is domestic individual, correction value for alignment is defined as domestic boundary-alignment ratio of  $C_i$  as in formula (1).

$$BS_1^{C_i} = S_2^{C_i} / S_3^{C_i} \quad (1)$$

When emission data is global consolidated, correction value for alignment is defined as global boundary-alignment ratio of  $C_i$  as in formula (2).

$$BS_2^{C_i} = S_2^{C_i} / S_1^{C_i} \quad (2)$$

## 2) Procedure of Business Process Range Alignment

Each company employs various categories of business process. Currently, environmental report is not sufficient to obtain emission data with unified range of business process. Therefore, emission data of the most extensive and exclusive business process is collected as much as possible.

Business process aligned emission data is obtained by summing up emission data of exclusive ranges of business process, which are aligned. Suppose that a given company  $C_i$  consists of  $n$  ranges of exclusive business process and it discloses emission data of substance  $M_j$  for each range of the process. Emission data with business process aligned is obtained as in formula (3).

$$ES_{1M_j}^{C_i} = \sum_{k=1}^n (E_{C_{ik}}^{M_j} \times BS) \quad (3)$$

where, boundary correction value  $BS$  is calculated from either formula (1) or (2) according to the  $E_{C_{ik}}^{M_j}$  boundary.

### 2.2.3 Company Size Alignment

#### (1) Necessity of company size alignment

In general, as company size grows, its emission increases. Standard emission is selected from those of companies with different size and presumed emission is obtained from the standard emission multiplied with the penalty factor. Without company size alignment, presumed emission for the companies that are smaller or larger than the one with the standard emission cannot be fair for comparison use. All of the company emission should be aligned to the biggest size company in advance.

#### (2) Procedure of Company Size Alignment

Emission data with boundary and business process aligned is adjusted to the company with the maximum sales in the industry by the sales ratio as in formula (4).

$$ES_{2M_j}^{C_i} = ES_{1M_j}^{C_i} \times \left( S_{max} / S_1^{C_i} \right) \quad (4)$$

where,  $S_{max}$  is sales of the biggest sales company.

### 2.2.4 Determine the Upper and Lower Bounds of the Penalty Factor

Non-disclosure emission penalty factor  $\alpha_{Mj}$  is calculated for a given substance. Firstly, the upper and lower bounds of the factor are determined because presumed emission should have limited influences on the corporate score of evaluation. Although the bounds should be set for each substance depending on its trait, they are set commonly across all substances because disclosed emission data is currently limited in this study. When more emission data is available in the future, those bounds should be set for each substance.

For a given substance, firstly, arrange emission data with their boundary, business process and company size aligned in ascending order to calculate ratios of adjacent emissions. The maximum value among those ratios is set to the upper bound of the factor. The minimum value is set to the lower bound.

Since standard emission and presumed emission are adjacent in the rank order and the penalty factor is the ratio between the two, choosing the lower and upper of the factor among those ratios of adjacent emissions in the rank order is appropriate. Definitions of the upper bound *Max $\alpha$*  and lower bound *Min $\alpha$*  are shown in formula (5) and (6) respectively.

$$\text{Max } \alpha = \max (ES_{2Mj}^{Ci+1} / ES_{2Mj}^{Ci}) \quad (5)$$

$$\text{Min } \alpha = \min (ES_{2Mj}^{Ci+1} / ES_{2Mj}^{Ci}) \quad (6)$$

$$\{i = 1, 2, \dots, NC-1 \quad j = 1, 2, \dots, m\}$$

,where boundary-aligned emission of company  $Ci$  for substance  $Mj$  :  $ES_{2Mj}^{Ci}$  is in ascending order. Zero divide is not considered.

### 2.2.5 Calculation of non-Disclosure Emission Penalty Factor

#### (1) Overview

Non-disclosure emission penalty factor is defined as in formula (7)

$$\alpha_{Mj} = \alpha_{Mj}^{OP} \times \alpha_{Mj}^{BASE} \quad (7)$$

Here,  $\alpha_{Mj}^{OP}$  is disclosure coefficient and  $\alpha_{Mj}^{BASE}$  is evaluation coefficient of standard emission

#### 1) Disclosure Coefficient

Disclosure coefficient is determined by the disclosure rate of emission data in industry. It is assumed that the disclosure coefficient increases at proportional rate to the disclosure rate. As disclosure rate becomes larger, disclosure coefficient is set so that penalty to the non-disclosing companies increases. In this method, it is regarded that mission data disclosed by one company could be disclosed by the others in the same industry. This provides those companies with the incentives of disclosure. If only leading companies disclose emission and disclosure rate is low in industry, it is not appropriate to depreciate the others. In that case disclosure coefficient is adjusted small in order to alleviate penalty.



The maximum value of the disclosure coefficient is set to the upper bound of the penalty factor  $\alpha_{Mj}$ . Minimum value is discussed later.

## 2) Evaluation Coefficient of Standard Emission

Since presumed emission is calculated based on the standard emission, it should be evaluated in terms of industry-wide emission level. If the standard emission is appreciated, associated presumed emission should be appreciated. Even if standard emissions of two industries are the same, their presumed emissions could be different because of the evaluation coefficient of standard emission. It influences penalty factor of each industry to differentiate the evaluation result for their emissions.

