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Contents

Case Example

Environmental Improvement in Hook and Loop Fastener Manufacturing

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1. Introduction

KURARAY FASTENING develops, manufactures, and sells a wide variety of hook and loop fastener products, such as trade name "Magic Tape" (woven surface fastener) and "Magilock (molded surface fastener)," and other related products.
Hook and loop fasteners are used as detachable fasteners like buttons and hooks, and also, they are used as binding materials and fixtures such as nails and adhesives. Compared to buttons, hooks, nails, and adhesives, hook and loop fasteners can be easily fixed and detached. They are now used in a wide variety of applications such as binding bands, cuffs for blood pressure monitors, shoes fasteners, glove fasteners, and diaper fasteners. Although generally not visible, they are also used to fix car seats in place, secure leather materials to seat pads, and to fix carpets and floor materials in place.
We at KURARAY have been making efforts to save resources and to reduce organic solvent discharge as well as CO_2 emission during the course of "Magic Tape" manufacturing. As part of these environmental activities, we have created and released an environmental label. This article introduces example applications of the environmental label and other efforts to produce environmentally-friendly products.

2. Release of the environmental label "ECO LEAF"

2.1.Environmentally sound technical development, product development, and life cycle assessment (LCA)

As the name suggests, a hook and loop fastener is a woven fabric made with hook-shaped and loop-shaped piles. Piles are usually glued to the surface with urethane adhesive. Therefore, a woven-surface fastener is made from a combination of woven nylon or polyester fiber and urethane adhesive. Our attempt to direct our endeavors toward the manufacturing of environmentally-friendly products started with review of the adhesive. In the first phase, the goal was to shift the adhesive from solvent urethane adhesive to a water-based urethane solvent. Then in the second phase, the goal was to develop a manufacturing method that allowed securing of piles without using any adhesive. As a result, water-based adhesive replaced the solvent adhesive in February 2002, and finally, an adhesive-free hook and loop fastener made from a polyester fiber (trade name "New Ecomagic") was placed on the market in August 2004. An LCA was conducted in order to make an easy-to-understand presentation of the effect of this new manufacturing technology on environmental improvement. The KURARAY group has already implemented the LCA program, and LCA for this manufacturing technology was also conducted in accordance with the internal standard. Within a life cycle, the scope of the assessment was up to the manufacturing stage. Substitute values were used for materials whose data was not available.

The assessment resulted in the integrated index of products using a ratio of solvent adhesive : products using water-base adhesive : adhesive-free products = 100 : 17: 10, meaning that the new manufacturing technology greatly contributed to environmental improvement.

Example of "Magic Tape" use - 1

Example of "Magic Tape" use - 2

2.2 Publication of the environmental label "ECO LEAF" certification status

Since the internally conducted LCA indicated the positive effect on environmental improvement as described above, we created a type-III transparent label called "ECO LEAF" to promote users' understanding of the characteristics of our products. The label was shown on "Magic Tape" A03800 and B10000 which were standard nylon products and on "New Ecomagic" A8693Y and B2709Y which were polyester, adhesive-free products. Since there were no Product Specification Criteria (PSC) that were applicable to our products, we created the PSC for hook and loop fasteners. In the case of our products, it took time to collect product process data as these products had only just been developed. The creation of the label was taking far longer than in the case of the usual general environmental label creation, but we released the label approximately 10 months after creation of the PSC establishment proposal. Table 1 shows the environmental burden data of our products. With the environmental label, we were able to show that the environmental burdens of our new product "New Ecomagic" were lower than standard products made with nylon.

Environmental label "ECO LEAF"

Table 1 Environmental burdens: total from all stages

	Magic Tape A03800 and B10000	New Ecomagic A8693Y and B2709Y
Environmental burdens causing warming (CO_2 conversion)	332 g	259 g
Environmental burdens causing oxidation (SO_2 conversion)	0.534 g	0.399 g
Energy consumption	5.53 MJ	4.68 MJ

The environmental burdens are for a pair of a hook and loop strips (width: 25 mm, length: 1 m).

3.1 Future environmental efforts in hook and loop fastener manufacturing

3.1 Environmental improvement in manufacturing processes

With the environmental label, we were able to quantitatively show that improvement of the manufacturing method led to reduction of environmental burdens. However, manufacturing of hook and loop fasteners still has environmental issues. We thus plan to make efforts to achieve the following goals:
- Reduction of use of environmental chemicals
- Increase of the ratio of adhesive-free products
- Development of hook and loop fasteners using plant-derived fabrics and resins
- Improvement of product durability

3.2 Development of applications and expansion of sales of products that contribute to environmental improvement

One of the characteristics of a hook and loop fastener is that it can be easily attached and used repeatedly. Wider applications of this characteristic are now being explored. For example, in the field of packing materials, use of binding bands that can be used repeatedly has been suggested. At the same time, use of hook and loop fasteners on returnable boxes, that are easily assembled and covered, has also been suggested. These applications are expected to contribute to reduction of packing material waste. Furthermore, in order to facilitate recycling of materials for building interiors, recyclable hook and loop fasteners that can replace adhesives and nails have been developed. As described above, expansion of product line-ups in this field has been planned.

4. Environmental improvement through the use of hook and loop fasteners

The objective of the environmental label for hook and loop fasteners introduced in this article was to show the achievement of environmental improvements in the manufacturing phase. Note, however, a hook and loop fastener itself is already environmentally friendly because it is easy to use and can be used repeatedly. Therefore, by effectively using this environmental-friendliness, we plan to not only use the fastener in the packing material field, but also make more product proposals that will contribute to environmental improvements such as use of this product on car seats (easy separation between the leather materials and seat pads and improvement of waste sorting and collecting) for effective use of resources and to secure carpets and floor materials in place for reduction of organic solvents.

Recent Life Cycle Assessment (LCA) Activities by the Plastic Waste Management Institute

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1. Introduction

The Plastic Waste Management Institute focused attention on life cycle assessment (LCA) as early as when LCA study started in Europe and positioned LCA as an important method for objective as well as quantitative evaluation of environmental impacts. In 1991, the environmental impact evaluation working group was established within the technical development committee of the institute. The working group learned the concept and method of LCA, collected inventory data, and evaluated resource consumption, energy consumption, and environmental burdens of treatment and disposal methods of used plastic. Furthermore, the working group analyzed eco-efficiency of treatment and disposal methods of used plastic while incorporating economic indices and weighting factors (Figure 1). The group then published reports as shown in Table 1.

This article introduces "2006 Eco-Efficiency Analysis for Plastic Container and Packaging Material Treatment," the report published in September, 2006.

Figure 1 History of LCA activities of the Plastic Waste Management Institute

- LCI accumulation and LCA analysis regarding plastic -

	Material mining to Manufacturing	Processing	Molded item	Treatment and disposal
Basic research	Learning of the concept and method 1992 Acquisition and translation of overseas information Plastic LCI in Europe 1995,2000			Package material waste disposal method LCA in Germany 1999
LCI data accumulation	General-purpose plastic LCI LDPE,HDPE,PP,PS EPS,PVC,PET 1999	Processing LCI Injection molding, film, and foaming 2000		
LCA (environmental impact assessment)			Plastic value investigation Liquid detergent containers, packaging materials for beverage transportation, and vehicle components 2004 Comparison of bottles and trays made of various materials 1995	Energy recovery value investigation LCA of treatment and disposal of plastic container and packaging 2001,2002 Industrial plastic waste mechanical recycling value investigation LCA of copy machines, car bumpers, and ATMs Recycling 2006
Eco-efficiency analysis (environmental impact / economic efficiency evaluation)				Energy recovery value investigation Analysis of eco-efficiency of recyclable plastic container disposal methods 2003,2005,2006

Table 1 LCA-related reports by the Plastic Waste Management Institute

No.	Publication	Report title
1	March, 1992	Environmental Impact Assessment of Treatments and disposal of Waste Plastic (Digest Version)
2	March, 1995	Environmental Impact Assessment (LCA) of Packaging Materials such as Plastic
3	March, 1995	LCA Consideration for General Plastic Waste Materials
4	December, 1995	Eco-Balance of Plastic in Europe
5	March, 1996	Research on Environmental Impact Assessment of Various Treatment Processes of plastic waste for Implementation of Mechanical Recycling and Energy Recovery : Establishment of a Plastic LCI Data Accumulation Method and Current Status of Plastic Recycling in Europe and the United States
6	March, 1997	Report on LCA Inventory Data Collection and Study
7	March, 1999	LCA of Plastic Packaging Material Waste in Germany (Abstract)
8	March, 1999	1998 Study Report on Infrastructure Development for Expanding the Waste Material Fuel Conversion Project: LCI Analysis of Plastic Treatment and Disposal
9	July, 1999	Study Report on Petrochemical LCI Data
10	January, 2000	Resin Processing Inventory Data Study Report: Mainly on General-Purpose Resin Processing
11	March, 2000	Eco-Balance of Plastics in Europe (Vol. 2)
12	March, 2001	LCA Study Report on Treatment and Disposal of Plastic Waste
13	March, 2002	Eco-Efficiency Analysis of Plastic Packaging Material Recycling Scenarios
14	March, 2003	Report on Examination of Waste Plastic Treatment and Disposal Systems using the LCA method
15	March, 2003	Eco-Efficiency Analysis of Waste Plastic Treatment and Disposal Systems
16	March, 2004	LCA of Plastic Products
17	March, 2005	Eco-Efficiency Analysis of Treatment of Plastic Containers and Packaging Materials
18	March, 2006	Case Examples of LCA of Copy Machines, Car Bumpers, and ATMs
19	September, 2006	2006 Eco-Efficiency Analysis of Treatment of Plastic Containers and Packaging Materials

2. 2006 Eco-Efficiency Analysis of Treatment of Plastic Containers and Packaging Materials

1) Background and Purpose

We published a report "Eco-Efficiency Analysis of Treatment of Plastic Containers and Packaging Materials" in March, 2005. After publication, we added and corrected information as follows in view of environmental changes:

(A)Refuse paper and plastic fuel (RPF*) for which there is a rapidly growing market has been added as one of the energy recovery methods, and the level of eco-efficiency of RPF has been clarified.

*RPF: It is a solid fuel created by melt-blending and molding waste plastic and waste paper or wood chips, and is used as a coal substitute.

(B)The 2006 Plastic Container and Packaging Material Recycling Guideline published by the Japan Containers and Packaging Recycling Association establishes that "in material recycling, when plastic removed by a gravity separation system is treated as industrial waste, its volume must be reduced by incineration and it must not be disposed in a landfill site as it is." The report has incorporated this statement.

