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Life-Cycle Assessment Society of Japan

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Incentive Award

Development of a Chair using LCA

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1. Introduction

SANKEI was established on August 15th, 1951, so it has been 57 years since its establishment. We are in the steel furniture manufacturing industry specialized in manufacturing of chairs. Our annual sales were 2.4 billion yen as of June, 2007, and we have 75 employees. The company is in Suzuka, Mie prefecture, an area rich in nature and famous for F1 races. As an affiliate company we have a sales company called SANKEI and an international base company called LEECO SANKEI in Thailand.

We have been proposing "RE5" as our environmental policy:

Reduce: to not produce garbage and to reduce energy consumption

Reuse: to design products that allow easy repair and parts replacement, and to achieve a long product life

Recycle: to make used chairs be easily disassembled, and to allow used materials to be easily sorted

Refine: to unify materials to be used, and to actively include recycled materials in product designs

Rebuy: to actively purchase recycled products.

By promoting this RE5, we hope to be a human as well as environmentally-friendly company.

2. Background

In 1992, the Rio Declaration was issued at the Earth Summit, and that year was marked as the first year that the global issues were fully addressed. Around the same time, in Japan, material prices dramatically increased due to the collapse of the bubble economy. Among a wide variety of materials, the price of molded plywood most strongly affected our business. The reason for its rising price was not deforestation control in exporting countries or increases in the material price itself, but simply the fact that export of products using this material increased. This was because molded plywood was often used in the center part of the chair seating surface at that time; therefore, we were greatly troubled by how much the price increased. In the midst of that situation, basic study on parts that could substitute for plywood began. There was also an attempt to incorporate environmental-friendliness, which was at that time not a very common practice, and we then started study on processing of chair cushions. The material that we chose to achieve both environmental-friendliness and cost reduction was polypropylene (PP). As a result of the research and development, we started to sell environmental products in 1996. Note, however, at that time in Japan, customers did not understand the concept of environmental-friendliness at all. In 1997, COP3 was held in Kyoto and Toyota released their first hybrid car, Prius, and then we realized that we had to address environmental issues. In response to this we further focused on development of environmental products.

3. Environmental Products - the 1st Attempt: Resource Recycling Chair

Resource recycling chairs developed in 1996 were disposed of after use. We then proposed to recycle the chairs without disposing of them. More specifically, the frame, which was the base part, of the traditional chair was metal. Molded plywood was used in the seating surface and backrest as a core board, polyurethane foam was used in the cushion, and a polyvinyl chloride sheet or acrylic cloth was used and fixed with staples as the chair surface. A new resource recycling chair would also have a metal frame. However, its cushion would have a PP injection molded product as its core material and a PP foam product as its filling, and the chair surface would be a PP cloth that is fixed by hot-melting of polyolefin. Parts thus produced with the same type of material could be collected after use, ground by a grinder, made into pellets by a granulator, and returned to resin parts. The development concept was to "produce a chair, and recycle it into a chair." We also internally installed a grinder and granulator to study reproduction technology. At that time, we believed that would be the ultimate ecological activity. Meanwhile, we started to question if "environmental-friendliness" and "recyclability" at the time really were environmentally friendly. It was around that time we came across the concept of life cycle assessment (LCA), recognized the necessity to use it, and purchased LCA software that was available in the market at that time. We started to teach ourselves to use it, but we had to give up after a few tries as it was too difficult.

4. Introduction of LCA

We were certified for ISO9001 in 1999 and then for ISO14001 in 2000. At the same time, we announced that we would use LCA when creating products as our environmental policy. Since no LCA-based assessment method was established at that time, we started with the use of an LCA check sheet. The LCA check sheet was created based on the requirements provided in the Law Concerning the Promotion of Procurement of Eco- Friendly Goods and Services, or the Green Procurement Law for short, and the Eco Mark criteria. The check sheet was, of course, useful only in checking and was not enough for quantitative assessment of environmental friendliness.

Around the same time, which was September, 2000, an industry-government-academia LCA research group was established in our local area, Mie. Our Development Department actively participated in the research group, and until the termination of the research group in 2005, we learned the basic concept of LCA and further studied it. In 2006, we were informed that companies were being sought to participate in the "product green performance support project," which was a project under the contract with the Ministry of Economy, Trade and Industry. We believed it would be an opportunity for us to promote LCA across the company and that we would be able to use the LCA method to develop chair products. We therefore applied for it and were selected.

5. Product Development Using the LCA Method

We compared a conventional folding chair and a new product, and developed the new product so that it would be more environmentally-friendly than the conventional chair.

5-1. Objective

・Understanding of the environmental impact of a chair generated during its life cycle
・Comparison of the impact on global warming
・Establishment of the foundation of design for environment (DfE) to be promoted together with LCA
・Disclosure of the result to our customers

5-2. Target items

The target items are SCF64 released in 1997, which was the latest product at that time, and DU07, which was to be newly developed. The figure on the left shows SCF64 and the one on the right shows DU07. Both have the basic functions of a folding chair in that they can be folded and stored.

Figure 1 SCF64

Figure 2 DU07

The external appearance of the chair is shown below. To increase storability, the rear leg of DU07 is designed to be shorter than the front one. Both types use aluminum pipes in the frame, and molded PP resin in the backrest and seating surface. As for the core material of the seat cushion, SCF64 uses wooden material, and DU07 uses recycled PP resin material. In both chairs, iron screws are used for assembly (Figure 3).

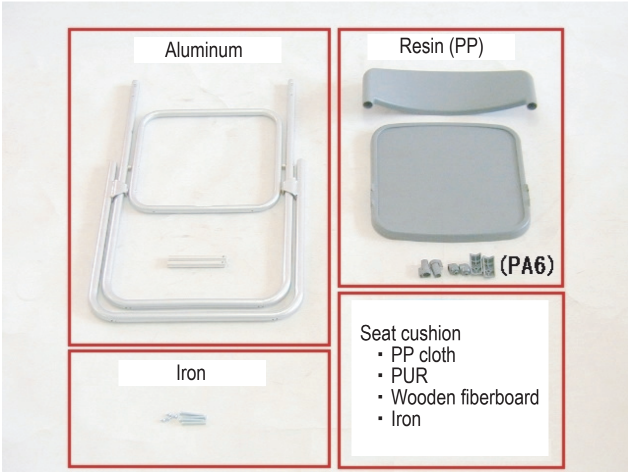

Figure 3 Parts (SCF64)

By using the materials described above, the product weight is 2.7 kg for the conventional product and the goal for DU07 is 2.1 kg.

5-3 System boundary

For both types, stages such as collection of material resources, processing of the material, manufacturing of the chair, assembly, transportation to the customers, and disposal after use will be inside the system boundary. The product use stage is excluded because how the chair is used depends on the user and also the chair itself does not use any energy.

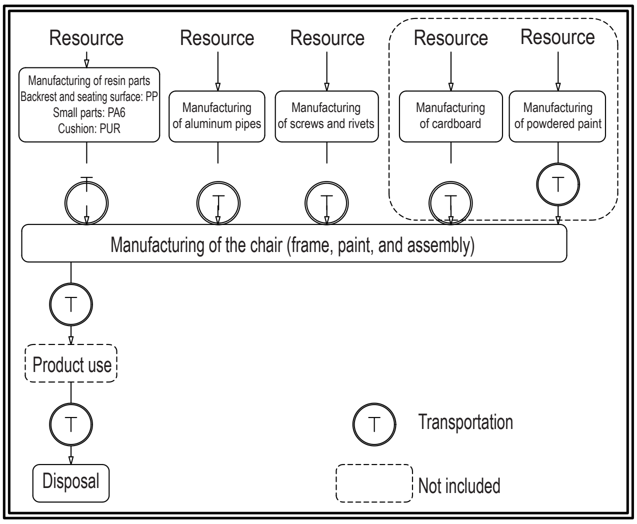

Figure 4 System boundary

5-4 Inventory analysis

The result of inventory analysis is shown in the table below. For each process, phase, stage, and emission source, emission of global warming chemicals such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) is calculated.

The inventory analysis result indicates that the manufacturing stage accounts for more than 98% of generation of global warming chemicals. It also indicates that the new product, DU07, has lower CO_2 emission than the conventional product (Figure 5).

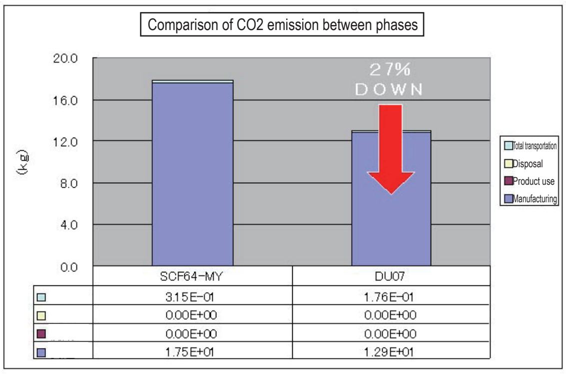

Figure 5 Inventory analysis result

5-5 Impact assessment

We used the IPCC-2001 100-year-index to characterize the area of global warming impact.

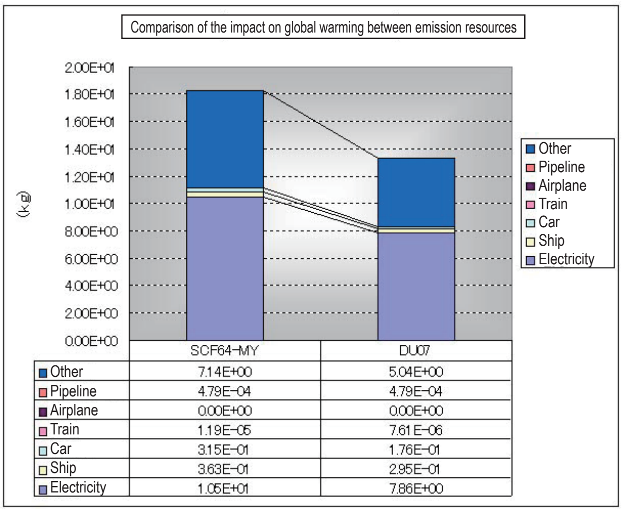

Figure 6 Impact assessment result

The graph above shows the impact assessment result. It shows that the electricity in the manufacturing phase accounts for approximately 60% of the total impact on global warming. It also shows that the new product can contribute to reduction of the impact on global warming by 27% compared to the conventional product. We were able to make the new product lighter by changing the aluminum pipe shape in the design phase, by using the processing technology to bend the thin wall part of the pipe, and by improving the aluminum welding technique.

5-6 DfE

We incorporated DfE and customer input in the design. For example, we received a comment from our customer that "it is difficult to clean the chair with a rag because the dust accumulates where it is hard to reach." Some parts of the conventional product had a sharp angle, and wiping could not sufficiently clean it; therefore, dust accumulated there had to be removed with a toothpick. For this reason, we removed as many sharp angles as possible from the new product so that a single wipe with a rag can clean it sufficiently (Figure 7).