Following two cases are distinguished:

- Just one company with standard emission is inferior to the others.
- Many companies including the one with standard emission are inferior to the others.

In the first case, the standard emission is depreciated in order for the penalty factor to become large. In the second case, the standard emission is depreciated in order for the penalty factor to become small.

Evaluation coefficient of standard emission is used to evaluate to what extent the standard emission lags behind from the average level of emission in the industry. This coefficient will contribute for decreasing the penalty factor  $\alpha_{Mj}$  when the standard emission of the industry is appreciated, or when the company does not lag behind the others. Evaluation coefficient of standard emission takes the maximum value one and the minimum value zero.

## (2) Procedure of Calculating non-Disclosure Emission Penalty Factor

### 1) Calculation of Disclosure Coefficient

In order to calculate disclosure coefficient for each substance, disclosure rate should be obtained. It is defined by the formula (8).

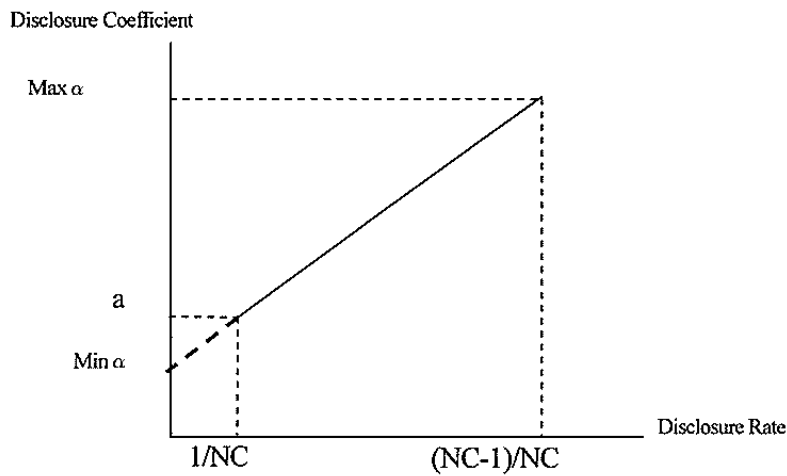
$$R_{Mj}^{OP} = NC_{Mj}^{OP} / NC \quad (8)$$

Figure 3 shows the relationship between Disclosure Rate and Disclosure Coefficient

Since the maximum number of the evaluation value of standard emission is 1.0, disclosure coefficient takes the upper bound of  $\alpha_{Mj}$  (i.e.  $Max\alpha$ ) when all but one company discloses emission data and the disclosure rate is the maximum (i.e.  $(NC-1)/NC$ ). Theoretically, non-disclosure emission penalty factor  $\alpha_{Mj}$  should take the lower bound value  $Min\alpha$  when disclosure rate is zero. However, it is not necessary to presume emission when no company discloses emission data.

Therefore,  $\alpha_{Mj}$  takes the lower bound value  $Min\alpha$  when just one company discloses emission. This is illustrated by the formula (9).

$$\alpha_{Mj}^{OP} = \{NC \times (Max\alpha - Min\alpha) / (NC - 1)\} \times R_{Mj}^{OP} + Min\alpha \quad (9)$$



**Figure 3 Relationship between Disclosure Rate and Disclosure Coefficient**

Here, let the disclosure coefficient in case disclosure rate is  $1/NC$  be “a” and the ratio of  $Max \alpha$  to “a” be the minimum value of the evaluation coefficient of standard emission. This results that  $\alpha_{Mj}$  ranges from more than or equal to  $Min \alpha$  to less than or equal to  $Max \alpha$

The minimum value of Evaluation value of standard emission:  $Min\alpha/a$

### (3) Calculation of the Evaluation Coefficient of Standard Emission

Evaluation coefficient of standard emission is a measure that evaluates to what extent the standard emission lags behind the other companies disclosing the emission, and is determined by the evaluation value of standard emission.

The amount of emission depends on the technology to reduce environmental loads. Standard emission is evaluated in terms of the technology ownership ratio and technology gap in the disclosing company group.

In order to calculate the evaluation coefficient of standard emission, firstly, the company group is divided into the standard group and superior group. Standard group produces more emission than the average of all companies and is regarded as those which do not own the reduction technology of the substance. Superior group produces less and is regarded as those with reduction technology.

Technology ownership ratio is a proportion of superior group companies in the all disclosing companies. Technology gap rate is ratio of average emission of the superior group to that of the standard group. Technology ownership ratio is translated to the point of technology ownership ratio and technology gap rate is translated to the point of technology gap rate. Those two points are equally weighted and added together as in the formula (10).

$$EV_{Mj} = EVP_1^{Mj} + EVP_2^{Mj} \quad (10)$$

, where  $\{0 \leq EV_{Mj} < 1\}$ ,  $\{0 \leq EVP_1^{Mj} \leq 0.5, 0 \leq EVP_2^{Mj} < 0.5\}$