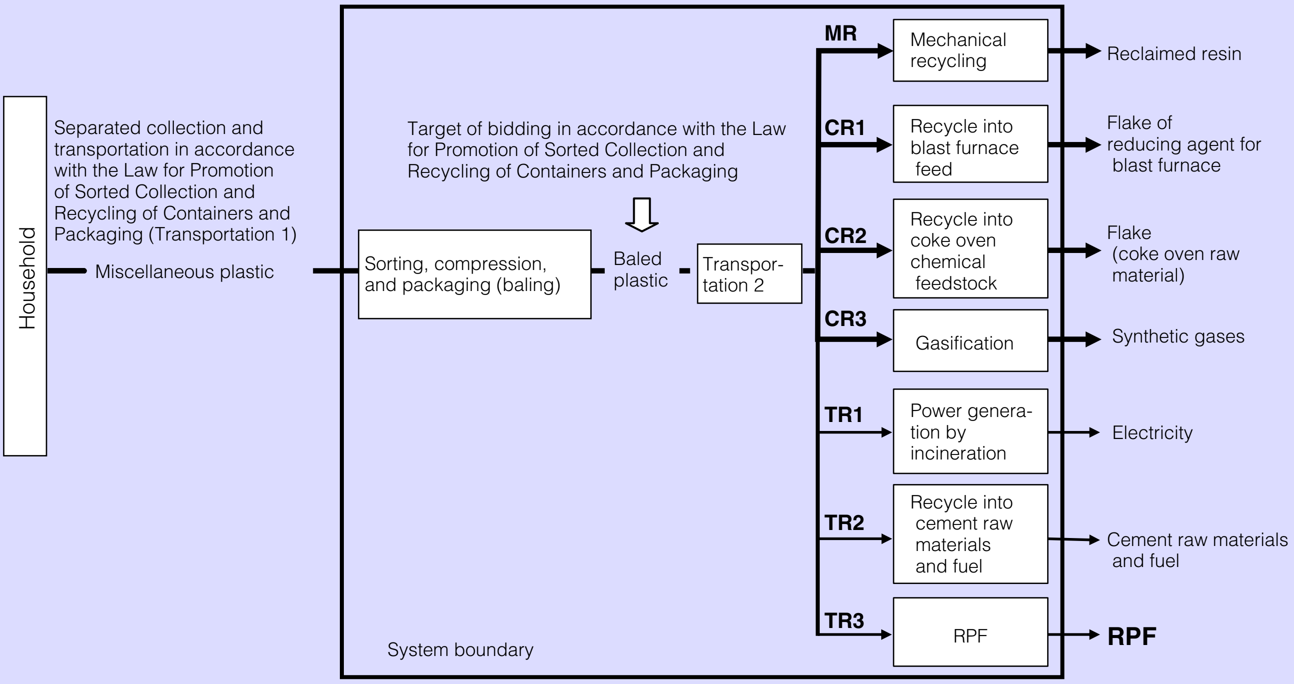
2) Target of analyses and system boundaries

Processes starting from collection of "miscellaneous plastic" in accordance with the Law for Promotion of Sorted Collection and Recycling of Containers and Packaging to sorting, compression, and packaging of the collected plastic (baling), transportation of the baled plastic to recyclers, and recycling of plastic in products were analyzed. Recycling methods to be assessed were mechanical recycling, blast furnace feed, coke oven chemical feedstock, gasification, power generation by incinaration, cement raw materials and fuel, and RPF (Figure 2). As a comparison, land-filling was assessed. Although waste-plastic-based power generation, plastic recycling into cement raw materials and fuel, and plastic recycling into RPF are not methods permitted under the Law for Promotion of Sorted Collection and Recycling of Containers and Packaging, they were nevertheless included in order to evaluate their characteristics in terms of eco-efficiency.

3) The product basket method

As the system boundary diagram indicates, different recycling methods result in different outputs. Every output is a product with value, and it allows producers and distributors to save products of the equivalent value. The method of conducting LCA of the environmental impact of a system that produces different outputs as described above is called the product basket method. Description of this method is provided below as this method was used in the eco-efficiency analyses of this article.

Figure 2 System boundary in LCA of recycling of "miscellaneous plastic" collected in accordance with the Law for Promotion of Sorted Collection and Recycling of Containers and Packaging



Note 1: MR stands for mechanical recycling, FR stands for feedstock recycling, and ER stands for energy recovery.

Note 2: Items indicated by thick lines are case examples in accordance with the Law for Promotion of Sorted Collection and Recycling of Containers and Packaging. Items indicated by thin lines are not subject to the law but are included here for analysis of characteristic differences from the case examples in terms of LCA.

The product basket method consists of the following three steps:

(A)Estimate outputs that are considered to have the same values as the actual outputs from individual systems.

(B)To each system add estimated outputs of the remaining systems to create system units having the same value of predicted outputs.

(C)Obtain environmental burdens of each system unit and compare the results.

Here, a simple yet detailed example of the product basket method is described (Table 2). In this example, environmental burdens are obtained by the product basket method on the assumption that plastic is recycled into reclaimed resin in the actual system, used in power generation by incineration in Comparison system 1, and is used in simple incineration in Comparison system 2. The actual output from the actual system is reclaimed resin flakes. A product assumed to have the equivalent value is new resin (x 0.3). The actual output from Comparison system 1 is electricity, and a product assumed to have the equivalent value is a public utility. There is no output from Comparison system 2. Based on these values, create system units having the same outputs. In other words, add public utility to the actual system, add new resin (x 0.3) to Comparison system 1, and add new resin (x 0.3) and public utility to Comparison system 2. After creating system units having the same set of outputs, environmental burdens of each system unit are compared.

4) Designing of treatment method units using the product basket method

For mechanical recycling (MR), blast furnace feed (FR1), coke oven chemical feedstock (FR2), gasification (FR3), power generation by incineration(ER1), cement raw materials and fuel (ER2), RPF (ER3), and landfill (LF), products that are considered to have the same value as each of the outputs listed above are added together to create system units having the same set of outputs. Table 3 shows the result.

Table 2 Examples of application of the product basket method to simple comparisons of waste plastic treatment and disposal systems

1. Outputs of waste plastic treatment and disposal systems and their estimated equivalents

Treatment and disposal system		Output	Estimated equivalent
Actual system	Reclaimed resin	Reclaimed resin flakes	New resin (x 0.3*)
Comparison system 1	Power generation by incineration	Electricity	Electricity (public utility)
Comparison system 2	Simple incineration	(None)	(None)

*From the quality perspective, it is assumed that reclaimed resin flakes are translated into 30% of the same volume of new resin.

2. System units having the same set of outputs to be used in comparison

System unit	Actual output	Estimated equivalent to be added
Actual system unit	Reclaimed resin flakes	Electricity (public utility)
Comparison system unit 1	Electricity	New resin (x 0.3)
Comparison system unit 2	(None)	New resin (x 0.3) + electricity (public utility)

Table 3 Designing of treatment method units using the product basket method

Analysis target	Output						
MR unit	Reclaimed resin (waste plastic)	Blast furnace feed (coal)	Coke oven chemical feedstock (coal)	Synthesized gases (newly manufactured)	Electricity (public utility)	Cement raw materials and fuel (coal)	RPF (coal)
CR1 unit	New resin (newly manufactured)	Blast furnace feed (waste plastic)	Coke oven chemical feedstock (coal)	Synthesized gases (newly manufactured)	Electricity (public utility)	Cement raw materials and fuel (coal)	RPF (coal)
CR2 unit	New resin (newly manufactured)	Blast furnace feed (coal)	Coke oven chemical feedstock (waste plastic)	Synthesized gases (newly manufactured)	Electricity (public utility)	Cement raw materials and fuel (coal)	RPF (coal)
CR3 unit	New resin (newly manufactured)	Blast furnace feed (coal)	Coke oven chemical feedstock (coal)	Gases (waste plastic)	Electricity (public utility)	Cement raw materials and fuel (coal)	RPF (coal)
TR1 unit	New resin (newly manufactured)	Blast furnace feed (coal)	Coke oven chemical feedstock (coal)	Synthesized gases (newly manufactured)	Electricity (waste plastic -based power generation)	Cement raw materials and fuel (coal)	RPF (coal)
TR2 unit	New resin (newly manufactured)	Blast furnace feed (coal)	Coke oven chemical feedstock (coal)	Synthesized gases (newly manufactured)	Electricity (public utility)	Cement raw materials and fuel (waste plastic)	RPF (coal)
TR3 unit	New resin (newly manufactured)	Blast furnace feed (coal)	Coke oven chemical feedstock (coal)	Synthesized gases (newly manufactured)	Electricity (public utility)	Cement raw materials and fuel (coal)	RPF (waste plastic)
LF unit	New resin (newly manufactured)	Blast furnace feed (coal)	Coke oven chemical feedstock (coal)	Synthesized gases (newly manufactured)	Electricity (public utility)	Cement raw materials and fuel (coal)	RPF (coal)

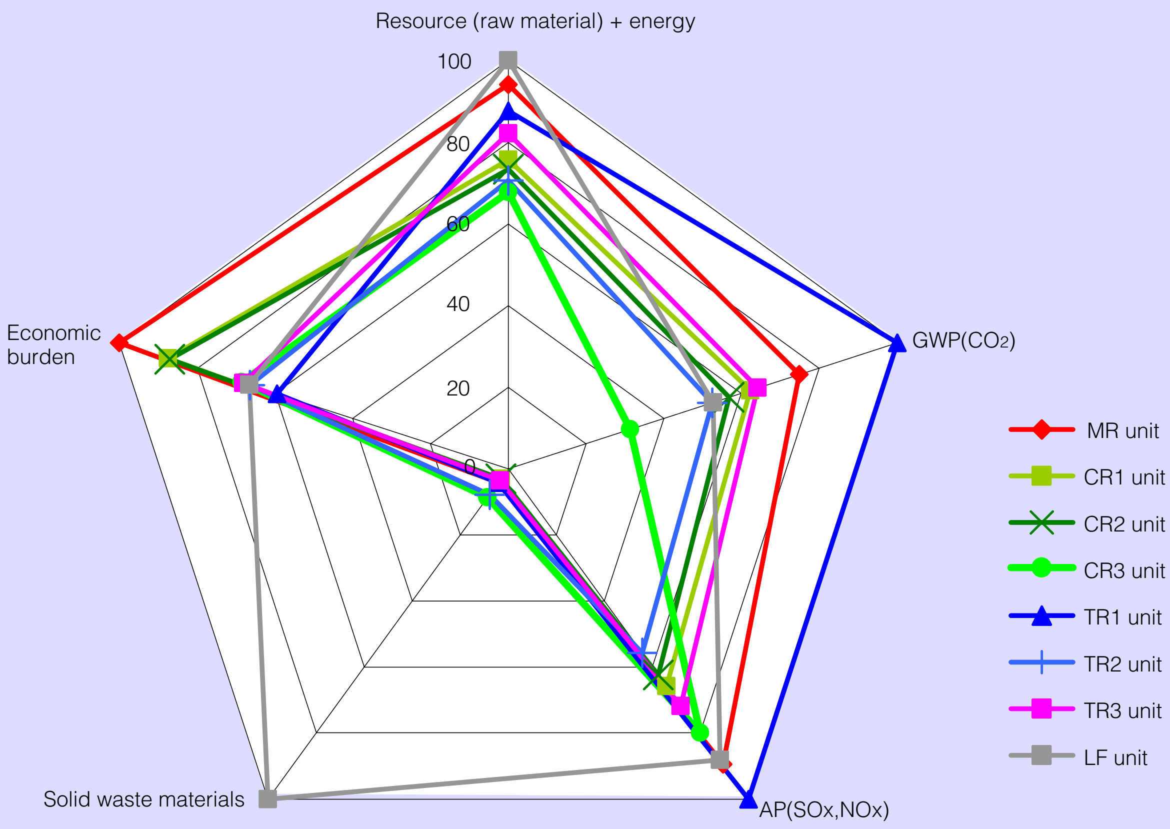
5) Results of relative comparison of environmental burdens and economic burden of the treatment methods

Relative levels of resource and energy consumption, CO_2 emission, acidic gases (SO_x and NO_x) emission, solid waste discharge, and economic burden, were compared among the treatment methods. For each item listed above, the treatment method that marked the highest level was given the value of 100, and the remaining methods were given relative values. Then the values for the treatment methods were plotted in a graph (Figure 3). Waste plastic-based power generation (ETR1) had the highest level of CO_2 emission, and mechanical recycling (MR) had the second highest level of CO_2 emission. The lowest CO_2 emission was by gasification (FR3). The reprocessed resin production had the second highest level of CO_2 emission because, when recycling plastic containers or packaging materials, approximately 50% of waste plastic is separated because it cannot be recycled into products when producing reprocessed resin, and incineration of the separated resin emits CO_2. Mechanical recycling resulted in the largest economic burden. This is because contract prices for production of reprocessed resin are high but the recycling rate is low.