Figure 7 Shape improvement

Also, when the conventional chair was used outdoors, dirt got into the screw holes of the stoppers attached to the parts on the pipes that would be in direct contact with the ground. As a result, when it was used indoors, the dirt fell off on the floor or scratched the floor. Therefore, we stopped using screws to attach the stoppers and instead started to use snap-on stoppers. By doing so, dirt would not get into the screw holes any more and screws would not be lost (Figure 8).

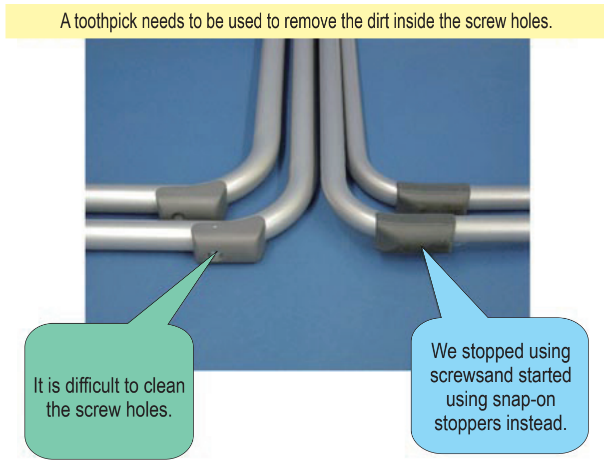

Figure 8 Improvement of parts attachment

We used snap-on parts on other parts of the chair; therefore, the number of screws used to attach parts decreased from 14 to 8.

6. Conclusion

The LCA result has indicated that our new product can reduce the impact on global warming by 27%. We can now quantitatively show how environmentally-friendly our product is, use this result as convincing data in product promotion, and actively disclose the result to our customers. Also, by actively using both LCA and DfE, factories can improve their processing technologies for better efficiency. For example, they can shift from lot production to cell production in order to reduce unnecessary stock and in-process inventory as well as to save energy. Our product can contribute to reduction of environmental impact. At the same time, it can be made lighter with an extra long life. Thus, not only green consumers but also general customers will use low environmental impact products without noticing it.

The environment that surrounds our industry will be increasingly demanding. In the EU, for example, there are already the RoHS, REACH, and EuP directives. What society needs will continue to change in the future.

We will use LCA to try to decrease input. We believe that as a result we can continue producing products and contribute to establishment of a sustainable society.

Reference

1) Japan Environmental Management Association for Indus try. Life cycle assessment support software "JEMAI-LCA Pro" (2006).

2) "IPCC 100-year index (2001)" as a coefficient for characterization of global warming.

Incentive Award

Development of an LCI Database and LCA Activities for Aluminium Materials

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Chairman, LCA Research Committee
Japan Aluminium Association

1. Introduction

Aluminium is a valuable metal resource that is essential in daily living. As there is now a growing tendency that material LCI assessment becomes mandatory under the product green procurement regulation and also the need for LCI data for various types of material is growing, the Japan Aluminium Association is one of the first associations to have focussed on LCA and used it as an important means for objective as well as quantitative assessment of the environmental impact. The Association established the LCA Research Committee under the Energy and Environmental Committee in June, 1993, to learn the concept and procedure of LCA, collect inventory data for individual products, conduct LCI assessment of the manufacturing, use, and recycling stages of products, and to release the assessment results (Table 1). This article provides an overview of the inventory report on scrap melting released in September, 2007.

No.	Month/ year of issuance	Title
1	1998/6	Creation of the Rolled Aluminium Products Inventory Database
2	1999/3	Study Report on Energy Saving in the Machine Industry Using Aluminium: Saving Energy by Using Aluminium as Can Stocks
3	1999/3	Study Report on Energy Saving in the Machine Industry Using Aluminium: Saving Energy by Using Aluminium as Rolling Stock
4	2002/4	LCI Assessment of Open-Loop Recycling of 350 ml Aluminium Cans
5	2002/11	LCI Analysis of Beverage Aluminium Cans Designed for Open-Loop Recycling
6	2002/11	CO_2 Reduction by Using Aluminium as Auto Materials
7	2002/11	Life Cycle Inventory of Various Types of Wrought Aluminium
8	2003/1	Overview of LCI Data of Rolled Aluminium Products: Aluminium Plates and Sheets
9	2003/1	Overview of LCI Data of Aluminium Paste
10	2004/4	Overview of LCI Data of Aluminium Foil
11	2004/10	Life Cycle Inventory of Aluminium and Steel Hood for Automobiles and Bumper Reinforcement
12	2004/10	Lightweighting Effect of Using Aluminium to Manufacture Cars, Calculated by the CO2 Emission Assessment Method
13	2005/3	Study Report on Life Cycle Cost Calculation for Aluminium Alloy Water Gates
14	2005/3	Overview of LCI Data for Primary Aluminium and Secondary Aluminium for Wrought Aluminium
15	2005/3	LCA of Lightweighting Effect in the Ideal Condition of Automobile Aluminization
16	2006/2	Overview of LCI Data of Various Types of Rolled Aluminium Products: Aluminium Extrusion Material
17	2006/2	Overview of LCI Data for Aluminium Product Processing: Colored Aluminium Products and Colored Aluminium Roofs
18	2006/11	CO_2 Emission and Economic Effect in the Business Model for Introducing Aluminium Light Vehicles
19	2007/9	Inventory Report on Scrap Melting

Table1 LCA related reports of Japan Aluminium Association

2. Inventory Report on Scrap Melting

1) Background and Objective

Japan Aluminium Association created a rolled Aluminium product inventory database in June, 1998, and released data on inventory of wrought Aluminium scrap melting. The environment has changed since then as new technologies have been brought in, and therefore, we reviewed the inventory based on the latest data.

2) Method

① System boundary

The subject of the study was the melting process by the melting furnace built exclusively for scrap installed in a rolled Aluminium factory, and the system boundary included the processes from feeding of scrap raw material into the furnace to creation of molten metal. This system boundary is marked with thick lines in Figure 1.

② Data collection

Using the same procedure as the previous study, data was collected from the 4 factories of the 3 companies. The study period was FY2005.

③ Calculation of the inventory

We calculated inventory per kg of product based on the weighted average. The product is the total of scrap molten metal and solidified scrap.

④ Background data

We used the database included in the LCA software JEMAI-LCAPro (Ver.2) created by the Japan Environmental Management Association for Industry to calculate LCI. LCI for electricity was obtained based on the domestic average value.

3. Result

Table 2 shows major inventory indicators for a kilogram of scrap melting. Only the energy directly used is included, and energy used in power generation is not included.

Table 3 shows life cycle inventory retroactively covers resource collection.

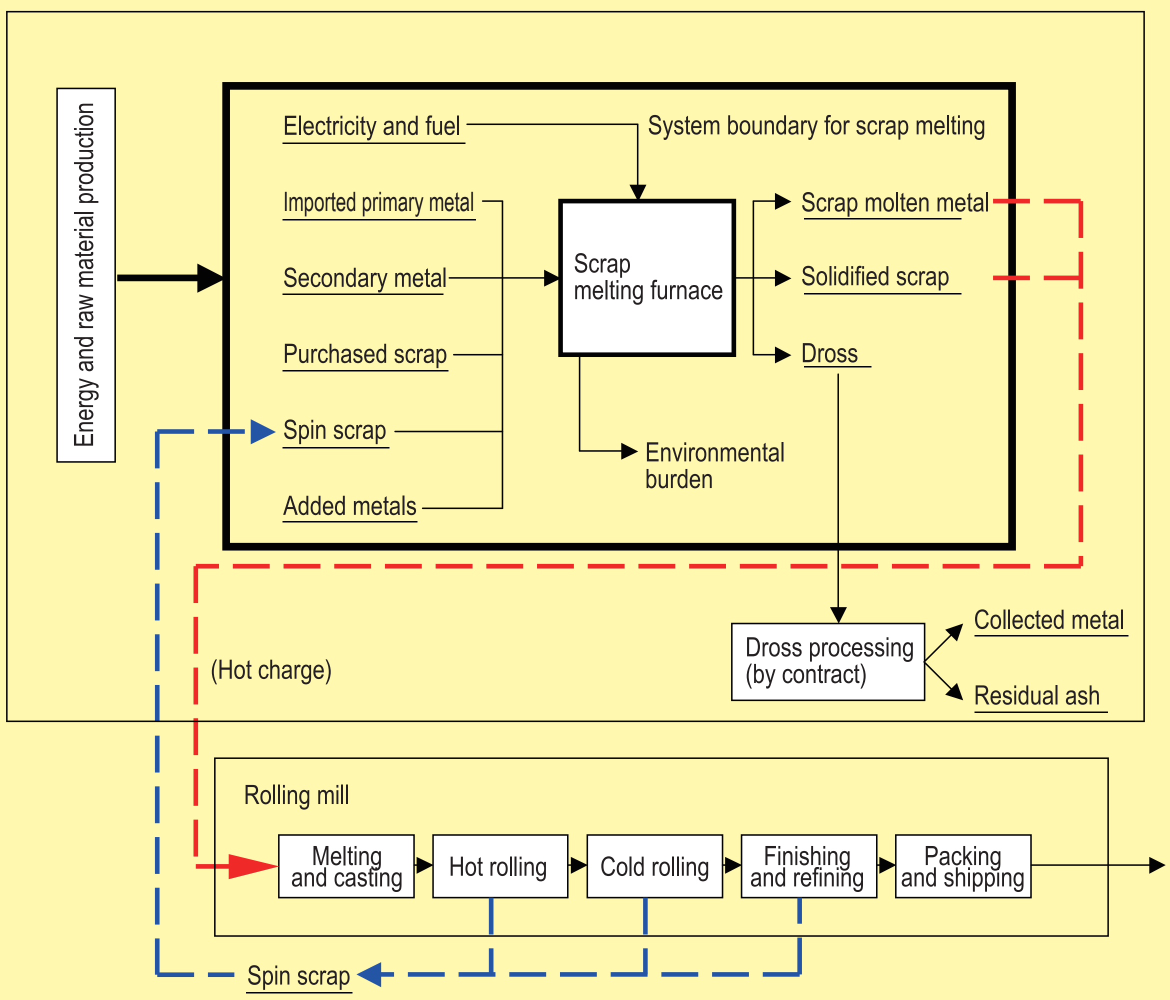

Figure 1 System boundary for scrap melting

	Item	Unit	All melting furnaces	Excluding induction furnaces	Remarks
Input	Primary metal	kg	0.001	0.001	
	Purchased scrap	kg	0.483	0.542	Including paints
	Spin scrap	kg	0.555	0.500	
	Secondary metal	kg	0.001	0.001	
	Magnesium	kg	0.0011	0.0012	
	Manganese	kg	0.0004	0.0004	
	Inputted raw materials (subtotal)	*kg*	*1.042*	*1.045*	
	Electricity	kWh	0.141	0.046	
	A heavy oil	L	0.010	0.011	
	B and C heavy oil	L	0.010	0.012	
	Kerosene	L	0.031	0.036	
	LPG	kg	0.0017	0.0020	
	City gas	N m^3	0.024	0.028	
	Energy consumption (total)	*MJ*	*3.63*	*3.80*	
	Electricity	*MJ*	*0.51*	*0.17*	Electricity: 3.6 MJ/kWh
	Fuel	*MJ*	*3.13*	*3.63*	
Output	Scrap molten metal	kg	0.946	0.992	
	Scrap block (solidified)	kg	0.054	0.008	
	Aluminium dross (contracted processing)	kg	0.034	0.032	
	Collected steam	kg	0.044	0.035	
	CO_2	kg	0.196	0.227	Calculated value
	NO_x	kg	0.000059	0.000069	Calculated value
	SO_x	kg	0.000060	0.000070	Calculated value
	Waste (industrial waste) to be processed by contract	kg	0.0029	0.0024	

Table 2 Inventory per 1 kilogram of scrap melting

	Item	Unit	All melting furnaces	Excluding induction furnaces
Input	Coal	kg	0.015	0.006
	Crude oil	kg	0.051	0.059
	Natural gas	kg	0.028	0.025
	Uranium (resource)	kg	0.0000012	0.000000004
	Bauxite	kg	0.0052	0.0059
	Aluminium scrap	kg	1.038	1.041
	Energy	MJ	4.80	4.44
Output	CO_2	kg	0.287	0.285
	NOx	kg	0.00020	0.00021
	SOx	kg	0.00018	0.00020

Table 3 Life cycle inventory per 1 kilogram of scrap melting

4. Comparison with the Previous Study Result

Table 4 shows a comparison of the study results between this time and the previous time (FY1996 data).