#### a) Point of Technology Ownership Ratio

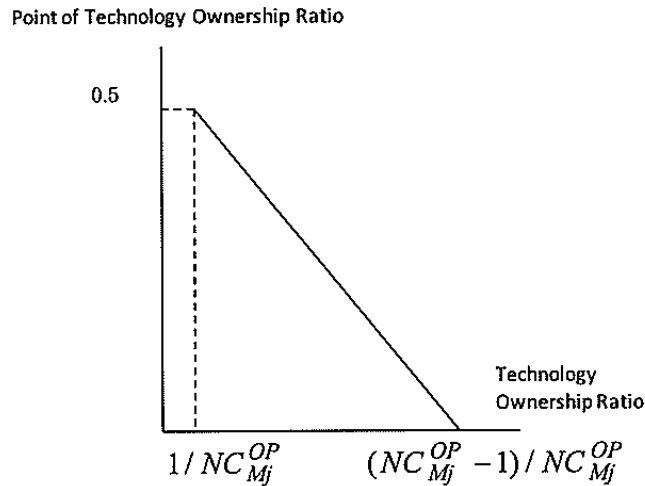
Figure 4 shows the relationship between technology ownership ratio and point of technology ownership ratio.

High technology ownership ratio means that number of superior group companies is large. This leads to decrease the point of technology ownership ratio.

As number of companies in the superior group increases and technology ownership ratio becomes higher, point of technology ownership ratio is set to lower value as in formula (12).

$$R_{Mj}^{D2} = ND_2^{Mj} / NC_{Mj}^{OP} \quad (11)$$

$$EVP_1^{Mj} = \{R_{Mj}^{D2} \times NC_{Mj}^{OP} - NC_{Mj}^{OP} + 1\} / \{2 \times (2 - NC_{Mj}^{OP})\} \quad (12)$$

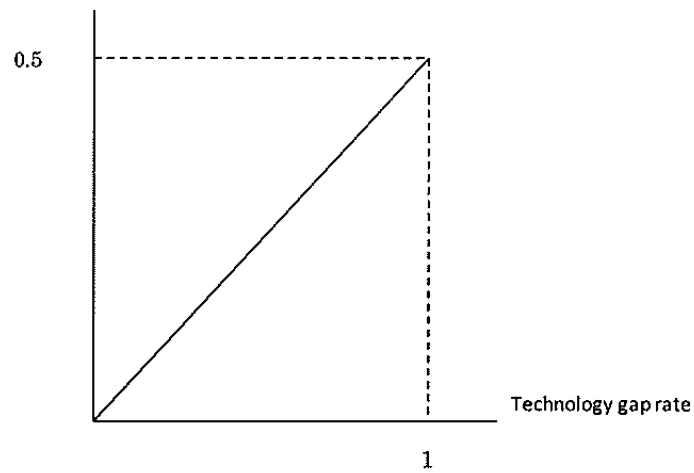


**Figure4 Relationship between Technology Ownership Ratio and Point of Technology Ownership Ratio**

#### b) Point of Technology Gap Rate

Relationship between technology gap rate and point of technology gap rate is shown in Figure 5. When average emission of the leading companies is smaller in comparison with the standard group and technology gap rate becomes smaller, point of technology gap rate becomes smaller. This means technology influence for reducing the emission becomes larger and leads to smaller point of technology gap rate in formula (14). Then the evaluation value of the standard emission becomes smaller as in Figure 6 to make penalty factor larger because such technology gap is regarded crucial.

Point of technology gap rate



**Figure5 Relationship between technology gap rate and point of technology gap rate**

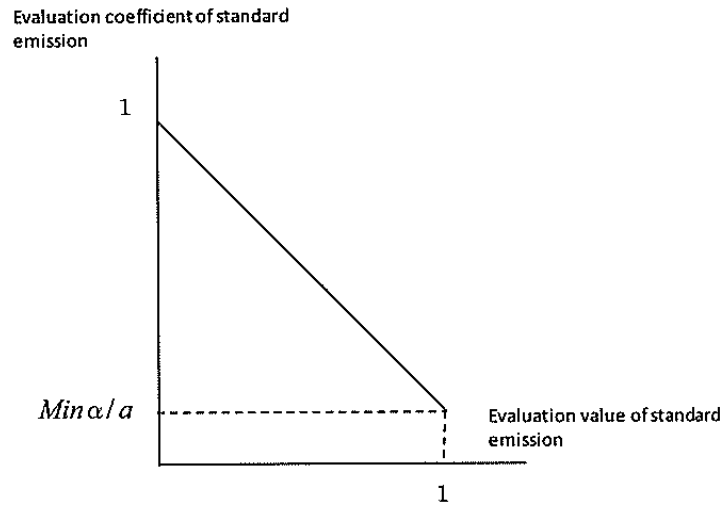
$$TG_{Mj} = ED_2^{Mj} / ED_1^{Mj} \quad (13)$$

$$EVP_2^{Mj} = TG_{Mj} / 2 \quad (14)$$

Evaluation value of standard emission is obtained by substituting formulas (10) and (12) into formula (14) in order to obtain the evaluation coefficient of standard emission. This is illustrated in Figure 6 and formula (15).

$$\alpha_{Mj}^{BASE} = (Min \alpha / a - 1) \times EV_{Mj} + 1 \quad (15)$$

Disclosure coefficient is obtained formula (9) and evaluation coefficient of standard emission is from formula (15). Then from formula (7), non-disclosure emission penalty factor  $\alpha_{nj}$  for each substance is obtained.