6) Environmental burden integration

Relative positioning of each type of environmental burden was shown in the previous section. In this section, these environmental burdens were integrated in order to clarify comprehensive and relative positioning of each treatment method. Integration was carried out by first normalizing each type of environmental burden, then multiplying the normalized environmental burdens by weighting factors, and finally by summing the obtained values.

Figure 3 Relative comparison of environmental burdens and economic burden of each treatment method



MR: mechanical recycling
CR1: recycling into blast furnace feed, CR2: recycling into coke oven chemical feedstock, and CR3: gasification
TR1: waste plastic-based power generation (efficiency: 20%), TR2: recycling into cement raw materials and fuel, and TR3: recycling into RPF

(A)Normalization
Resource consumption and energy consumption were normalized by being divided by the total domestic consumption. Environmental burdens were normalized by being divided by the total domestic emission.

(B) Weighting factors
Referred to the weighting factor used by the German Federal Environmental Agency, the social coefficient in accordance with the panel method of BASF (a German company), and the social coefficient used by the Fraunhofer Institute, APME (currently Plastic Europe), the weighting factors for this study were set as follows:
Resource consumption: 25, energy consumption: 25, emission into the air: 35, and discharge to the soil: 15.
Breakdown of emission into the air: CO_2 & SO_x and NO_x = 83 and 17, respectively.

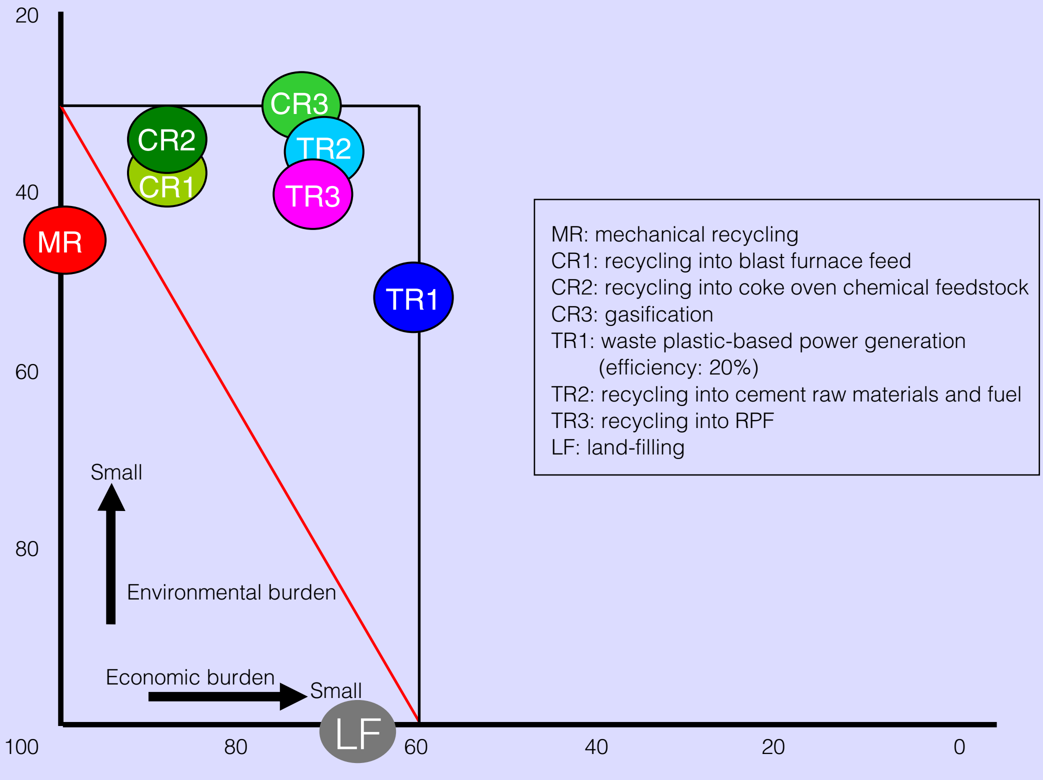
7) Result of eco-efficiency analysis of each treatment method

Figure 4 shows the result of eco-efficiency analysis of each treatment method. The vertical axis indicates the level of environmental burden. The burden decreases as the scale on the axis goes upward. The horizontal axis indicates the level of economic burden, and the burden decreases as the scale on the axis moves to the right. Therefore, the top right portion of the graph is the high eco-efficiency area, and the bottom left region is the low eco-efficiency area. The high eco-efficiency area included gasification (FR3), recycling into cement raw materials and fuel (ER2), recycling into RPF (ER3), and waste plastic-based power generation (ER1). The second best area included recycling into coke oven chemical feedstock (FR2) and recycling into blast furnace feed (FR1). Finally, mechanical recycling and land-filling were in the low eco-efficiency area.

3. Conclusion

After five years of full enforcement, relevant ministries reviewed the Law for Promotion of Sorted Collection and Recycling of Containers and Packaging. Then, the revised Law for Promotion of Sorted Collection and Recycling of Containers and Packaging was approved in the 164th Diet deliberation although it had additional resolutions. Now, the ministerial ordinance has been revised, public comments has been collected and incorporated, and the ordinance has been fully established. For the processes described above, this report has been cited by the deliberation committee.
The Law for Promotion of Sorted Collection and Recycling of Containers and Packaging will be revised again in five years. The government will conduct LCA of plastic container and packaging waste treatments and incorporate the results into law revision. Meanwhile, various organizations are now more actively involved in LCA.
We also plan to contribute to society by improving accuracy of the eco-efficiency analyses reported in this article based on field surveys and by releasing analysis results.

Figure 4 Eco-efficiency of each treatment method



LCA of System Products by the Hitachi Group

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1. Introduction

At the beginning of 1990's, the Hitachi group developed an LCA method for hardware products, and incorporated LCA results into product development or external sales[1]. An LCA tool is currently included in environmental design assessment[2] conducted at the time of product development such that both design and life cycle assessment can be conducted at the same time to support development of environmentally-friendly products[3]. Figure 1 shows the overview of the LCA tool included in the environmental design assessment.

When you input weights of materials constituting products, packaging materials, time (or cost) required for processing-assembly-distribution cycle, and recovery methods in a product information sheet, the LCA tool calculates the volume of CO_2 emission by multiplying the input data of each item by the corresponding basic unit of carbon dioxide (CO_2, hereinafter). The calculation results are thereafter used as burdens on procurement, recycle and disposal stage in LCA of system, software, and service products (so-called "system products") as described in after Chapter 2.

We started to develop the LCA method of system products in 2003. As the result, SI-LCA (System Integration - Life Cycle Assessment)[4, 5, 6] was developed as a method to convert environmental burdens over entire life cycle into the volume of CO_2 emission and to evaluate it. Here, a life cycle consists of various stages such as system design, development, procurement, manufacturing, use, recycling and disposal stage.

This paper presents the outline of SI-LCA, its case study and how SI-LCA is used within the Hitachi group, and then highlights issues to be addressed in the future.

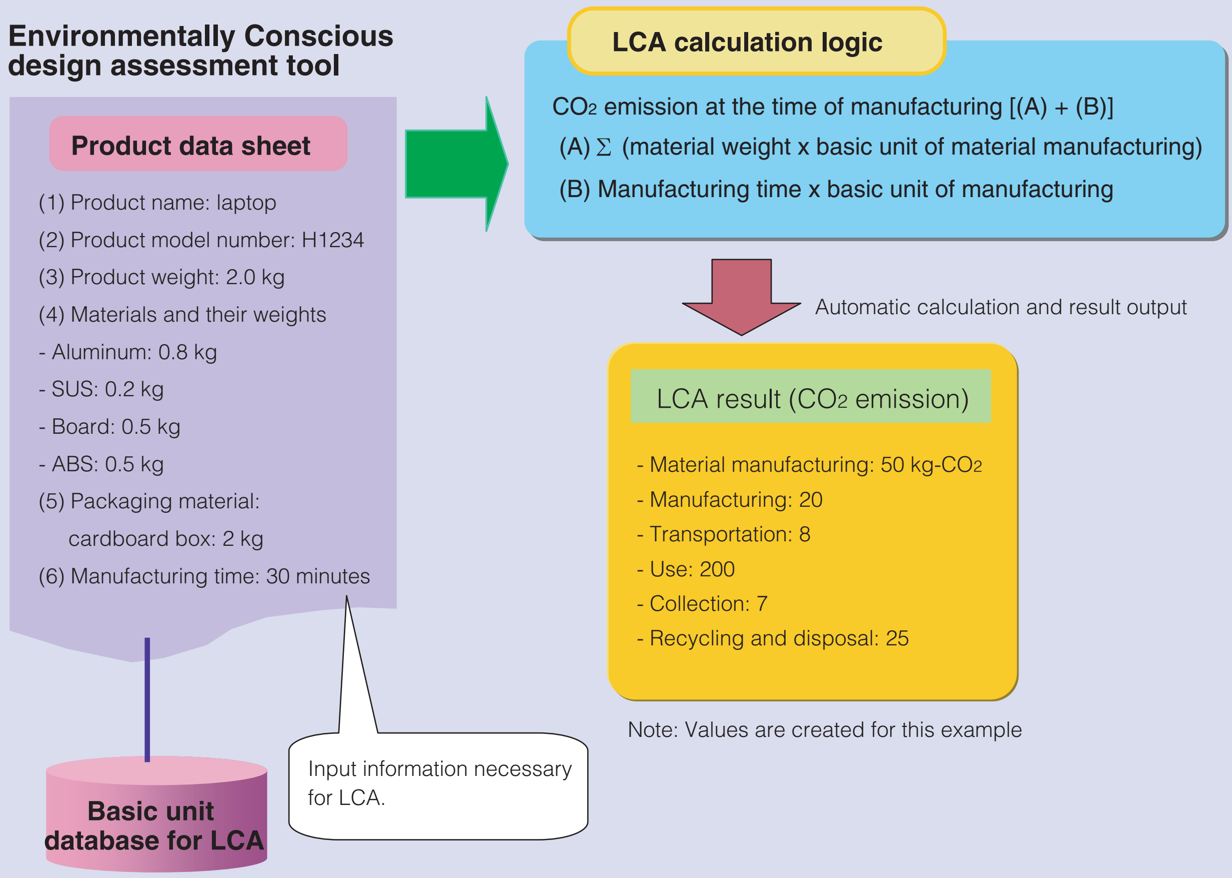

Figure 1 Overview of LCA calculation in environmentally-friendly product assessment