The specific energy consumption at factories increased by 6%, from 3.44 MJ/kg to 3.63 MJ/kg, but in terms of energy on the basis of power generation efficiency, there was a decrease by 20%, from 5.54 MJ/kg to 4.44 MJ/kg. This is attributed to the fact that expansion of incinerating melting furnace led to a relative decrease in electricity consumption and an increase in fuel consumption.

5. Energy used in Melting in Terms of Life Cycle

The energy directly used in scrap melting is as described above. Life cycle energy (LCE) consumption and life cycle CO_2 ($LCCO_2$) emission, however, decreased by approximately 15% and approximately 7% respectively as shown in Table 5. Energy necessary to manufacture primary metal (LCE) was 140.9 MJ/kg, and the energy required for scrap melting accounted for approximately 3.4% of the energy necessary to manufacture primary metal.

Item		Unit	Previous study (1996)	Present study (2005)
Subject melting amount		kt	113.7	195.4
Input	Raw materials input (subtotal)	kg/kg	1.051	1.042
	Electricity	kWh/kg	0.360	0.141
	A heavy oil	L/kg	0.0285	0.0099
	B and C heavy oil	L/kg	0.0067	0.0103
	Kerosene	L/kg	0.0186	0.0306
	LPG	kg/kg		0.00017
	City gas	N m³/kg	0.0009	0.0242
	Energy consumption (total)	MJ/kg	3.44(5.54)	3.63(4.44)
	Electricity	MJ/kg	1.30(3.39)	0.51(1.30)
	Fuel	MJ/kg	2.14	3.13
Output	Scrap molten metal	kg/kg	0.917	0.946
	Scrap block (solidified)	kg/kg	0.083	0.054
	Aluminium dross	kg/kg	0.048	0.034
	Collected steam	kg/kg		0.044
	CO_2	kg/kg	0.157	0.196
	NOx	kg/kg	0.00002	0.000059
	SOx	kg/kg	0.00020	0.000060

Note: for energy, the figure inside the parentheses takes power generation efficiency (38.9%) into account

Table 4 Scrap melting inventory (per kilogram of {molten metal + blocks})

Item	Unit	Previous study (1996)	Present study (2005)
Energy (LCE)	MJ/kg	5.70	4.80 (4.44 *)
CO_2($LCCO_2$)	kg/kg	0.309	0.287(0.285 *)

Figures with the * symbol within parentheses represent figures without values for induction furnaces.

Table 5 LCE and $LCCO_2$ for scrap melting

6. Dross Assessment

Dross processing was assessed by using the input energy obtained in the previous study, and the amount of collected metal was assessed using the result of the present study. Table 6 shows the inventory for processing 1 kilogram of dross.

Table 7 shows the scrap melting inventory when the metal collected as a result of the dross processing was assessed and taken into account as a recycled block.

7. Summary

①Although the direct energy spent at factories increased compared to the previous study because of the increase in the number of incinerating melting furnace, the life cycle energy (LCE) consumption and life cycle CO_2 ($LCCO_2$) emission decreased by approximately 10% to 15%. Use of regenerative burners and improvement of incineration technologies have produced positive results.

②LCE of scrap melting is approximately 3.4% of LCE of manufacturing of primary metal. The energy conventionally used for manufacturing of primary metal was 132 MJ/kg, which was primary metal smelting energy (alumina refining and electrolytic refining) obtained by the Chemical and Economic Research Institute[1]. This was direct energy that did not include energy for other raw materials or transportation.

Based on the figure above, the direct energy for scrap melting obtained in the present study, which was 3.63 MJ/kg, would be 2.8% of the energy required for the smelting of primary metal.

8. Conclusion

The aluminium manufacturing industry should promote manufacturing from the LCA perspective that takes the overall life cycle into account and study the advantages of energy saving at the product use stage with aluminium products. As for recycling of aluminium, recycling of aluminium cans has been widely recognized and understood in socially, but it is further necessary to review the cascade recycling system for aluminium Automotive products (higher rank to lower rank, wrought material -> mold or die cast) so that a recycling system can be established in the Auto design phase for each item type.

It is now predicted that the importance of effective use of advantageous characteristics of aluminium to establish a sustainable society will increase in the future for our country which relies on overseas countries for resources.

1)Chemical and Economic Research Institute: Report on Analysis and Study of Energy of Basic Materials (1993)

	Item	Unit	Basic unit	Remarks
Input	Aluminium dross	kg	1.000	Including paints
	Electricity	kWh	0.253	Previous study
	LPG	kg	0.0065	
	Energy	MJ	1.24	Electricity: 3.6 MJ/kWh
Output	Collected metal	kg	0.304	Current study
	Residual ash	kg	bal.	
	CO_2	kg	0.019	Calculated value
	NOx	kg	0.000008	Calculated value
	SOx	kg	0.000000	Calculated value

Life cycle	LCE	MJ	2.93	
	$LCCO_2$	kg	0.126	
	LCNOx	kg	0.00006	
	LCSOx	kg	0.00002	

Table 6 Dross processing inventory

	Amount of input	Energy (MJ)	CO_2 emission (kg-CO_2)	Remarks
Scrap molten metal	Scrap: 1.0 kg	4.80	0.288	
Dross processing	Dross: 0.04 kg	0.099	0.0045	
Recycled blocks (excluded)	Metal: 0.0103 kg	−0.049	−0.0030	Amount equivalent to the amount of collected metal
Total		4.85	0.290	

Table 7 Scrap melting inventory

Incentive Award

Eco-Pro-Net

- Product Development Support Network for Creating Environmental Added Value -

Seizo Kato
Special assistant of the president, Mie University
Representative of Eco-Pro-Net

We are honored that our paper "Eco-Pro-Net: Product Development Support Network for Creating Environmental Added Value" received the 4th LCA Japan Forum Incentive Award for LCA dissemination and human resource development activities promoted by the industry-government-academia network. We would like to thank all who gave us support. This award certainly makes us more responsible than ever for our actions in the future, and we plan to turn this responsibility into effective environmental practices.

Eco-Pro-Net (http://www.ecopronet.jp/) started as an activity to upgrade active "monozukuri," which could be translated as "the art of manufacturing," in the Tokai region to environmentally-friendly monozukuri. The Tokai region originally had an active monozukuri culture, but about 10 years ago, improvement of management strategy was required from the environmental perspective. Then, "Environmental Partnership Organizing Club (EPOC)" was established and implemented. Through its activity, we learned that many corporate managers were highly conscious of environmental matters, were engaged in environmental improvement activities, and were practicing environmental management. We also learned that a wide variety of environmental technologies had been accumulated across the supply chain.

Our awareness of environmental technologies further increased during EXPO 2005 AICHI JAPAN, and we started to think more and more that "although environmental measures at the end of the life cycle such as disposal and recycling are important, aren't environmental measures at the beginning of the life cycle such as material procurement more important?" Meanwhile, the ROHS Directive was issued in Europe and we were required to take action to conform to it. Under these circumstances, we had a strong feeling that "quantitative methods such as LCA and DfE must be incorporated into products."

Many companies that had already implemented this idea however gave us input such as "active environmental measures including energy-saving or waste water treatment would not raise product added value," and "the market for green products would not expand even though they were produced using LCA or DfE." Meanwhile, science-based environmental quality assurance and globalization of the eco-design method or eco product assessment standards were required for industrial products mainly used overseas. Not only large companies but also intermediate level companies as well as medium and small companies were required to do the same.

In order to overcome these issues, joint establishment of strategies together with the supply chain was essential. In particular, improvement of the eco design capability of intermediate level companies as well as medium and small companies that would be playing the main role in these strategies and creation of the eco product market were considered urgent tasks, and the Monozukuri Eco Design Promotion Forum was established as an industry-government-academia network in 2004. The Forum had 2 working groups for "eco design leader development" and for "education and interaction for promotion of eco design" to establish and implement specific educational programs, hold symposiums, seminars, and exhibitions, and to carry out Internet-based information distribution. We received a lot of help from the Chubu Bureau of Economy, Trade and Industry (a regional bureau of METI), during the establishment of the forum, but we then started to work on it independently as our own project. As a result, we set a goal to create our own eco design platform that would be useful to further improve ourselves in the eco design field.

"Eco-Pro-Net: Product Development Support Network for Creating Environmental Added Value" (operation started in October, 2006) was thus created. The name of the project was designed to include 3 "Eco-Pros" that were: "Eco-Products" for green product monozukuri culture, "Eco-Profit" for creation of added value and markets through green products resulting in profit generation, and "Eco-Professional" for development of human resources with skills in the environmental field. The goal of the project was to create an organic network with the above 3 Eco-Pro concepts as the key. In the actual project activity, we would help intermediate level companies as well as medium and small companies become aware of the fun of eco design and then to learn, start, use, and disseminate its concept. We also planned and held events that would match the capability of the participating companies (annual symposium, 4 seminars and lectures in total, 2 training sessions, and 8 workshop sessions). We further provide eco design-related consulting services to the participating companies. Member companies can always join the events and services described above, and also, information on these events, news, and domestic as well as international trends are distributed not only on the Internet but also via e-mail magazines. Currently, approximately 300 companies (70% of them are intermediate level companies, medium companies, and small companies) are participating. There is no membership charge, and any company that agrees with the philosophy of Eco-Pro-Net can become a member at any time by accessing the URL introduced earlier.

Through the Eco-Pro-Net activities, we have been producing positive outputs. For example, we have received a development fund for our green performance advancement project, examples of our eco-design product development were exhibited at Eco-Products Exhibition or other environment-based business exhibitions, the eco design capability of the overall supply chain was improved, and we established the product differentiation scheme by promptly incorporating eco-design in products. Some of the eco products that received the LCA Japan Forum award were included in our activity achievements. The most noteworthy achievement was that the collection of the eco design product examples showing 57 sample products was organized based on what kind of environmental aspects that were focused on. Almost 70% of the samples were products manufactured by medium and small companies.

