H-9 Development of environmental accounting and indicators for measuring sustainability at company, industry and national level (Abstract of the Final Report)

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1. Background

Although the term "Sustainable Development" and the concept "integration of environmental and economic/industrial policy" widely spread nowadays, the common understanding of their concrete meaning is still inadequate and the course towards the realization of these concepts is not yet clear.

Conventional national economic indicators and industrial productivity indicators have inadequately addressed the sustainability of the environment, and they are not appropriate for decision making with environmental consideration. Indicators to assess sustainability of each economic activity at various scales are required.

Towards the World Summit for Sustainable Development (WSSD, so-called Rio plus 10) in Johannesburg in 2002, endeavors to develop indicators of sustainable development have been getting active. On the other hand, as the drafting of the revised SEEA (Integrated System of Environmental and Economic Accounting) 2003 edition was underway, update of environment and economic accounting in Japan is necessary. In addition, as a set of environmental performance indicators is being used for companies' rating, reliable and harmonized set of indicators is urgently required.

2. Objectives

On the basis of such a background, this study aims at developing indicators and accounting method to quantify the level of sustainability at three different levels of the economy, namely products and companies, industrial sectors, and the national economy as a whole.

3. Methods, results and discussions

3.1 The research on the reconstruction of Integrated Environmental and Economic Accounting following the revision of SEEA2000

We clarified the differences between the Environmental Protection and Resource Management Accounts proposed by the SEEA 2003 (System of Environmental and Economic Accounting) and the Environmental Protection Expenditure Accounts that have been compiled in survey research and summarized the systems of these accounts. As a result, it was decided to compile a Table of Supply of Environmental Protection and Usage Table; estimations of the 1990, 1995, and 2000 accounts were conducted.

In this research, the 1990, 1995, and 2000 accounts were recorded approximately three times every five years. Economic activity was recorded on the National Accounting

Matrix (NAM), and Environmental Accounts (EA) were broken down and recorded on (1) substance accounts, (2) environment accumulation accounts, and (3) environmental problem accounts. Pollution substance records in particular describe the production and consumption sectors to clarify the relations between economic activity and pollution substance.

Table 1 presents the relation between CO_2 pollution substance and all economic activities that consist of production and consumption. We determined that the amount of CO_2 pollution substance discharge for each output has a downward tendency. Conversely, however, the amount of CO_2 pollution discharge for all final consumption shows an upward tendency. From this point, CO_2 pollution discharge by production activity is lower than that of consumption activity. This relation might be result of government policy or industrial efforts.

It can be said that the amount of CO_2 discharge produced by final consumption activities is deteriorating, though that by production activity is increasing. For the year 2000, the amount of CO_2 discharge for each output against the amount of CO_2 discharge for each amount for final consumption was 1.8.

Table 1 Relation Between Amount of Activity in NAMEA According to Section, and Amount of CO_2 Discharge According to It

	Unit	1990	1995	2000	95/90	00/95
Amount of exhaust for each output	(t-CO2/billion yen)	111.6457	110.0818	108.0461	0.986	0.982
Output	(one billion yen)	859,688.1	922,938.0	941,518.8	1.074	1.020
Amount of exhaust by production activity	(1,000t-CO2)	959,805	1,015,987	1,017,274	1.059	1.001
Amount of exhaust for each amount of the final consumption	(t-CO2/billion yen)	55.7467	55.7501	59.8816	1.000	1.074
Amount of the final consumption	(one billion yen)	291,161.4	349,633.2	369,769.5	1.201	1.058
Amount of exhaust by the final consumption activity	(1,000t-CO2)	162,312	194,921	221,424	1.201	1.136
Output/amount of the final consumption	—	3.0	2.6	2.5	0.894	0.965
Amount of exhaust by production activity／Amount of exhaust by the final consumption activity	—	5.9	5.2	4.6	0.881	0.881
Amount of exhaust for each output／Amount of exhaust for each amount of the final consumption	—	2.0	2.0	1.8	0.986	0.914

N_2O, CH_4, NOx, and SO_2 (estimated as pollution substance at environmental account) are also divided between the production and consumption sectors.

Comparing CO_2 discharge among industrial sectors, the manufacturing industry is the highest with 38.2 percent. But, at the discharge ratio/output ratio and at the discharge ratio/worker ratio, electricity, gas and water supply are the highest with 14.0 percent and 54.6 percent.