2. LCA method and LCA tool for system product
2.1 Development of an assessment method

For the development of SI-LCA, we established the following policy:

(1) A system product consists of combinations of hardware products (hereinafter devices) and software products (hereinafter software). Therefore, environmental burdens of devices and software should be assessed at the same time.
(2) Assessment should be performed over the entire life cycle of the system.
(3) Factors for positive and negative effects should be quantitatively calculated.
(4) A user-friendly assessment program should be developed.
An assessment method was examined based on the policy. After we selected stages that were considered to produce environmental burdens within the entire life cycle of a system, we examined them as to whether they should be included as the assessment targets or not. As the result, 10 stages shown in Figure 2 were selected as the assessment targets. Note that CO_2 is the environmental burden to be outputted. Also, for each stage, items listed in Table 1 were examined as factors that led to the generation of environmental burdens.

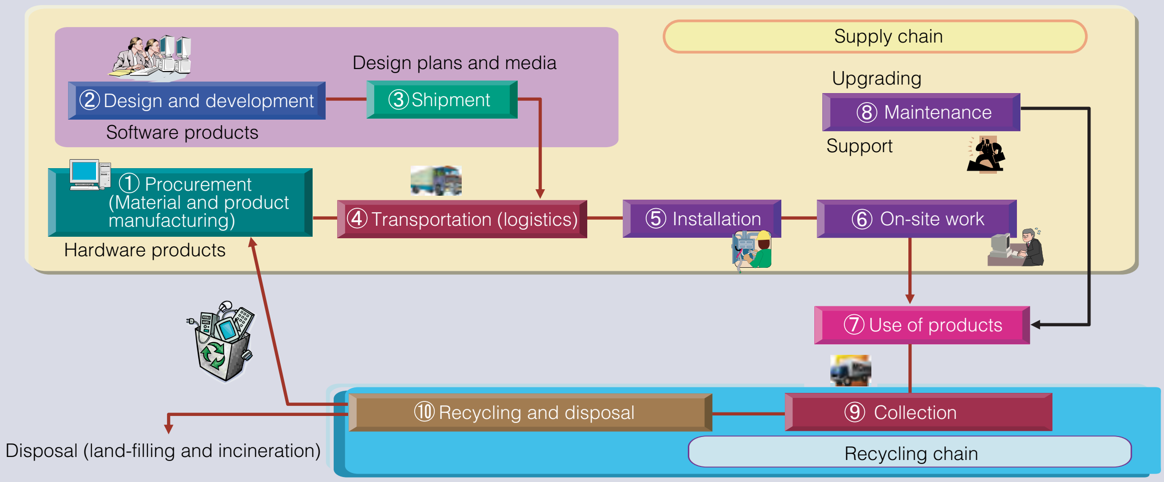

Figure 2 SI-LCA target stages

Table 1 Environmental burdens to be assessed in each life cycle stage

No.	Stage	Assessment target
1	Procurement	Manufacturing of device or packaging materials, and product manufacturing (processing and assembly)
2	Design and development	Design and development of system configuration or software
3	Shipment	Manufacturing and shipment of program storing media or documents
4	Transportation	Transportation of devices to customer
5	Installation	Installation of devices
6	On-site work	Launching of systems
7	Use	System operations at customer's offices (paper or power consumption, traveling by cars, burdens associated with various types of work, other factors that generate environmental burdens)
8	Maintenance	Maintenance and upgrading of devices or software during a system operation period
9	Collection	Transportation of used devices to recycling factories
10	Recycling and disposal	Recycling and disposal of devices

Case Example

We describe assessment methods for each stage of procurement, recycling, disposal, design, development, use as follows.
We have put great effort and creativity into establishing the assessment methods, particularly for these stages.

(1) Procurement and recycling / disposal

We created a system to collect automatically LCA data obtained for "material and product manufacturing" and "recycling and disposal" through environmentally conscious design assessment described in Chapter 1. Tabulating LCA data for all devices constituting a system would allow calculation of the amount of CO_2 emission for the procurement, recycling and disposal stages.
Note that, when LCA data for other manufacturers' products were required, LCA data for our equivalent products were used.

(2) Design and development

When various types of system products are designed and developed in one building or on one floor, it may be impossible for us to obtain each environmental burden associated with product designing or development for each individual product by tabulating and calculating energy and consumption.
For this reason, we established a method to assess environmental burdens associated with designing and development of a target system using an index called business office eco-efficiency. This business office eco-efficiency can be obtained by dividing the business sales by the environmental burdens of the entire business establishment (building). Formulas are as follows:
●Business office eco-efficiency (α)
Business sales (a) / business establishment environmental burdens (a')... (A)
●Environmental burdens associated with designing and development of each product (b')
= Design and development cost (b) / business office eco-efficiency (α)... (B)
Note that the installation, on-site work, and maintenance stages are also assessed using business office eco-efficiency.

(3) Product use

Assessment targets in the product use stage and the assessment method are described below.

(a) Paper consumption
At first the number of sheets of paper consumed is converted into weight. The environmental burden is calculated by multiplying the obtained weight by the basic unit of CO_2 emission at the time of paper production.

(b) Travel by car
This environmental burden is calculated by multiplying the distance of travel associated with system use and the basic unit of CO_2 emission per passenger.

(c) Work
Burdens associated with various types of work still required even after new system products are installed are first converted into power consumption (kWh/man-hours) and then multiplied by the basic unit of CO_2 emission for electricity to calculate the environmental burdens. It is known that lighting and energy required for ventilation associated with work produce environmental burdens and thus are also the targets of assessment.

(d) Other factors that produce environmental burdens
Burdens on Internet infrastructures due to data transmission or use of public transportation systems are also known to produceenvironmental burdens. Environmental burdens are obtained for each of the items that are expected to produce environmental burdens.

2.2 Overview of the assessment tool

Figure 3 shows an example of the input interface of the new assessment tool SI-LCA. A stage is first selected from the list of stage names on the left side of the screen before data are inputted. The screen for the selected stage shows types of environmental burdens associated with that stage. After all applicable environmental burden values are inputted, calculation is executed when the Confirm (Calculate) button is pressed

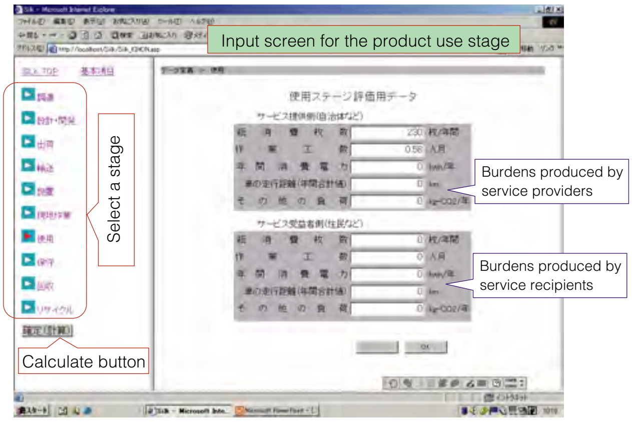

Figure 3 SI-LCA input interface (example)

The assessment result shows the amount of CO_2 emission for each stage. At the same time, a bar chart as shown in Figure 4 is provided. Note that, in addition to the environmental burden for the entire life cycle (bottom half of the screen), the assessment result for the product use stage in which users are most interested, is displayed separately (top half of the screen).

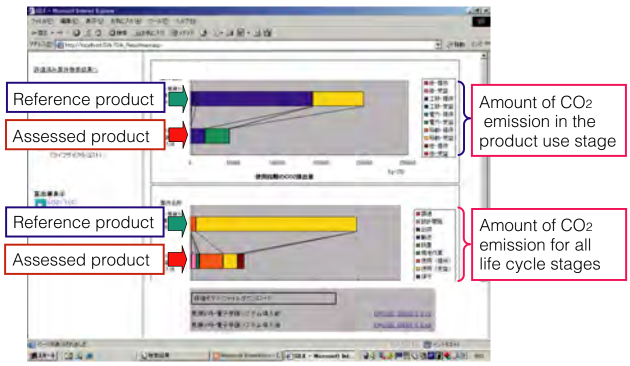

Figure 4 Example of the SI-LCA assessment result screen

3. Assessment example

In general, the product use stage accounts for most of the burdens in a system product lifecycle. Some products ,however , have high environmental burdens in other stages. To explain these variations, we show case examples of electronic form system assessment and EXPO 2005 AICHI admission ticket system assessment.

3.1 Electronic form system

3.1.1 Overview of an electronic form system and an assessment model[5)]

This electronic form system automatically transfers data to servers, stores data, and manages data instead of printing out forms, in order to allow viewing and searching of forms using client PCs. Compared to conventional systems, this system contributes to paperless operation and reduction of printed form delivery. The example of use of this system at supermarkets in the Tokyo metropolitan area is described below. Figure 5 shows the business model prior to the system installation, and Figure 6 shows the business model after the system installation.

Before the system installation, 200,000 forms were printed out at the output and distribution center. The forms were delivered to 10 bases twice a day, and at each base, the forms were sorted and distributed to 10 departments. In each department, staff members looked for an objective forms by hand and viewed them.

After the system installation, forms were not outputted unless necessary (20,000 forms which was one-tenth of what was printed out before the installation). The outputted forms were delivered to 10 bases once a day. At each base, the forms were sorted and distributed to 10 departments. Forms that did not need to be printed out were stored in the server. Therefore, most forms could be searched or viewed by accessing the server. Note that the assessment periods before and after the installation was set to 1 year each.