As the EuP Directive intended, eco design is now the global market standard which would decide the future of companies. Through the Eco-Pro-Net activity, however, we clearly understood that they key to success was "to first design performance, quality, and cost that would satisfy the market need, conform to regulations, and then release environmentally friendly products" and that, for this, human resource development was essential. It seemed that organizational activities to accomplish the daily goal of companies, manufacturing of products that would sell, directly resulted in eco design, and that we should not be too pressured by the word "eco design." We hope that our Eco-Pro-Net project would contribute to fostering of a culture where "environmentally friendly monozukuri is the daily practice" and "monozukuri automatically contributes to the environment."

Approx. 60% Reduction of CO2 Emissions in An Entire House

Taeko Aoe
Corporate Environmental Affairs Division
Panasonic Corporation

1. Introduction

The "Approx. 60% Reduction of CO_2 Emissions in An Entire House" project was implemented in order to examine the technological feasibility of reduction in household greenhouse gas emissions. Here, the term "technology" refers to a wide variety of technologies as a whole incorporated into products that have been introduced to the market by producers and that can also be selected by consumers. In this project, to be specific, using the data obtained in 1990 as a reference, we evaluated the greenhouse gas emission of approximately 100 products including housing equipment and house structure, in addition to home appliances, and measured the trend in reduction of greenhouse gas emissions.

In 2005, we placed 60% reduction of green house gas emissions throughout a life cycle of those products in an entire house by 2010 compared to 1990 level" as a corporate target. And it was achieved in 2007, three years ahead of schedule, and as of October 2008, an amount of emissions was reduced by 62%.

We introduce this achievement as "Approx. 60% Reduction of CO2 Emissions in An Entire House" via TV commercials, advertisements, showrooms, and exhibitions. Furthermore, since 2004, we have been working on dissemination of what we call "life cycle thinking" by for example giving lectures at schools on the environment based on life cycle thinking.

This article will introduce overviews of these activities.

2. Overview of the Assessment Method

Assuming a model household, we selected a list of products to be used in a model house.

The household model we have set is a 3-generation family of a grandmother, parents, and a child living in a two-story house. We selected a 3-generation family in order to incorporate the needs of multiple generations into products to be assessed. The floor area of the house has been set to 136.9 m2, which is the average floor area of a newly built and purchased house. The floor plan contains a living room, dining room, kitchen, 3 bedrooms, 1 Japanese style room, one bath, and 2 WCs (one per floor). This house has been assumed to be located in the central part of Honshu in Japan. Refer to the following URL for the floor plan of this model house:
http://panasonic.jp/eco/product/co2_discharge/plan.html

Products used in this house have been selected based on the rate of diffusion to general households. Also, we have added the home energy management system (HEMS) and the solar power generation system that can contribute to reduction of the environmental impact.

Recently, many types of products have increased their sizes. Examples of this trend include; TVs (33 inch CRT display to 50v inch plasma display), refrigerators (425 liters to 550 liters), and washers and dryers (6 kg to 9 kg for washing and 4.5 kg to 6 kg for drying).

To this house, we have also added: a dishwasher and garbage disposal unit as household products; a fax machine, PC, digital camera, and cell phone as information-communication products; and a water conditioner, electric toothbrush, and massage chair as health products.

Refer to the following URL for the list of products used in this model house:
http://panasonic.jp/eco/product/co2_discharge/index.html

Greenhouse gas emissions throughout the life cycle of these products (excluding the house itself) including production, transportation, product use, used product transportation, and recycling and disposal phases are assessed based on JEMAI-LCA inventory data. Note that the standard values specified in the product specifications or by the industry have been used as the standard service conditions for these products, and they are supposed to incorporate differences in usage or performance under various natural conditions. Reference values or voluntary standard values have been applied to those products with no specific standard values specified in the product specifications or by the industry.

The house used in this model is designed as an industrialized house (prefab house) with a light-gauge steel structure and large panels. An emission and reduction assessment was carried out on the base, building frame, exterior finish, and interior finish of this house, and for each element, its greenhouse gas emission throughout the life cycle of the house was obtained for the production, transportation, building (construction), operation (use), repair (maintenance), and recycling and disposal phases using the Building LCA Calculation Software (developed by the Architectural Institute of Japan).

Since each product has a different length of lifetime, greenhouse gas emission throughout a life cycle of each product is first calculated, and the result obtained is then divided by the product lifetime (in years) such that the greenhouse gas emission of each product for each year can be calculated. Then, by adding the yearly emission of each product, the greenhouse gas emission for the entire household for a year can be calculated.

3. Overview of the Assessment Result

An amount of greenhouse gas emissions per year has increased due to the inclusion of a dishwasher, garbage disposal unit, and massage chair, and also due to the increase in size of appliances such as TVs and dehumidifiers. Back in 1990, air conditioners, hot water suppliers, lighting equipment, refrigerators, washer/dryers, and heated toilet seats with warm water sprays were the 6 most power consuming products, accounting for approximately 75% of the entire greenhouse gas emission. An amount of power consumption during the use of these products, however, has decreased and therefore emission was reduced by 42%. Furthermore, the emission was reduced by another 20% due to the introduction of the home energy management system (HEMS), improvement of thermal building insulation, and introduction of the solar power generation system. As a result of these comprehensive approaches to emission reduction, the total emission was reduced by 62% compared to a 1990 level.

Although this assessment result only applies to a specific model hosuehold, it still quantitatively suggests that greenhouse gas emission can be reduced through the introduction of the latest energy-saving technologies.

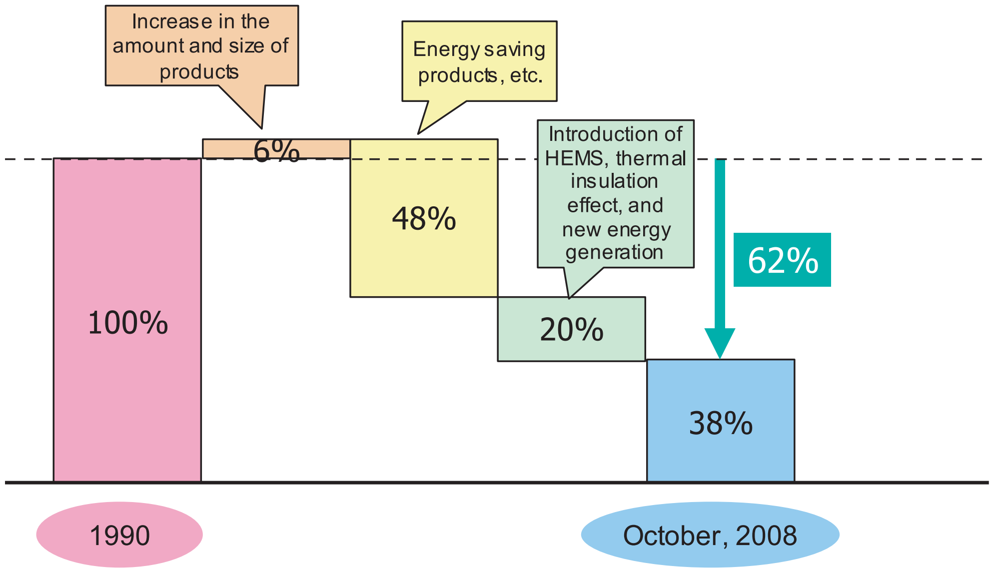

Figure 1: Breakdown of increase and decrease in greenhouse gas emission

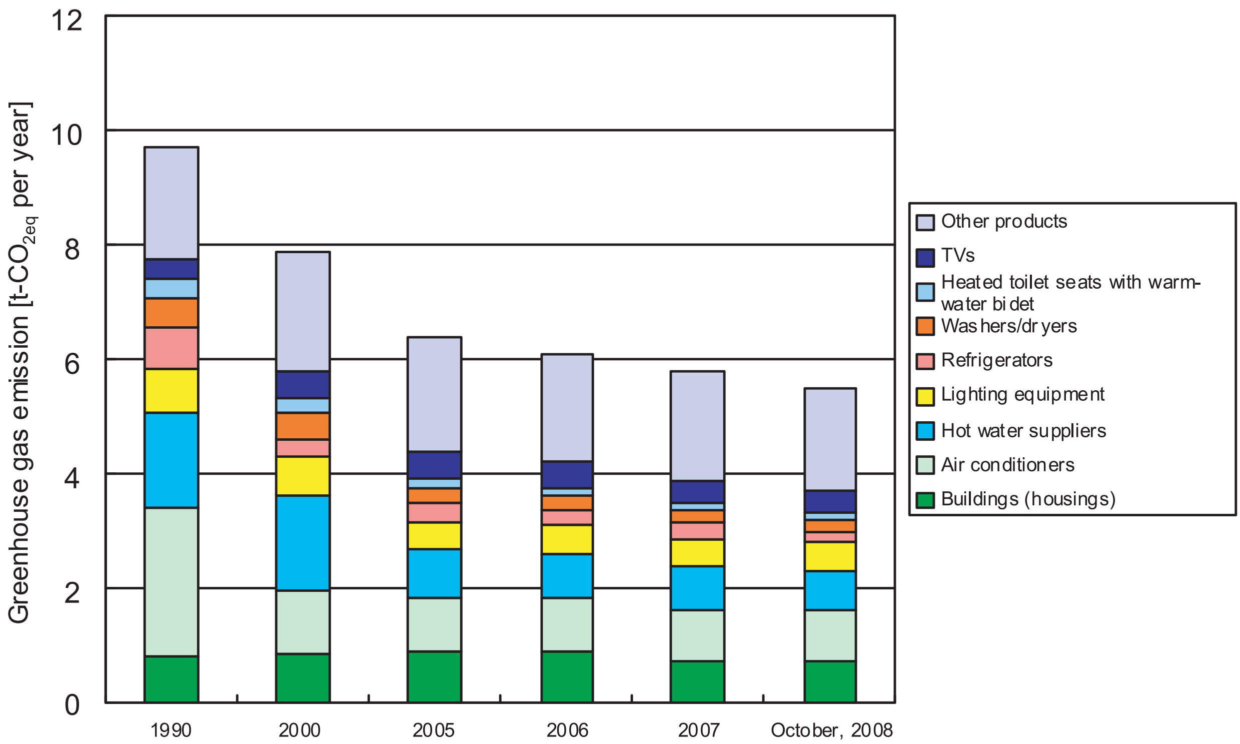

Figure 2: Changes of the greenhouse gas emission as a result of improvement of energy-saving efficiency and breakdown by product

4. Conclusion

Since 2004, with the goal of disseminating the concept of what we call "life cycle thinking," we have been giving lectures on the environment based on life cycle thinking. In these lectures, we have been using the result of our study on how CO_2 emission can be reduced in an entire home.