**Figure 6 Relationship between Evaluation value of standard emission and Evaluation coefficient of standard emission**

### c) Exception Handling

In some particular cases, the following exceptions handlings are necessary.

- If a company's emission is equal to the average emission, that company is included in both standard and superior groups for calculation.

- If just one company discloses emission for a substance, standard emission cannot be evaluated. Coefficient of standard emission is trivially set to zero

- If there are multiple companies disclosing emission data for a substance and all of their emissions are equal, evaluation value of standard emission takes the maximum value one.

- If just two companies disclose their emissions, point of technology ownership ratio cannot be calculated from the formula (12). In this case, one of the two is regarded as a member of the superior group and the other in the standard group, and the point of technology ownership ratio is set to 0.25. It is the middle vale of the point of technology ownership ratio that ranges from 0.0 to 0.5. If emissions of those two companies are the same, the point of technology ownership ratio is set to 1.0.

### 2.2.6 Calculation of Presumed Emission and Environmental burden in single score method

Presumed emission for each substance is calculated as follows:

$$P_{Mj} = \max ES_{2Mj}^{Ci} \times \alpha_{Mj} \quad (16)$$

Then, single-scored environmental load is calculated with EcoFactor in JEPIX

$$EL_{Ci} = \sum_{j=1}^m (ES_{2Mj}^{Ci} \times EF_{Mj}) \quad (17)$$

Then, single-score environmental load is calculated with EcoFactor in JEPIX. Here, presumed Emission  $P_{Mj}$  is used when  $ES_{2Mj}^{Ci}$  is not disclosed.

### 3. CASE studies

The proposed method is applied to automobile industry and Precision machinery industry.

#### 3.1 Automobile Industry

Emission data of six selected company are collected in automobile industry form their environmental report in 2006. Table 1 shows disclosure coefficient  $\alpha_{Mj}^{OP}$ , evaluation coefficient of standard emission  $\alpha_{Mj}^{BASE}$ , and non-disclosure emission penalty factor  $\alpha_{Mj}$  for each substance. In this case,  $Maxa$  is 3.88,  $Min$  is 1.00. In Table 1, N/A means that the emission data of the substance is disclosed by all of the companies or is not disclosed by any of the companies.

Evaluation results of the six companies are shown in Table 3. Those boundaries are aligned to domestic consolidated. Presumed emissions are marked with asterisk (\*). Figure 7 shows the final result of the total environmental load of each company. For comparison, JEPIX without presumed emission and CO<sub>2</sub> evaluations are shown.

**Table 1 Non-Disclosure Emission Penalty Factors in Automobile Industry**

	Disclosure coefficient $\alpha_{Mj}^{OP}$	Evaluation coefficient of standard emission $\alpha_{Mj}^{BASE}$	nDEP factor $\alpha_{Mj}$
CO <sub>2</sub>	N/A	N/A	N/A
ODP	N/A	N/A	N/A
Dichlorobenzene	1.578	1.000	1.578
Ethylene	1.578	1.000	1.578
NOx	2.728	0.966	2.635
SPM10	N/A	N/A	N/A
BOD	1.578	1.000	1.578
COD	2.153	0.852	1.835
N	1.578	1.000	1.578
P	1.578	1.000	1.578
Landfill	N/A	N/A	N/A

### 3.2 Precision Machinery Industry

Emission data of six selected company are collected in precision machinery industry form their environmental report in 2006. Table 2 shows disclosure coefficient  $\alpha_{Mj}^{OP}$ , evaluation coefficient of standard emission  $\alpha_{Mj}^{BASE}$ , and non-disclosure emission penalty factor  $\alpha_{Mj}$  for each substance.

**Table 2 Non-Disclosure Emission Penalty Factors in Precision Machinery Industry**

	Disclosure coefficient $\alpha_{Mj}^{OP}$	Evaluation coefficient of standard emission $\alpha_{Mj}^{BASE}$	nDEP factor $\alpha_{Mj}$
CO <sub>2</sub>	N/A	N/A	N/A
ODP	N/A	N/A	N/A
Dichlorobenzene	17.075	0.114	1.941
Ethylene	33.120	0.994	32.910
NOx	33.120	0.624	20.665
SPM10	41.143	0.819	33.681
BOD	9.052	1.000	9.052
COD	25.097	0.462	11.586
N	17.075	0.711	12.143
P	17.075	0.689	11.762
Landfill	N/A	N/A	N/A

Table 1 shows disclosure coefficient  $\alpha_{Mj}^{OP}$ , evaluation coefficient of standard emission  $\alpha_{Mj}^{BASE}$ , and non-disclosure emission penalty factor  $\alpha_{Mj}$  for each substance. In this case, *Maxa* is 41.44, *Min* is 1.03. In Table 2, N/A means that the emission data of the substance is disclosed by all of the companies or is not disclosed by any of the companies.

Evaluation results of the six companies are shown in Table 3. Those boundaries are aligned to domestic consolidated. Presumed emission is marked with asterisk (\*).

Figure 8 shows the final result of the total environmental burden of each company. For comparison, JEPIX without presumed emission and CO<sub>2</sub> evaluations are shown.