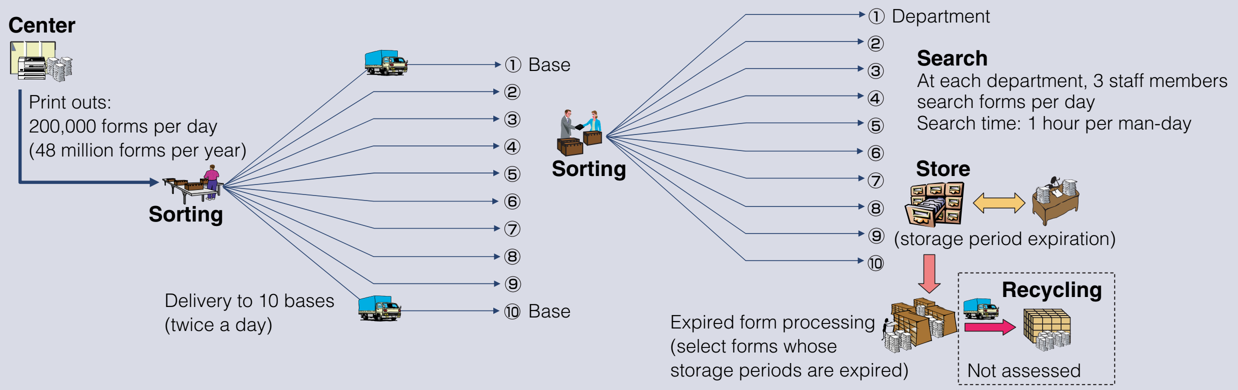

Figure 5 Business model prior to the electronic form system installation

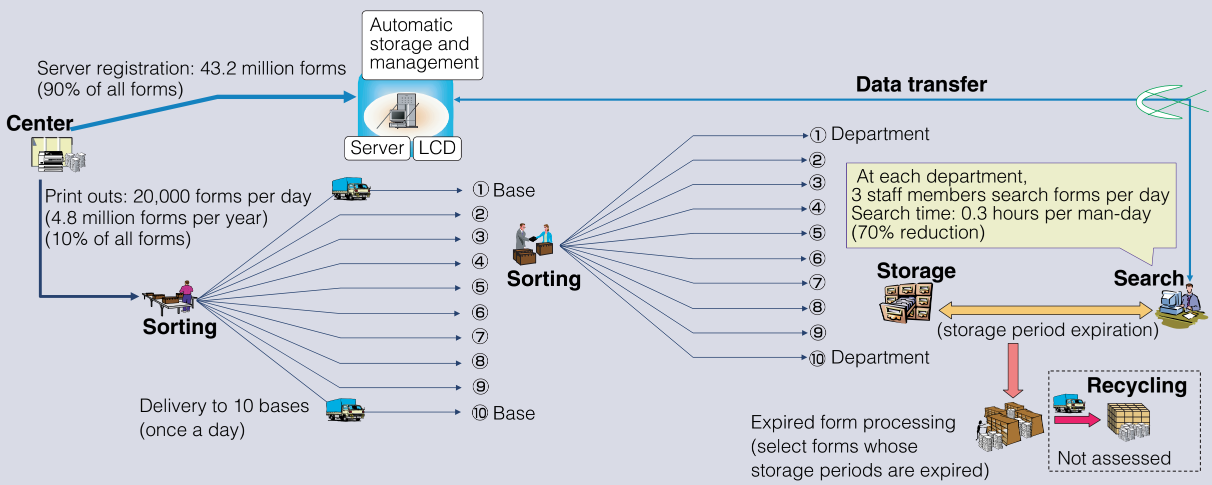

Figure 6 Business model after the electronic form system installation

Case Example

3.1.2 Assessment result

Table 2 shows assessment results for individual stages, and Figure 7 shows a graph of the assessment results. Most CO_2 reduction resulting from the system installation occurred in the product use stage where the printing papers and their transportation were reduced.

Table 2 Assessment results before and after the electronic form system installation

Stage	Before installation ($kg\text{-}CO_2$)	After installation ($kg\text{-}CO_2$)
Procurement	13,800	4,670
Design and development	0	1,310
Shipment	0	12
Transportation	34	11
Installation	7	4
On-site work	0	607
Use	571,000	100,000
Maintenance	0	27
Collection	28	9
Recycling and disposal	7	14
Total	585,000	107,000
Reduction (%)		82.0

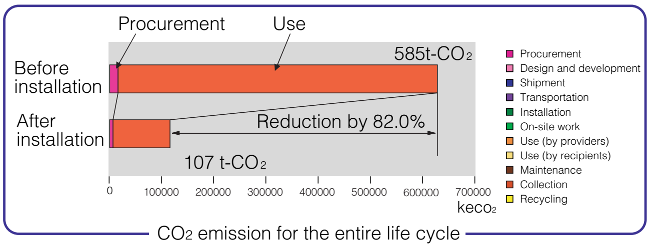

Figure 7 Assessment results before and after the electronic form system installation

3.2 EXPO 2005 AICHI admission ticket system

Section 3.2 describe an example in which the product use stage accounted for a very large part of environmental burdens. However, depending on how systems are used, other stages may account for a large part of environmental burdens, too. As an example, assessment of the admission ticket system used in EXPO 2005 AICHI, an international exposition held in 2005, is introduced in this section.

3.2.1 Assessment model

At the Expo, Hitachi's μ-Chip, which is a kind of radio frequency identification (RFID) system, was used in the admission ticket control system to automate admission control. This admission ticket system was compared to a paper-base admission control system involved ticket-tearing. We obtained information from the Japan Association for the 2005 World Exposition on the μ-Chip-based admission ticket system such as the entrance gate specifications, for example, the number of gates installed and devices constituting the system in order to create the assessment model. As for the ticket-tearing system, we created a virtual model for comparison that allowed the same level of admission control as the μ-Chip-based admission ticket system. Figure 8 shows the assessment model.

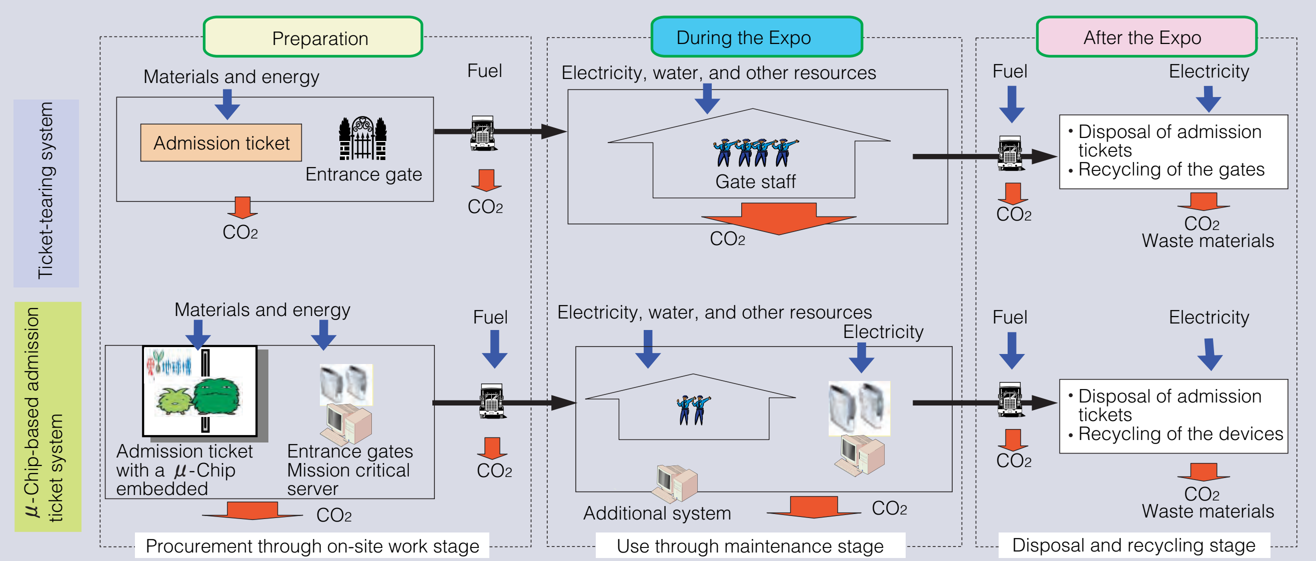

Figure 8 Admission ticket control systems for comparison

3.2.2 Assessment result

Figure 9 shows the result of SI-LCA. As seen in the result, in this example, burdens generated during the period spent on preparing for the Expo, which were burdens associated with production of entrance gates and admission tickets, accounted for a large part of environmental burdens. This was because the Expo (the product use stage) was held only for 6 months, and the burdens generated during the Expo was not as large as the example introduced in Section 3.1.

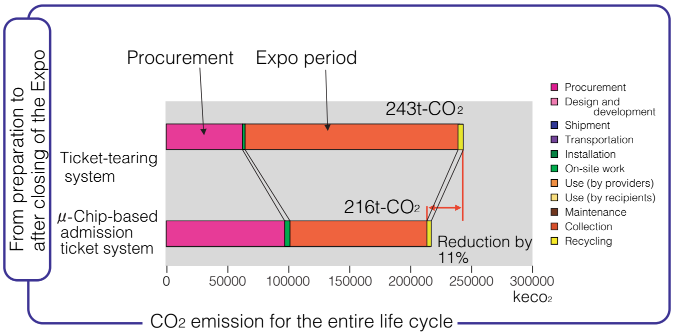

Figure 9 Result of EXPO 2005 AICHI admission ticket system assessment (for the entire life cycle)

4.Assessment target stages from the assessment result perspective

When the period for using the system is short as seen in the case of the Expo or depending on the environmental burden elements during the product use stage, the burdens in stages other than the product use stage may become high. Therefore, even though the amount of CO_2 emission is successfully reduced during the product use stage, this may not result in a dramatic reduction in terms of the entire life cycle.
Also, environmental burdens in the design and development stage may increase because of long design and development stage when products with low versatility such as products with unique customer specifications must be developed. For this reason, the assessment of the entire life cycle of a system product is considered valuable.

5. Issues
5.1 Internal deployment of SI-LCA

The main objectives of SI-LCA are as follows:
(A)Provision of quantitative data to customers to show the reduction effect of environmental burdens about the installation of system products offered by the Hitachi group
(B)Development of products that can reduce environmental burdens (in the Hitachi group) not only in the product use stage but also in the other stages as well
In order to achieve the goal listed above, system engineers (SEs) and sales personnel must learn to be able to conduct SI-LCA. Currently, LCA methods are introduced at a group company committee and in internal training programs in order to achieve group-wide deployment of SI-LCA.
User-friendliness of SI-LCA needs to be improved and its templates need to be created to facilitate assessment model creation in order to promote implementation of SI-LCA within the group. Therefore, we have been working on these issues while carrying out product assessment[7, 8].