It has been pointed out that it is more difficult to encourage individuals to take eco-friendly actions to address global environmental issues than to address local or regional ones. It is assumed to be because, unlike local or regional environmental issues, it is difficult for individuals to grasp how global environmental issues are related to their daily living, since an extremely large amount of resources are used and disposed of in an out-of-reach places, which causes negative impacts on the environment. This means that mastering of life cycle thinking may contribute to the promotion of eco-friendly behavior. In fact, questionnaires administered before and after the lectures have so far indicated that mastering of life cycle thinking may encourage individuals to think about engaging in eco-friendly actions.

We will continue our project to reduce household greenhouse gas emissions which leads to a decrease in the negative impact on the environment, and will implement educational as well as awareness-raising activities by effectively using the research results.

Chairman's Award

Disclosure of Ajinomoto Group's Food-Related Material CO_2 Emission Factor Database

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1. Introduction

In 2003, the Ajinomoto Group released the Ajinomoto Group Zero-Emission 05/10 Plan and has been implementing various projects in order to minimize the environmental load that is generated in a wide variety of industrial areas. We have been actively carrying out LCA based on our belief that minimization of the environmental load requires assessment of not only the environmental load generated in the manufacturing process, but also the environmental load of the entire life cycle, which starts with raw materials and ends with product disposal. In particular, starting with full implementation of LC-CO_2 calculation of packaging containers in 2003, we established in 2004 the Food Study Group in the Institute of Life Cycle Assessment, Japan, jointly with Mr. Atsushi Inaba, a professor at the University of Tokyo, and Nippon Flour Mills, Co., Ltd. Since then we have been proactively developing an academic-industrial alliance in the field of the food LCA with relevant companies and university researchers.

In relation to CO_2 emission factors that are necessary to calculate LC-CO_2, I would like to introduce in this article an overview of "Ajinomoto Group's Food-Related Material CO_2 Emission Factor Database ("the Ajinomoto Database", hereinafter)" that we publish on our group website.

We believe that the Ajinomoto Database is useful when there are no established databases available, which is often the case for food materials, or when approximate CO_2 emission factor values that do not change with seasons or places are required. In this article, I would like to introduce an overview of the database with some technical information hoping that not only researchers but also general readers of this article can make better use of our Ajinomoto Database.

Note: the Ajinomoto Database is available at:
Ajinomoto> Corporate Information> CSR bout of> Environment>
http://www.ajinomoto.co.jp/company/kankyo/lc-co2/index.html

2. Overview and Characteristics of the Ajinomoto Database

Recently, as seen in the concept of food mileage (food miles), interest in the environment in terms of food has been increasing, and at the same time, calculation of food LC-CO_2 has been required more and more due to, for example, a trial project implemented by the "Carbon Footprint System Implementation and Promotion Study Group" of the Ministry of Economy, Trade and Industry (METI). Note that the concept of the carbon footprint is essentially the same as LC-CO_2. One of the largest problems in calculation of a food carbon footprint was how to select the most appropriate CO_2 emission factor for each ingredient, but there were almost no CO_2 emission factor databases in the food industry. In light of this situation, in September, 2006, CO_2 emission factors essential in LC-CO_2 calculation were disclosed in the first edition of the Ajinomoto Database, and the revised version was released in April, 2007. In the Ajinomoto Database, a wide variety of ingredients are converted into emission factors in the unit used in trade or measurement of respective ingredients (such as weight and volume (m^3)) based on the Embodied Energy and Emission Intensity Data for Japan Using Input-Output Table (3EID), which has been created based on the CY 1990, CY 1995, and CY 2000 input-output tables published by the National Institute for Environmental Studies. As a result, information has been collected into a highly objective and transparent database that provides CO_2 emission factors of 1254 items across 124 industrial fields. Major characteristics of the Ajinomoto Database are as follows:

① The database has been created using highly objective data such as the 3EID data provided by the National Institute for Environmental Studies and input-output tables published by the Ministry of Internal Affairs and Communications (MIC).
② Each CO_2 emission factor is expressed as the CO_2 emission volume per trade/measurement unit such as the amount of CO_2 per kilogram.
③ The database has been made available to the public on the Internet.

[Note] An input-output table shows how goods and services move between economic sectors (in Japan, the domestic economy is divided into 400 sectors) per year and is expressed in yen. This table facilitates understanding of the indirect environmental load associated with production. LC-CO_2 can be analyzed either by process analysis (the so-called "aggregation method") or by input-output analysis, and in the Ajinomoto Database, emission factors are determined using input-output analysis. The basic environmental load unit shown in the 3EID published by the National Institute for Environmental Studies indicates the size of environmental load (CO_2 emission in this case) generated directly or indirectly in association with unit production activity (production volume equivalent to one million yen). Here, direct and indirect emissions, in the field of agricultural products for example, include not only direct CO_2 emission as a result of using fuel to operate agricultural machines but also CO_2 emission that can be derived from input-output analysis such as CO_2 emission in association with manufacturing of agricultural machines.

3. Usage of the Ajinomoto Database

Let us assume that someone wonders how much CO_2 is generated when producing 1 kg of brown rice. The Ajinomoto Database answers this question: 0.403 kg or 403 g (the average of data obtained in CY1990, CY1995, and CY2000 ("1990", "1995","2000" , hereinafter)).

This section provides technical information in detail in order to answer the question we often receive from our database users: "how is this figure determined?"

When calculating a carbon footprint (LC-CO_2), a CO_2 emission factor is considered to be most useful when it shows CO_2 emission in its trade or measurement unit such as [kg-CO_2/kg-food]. However, CO_2 emission factors based on the 3EID are calculated using input-output tables where flows of domestic goods called money are regarded as flows of material, and are expressed as [t-CO_2/million yen-food]. This, then, needs to be converted into weight. As an example, the series of calculations to obtain 0.403 kg of CO_2 emission for 1 kg of brown rice are shown below. In this example, rice produced in 1995 is used.

1) Basic environmental load unit based on the 3EID published by the National Institute for Environmental Studies (there are 2 figures based on 1995 producer's price)
① type I: 0.3944 t-C/million yen (= A)
②type II: 0.3497 t-C/million yen

2) A brief description of the difference between the 2 figures above is as follows. When calculating the final induced environmental load using input-output tables, in the first case, imported goods are handled in the same way as domestically-produced goods, and the environmental load of imported goods is included in the calculation (meaning that it is assumed that direct and indirect CO_2 emission of the imported goods is the same as that of domestically produced goods). On the other hand, in the second case, imported goods are handled differently from domestically produced goods so that the environmental load of the imported goods is considered to be nonexistent. Therefore, the difference in the 2 figures above is attributed to the difference in models used. Considering the fact that a high percentage of products are imported in the food industry, the Ajinomoto Database uses the result of the calculation using Model ① above (= A).

3) In order to convert the CO_2 emission, the following calculation needs to be performed:
A x CO_2 formula weight/C formula weight = 0.3994 x 44/12 = 1.446 t-CO_2/million yen (= B)

4) To convert B above into a figure in [t-CO_2/million yen-food], it is necessary to multiply B by something in [million yen-food/t-food], and this "something" is a food price. For this, use the endogenous sector production unit price shown in the Sector- and Item-Specific Domestic Production Volume Chart attached to the FY1995 input-output table published by the MIC. For example, brown rice is included in a basic goods category called "rice," and the 1995 producer's price for brown rice was 280,198 yen/t-brown rice (= C).

5) Therefore, the amount of CO_2 generated from using a ton of brown rice produced in 1995 is B x C = 1.446 x 0.280198 = 0.405t-CO_2/t-brown rice (= D).

Results of these calculations are summarized in Table 1 below. The value D above is indicated by an up-arrow under 1995.

4. Structure of the Ajinomoto Database

Using the table above, this section describes the structure of the Ajinomoto Database. We believe that if you understand the two rows in the table, you will have a general understanding of the structure of the figures shown in the 30-page Ajinomoto Database. Also, I would like to emphasize here that the Ajinomoto Database consists only of the 3EID data and producers' prices derived from the Sector- and Item-Specific Domestic Production Volume Chart attached to input-output tables to realize high transparency and objectivity for the database.

In the table above, rice is selected as a basic category. This basic category has been divided into 399 sectors in the 3EID (for example, there are rice, wheat, potatoes, beans, vegetables, fruits, crops as sugar materials, … other individual services, office supplies, and items of unknown category, in the order of sector number). Each of these basic categories is further broken down into items that are

Basic category	Item number	Item	1990 3EID			1995 3EID			2000 3EID			Remarks	3-year average			
			Unit	Sector- and Item-Specific Domestic Production Volume Chart attached to the input-output table	CO_2 emission factor	Unit	Sector- and Item-Specific Domestic Production Volume Chart attached to the input-output table	CO_2 emission factor	Unit	Sector- and Item-Specific Domestic Production Volume Chart attached to the input-output table	CO_2 emission factor		Unit	Average CO_2 emission factor (f)	Standard deviation (σ)	Standard deviation ratio (σ/f)
				Producer's price (yen/unit)	t-CO_2/ unit		Producer's price (yen/unit)	t-CO_2/ unit		Producer's price (yen/unit)	t-CO_2/ unit			t-CO_2/ unit	t-CO_2/ unit	%
1		Rice	Million yen		1.328	Million yen		1.446	Million yen		1.694		Million yen	1.490	0.187	13%
	1	Brown rice	t	292,307	0.388	t	280,198	0.405	t	244,442	0.414		t	0.403	0.013	3%

↑

Table 1: Structure of a CO_2 emission factor in the Ajinomoto Database

listed with item numbers. The value B above, which is 1.446t-CO_2/million yen has been fixed as FY1995 CO_2 emission per producer's price in the rice category. In the Ajinomoto Database, as seen in Table 1, such fixed values are typed in white in blue cells. These figures are the key figures that are applied to all items in the rice category. Also in the table, the value C, which is the 1995 producer's price for the items under the larger category, is cited from the Sector- and Item-Specific Domestic Production Volume Chart attached to the 1995 input-output table and is shown as 280,198 yen. These values are used to calculate CO_2 emission factors per trade/measurement unit (ton, in this example), and the value obtained 0.405t/t is inputted in the table. In the same manner, values are derived from the input-output table and the 3EID for 1990 and for 2000, and the results obtained are then put together in sheets to constitute parts of the Ajinomoto Database.

Note that the rightmost column of the database shows an average of 1990, 1995, and 2000 figures, a standard deviation on the assumption that the data forms a standard distribution, and a value called variation coefficient (%) which is obtained by dividing the standard deviation by the average value. In this table a remarks field has been added to record integration, creation, and deletion of industrial categories in the input-output tables from 1990 to 2000.

Under the basic categories, there are 1254 items across 124 industrial fields for which a basic CO_2 emission unit has been created by deriving a producer's price from the Sector- and Item-Specific Domestic Production Volume Chart. Since trade/measurement unit conversion cannot be performed for items for which producers' prices are not available, the basic CO_2 emission unit for these items is expressed as "/million yen." There are still 750 of them.