## 4. Discussions

### 4.1 Automobile Industry

A comparison between the single-score indicator of stress on the environment calculated with our proposed method and that measured by the JEPIX reveals a large difference between the two indicators for each evaluated company. One reason is the limited number of data items disclosed by each company on its emissions. Since the undisclosed data are treated as zero emissions by JEPIX, the single-score indicator measured by JEPIX decreases as more emission data become undisclosed. However, the proposed method uses presumed emissions, which incorporate a penalty, in place of undisclosed data. Therefore, the greater the number of undisclosed emission data, the higher the value of the single-score indicator. This explains the noticeable difference between the proposed method and JEPIX in evaluating companies.

In particular, Company B is significantly affected by presumed emissions. The company receives the most favorable score with JEPIX, but scored least favorably with our proposed method because it discloses only data on CO<sub>2</sub> and landfill. Conversely, Company C receives the least favorable score with JEPIX while scoring most favorably with the proposed method. Compared to the other evaluated companies, Company C makes public numerous emissions data and is the only one disclosing data on dichlorobenzene which has a considerable environmental impact. Therefore, the company receives a considerably lower evaluation with JEPIX than the others, but the proposed method yields a high evaluation for the company because the application of presumed emissions is limited. These facts show that the proposed method provides an incentive to disclose information, as greater disclosure leads to a better evaluation.

A trend for the entire industry is that the willingness to disclose emissions data is generally low, with even the most open company providing data on only five of the eleven substances. The companies in the automobile industry have low disclosure levels and are considerably affected by the existence of the presumed emissions used in the proposed method which include penalties.

### 4.2 Precision Machinery Industry

One characteristic of the precision machinery industry is the existence of companies, like Companies G and L, with little difference between our proposed method and JEPIX in terms of measured stress on the environment. The two companies show very high levels of disclosure for the data on nine and ten, respectively, out of the eleven substances being made public. This led to the result that Company L, in particular, receives a relatively low evaluation with JEPIX, but obtains a relatively high evaluation with the proposed method. Similarly to the case of the automobile industry, companies with high disclosure levels benefit from the incentive to disclose information in the precision machinery industry.

For the industry as a whole, one can find great differences in the disclosure level among the companies considered, with highly open companies like Companies G and L at one end and a company disclosing data on only CO<sub>2</sub> and landfill (namely, Company J) at the other. In addition, the upper bound of the



penalty factor  $Max\alpha$  for the automobile industry is 3.88 while that for the precision machinery industry is 41.14, which is a rather large value. For this reason, large presumed emissions are assigned to undisclosed data on polluting substances for companies with a small number of disclosed data items, such as Company J, leading to their low evaluations relative to other companies.

### **4.3 Examination of the Proposed Method**

As a result of using the proposed method, its function of providing a disclosure incentive is confirmed for both the automobile and precision machinery industries, and the single-score indicator of stress imposed on the environment reflecting this incentive function is calculated. Also, because of the small number of disclosed data items in both industries, the influence of presumed emissions is significant. Under the proposed method, this tends to easily produce favorable evaluations for companies that merely have high disclosure levels. If companies' disclosure levels increase in the future, it will be difficult for them to gain high evaluations by simply disclosing many types of emissions data, and they will start competing with one another in terms of their emission levels, taking a certain disclosure level as given. The proposed method can promote competition in the disclosure level, which would then turn into competition in the emissions level.

Environmental reports of a number of businesses set a target for reducing stress on the environment which centers on the reduction of CO<sub>2</sub> emissions. The proposed method provides an incentive to disclose information on many kinds of environmentally hazardous substances, which would promote early disclosure of emission levels of not only CO<sub>2</sub>, but also other environmentally hazardous substances. The method also poses a question regarding the existing CO<sub>2</sub>-centric environmental performance assessments.

## **4.4 Possible Extensions**

### **4.4.1 Integration with Financial Data**

By integrating, based on our proposed method, the single-score indicator for stress on the environment with financial data, such as those in financial statements, the method can be developed into one which evaluates companies' environmental performance from both a quantitative aspect (i.e., environmental impacts) and a monetary aspect (i.e., finance). In particular, since the proposed method is an integrative method which considers the existing disclosure levels as given, it can readily integrate the single-score indicator with financial data without waiting for companies to improve their disclosure levels.

Furthermore, the integration with financial data is easy under the proposed method as the organizational boundaries used for financial data and the single-score indicator calculated using the method coincide with each other. There is no need to adjust the boundary used for financial data because the companies' boundaries in the proposed method are set uniformly on a consolidated basis.

Building on such characteristics of our proposed method, one could construct, for example, an index of management efficiency in reducing stress on the environment. It is also possible to create an index measuring efficiency in environmental investment by integrating the single-score indicator of the proposed method with conservation costs in environmental accounting.

#### **4.4.2 Comparisons among Companies in Different Industries and Cross-Industry Comparisons**

This paper has compared companies within the same industry. Comparisons among companies in different industries or cross-industry comparisons can be considered as a next step.

Comparisons among companies in different industries require making adjustments for industrial attributes reflected in emissions data, in addition to maintaining consistency in the organizational boundary, operational categories, and the corporate size considered for emissions data from various companies. In particular, making adjustments for industrial attributes will be an important process consisting of corrections for unique industrial properties contained in emissions data and modifications to make companies' emissions data comparable across different industries. This leads to base values for emissions, which are obtained with the same method used in the case of same-industry comparisons, and enables the calculation of penalty factors and presumed amounts of emissions. The adjustments for industry attributes cannot be achieved with only emissions data and, thus, require evaluations based on qualitative information such as manufacturing processes used in different industries.