The decoupling index of the DPSER index group was made by using NAMEA. Decoupling is a concept that separates economic utility and environmental disutility. Decoupling arises when the growth rate of economic driving force (DF) exceeds the growth rate of environmental pressure (EP). In the estimation of decoupling, the decoupling ratio is used; it is estimated on the basis of D and P at the beginning and end of the period. Decoupling arises when the decoupling ratio takes any value between (0,1) and reaches the maximum when the decoupling ratio is equal to zero. Next year we will compile DPSER indicators and decoupling indicators on the basis of the framework developed this year. The decoupling ratio is calculated from the following expressions.

$$\text{Decoupling ratio} = \frac{\left(EP / DF \right)_{\text{end period}}}{\left(EP / DF \right)_{\text{beginning period}}}$$

Although it was unrealized in the years from 1990 to 1995, when the decoupling index was created, for the greenhouse effect using the above-mentioned formula, in 1995 to 2000, and 1990 to 2000, it was realized.

Data

	Real GDP	GWP
1990	460,925	1,187,050
1995	496,911	1,323,288
2000	532,541	1,332,945

Decoupling Ratio

	Decoupling Ratio	Decoupling realized or unrealized
90-95	1.034	Unrealized
95-2000	0.940	Realized
90-2000	0.972	Realized

note : The unit of GWP (potential of global warming for each GDP) is 1000t- CO_2.

Moreover, the decoupling index according to industry was made by using data from the section division that had been obtained for the estimate of NAMEA. For CO_2, the decoupling index of electricity for it to have a significant influence on the pollution substance and gas and water supply was estimated by the following expressions.

$$\frac{(EP)}{(DF)} = \frac{(\text{Amountof CO2exhaust})}{(\text{Amountof total electric power demand } (kWh))}$$

$$\frac{(EP)}{(DF)} = \frac{(\text{Amount of CO2 exhaust})}{(\text{Amount of fossil fuel turning on})} \times \frac{(\text{Amount of fossil fuel turning on})}{(\text{Electric power generation})} \times \frac{(\text{Electric power generation})}{(kWh)}$$

As a result, although CO_2 realized the decoupling, the decoupling ratio represents a situation that it is getting worse, to 0.93 for 1995-2000, up from 0.90 for the 1990-95 period. The discharge cannot be controlled completely.

Data

	Amount of CO_2 exhaust (A)	Total electric power demand (B)	Amount of fossil fuel turning on (C)	Electric power generation from amount of fossil fuel turning on (D)
1990	341,904	857,272	34.3	162,810
1995	356,335	989,880	31.3	123,503
2000	366,330	1,091,500	25.2	61,151

Decoupling ratio: (A) / (B) = (A)/(C) × (C)/ (D) × (D)/ (B)

	(A)/(B)	(A)/(C)	(C)/(D)	(D)/(B)	Decoupling realized or unrealized
90-95	0.90	1.14	1.20	0.66	Realized
95-2000	0.93	1.28	1.63	0.45	Realized
90-2000	0.84	1.46	1.96	0.29	Realized

Finally, in this stage, this NAMEA was estimated as provisional figures because we always faced some kind of lack of environmental data. For example, NOx discharge of household sector, which consisted of the consumption sector, may be overestimating the actual situation of household NOx discharge by lack of proper data that describe the amount of car pollution of the household sector .

3.2 Development of environmental and resource efficiency indicators using Material Flow Accounting

This sub-theme aims at the development of environmental/resource efficiency indicators on the basis of the physical accounting framework, which keeps consistency with existing economic Input-Output tables. This study has been carried out under the intensive collaboration/cimmuncation with internatioal research network of Material Flow Analysis/ Accounting

During the three years project, the framework of Multi-Dimensional Physical Input Output Tables (MDPIOT), of which draft had been designed during the precedent research, was improved and designed to meet several priority issues. The first major extension is description of physical material flows associated with international trade, which takes places outside of national boundary (so-called hidden flows or ecological rucksacks). Because of limited data availability for other countries than Japan, draft PIOT has focused on material flows within the boundary and accounted only for direct import and export flows. However, as pointed out by precedent studies, hidden flows at upstream of imported resources and raw materials may cause significant environmental pressures. To compromise with limited data availability, only the material flows induced by imports to Japan are described as a satellite table, to avoid the enormous difficulty in compiling fully multi-lateral physical I-O tables.