5. Ajinomoto Database Strengths and Issues

The Ajinomoto Database is created with data obtained using input-output tables. There are 5 major advantages in using input-output tables to calculate inventory:

1) All indirect environmental loads can be acquired.
2) Environmental loads can be calculated within a unified system boundary (in the case of the Ajinomoto Database, the entire domestic economic boundary can be used as an apparent boundary).
3) If environmental load data is appropriately set, the same data set can be used to calculate various environmental loads.
4) Using existing data from input-output tables, it is possible to estimate indirect environmental loads without spending any more effort than process analysis (aggregation method).
5) An input-output table provides data with high objectivity and transparency.

Listing the strengths of the database as above may seem to emphasize that CO_2 emission factors provided by the Ajinomoto Database are extremely useful, but there are issues raised by inventory calculation using input-output analysis. Therefore, it is important to keep the following issues in mind when using the database.

(1) Roughly defined industrial field-specific categories

The structure of the Ajinomoto Database is based on an input-output table in which domestic goods and services are roughly divided into 400 sectors. Therefore, the emission factor for brown rice in the example above is in fact determined for ordinary brown rice produced in some fiscal year, meaning that it is not possible to compare LC-CO_2 between brown rice produced in the Kanto region (Eastern Japan) and brown rice produced in the Kansai region (Western Japan). To compare LC-CO_2 of these two types of brown rice, their inventories must be calculated by process analysis (aggregation method).

(2) Environmental load associated with assessment of the influence of price differences between imported and domestically produced products and also environmental load associated with transportation of imported products

Except for rice, Japan depends heavily on imports for crops and oil seeds, and in some cases, imported food prices are several times higher than prices of domestically produced food. When imported crops are processed, in the 3EID, calculation of their CO_2 emission burdens caused by such processing yield lower results than the actual values depending on the abovementioned price differences. As a result, CO_2 emission factors for primary processing of imported foods, such as flour milling, oil pressing, and feed production, are lower than the actual values.

Although the data may not be perfectly accurate due to the difference between system boundaries, as seen in the table, the 3EID method is quite likely to generate discrepancies between the calculated values and the actual values for primary processing of foods for which Japan depends on imports.

Furthermore, flows of goods and services that are not covered by the input-output table may not be accurately incorporated into the database. For example, the environmental load associated with transportation of imported products is not incorporated.

(3) Discrepancies between producer's price-based emission factors and purchaser's price-based emission factors

Related to the above, the foundation of the Ajinomoto Database is the volume of CO_2 generated per 3EID-based producer's price. Therefore, when the database is used in terms of consumption of the products or the products being raw materials for other products, it is necessary to incorporate the CO_2 burden generated in transportation or sales of the products.

Item	Production-based CO_2 emission factor in the 3EID for 2000	Producer's price for 2000 in accordance with the input-output table for 2000	Weight-based CO_2 emission factor correspond-ing to the 3EID for 2000	Import price in 2000	Weight-based CO_2 emission factor for imported product correspond-ing to the 3EID	Price difference between imported and domestically produced products (B/D) = (C/E)	Weight-based CO_2 emission factor obtained by the aggregation method	Ratio between the values obtained by the aggregation method and the 3EID method: Ratio I	Ratio between the values obtained by the aggregation method and the 3EID method: Ratio II	Reference for the aggregation method
	A	B	C = A × B	D	E = A × D	F	G	H = G/C	I = G/E	
	kg-CO_2/ 1,000 yen	1,000 yen/ ton	kg-CO_2/ ton	1,000 yen/ ton	kg-CO_2/ ton	-	kg-CO_2/ ton	-	-	
Wheat	2.17	164	357	19.1	41.5	8.6	383	1.07	9.22	*1
Flour	2.49	122	304	-	-	-	520	1.71	-	*1
Soybeans	1.13	235	266	27.5	31.1	8.5	412	1.55	13.26	*2
Edible soybean oil	3.27	110	360	-	-	-	1190	3.3	-	*2
Soy meal	3.27	34.7	114	24	78.4	1.4	357	3.14	4.55	*2
Japanese-produced steer beef	2.03	1,655	3,357	50.8	1,031	3.3	10,600	3.16	10.28	*3

*1 Toshisuke Ozawa, et al., "Estimation of LC-CO_2 for Wheat, Flour, and a Loaf of Bread," the Collection of Abstracts for the 2nd Meeting of the Institute of Life Cycle Assessment, Japan (2007).

*2 Kunimitsu Sato, et al., "LC-CO_2 of Edible Soybean Oil and Soy meal," the Collection of Abstracts for the 2nd Meeting of the Institute of Life Cycle Assessment, Japan (2007).

*3 Akifumi Ogino, et al., "Evaluating Environmental Impacts of the Japanese Beef Cow Calf System by the Life cycle Assessment Method," Animal Science Journal (2007), pp. 78, 424, and 432.

Note: Import prices have been cited from CY2000 data of AGROTRADE HANDBOOK 2004 JETRO.

Table 2: Example of an examination of the influence of price differences between imported and domestically produced products

(4) CO_2 burden generated in product use or disposal

The Ajinomoto Database is based on the 3EID, consisting of accumulated CO_2 data associated with the environmental impact caused by production such as the CO_2 burden of items or their energy that are introduced into a particular industrial sector. This means that the CO_2 burden caused by use of these items is not included. One of the major examples is fossil fuel. CO_2 induced by use of fossil fuel is included in its CO_2 emission factor; however, CO_2 emission at the moment of fossil fuel combustion is not included. (CO_2 emission factors in both the 3EID and the Ajinomoto Database are categorized in terms of products and also of industrial fields, and the concept of this induced CO_2 may be understood more easily when it is viewed in terms of an industrial field.) If it is expected that CO_2 is generated when a product is used for a particular purpose, addition of CO_2 data to the 3EID is important. Also note that the database does not include any estimates of environmental impact generated outside production activities in which financial transactions are carried out. Environmental load associated with product disposal is one of the examples.

(5) Discrepancies between input-output data tabulated every 5 years and the latest environmental load data

In Japan, the input-output data is tabulated every 5 years, and after tabulation, it takes 3 to 4 years before the new tabulation result is published. Therefore, it is highly likely that there are discrepancies between the actual and estimated environmental load data for industrial sectors in which technological innovation takes places rapidly. Taking changes in data between different fiscal years into account, average values for the data obtained in 1990, 1995, and 2000 are included in the Ajinomoto Database.Although the data may not be perfectly accurate due to the difference between system boundaries, as seen in the table, the 3EID method is quite likely to generate discrepancies between the calculated values and the actual values for primary processing of foods for which Japan depends on imports.

Furthermore, flows of goods and services that are not covered by the input-output table may not be accurately incorporated into the database. For example, the environmental load associated with transportation of imported products is not incorporated.

6. Conclusion

The Ajinomoto Database is available for viewing at our company website. When you refer to the database, please indicate the database as the source. Since the publication of the database, we have received a large number of questions regarding the usage of the database, such as how this table should be read and understood and the rules to be observed when using this table, from not only researchers but also general consumers.

We, the Ajinomoto Group, truly hope that many people access and use this database with a good understanding of its strengths, issues, and weaknesses as described above. We also hope that publication of a database that covers a wide range of foods can contribute to reduction of environmental loads in society and also to the promotion of development of products of high value.

To conclude this article, we would like to express our gratitude to domestic as well as international researchers, those who are in the food or other industries, and the general consumers who sent us questions and comments after the database was published. Also, our database was

published. Also, our database was published on the Internet after confirming that it had no problems following our presentation and discussion at the Food Study Group, the Institute of Life Cycle Assessment, Japan. Therefore, we also would like to express our gratitude to the members of the Food Study Group.

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Incentive Award

LCA of a Uniform

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1. Introduction

As the name suggests, a uniform is defined as clothing of a single pattern that is worn by a group of people. Differing from general clothing that is selected based on tastes of individuals, uniforms of a particular group have the same composition, same color, and are worn in one location; therefore, they are characterized by being easier to be collected and recycled than general clothing.

A review of changes in recent eco-friendly activities in the uniform field has shown that around the time of implementation of the Law on Promoting Green Purchasing in 2001, needs for the purchase of eco-friendly uniforms increased, and as a result, manufacturing of uniforms using recycled PET bottles has become widely practiced. At the same time, the concept of 3R for establishing a recycling-oriented society started to spread, and in the industrial world, activities aiming to realize zero-emission for both direct and indirect materials were further encouraged. Then, the need for recycling of used uniforms became significant. In response to this situation, uniforms were often simply subjected to incineration or heat recovery; however, as the basis for recycling developed, activities to prevent uniforms from turning into garbage were fully implemented.

Meanwhile, the impact of greenhouse gasses on global warming has become apparent, and therefore, measures to reduce greenhouse gasses were implemented to realize a low-carbon society. Conventionally, uniforms were recycled often based on the understanding that reduction of waste was the main objective, but recently, environmentally-advanced companies have started to request "visualization of the CO_2 status" to allow themselves to quantitatively understand the volume of greenhouse gas reduction that can be achieved through recycling. We, Chikuma & Co., Ltd., too, concluded that not only waste reduction as a result of uniform recycling, but also the environmental impact of uniform recycling on global warming must be quantitatively understood. We thus applied for the FY2007 Green Performance Advancement Promotion Project of the Ministry of Economy, Trade and Industry (METI) and were selected; therefore, we conducted uniform LCA.

2. Uniform LCA

Using our typical products, we compared the impact of our uniforms on global warming between two scenarios; in one scenario, environmental measures were taken for the entire life cycle of the uniforms, and in other scenario, no particular environmental measures were taken.

2-2. Objective

The main objective of LCA for us, a manufacturer of various types of uniforms and a seller of uniform materials, was to quantitatively understand the impact on global warming of the uniform recycling procedure that we are carrying out in accordance with the concept of the extended producer responsibility and to effectively use the data obtained to further develop environmental load reducing products and systems.

2-3. Subject

The subject of LCA was a men's work uniform (jacket and pants), and the product feature setting for this LCA was that the uniform was worn in 3 seasons (8 months) excluding the summer, worn for 8 hours a day and 5 days a week, and each operator was given 3 sets of the uniform, and the lifetime of each uniform set was 3 years. The assessment was carried out for a ton of the large size uniforms that were most frequently used.

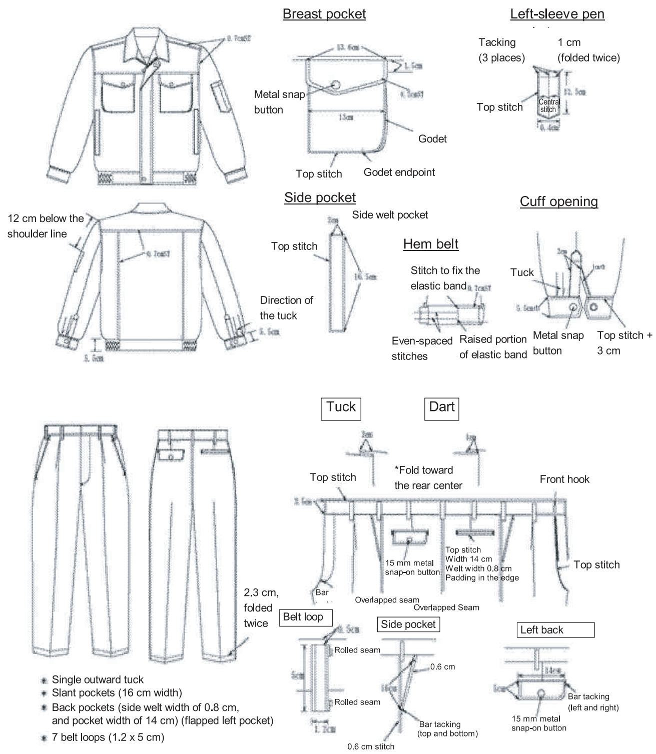

Figure 1: LCA subject

Table 1 shows the weight and material of the parts of the LCA subject shown in Figure 1.