Cross-industry comparisons are performed by evaluating each industry, but not each company. The process starts with setting consistent boundaries and operational categories for emissions data for each environmental load substance in each industry. This is followed by the determination of a consistent industrial size and adjustments for industrial attributes. With emissions data obtained after these treatments, standard emissions, penalty factors, and presumed emissions are calculated, enabling cross-industry comparisons.

### **4.5 Issues for Future Consideration**

#### **4.5.1 Method Used for Scale Adjustments**

In maintaining consistency in the organizational boundary and corporate size, emissions data are adjusted using sales amount. Our proposed method uses this type of adjustment, assuming that the amount of environmental stress is proportional to sales. However, a question remains regarding the appropriateness of this adjustment technique. For instance, in dealing with organizational boundaries, one must consider differences existing between a company under evaluation and its subsidiaries in terms of the level of efforts to reduce stress on the environment; with respect to corporate size, one may face varying levels of such efforts among different companies. In such a situation, the technique that simply adjusts the amount of emissions proportionally to sales does not necessarily lead to a correct evaluation.

In response, one needs to either make adjustments using a proportional relationship with capacity utilization or the quantity of products manufactured, or incorporate into adjusted values the results of qualitative analyses on the details of corporate efforts to reduce stress on the environment. However, in reality, information on capacity utilization or production quantity is not sufficiently available, or the scope covered by such information may not match the scope considered in environmental reports. Therefore, the aforementioned remedies are difficult to apply, given the existing levels of disclosure in environmental reports. Moreover, even if qualitative evaluations are conducted, environmental reports are the main

source for external assessments, making it necessary to examine what standpoint is used in conducting such qualitative evaluations and how they are reflected in adjusted values.

#### **4.5.2 Case with All Disclosed Emissions Being Zero**

For a given substance, if the emission data show zero emissions for all companies disclosing the information, the corresponding standard emission becomes zero, and, thus, the relevant presumed emission becomes zero regardless of the value of the penalty factor. In this case, no incentive exists for disclosing information, and one needs to evaluate qualitatively the level of efforts made by non-disclosing companies in reducing the emission of that substance. If non-disclosing companies simply do not make their emission data public, zero is assigned to their presumed emission. If, however, they are judged to be withholding data that are inconvenient for their own benefits, an appropriate amount of presumed emission must be assigned based on presumed emissions for other substances. Since different substances require different qualitative judgment, clear criteria and a method to determine proper amounts for presumed emissions must be established.

#### **4.5.3 Case with an Extremely Large Upper Bound for the Penalty Factor $\alpha_{Mj}$**

When considerable differences exist among emission levels of disclosing companies for a given substance, the upper bound for the penalty factor  $\alpha_{Mj}$  becomes very large, and penalty factors, calculated with that upper bound, are used for other environmentally hazardous substances. That is, significant differences in emission levels for a certain polluting substance has effects on the treatment of other substances, which is not desirable in terms of independence in evaluation that should be maintained across different substances. In the examples considered in this study, this has been shown to be a quite noticeable issue in the precision machinery industry.

The problem, however, can be automatically solved if the upper bound of the penalty factor  $\alpha_{Mj}$  can be determined with improved disclosure levels for each environmentally hazardous substance. Under the existing levels of information disclosure, one remedy can be the method to restrict the upper bound by setting the average of three highest values as the penalty factor  $\alpha_{Mj}$ .

## 5. Conclusion

Whether or not a company discloses information on its emissions of environmentally hazardous substances in, for example, its environmental reports has essentially nothing to do with the actual impact that the company's operations has on the environment. However, while recognizing the possibility that requesting external reports makes the quality of the information provided on a company's ecological impact unreliable, Schaltegger and Burritt argue that external stakeholders must provide corporate managers with incentives to explain all matters in a transparent fashion [8]. Therefore, it can be considered that transparency enhanced by information disclosure has a strong correlation with the quality of information on polluting substances.

The integrative indicator plays the role of money in financial accounting, so to speak, by taking into account polluting substances with different physical and chemical properties and various environmental impacts in order to make explanations for external stakeholders clearer. We have determined that informational transparency would increase the reliability of a single-score indicator and have integrated it with an incentive for information disclosure.