5.2 Development into eco-efficiency assessment

Standardization of methods of assessing environmental burdens of system products was discussed by the IT Solution Working Group (WG) of the Japan Environmental Efficiency Forum of the Japan Environmental Management Association for Industry. With assistant professor Matsuno from the graduate school of Tokyo University as the chairman, 8 companies participated in this WG. The WG then published "2005 Guidelines for Assessment of Eco-Efficiency of Information and Communication Technology (ICT)9)" in March, 2006. Also, the Japan Environmental Management Association for Industry published "Environmental Assessment of IT Society - Green IT -" in July, 2007 to provide detailed description of the guideline.
The Hitachi group also participated in this standardization project and was able to establish an SI-LCA method that conformed to the guideline.
Note that this guideline provides the conceptual background and important points of eco-efficiency assessment. In addition to understanding the environmental burden reduction effect of use of system products, we hope to start conducting eco-efficiency assessment in the future. For this, however, quantification of value (benefit), which will be the numerator in calculations, will be an problem. It is more difficult to quantify the value provided by system products than to quantify the value of hardware products for which the calculation method of functions (value) has already been established by the Japanese Industrial Standards (JIS). The guideline states that ICT value can be expressed using physical, perceptual, and economic indices. Based on this statement, we hope to explore the method of quantifying value and to use it in eco-efficiency assessment while continuing our product assessment activities.

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LCA of Plastic Beer Bottle Cases and Plastic Pallets

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Since the establishment of Kaitakushi Brewery in Sapporo in 1876, we, Sapporo Breweries, have been studying and developing barley and hop breeds that are the main ingredients of beer and low-malt beer for 131 years. Because of our commitments to quality and safety of the ingredients, in 2006, we promoted the collaborative contract farming system such that Sapporo Breweries and ingredients producers cooperate to grow the ingredients. As a result, barley and hops are now 100% produced through collaborative contract farming. More specifically, all the barley and hop growing processes before delivery to Sapporo Breweries are carried out based on close consultation between Sapporo breweries and the producers, and for these growing processes, decisions are jointly made on breed selection, cultivation method, timing of seeding, agrichemical and fertilizer usage, timing of harvesting, post-harvest sorting, warehouse management state, storage state, and transportation state.

In general, LCA has so far only been conducted with product containers. We however conducted LCA of not only containers but also each product using data of all production processes such as data on the ingredients during production period obtained from the system for the collaborative contract farming, manufacturing data, and logistics data. As a result, we were registered as a critical reviewer by the Japan Environmental Management Association for Industry[1] (assessed products: Large-size Sapporo Black Label 633 ml bottle, Sapporo Black Label 350 ml can, and Hokkaido Namashibori 350 ml can). For the products we offer to our customers, we have been making efforts to be environmentally-friendly and to protect resources in all manufacturing stages from ingredients handling to container packaging.

This report introduces one of our recent examples of LCA: LCA on plastic cases and pallets.

1. Introduction

The Law for Promotion of Sorted Collection and Recycling of Containers and Packaging was fully implemented in April 2000, and plastic recycling is steadily increasing. In Japan, the amount of industrial waste and general waste has been the same for some time. The amount of waste plastic has also been the same, and it is now 10.01 million tons per year. According to the statistical data of 2003, 5.84 million tons of the waste plastic is reused by means of material recycling, chemical recycling, and thermal recycling. The breakdown of the 10.01 million tons of waste plastic is as follows: 9.13 million tons are from used products, and 0.88 million tons are from production or processing failure. Only 8.5% of waste plastic from used products, which is 0.78 million tons, is recycled by means of material recycling. Meanwhile, waste plastic from production or processing failure is 100% recycled. Therefore, recycling of waste plastic from production or processing failure accounts for a large part of material recycling of waste plastic. This is because plastic from production or processing failure has stable quality and characteristics. By contrast, plastic from used products is not likely to be recycled through material recycling because foreign materials or objects may be mixed in with this type of plastic[2].

One of the few examples of material recycling of waste plastic from used plastic is material recycling of plastic beer bottle cases (P-cases, hereinafter) into plastic pallets (P-pallets, hereinafter). P-cases currently used in the market are either made of polyethylene (PE) or polypropylene (PP). These P-cases are always collected at beer manufacturing factories; therefore, it is possible to collect a relatively large number of cases, and all used P-cases become the ingredients of P-pallets.

P-cases for beer bottles are used as secondary packaging of beer bottles while P-pallets are used for wider purposes such as secondary and tertiary packaging for carrying P-cases, cans, and barrels. Although beer manufacturers use their own P-cases, P-pallets were standardized among beer manufacturers and other brewers. As a result, P-pallets are shared by these manufacturers (34 companies as of the end of 2005) and cumulatively over 9.7 million P-pallets have been provided to these manufacturers by the end of 2005[3].

2. Objective

After P-cases reach their product life, 10-cases worth of plastic material is recycled into one P-pallet, and waste P-cases are 100% recycled into P-pallet material. The objective of this report is to clarify the advantage of manufacturing P-pallets from waste P-cases instead of from new materials by: using the LCA method which allows quantitative assessment of environmental impacts; defining a life cycle flow of P-cases and P-pallets; assessing their environmental impacts; and by comparing the assessment results with the case where P-pallets are manufactured using new material.

3. Method

3.1 Method

Based on interviews with P-case and P-pallet manufacturers, life cycle flows and LCI data were created to see how the cases and pallets were handled throughout their life. Then, based on the values obtained, environmental impacts of P-cases and P-pallets were calculated using LCA software JEMAI-LCA Pro (Japan Environmental Management Association for Industry).

3.2 Functional unit of LCA and scope of the survey

As environmental burdens, a global warming potential (1 GWP = 1 kg-CO_2) and an energy consumption coefficient (MJ) were obtained mainly from carbon dioxide emission. In this report, IPC 100 index (2001) is adopted for GWP. Also, a 1 kg mass of P-pallet material is defined as a functional unit.

The scope of the survey included the PE production stage, P-case manufacturing stage, P-case grinding and raw material production stage, P-pallet manufacturing stage, and the transportation stage associated with each of the stages listed previously. Note that the product use stages for P-cases and P-pallets were excluded from the survey because P-cases and P-pallets were simply used at beer factories or during distribution, and no processing was performed with them or no additional values were attached to them. Survey data was created based on the actual result of 2000.

3.3 Target products

The following products were assessed:

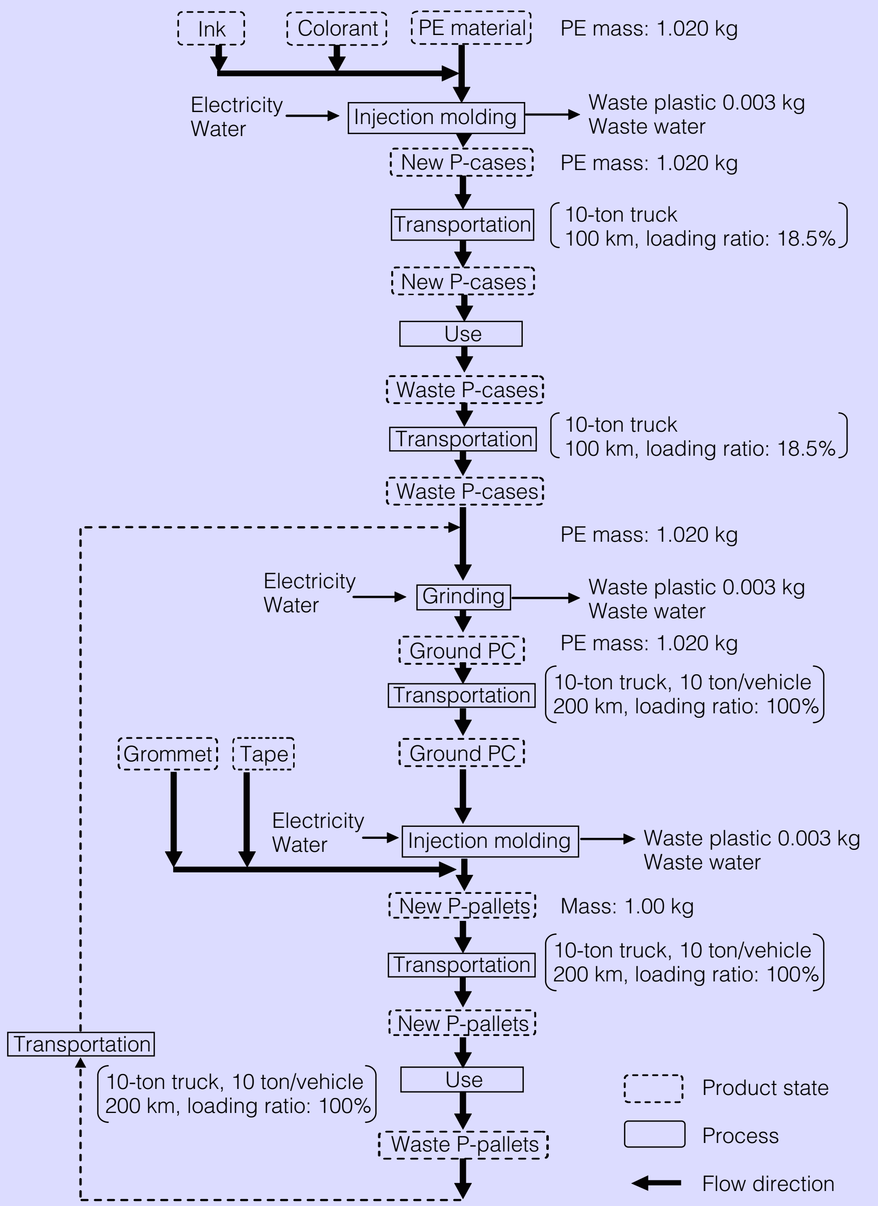
- P-cases: for large beer bottles, 2.2 kg mass, and made of PE
- P-pallets: 19.0 kg mass and 97% made of PE

4. Result

4.1 Life cycle flow

Figure 1 shows the life cycle flow of P-cases and P-pallets. Note that this report mainly deals with P-cases and pallets that are made of PE. Waste P-pallets are ground and recycled as P-pallet materials, but this processing has been excluded from the flow (dotted lines with an arrow in Figure 1).

Figure 1 Life cycle flow



4.2 Life cycle inventory (LCI) analysis

Table 1 shows LCI data obtained from the quantity data that has been examined. The total energy consumption was 75.94 MJ, and the global warming potential was 1.51 GWP. This section provides details of the survey result. In addition to PE, the following materials are used when P-cases are manufactured: ink (0.01 %), colorant (Master Batch; 4.8%), and industrial water. Since these materials are used in a very small amount, they were excluded from the analysis. As with the case of the P-cases, in addition to ground PE, grommet (slip-stopper for forks of forklifts) elastomer (1.1%), grip tape LDPE (2.1%), colorant, and ink are used in the manufacturing of P-pallets, but they were excluded from the analysis since they were used in a very small amount. If waste P-pallets are ground in the same manner as waste P-cases, they can be recycled into new P-pallets (Table 1 excludes recycling of waste P-pallets). As for transportation, the distance of transportation by trucks was estimated by measuring the distance between bases on a map. Note that transportation of raw materials was excluded from the analysis.