Parts	Finished weight (in grams)			Composition	Overall	Material loss in the cutting phase (in grams)			Overall
	Jacket	Pants	Total		Composition ratio	Jacket	Pants	Total	Weight
Outer material	450.3	353.7	804.0	Polyester-cotton blend fabric	79.0%	68.0	64.6	132.6	936.6
Interlining cloth	18.9	4.3	23.2	P	2.3%	2.7	1.1	3.8	27.0
Sleek	9.5	27.0	36.5	P	3.6%	2.4	4.8	7.2	43.7
Thread for plain seam	7.4	5.8	13.2	P	1.3%				13.2
Thread for lock seam	3.8	6.2	10.0	P	1.0%				10.0
Inside belt		9.0	9.0	P	0.9%				9.0
Flat elastic tape	13.0		13.0	EPDM	1.3%				13.0
Zipper	17.5	5.8	23.3	◎	2.3%				23.3
Metal snap-on button	12.0	2.0	14.0	POM	1.4%				14.0
Eco-name tag	0.5	0.4	0.9	P	0.1%				0.9
Name tag	0.2	0.1	0.3	P	0.0%				0.3
Bag	18.8	14.2	33.0	LPDE	3.2%				33.0
Quality label	0.1	0.1	0.2	N100%	0.0%				0.2
Hang-tag	1.3	1.3	2.6	Paper	0.3%				2.6
Loop pin	0.1	0.1	0.2	N100%	0.0%				0.2
Total	553.4	430.0	983.4			73.1	70.5	143.6	1127.0

◎ Zipper materials: tape = P, element = POM N, and slider = zinc die cast.
P = virgin polyester, POM = polyacetal, N = nylon,
EPDM = ethylene propylene diene monomer, LPDE = low-density polyethylene, and
(shaded) = cutoff data

Parts number	T1695
Parts name	Antistatic twill
Blend ratio	80% polyester and 20% cotton
Density (vertical x horizontal)	125 threads x 62 threads (per an inch)
Weave type	Combined woven twill
Threads	T 65% / cotton 35%, thread size #22 / single yarn x T150de two-ply yarn
Weight	245g/m^2
Width x length	150 cm x 50 m
Dyeing	Piece dyeing

Raw material composition	Conventional product
Polyester	703.1
Cotton	201.0
LDPE (low-density polyethylene)	33.0
Polyacetal	21.8
EPDM	13.0
Zinc die-cast	7.0
Nylon	1.5
Total weight	980.4

Table 1: Material and weight of parts used in the LCA subject (in grams)

The outer material of the uniform was combined woven twill of 80% polyester and 20% cotton, and the total uniform weight was 980.4 g (including the bag). Of which, the outer material was 804 g (accounting for approximately 80% of the total weight), and the amount of waste generated by cutting the material in the manufacturing phase was estimated at 143.5 g (yield ratio: approximately 87%) per uniform set. Materials for creating quality labels, hang-tags, and loop pins were excluded from the assessment since they represented only a small amount.

2-4. Life Cycle Scenarios (the Scope of the Assessment)

The assessment was carried out for the two life cycle scenarios (A) and (B) that we created. Scenario (A) is the lifecycle of a conventional product for which no particular eco-friendly measures are implemented, and Scenario (B) is a lifecycle of an improved product for which eco-friendly measures are implemented.

(A) Conventional product
In this scenario, virgin materials (derived from petroleum) were used to create polyester for the outer material, waste (material loss in the manufacturing phase) was incinerated, and the used uniform was incinerated.

(B) Improved product
In this scenario, recycled materials (derived from used PET) were used to create polyester for the outer material, waste (material loss in the manufacturing phase) was subjected to material recycling, and the used uniform was subject to chemical recycling.

*Underlines show differences between scenarios (A) and (B).

2-5. System Boundary

Figure 2 shows the scope of the LCA in this article.

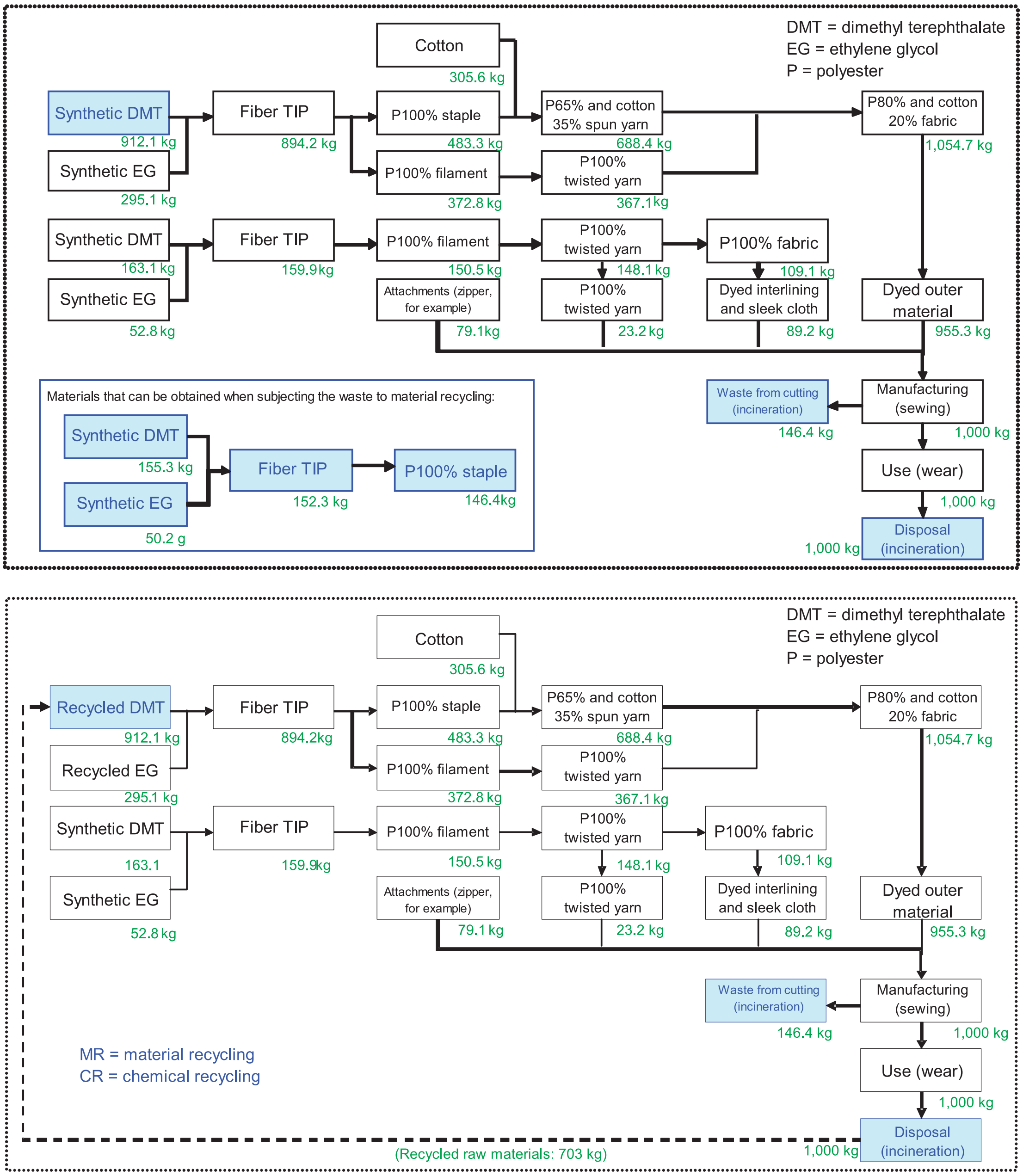

Figure 2: Scope of the assessment: top figure = conventional product, and bottom figure = improved product.
*Blue squares = differences between the conventional and improved products.

Differences between the two life cycles shown in Figure 2 are: ① polyester material, ② handling of waste from cutting, and ③ handling of used materials in the disposal phase. ① is a comparison between the case in which dimethyl terephthalate (DMT) is manufactured from its virgin raw material (synthetic DMT) into polyester and the case in which used uniforms containing polyester of 80% or more are re-used as a polyester raw material (recycled DMT). ② is a comparison between the case in which the waste discharged from a sewing plant is incinerated in a neighboring area and the case in which the waste is subjected to material recycling (MR) to be described later. It should be which dimethyl terephthalate (DMT) is manufactured from its virgin raw material (synthetic DMT) into polyester and the case in which used uniforms containing polyester of 80% or more are re-used as a polyester raw material (recycled DMT). ② is a comparison between the case in which the waste discharged from a sewing plant is incinerated in a neighboring area and the case in which the waste is subjected to material recycling (MR) to be described later. It should be noted here that a quantitative comparison under the same set of conditions requires addition of the environmental load to the conventional product, and the volume of the environmental load to be added needs to be the same as the environmental load generated when the items obtained as a result of recycling are produced from the virgin material. Therefore, the environmental load thusly obtained is added inside the system boundary for the conventional product scenario. ③ is a comparison between the case in which used uniforms are incinerated and the case in which used uniforms are subject to chemical recycling (CR) to be described later.

2-6. Transportation Scenario

Figure 3 shows the transportation scenario for both the conventional product and the improved product.