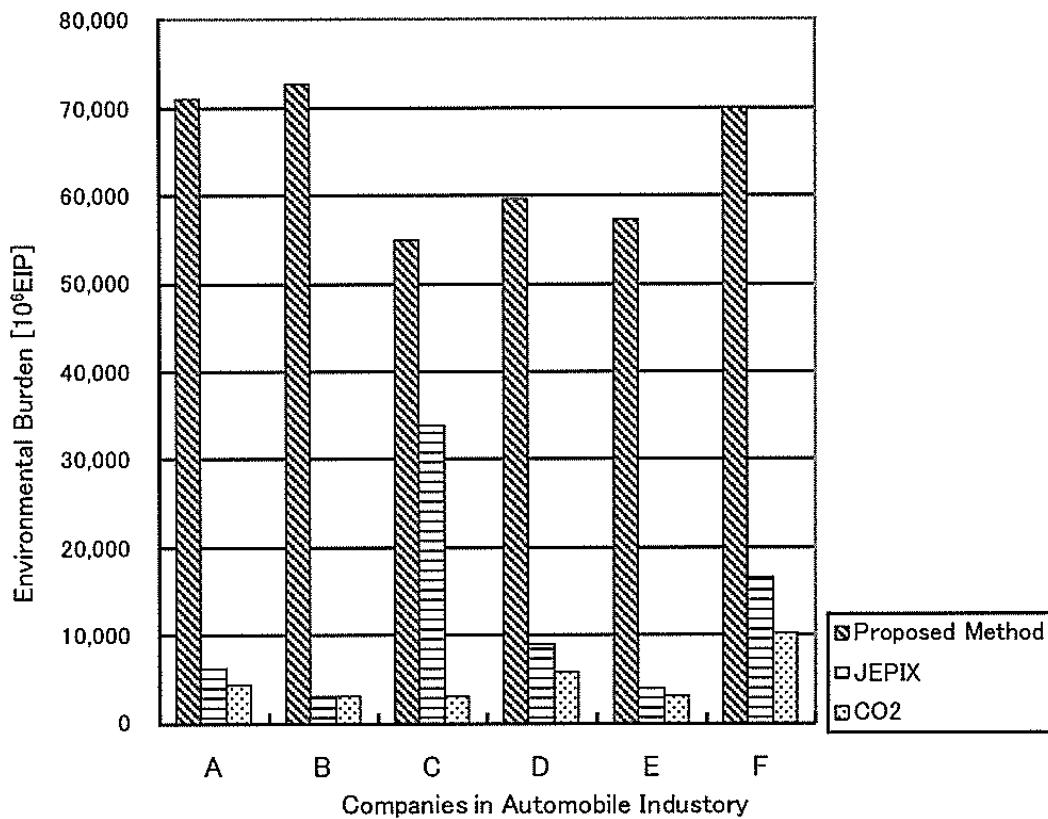
The estimation of undisclosed emissions for a company can be obtained with methods which are different from the one considered in this study, such as the use of averages or least favorable values among the other companies. However, for some environmentally hazardous substances there are many cases in which collected data is not sufficient to calculate average values. This problem becomes more apparent in situations in which explanations do not exist for the mechanism of, or the significance of, ecological impacts of substances under consideration, or in which they are not recognized by corporate managers or external stakeholders. Today's disclosure level for emerging information on asbestos used in the past provides an example of this type of situation. Our proposed method is expected to be useful for such situations which require instant responses.