When energy consumption in the entire life cycle, from PE manufacturing to transportation, was expressed in percentages, PE material production accounted for 76% of energy consumption. Energy consumption by the P-pallet manufacturing stage was the second highest at 16%. As for global warming, PE material manufacturing accounted for 48% of the entire global warming potential. The second highest percentage was 33% and was attributed to P-pallet manufacturing. When P-case manufacturing and P-pallet manufacturing were compared, P-pallet manufacturing caused energy consumption and global warming 4.5 times more than P-case manufacturing. In other words, for 1 kg of PE, P-pallet manufacturing resulted in higher environmental burdens than P-case manufacturing. This is because, while the manufacturing of P-cases requires one-time molding, P-pallet manufacturing is complicated since it requires molding of the top and the bottom parts, gluing of these two parts, and attachment of glue tapes. Furthermore, P-case manufacturing processes involve a lot of manual labor while P-pallet manufacturing is automated and thus consumes a lot of energy to operate the manufacturing system.

Table 1 LCI data

	Use of resources		Energy consumption	Waste material		Global warming
	PE kg	Water L	MJ	Waste plastic kg	Waste water L	GWP
PE manufacturing	1.02		57.98			0.73
P-case manufacturing			2.72	0.003		0.11
Grinding		0.79	1.05	0.010	0.79	0.04
P-pallet manufacturing		1.10	12.30	0.007	1.10	0.50
Total Transportation			1.89			0.14
Total	1.02	1.89	75.94	0.020	1.89	1.51

5. Discussion

Currently, material recycling is carried out by using waste P-cases as materials for P-pallet manufacturing. Assuming that P-pallets or P-cases are manufactured by other procedures, Table 3 shows the LCA results and environmental burdens for individual procedures. Note that Table 3 excludes data on combustion energy of PE, which is 46.05 MJ, since it is shown in Table 2.

Manufacturing of P-pallets from new PE results in the highest environmental burden level. Recycling of waste P-cases or waste P-pallets into new P-pallets has the same environmental burden level which is lower than in the case where new PE is used to manufacture P-pallets. As with the case of P-pallet manufacturing, manufacturing of P-cases using waste P-cases results in a lower environmental burden level than in the case where new PE is used to manufacture P-cases.

Next, combustion energy of plastic is discussed. Here, it is necessary to understand that, as shown in Table 2, plastics like PP and PE have the same level of combustion as kerosene[4]. As shown in Table 1, energy of 57.98 MJ needs to be consumed to produce 1 kg of new PE. Combustion energy of PE however, as shown in Table 2, is 46.05 MJ. Therefore, the actual energy consumed up to the point where PE is produced is only 11.93 MJ (57.98 - 46.05 = 11.93). In LCA of plastic materials having high combustion energy such as PE in this example, how to assess energy is considered an important point[5]. When plastic's combustion energy cannot be effectively used due to, for example, incineration of used plastic products or using them in land-filling, its combustion energy is considered to have no value. However, technologies such as recycling of waste materials into fuels or power generation from garbage are now being actively pursued, and it is expected in the future that the combustion energy of used plastic can be more effectively used. As shown in the bottom row in Table 3, this study indicated that a total of 70.02 MJ of energy is consumed when P-pallets are manufactured using new PE, and when combustion energy of PE is excluded, the actual energy consumption is 23.97. Likewise, it is 14.23 MK when P-cases are manufactured using new PE. In any case, even though combustion energy of PE is considered, manufacturing of P-pallets or P-cases using new PE resulted in higher environmental burdens then in the case where P-pallets or P-cases are manufactured using waste P-pallets or P-cases.

Note that new PE is used in the actual P-case manufacturing in order to maintain the required case strength and to assure that there will be sufficient waste P-cases to be used as P-pallet material.

Table 2 Combustion energy [4)]

Material	Calorific value [MJ/kg]
High density polyethylene	46.05
Polypropylene	44.13
PET	23.10
Kerosene	44.10

Table 3 Comparison of manufacturing methods (per 1 kg of P-pallets or P-cases)

	Manufacturing of 1 kg of P-pallets from new PE		Manufacturing of 1 kg of P-pallets from P-cases		Manufacturing of 1 kg of P-pallets from P-pallets		Manufacturing of 1 kg of P-cases from new PE		Manufacturing of 1 kg of P-cases from P-cases	
	Energy consump-tion MJ	Global warming potential GWP	Energy consump-tion MJ	Global warming potential GWP	Energy consump-tion MJ	Global warming potential GWP	Energy consump-tion MJ	Global warming potential GWP	Energy consump-tion MJ	Global warming potential GWP
PE production	57.24	0.72					57.02	0.71		
P-case manufacturing							2.67	0.11	2.70	0.11
Grinding			1.05	0.04	1.05	0.04			1.05	0.04
P-pallet manufacturing	12.03	0.50	12.30	0.50	12.30	0.50				
Total Transportation	0.48	0.03	1.30	0.09	1.30	0.09	0.59	0.04	1.19	0.09
Total	70.02	1.25	14.65	0.63	14.65	0.63	60.28	0.86	4.94	0.24
Total excluding 46.05 MJ of combustion energy	23.97	—	14.65	—	14.65	—	14.23	—	4.94	—

6. Conclusion

In this report, we conducted LCA of P-pallet and P-case manufacturing and recycling stages based on the information obtained through interviewing manufacturers. The result indicated that recycling of P-cases into P-pallets resulted in lower environmental burdens than using new PE to manufacture P-pallets. Therefore, waste P-cases are considered to be used effectively. The analysis also indicated that recycling resulted in lower environmental burdens even after the combustion energy of PE was deducted.

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Report

Introduction of LCA education to universities and development of environmental consciousness

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1. Introduction

While the question has been raised as to how the environment, science, technology, economic efficiency, and sociality should be integrated so as to solve environmental issues, the necessity of environmental education at universities has grown and development of practical and environmentally-conscious human resources has become important. For this reason, Shinshu University begun creating environmental management systems (EMS) at all its campuses, starting with the acquisition of the EMS (ISO14001) certification at the Wakasato Campus (faculty of engineering) in 2001. In 2004, this project was selected as a "distinctive university education support program (education GP)" by the Ministry of Education, Culture, Sports, Science and Technology. Then, the university set its sights on the development of awareness of the environment from the life cycle point of view by encouraging people to be environmentally-conscious in their daily lives. In October, 2007, we were able to obtain the EMS certification at the Matsumoto Campus (the faculty of medicine and its affiliated hospital will obtain the certification in 2009), and now all seven campuses are EMS certified. Currently, the students in these campuses are powerful promoters of environmental management or preservation activities, creating what we call eco-campuses.

Also, since students are both consumers and a part of the society, they must be able to make decisions on environmentally-conscious consumption as well as purchasing to contribute to the formation of a sustainable society and also to think about these activities from the life cycle point of view. In order to develop the ability to realize the above, the university started a course on life cycle assessment (LCA). It was introduced in 2000 as a basic course for all departments, specifically targeting 3rd and 4th year engineering students. Then, in 2002, it became available as a 1st year liberal arts course for all faculties and departments.

This article reports how students' awareness of environmental issues changed before and after they participated in the LCA lecture and training when the LCA education was first introduced. Note that this report is based on the result of a free-answer survey (multiple answers were allowed) administered to these students[1].

2. Objective and method

Since questions on LCA started to be included in the national central test for university[2], every year, I have asked our students on the first day of the course if they knew anything about LCA, even if only by name. In many cases students were too shy to raise their hands, but still, there were always only a few students who showed that they knew or had heard of LCA. Most students learned about LCA for the first time in my course.

In the course, we examined an overview of the current global issues, examined LCA of blow-type hair dryers and laptops, as examples of products that were already distributed, in use, and familiar to us, using calculators and PCs in order to learn calculation methods and how to interpret the results. In the 1st year course, the students learned the ISO14040-specified essential skills for defining the objective and setting the scope of the survey, conducting life cycle inventory (LCI) analysis, conducting life cycle impact assessment (LCIA), and interpreting the assessment results. In the 3rd and 4th year, students studied not only the requisite skills but also elective skills called the damage assessment skills (assessment of health effects on individuals). Through this, the objective of this course was to promote students' understanding of how to read the environmental reports released by companies or organizations and how to interpret quantitative environmental information on products closely related to our daily lives such as the Type Ⅲ environmental label (ECO-LEAF) using LCA method. Also, a shift from vague awareness of the environmental issues and passive actions to active participation or decision making in environmental activities was another objective of this course.

3. Result and discussion

Figure 1 shows the changes in the number of students enrolled in the LCA course, starting from the year in which this course was first introduced. As a result of the acquisition of the EMS certification at all the campuses and being selected as the education GP, at Shinshu University, university policy and the approach to environmental issues are widely announced on the university website or in each faculty building. Also, starting from 2006, all 1st year students must take a 2-credit course on the environment regardless of their faculty or department. For this reason, the number of 1st year students taking the LCA course has been increasing.

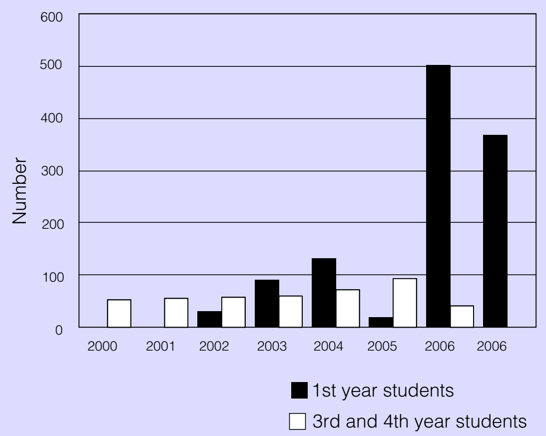

Figure 1 Changes in the number of LCA course students

The answers provided in the survey administered during the class were divided into the following six types: (A) effect of introduction of LCA, (B) knowledge of LCA, (C) examination and changes in lifestyle, (D) consumer awareness, (E) approach to environmental issues, (F) recycling, and (G) others. Description of each answer type is as follows. (A) The effect of introduction of LCA describes what the students learned through LCA practice. (B) Knowledge of LCA describes issues and opinions of the students about LCA methods or calculation. (C) Examination and changes in lifestyle describes whether or not LCA provided the students with an opportunity to review or examine their lifestyle. (D) Consumer awareness describes if the students as consumers experienced changes in awareness of environmental issues. (E) Approach to environmental issues describes how the students approached environmental issues from a personal to global level based on the results of LCA of products that they used in their lives. (F) Recycling describes how the students changed their awareness of recycling. (G) Others includes opinions of the students about how the lecture was given or students' acquisition of PC skills.