Another major improvement is the addition of a sub-module to calculate the inter-sectoral material flows induced by final demands. Physical flows of natural resources from the environment to the economy, those of environmental burdens (pollutants and wastes) from the economy to the environment, hidden flows associated with these flows, as well as those of specific typical commodities (e.g., energy carriers, iron and steel) among economic sectors can be calculated per unit amount of monetary/physical final demand.

Based on the revised and extended framework, the empirical data for 1990 and 1995 was compiled according to three major resource categories, namely, fossil fuels, metals and construction minerals. Preliminary PIOT for biomass was also compiled. Documentation of procedures for estimating intersectoral physical material flows from existing data was improved to prepare for the disclosure of the whole tables. In addition, detailed emission inventories of CO_2 and traditional air pollutants by 400 industrials sectors were compiled for 1990 and 1995. They were named 3EID (Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables), and provided for public use as a data book and via website. The 3EID has been actively used by other sub-themes of this research project as well as many outside users.

Calculation of the environmental and resource efficiency indicators is one of the most promising usage of the MDPIOT. How to derive the indicators of environmental efficiency and resource efficiency from MDPIOT was illustrated. On the other hand, to meet the needs for more timely and longer trend analysis, another new dataset that consists of SNA-IO tables and sectoral resource inputs was compiled. The dataset contributed to set a nation-wide numerical target of resource-efficiency in "The Basic Plan for Recycling-Based Society". Structural decomposition analysis was applied to explain the improvements in resource efficiency in last two decades. Improvements in resource efficiency in individual industry and the changes in final demand are the two major factors. Drastic improvements of resource efficiency was observed for some industries such as machinery industry, whereas there found small changes in others such as basic material industry.

On the other hand, the dataset for the nation-wide MFA to calculate indicators such as DMI (Direct Material Input), DPO(Direct Processed Output), NAS (Net additions to Stock) was revised to catch up with the revision of statistical data behind them. Several methodological revisions were also made mainly to keep more consistent material balance reflecting water contents, oxygen in metal ores, and so on.

In addition, commissioned studies at three universities were undertaken.

The objective of the study at Nogoya University is to develop a methodology to better integrate different indices to assess environmental impacts of industrial and economic activities and evaluate their environmental efficiency, and to develop a method to analyze material flows at local level. Following studies were undertaken for this objective.

(a) The use of ecological footprint (EF) for the evaluation of environmental efficiency; Different indices have been developed for the evaluation of environmental efficiency. The energy consumption and the associated CO_2 emissions, and total material input (TMI) are often used as indices to represent the environmental impacts associated with production and consumption styles in modern industrial society, while ecological footprint (EF) is more closely related to land intensive human activities such as agriculture and forestry. A calculation was made for the amount of land resources embodied in the final demand of each industry sector in Japan by using IO tables. Forestry, construction and food processing industries are the sectors which exhibit the largest amount of EF in contrast to the fact that the embodied energy and CO_2 values are larger for manufacturing industries. A proper combination of these different indices may present an improved methodology for evaluating the environmental efficiency of human activities.

(b) Evaluation of the measures taken at local level to build a sound material cycle society; This study explores a framework of the "dual flow accounting system" comprising material balance sheet on one hand, and money balance sheet on the other hand. It proposes a practical method of preparing these sheets by using economic and waste data available at local level, and applies that method to Aichi Prefecture and Nagoya City. The proposed framework is similar to that of material flow analysis and IO tables developed at national level, but it is designed so that the roles of local stakeholders such as municipal solid waste department of municipalities and household sector are more clearly represented and analyzed.

(c) Organic resources circulation in urban area; The material flow relevant to the organic matter resources circulation which accompanied especially with eating habits of residents for Nagoya-City was built and examined. As a result, nonrenewable energy corresponding 10% of carbon content of kitchen refuse and 30% of carbon content of sewage was inputted to organic waste treatment. Moreover, environmental load, economical efficiency, efficiency of 3 scenarios (energy recovery by waste incineration, digested gasification and material recycling (i.e., manufacture of poly-lactic acid) was evaluated when scenarios was introduced. The result shows that the digested gasification is the best scenario.