**Table 3 Results of Automobile Industry**

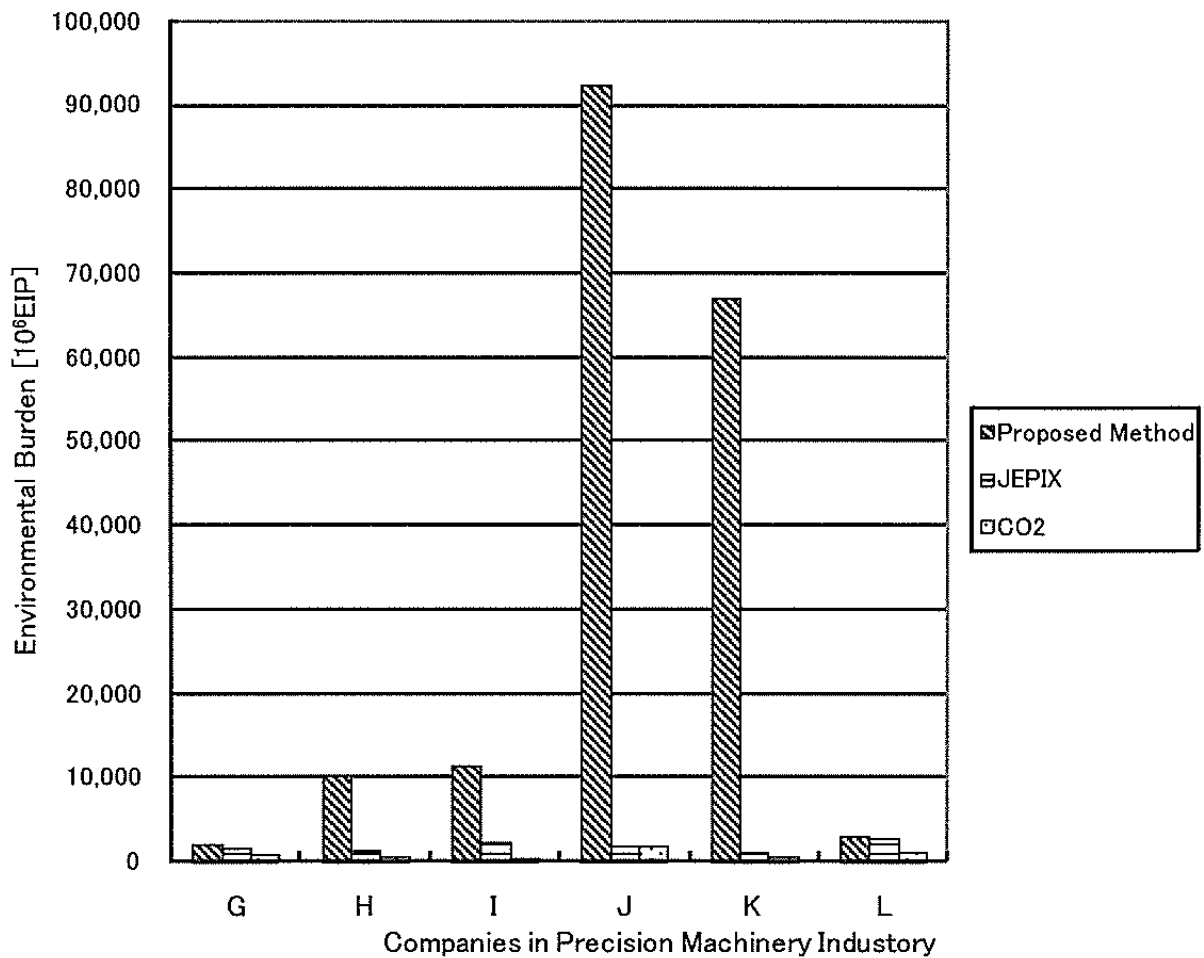
Substance	unit	Ecofactor	Company A	Company B	Company C	Company D	Company E	Company F
CO <sub>2</sub>	1000t-CO <sub>2</sub>	984,989	4,500	3,088	3,078	5,794	3,049	10,363
ODP	ODP-t	429,282,094						
Dichlorobenzene	t	45,050	<i>*399,229</i>	<i>*399,229</i>	252,952	<i>*399,229</i>	<i>*399,229</i>	<i>*399,229</i>
Ethylene	t	2,167,798	<i>*14,042</i>	<i>*14,042</i>	8,897	<i>*14,042</i>	<i>*14,042</i>	<i>*14,042</i>
NO <sub>x</sub>	t-NO <sub>x</sub>	675,917	<i>*24,055</i>	<i>*24,055</i>	<i>*24,055</i>	2,354	1095	9,131
SPM10	t-SPM10	4,899,335						
BOD	t-BOD	169,104	<i>*474</i>	<i>*474</i>	<i>*474</i>	301	<i>*474</i>	<i>*474</i>
COD	t-COD	3,271,791	140	<i>*827</i>	<i>*827</i>	451	<i>*827</i>	<i>*827</i>
N	t-N	7,973,166	95	<i>*150</i>	<i>*150</i>	<i>*150</i>	<i>*150</i>	<i>*150</i>
P	t-P	84,428,019	8	<i>*13</i>	<i>*13</i>	<i>*13</i>	<i>*13</i>	<i>*13</i>
Landfill	t	58,669	0	0	1,045	835	2,834	3,685
Environmental burden (Proposed Method) [10 <sup>6</sup> EIP]			71,094	72,781	55,089	59,566	57,390	70,075
Environmental burden (JEPIX) [10 <sup>6</sup> EIP]			6,328	3,042	33,776	8,873	3,909	16,595
Environmental burden (CO <sub>2</sub> ) [10 <sup>6</sup> EIP]			4,432	3,042	3,032	5,707	3003	10,207

**Table 4 Results of Precision Machinery Industry**

Substance	unit	Ecofactor	Company G	Company H	Company I	Company J	Company K	Company L
CO <sub>2</sub>	1000t-CO <sub>2</sub>	984,989	707	431	201	1,684	499	938
ODP	ODP-t	429,282,094	0	0	*0	*0	*0	*0
Dichlorobenzene	t	45,050	213	449	35,564	*1,170,415	*1,170,415	864
Ethylene	t	2,167,798	27	95	35	*1,971	*1,971	81
NO <sub>x</sub>	t-NO <sub>x</sub>	675,917	490	552	255	*36,098	458	1,072
SPM10	t-SPM10	4,899,335	*95	*95	*95	*95	*95	11
BOD	t-BOD	169,104	5	25	19	*285	*285	*285
COD	t-COD	3,271,791	8	*640	*640	*640	*640	53
N	t-N	7,973,166	7	*413	*413	*413	*413	35
P	t-P	84,428,019	1	*37	*37	*37	*37	4
Landfill	t	58,669	390	586	1,465	603	0	520
Environmental burden (Proposed Method) [10 <sup>6</sup> EIP]			1,779	10,033	11,106	92,111	66,819	2,742
Environmental burden (JEPIX) [10 <sup>6</sup> EIP]			1,311	1,063	2,137	1,694	801	2,694
Environmental burden (CO <sub>2</sub> ) [10 <sup>6</sup> EIP]			696	425	198	1,659	492	924



**Figure 7 Results of Automobile Industry**



**Figure 8 Results of Precision Machinery Industry**

#### NOTE

(1) If all of the companies do not disclose emission data of a given substance, presumed emission of that substance cannot be calculated. However, in terms of comparison among companies in that group, presumed emission is unnecessary in that case.

It is assumed that at least one emission data of substance should be disclosed by all of the companies because it is necessary for setting the upper and lower bounds of penalty as stated in 2.2.4.

(2) If the boundary of emission is domestic, boundary alignment is unnecessary.

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