Figure 2 shows the result of the survey administered after the 1st year students finished training of requisite LCA skills (2nd term, 2004). A total of 160 answers were divided into the above-listed six types. For (A) the effect of introduction of LCA, there were 49 answers (31%). Examples of the answers were as follows: "I did not have any clear image of environmental issues before, but seeing specific values made me understand their immediate importance," "I learned to see environmental issues from a new perspective," and "I was able to understand some of the concepts of environmental burdens and energy-saving products." For (B) knowledge of LCA, there were 23 answers (14%). Examples of the answers were as follows: "I was able to understand how to conduct LCA and the meaning of calculation," "I believe information on LCA should be known by people and should be given to people," "I think calculation is difficult," and "I think calculation is quite interesting." For (C) examination and changes in lifestyle, there were also 23 answers (14%). Examples of the answers were as follows: "I want to decrease unnecessary use of energy," "I would like to save energy at home," "I will remember what I learned the next time I purchase an appliance," and "I should reexamine energy consumption in my daily life." For (D) consumer awareness, there were 15 answers (9%). Examples of the answers were as follows: "Dramatic changes in consumers' awareness will be necessary soon," "The benefit of development of energy-saving products relies on consumers' awareness of energy saving," and "Customers must be careful of how they use blow-type hair dryers." For (E) approach to environmental issues, there were 36 answers (23%). Examples of the answers were as follows: "I never used to think about the environment when I purchased products," "We should support eco-friendly development of developing countries," and "The most effective solution to the environmental issue is eco-friendly actions by individuals instead of national or city-level actions." For (F) recycling, there were 12 answers (8%). Examples of the answers were as follows: "I became interested in recycling when I saw actual values related to recycling," "I reconfirmed the benefit of recycling," and "I would like to recycle resources too." For (G) others, there were 2 answers (1%). The answers were as follows: "I used a PC very often within these 2 weeks and I really felt like I was living in the information society," and "Among topic-specific lectures, LCA was one of the most difficult topics that I studied."

Although 1st year students studied about LCA for the first time, they had already been exposed to general information or knowledge of environmental issues through senior high school classes, newspapers, TV, and advertisements. Therefore, not only what they felt about the LCA results, but also a wide range of answers such as changing lifestyle, improvements that consumers could make, and environmental issues in society were submitted. Environmental issues were vague ideas for the students, but learning about LCA seemed to motivate the students to obtain new knowledge from the LCA results or to participate in environmental protection activities.

Next, figure 3 shows the result of the survey administered after the 3rd and 4th year students finished training of requisite LCA skills (1st term, 2004). As with the case of the survey with the 1st year students, a total of 81 answers were divided into the six types mentioned above. For (A) the effect of introduction of LCA, there were 33 answers (41%). Examples of the answers were as follows: "Environmental burdens can be quantitatively assessed," "Calculation gave us a clearer image," "LCA let me develop a new way of thinking," and "I now think differently." For (B) knowledge of LCA, there were 22 answers (27%). Examples of the answers were as follows: "If presented in an easy-to-understand way, people can raise their awareness of environmental issues," "Both in arts and science, we all need to learn how to perform LCA," and "It is hard because there are a lot of calculations to do." For (C) examination and changes in lifestyle, there were 3 answers (4%). The answers were as follows: "I felt it was necessary to try to reduce environmental burdens in our daily lives," "We need to think carefully when we use energy," and "We need to decrease unnecessary use of energy." For (D) consumer awareness, there were 4 answers (5%). Examples of the answers were as follows: "Consumers must think about environmental issues when they make purchases," "Consumers need to actively perform LCA," and "Consumers need to think carefully about the use of energy." For (E) approach to environmental issues, there were 9 answers (11%). Examples of the answers were as follows: "Our view of environmental issues is very vague, and it is difficult to realize these issues do exist even though we conceptually understand what they are," "I confirmed my belief that a large amount of CO_2 was still emitted," and "the expression energy-saving is too abstract, and therefore, it is necessary to provide more concrete and detailed information." For (F) recycling, there were no answers (0%). For (G) others, there were 10 answers (12%). Examples of the answers were as follows: "It was easy because I used a PC," "Manufacturing of one product involves many tasks," and "The course was easy to understand because I took the LCA course when I was in 1st year."

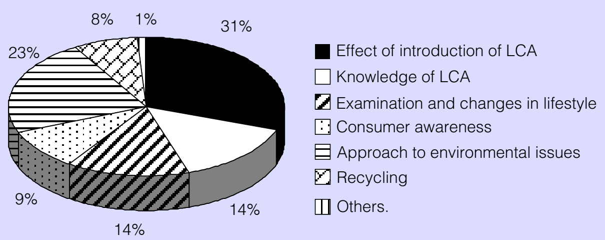

Figure 2 Result of the survey with the 1st year students (after training of requisite skills)

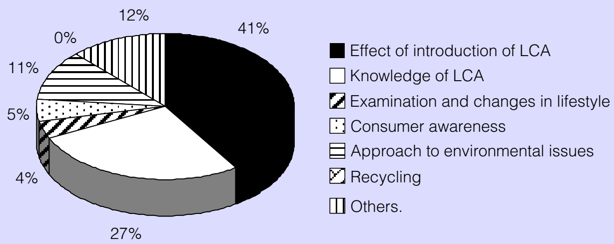

Figure 3 Result of the survey with the 3rd and 4th year students (after training of requisite skills)

Figure 4 is an integration of Figures 2 and 3 that show the result of the survey conducted with 1st year students and 3rd and 4th year students after LCA practice was finished. The 3rd and 4th year students often provided comments on LCA methods, LCA results, and discussions based on the LCA results. Answers regarding the effect of introduction of LCA and knowledge of LCA accounted for about 68%, which was a dramatically different percentage from the proportion of answers submitted by the 1st year students. The 3rd and 4th year students take courses specialized in the environment within the department they are registered in, and within the departments, the EMS student committee is actively promoting the creation of eco-campuses. Therefore, they have more knowledge than the 1st year students about environmental issues in general or information useful for solving these issues. This seems to be the reason why the 3rd and 4th year students often submitted answers regarding LCA since they were interested in the method of assessment of LCA itself and the method of calculation in the LCA assessment.

Finally, the 3rd and 4th year students studied not only the requisite skills but also elective skills called the damage assessment skills (assessment of health effects on individuals). The same survey was conducted after the training and its result is shown in Figure 5. There were a total of 38 responses. There were 17 answers (31%) for (A) the effect of introduction of LCA, 10 answers (26%) for (B) knowledge of LCA, 0 answers (0%) for (C) examination and changes in lifestyle, 1 answer (3%) for (D) consumer awareness, 7 answers (18%) for (E) approach to environmental issues, 0 answers (0%) for (F) recycling, and 3 answers (8%) for (G) others. As with the case of Figure 3, answers regarding the effect of introduction of LCA and knowledge of LCA accounted for about 71%, and the result thus indicated that the students' interest focused on understanding and interpretation of the LCA method once they learned how to conduct the assessment in detail. Note however, the number of responses collected was approximately 47% of the previously introduced survey whose result is shown in Figure 3. For this, it is suspected that the response ratio may have been affected by whether or not the students believed in the value of mastering highly specialized but non-requisite assessment skills. In the future, it may be necessary to examine the lecture coverage and method to teach more versatile elective skills.

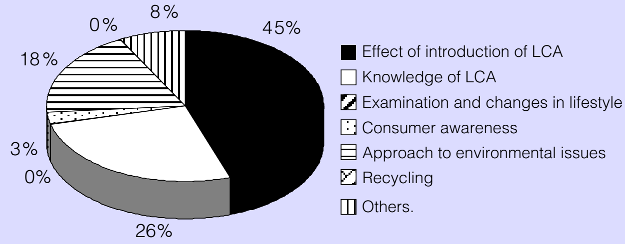

Figure 5 Result of the survey with the 3rd and 4th year students (after training of elective skills)

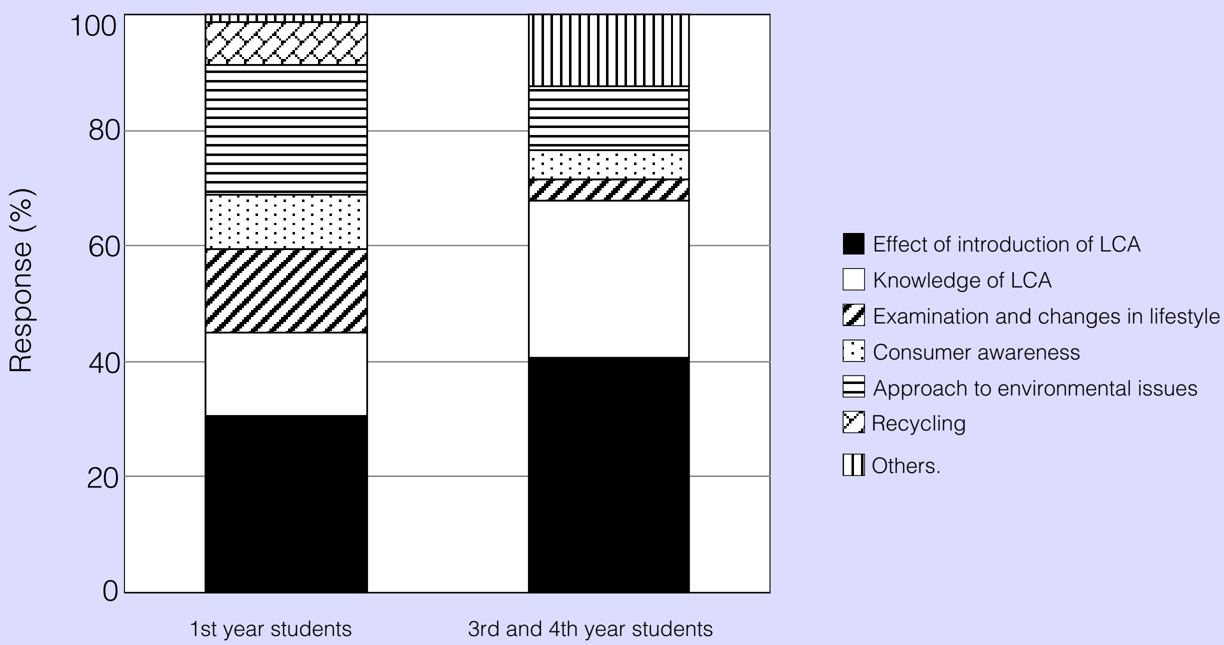

Figure 4 Comparison of the results of the survey with the 1st year students and 3rd and 4th year students (after training of requisite skills)

4. Conclusion

In addition to the traditional practical education through acquisition of the EMS certification, LCA courses were newly introduced. This resulted in a large number of changes in the students' awareness of environmental issues.

Many students seemed to be interested in environmental issues, but such concepts were unclear to them. Therefore they seemed to collect information on these issues. By learning how to quantitatively assess environmental impacts of products that they used everyday and by calculating environmental burdens, environmental impacts, and damage caused by those products, the students seemed to further develop their interest in assessment methods, and at the same time, started to be conscious of reviewing their lifestyle or eco-friendly activities. For example, after the training, many students made comments about improvement in the use of appliances, which they used to use without much thought, or energy saving such as reducing the time they spend drying their hair using blow-type hair dryers and purchasing energy-saving PCs.

By being introduced into the university, the LCA course has not only promoted students' understanding or mastering of the LCA method but also, in order to lead to solutions to immediate environmental issues as well as global environmental issues, the course has provided information useful for reviewing conventional lifestyles and raised individuals' awareness of the necessity of new environmental improvement actions in environmental protection activities associated with consumption and social life. It is hoped that the LCA course will be linked with other environment-related courses or practical EMS education and be implemented widely as a new course for developing environmentally-conscious members of society.

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