(d) Validity of cascade recycling of paper resources; A cascade recycling is a proper method to increase resource productivity. However, actual waste recycling system doesn't take advantage of this recycling. In this study, a model of a waste paper recycling system with the cascade recycling was proposed, and an evaluation of the effectively of the cascade recycling by the resource productivity and the economic efficiency on this model. As a result, as long as the planner takes consideration of the resource productivity and the economic efficiency into the actual waste paper-recycling system, there might be more efficient allocation rate from paper wastes category to paper product ones.

The study at Kumamoto University on accounting framework consists of four parts. First, in response to the publication of the SEEA2003 final version, the whole picture of the SEEA2003 physical flow accounts and the relationships of the NAMEA to those accounts were examined and it was shown that these accounts had the same accounting structure as the NAMEA. Secondly, the accounting structure of the NAMEA was shown in detail and the modified framework for the Japanese NAMEA was proposed with incorporating the accounts for the hidden material flows induced by the imports, and the accounts for the land use compared with the ecological footprint. Thirdly, it was shown that the SEEA93, the MDPIOT, the NAMEA, I-O table and the SAMSEEA(SAM including the SEEA) were related to the NAM via the PAFEE (Physical Accounting Framework for the Environment and Economy) and the MAFEE(Monetary Accounting Framework for the Environment and Economy), and those accounts composed an accounting system. Thus this accounting system enhances the mutual consistency, reliability and comparability of the various kinds of the indicators which were derived from each account. Finally, the further improved framework for the Japanese NAMEA was developed with introducing the accounts for the waste disposal flow which could not be shown in the NAMEA. It is a fruitful framework which can represent not only the disposal flow of the waste but also the internal disposal flow of the pollutants in detail.

Finally at Sapporo University and Doshisha University, a study on Ecological Footprint (EF) was conducted. Fourteen years have passed since the development of Ecological Footprint (EF) in Canada in 1990. The EF is an indicator which compares humanity's demand on natural income with natural capital's capacity to produce flows of natural resources and services. This indicator has been recognized worldwide (especially in Europe) as powerful planning tool to achieve goals of sustainable development. In particular, in the United Kingdom (UK) this indicator has been applied in the actual policy making arena on sub-national levels. In this study, we have intended: 1) to identify the reasons why EF has been accepted widely in the UK; 2) to investigate the technical improvements of EF methods and the roles of other material/energy analyses for that improvement; and 3) to derive lessons in terms of how Japan can benefit from the use of EF in the policy arena, especially on sub-national levels.

We have observed several innovative uses of EF in the UK. For example, the Walsh Assembly decided to employ EF as an indicator to monitor Wale's sustainability. The Scottish Cabinet is encouraging local authorities to use EF. We identified some factors contributing to the increased use of EF in those nations. 1) Strong pressure and support from environmental NGOs/researchers. 2) Mutual trust and corroboration between NGOs/ researchers, politicians and bureaucrats/planners. 3) Technical improvements of EF calculation methods using MFA, and LCA, which have been partly facilitated by the European Union. 4) Development of computer software for the use of local governments. Japan has much to learn from their rich experiences of EF application.

3.3 Development and application of tools to measure the eco-efficiency and the resource productivity of industry

Previous researches on Environmental Efficiency and Resources Productivity were reviewed and evaluated in this research. Especially, targets, used parameters, considered boundaries and/or allocation methods of the indices proposed by the previous researches were investigated and put in order. The results indicate that the system boundary should be carefully developed to adequately evaluate Environmental Efficiency and Resources Productivity of overall sectors. Addition to the above mentioned investigation, relations between LCA, MFA, LCC and environmental accounting were analyzed. If the "service" written in Environmental Efficiency is expressed by economic factors, it has advantages on the related methods. Considering precise mass balances, background data of energies and basic materials production were developed to apply for the analyses of Resources Productivity and Environmental Efficiency. In addition, ore grades of mineral resources, which refined products are exported to Japan, were investigated and reflected to the inventory data. Estimated amounts of several mineral deposits and their demands were surveyed, and static lives of the minerals were calculated.

The case study which calculated the CO_2 Efficiency at material, product, company, stage of industrialization was carried out. "CO_2 Efficiency" was calculated to discuss the Environmental Efficiency of industries using the results of the I-O table analysis. The ratio of the CO_2 emissions including direct emissions as well as indirect emissions in an industry to its producer's price was defined here as the "Total CO_2 Efficiency" of the industry. On the other hand the ratio of the direct CO_2 emissions excluding indirect emissions in an industry to its gross value added was defined as the "Direct CO_2 Efficiency" of the industry. The difference of the direct CO_2 efficiencies between industries was significant, reflecting the energy intensity of each industry, but the total CO_2 efficiencies between industries were comparatively small. The ratio of the indirect CO_2 emissions excluding direct emissions to the cost paid by the industry was defined here as the "Indirect CO_2 Efficiency".

We compared the company-level direct CO_2 Efficiency and industry-level direct CO_2 Efficiency. Three beer companies were chosen as examples for the calculation of company direct CO_2 Efficiency, by comparing their gross incomes with tax deducted to direct CO_2 emissions available from their environmental reports. The industry direct CO_2 Efficiency of the industry to which the companies belong (beer) was derived from the I-O table (399 categories) analysis as described above. It was found possible to evaluate the companies' relative environmental performances within the industry sector by comparing their company CO_2 Efficiency to that of industry CO_2 efficiency directly. In addition to the beer company, we calculated the company CO_2 Efficiencies for 45 companies through 10 industry sectors by obtaining the data from their environmental reports. No close much of company direct CO_2 Emissions was found neither against the industry CO_2 efficiency nor among the companies belonging the same industry sector, suggesting that the companies which belong to many industry sectors can not be evaluated accurately only with an industry CO_2 efficiency. The CO_2 efficiency as a standard of one company can be expressed by a weighting average of the industry CO_2 efficiency, when the company belongs to several industry sectors. If the company CO_2 efficiency is more efficient than the standard industry CO_2 efficiency, the company's environmental activity is determined to be better than industry average.

It is possible to calculate the amount of CO_2 emissions directly released from companies and industries because the boundaries of companies and industries are clearly defined. Therefore, calculation of total, direct and indirect CO_2 Efficiency is possible. Total CO_2 Efficiency at a product level can be calculated up to manufacturing process in the same way as company and industry levels by using product price. However, the problem with calculation of direct CO_2 emissions is specification of the boundary of direct CO_2 emissions concerning manufacturing process of the target products. Therefore, we defined the amount of CO_2 emissions concerning assembly and production of parts of the target products as direct CO_2 emissions. Further, we defined the amount of CO_2 emissions released from material input of iron, steel, and/or plastic articles from other industries as indirect CO_2 emissions.

In order to evaluate the applicability of this evaluation method, we conducted case studies by using Type III label data on copy machines and quick snaps which are LCI standardized by Product Specification Criteria (PSC). It was found that the values for product CO_2 Efficiencies were higher than that of both direct and indirect emissions at industry level. It may be attributed to the fact that the concerning products are rather value-added than others in the concerning industry as well as that the price is estimated higher and environmental burden is estimated lower for the products. Moreover, the CO_2 emissions estimated based on the I-O table analysis is the average amount of the concerning industry. Subdivision of industry CO_2 emissions down to product-level must be done carefully as always discussed by the same token as comparing the results of bottom-up LCA results to that of the I-O table analysis.

It was confirmed that the concepts of LCA, MFA, LCC and environmental accounting can be applied for the development of Environmental Efficiency and Resources Productivity. It was also confirmed that the system boundary should be carefully developed to adequately evaluate Environmental Efficiency and Resources Productivity of overall sectors. The material-, product-, company-level CO_2 Efficiencies are obtained based on the bottom-up approach, whereas, the industry-level CO_2 Efficiency is calculated from the top-down approach. By comparing the two approaches, the appropriateness and the limitations of this evaluation method have been confirmed. Moreover, the characteristics of material-, product- and company-level CO_2 Efficiencies have been defended. In addition, the CO_2 efficiency as a standard of one company can be expressed by a weighting average of the industry CO_2 efficiency, when the company belongs to several industry sectors. If the company CO_2 efficiency is more efficient than the standard industry CO_2 efficiency, the company's environmental activity is determined to be better than industry average. To establish evaluation tools for sustainable development, original indices of Environmental Efficiency and/or Resources Productivity, which indicate environmental activities of industries or companies, should be further discussed in this research.