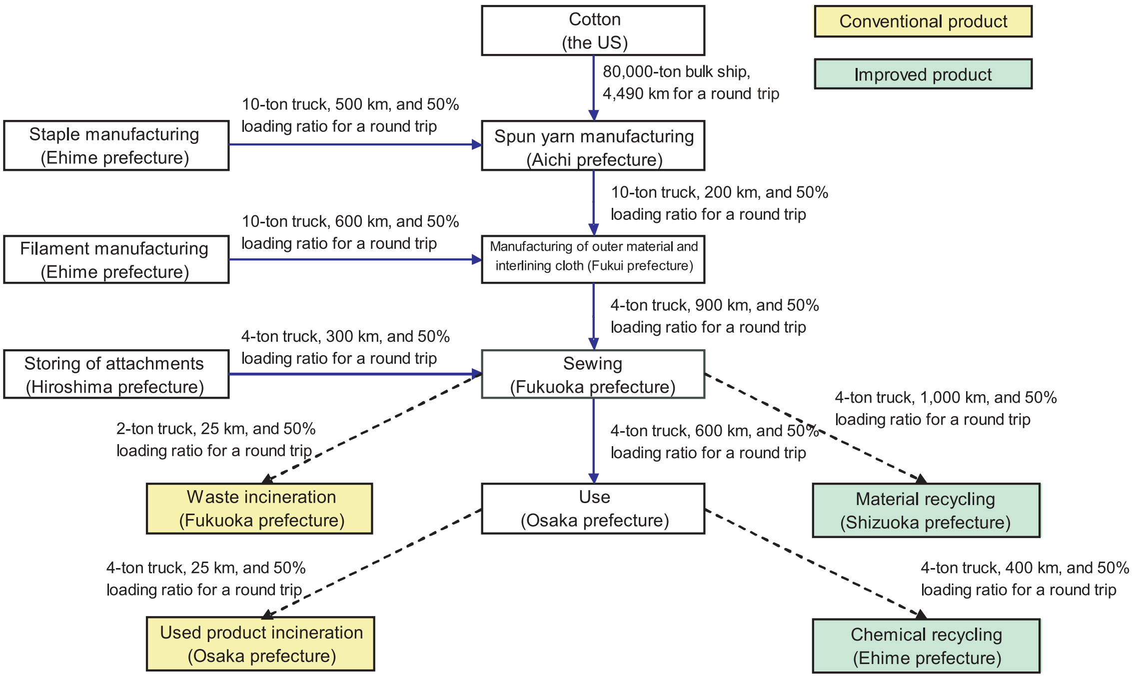

Figure 3: Transportation scenario

In Figure 3, there is a transportation scenario applied to both the conventional and improved products, but there are some differences in the manufacturing and disposal phases; therefore, these differences are shown separately in different colors. Incineration is assumed to be carried out in an area near the site where the waste was generated (transporting distance assumed to be within 25 km), and if the waste is subject to recycling, the transportation distance to the recycling facilities is added. Note that, for CR, the environmental load caused by transportation is not added since the site of recycling and the site of recycled polyester material manufacturing are the same (inside Ehime prefecture).

2-7. Two Recycling Methods

Figure 4 shows chemical recycling (CR) and material recycling (MR) flows. The CR flow on the left shows the technology called new raw material recycling developed by Teijin Fibers Ltd. This is a horizontal recycling system in which, by separating and removing dyes and additives from polyester products and refining the remainder, it is possible to collect DMT of the same or higher quality than DMT manufactured from petroleum and use it to manufacture fibers again. Meanwhile, the MR flow on the right shows a recycling technology that subjects not only products mainly consisting of polyester, but also blended materials such as cotton and wool, to a felt making process known as the fiberizing process, and the felt obtained from this process is then subject to what is called cascade use (use in multiple phases) as soundproofing or sound absorbing materials for cars. In the improved product life cycle scenario in this study, we make the assumption that used uniforms were subject to CR and waste generated in the manufacturing process was subject to MR.

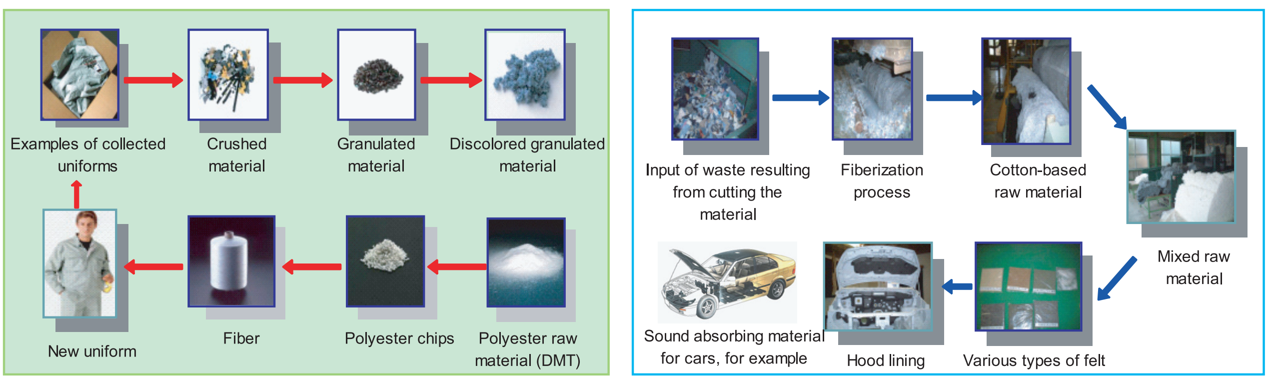

Figure 4: Flow charts of chemical recycling (left) and material recycling (right)

2-8. Inventory Analysis Result

In this assessment, we selected CO_2, N_2O, and CH_4 as the materials of concern in order to focus on the impact on global warming. Table 2 shows the result of tabulation of input and output for the entire life cycle based on the above-mentioned conventional as well as improved product inventory analysis.

Comparison between the conventional and improved products (per ton)

	Item	Unit	Conventional product	Improved product	Effect of improvement	
					Improved product - conventional product	Improved product/ conventional product
Input	Energy (not specified)	MJ	4.60E+03	4.57E+03	4.57E+03	4.57E+03
	Coal as raw material	kg	5.19E+02	5.16E+02	4.57E+03	4.57E+03
	Fuel coal	kg	1.68E+03	1.65E+03	4.57E+03	4.57E+03
	Natural gas	kg	1.09E+03	1.07E+03	4.57E+03	4.57E+03
	Liquid natural gas	kg	1.16E+00	1.16E+00	4.57E+03	4.57E+03
	Crude oil	kg	3.80E+03	3.55E+03	4.57E+03	4.57E+03
	Uranium (resource)	kg	1.58E-01	1.58E-01	4.57E+03	4.57E+03
	Water	kg	1.87E-01	1.76E-01	4.57E+03	4.57E+03
	Aluminum (resource)	kg	9.18E-02	8.67E-02	4.57E+03	4.57E+03
	Copper (resource)	kg	1.99E-02	1.88E-02	4.57E+03	4.57E+03
	Lead (resource)	kg	7.20E-04	6.80E-04	4.57E+03	4.57E+03
	Zinc (resource)	kg	4.82E+00	4.82E+00	4.57E+03	4.57E+03
Output	CO2	kg	2.06E+04	1.77E+04	4.57E+03	4.57E+03
	CH4	kg	8.01E-01	7.62E-01	4.57E+03	4.57E+03
	N2O	kg	8.35E-01	8.04E-01	4.57E+03	4.57E+03

Table 2: Inventory analysis result

2-9. Impact Analysis

The output volume of the three materials of concern in Table 2 were characterized (indicated as CO_2 equivalent) using GWP100 (IPCC-100 years (2007)) as a global warming factor and plotted as bar graphs as shown in Figure 5.

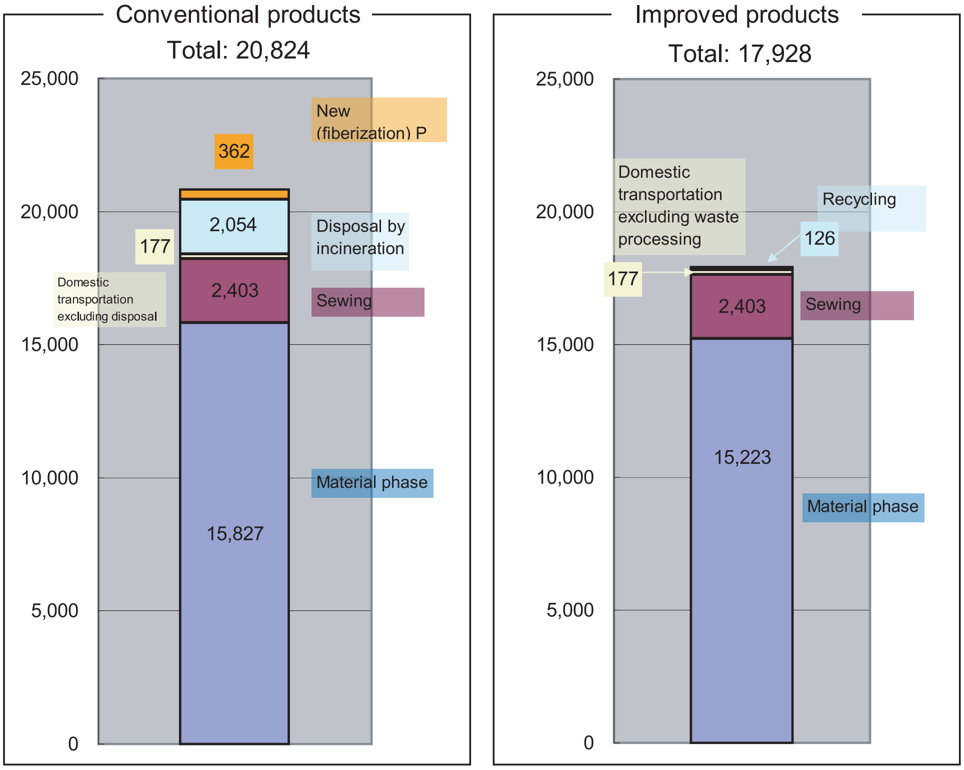

Figure 5: Post-characterization comparison of the impact on global warming (comprehensive comparison) in kg-CO_2eq

When the index numbers indicating the impact on global warming were added for the entire life cycle of the conventional and improved product respectively, the impact of the conventional product was 20,824 kg-CO_2eq while the impact of the improved product was 17,928 kg-CO_2eq, and the difference between the two, which was 2,896 kg-CO_2eq, would be the volume of the impact that could be reduced, meaning that approximately 13% of improvement could be expected overall. Also, since for both cases, the environmental load generated during the material phase accounted for 75% or higher of the total environmental load throughout the life cycle, the assessment indicated that for uniforms manufactured domestically like the ones in this study, the environmental load of the material (fabric) manufacturing phase was relatively higher than other phases.

Instead of the environmental load for the entire life cycle, Figures 6 and 7 show only the differences between the conventional and improved products.

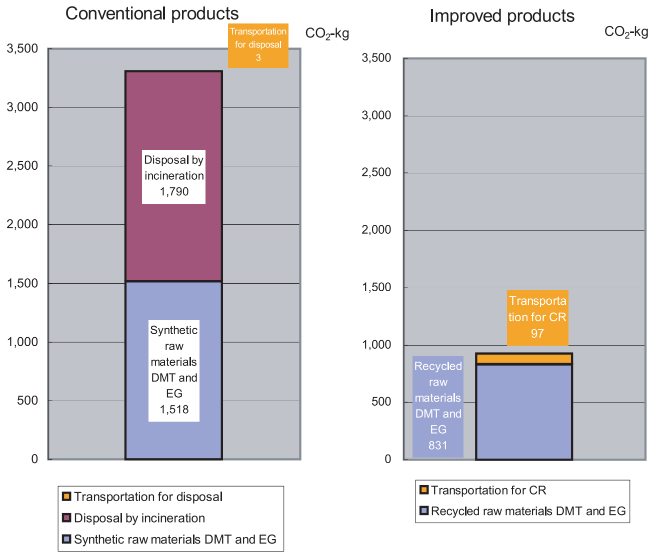

Figure 6: Outer material manufacturing and processing of used uniforms

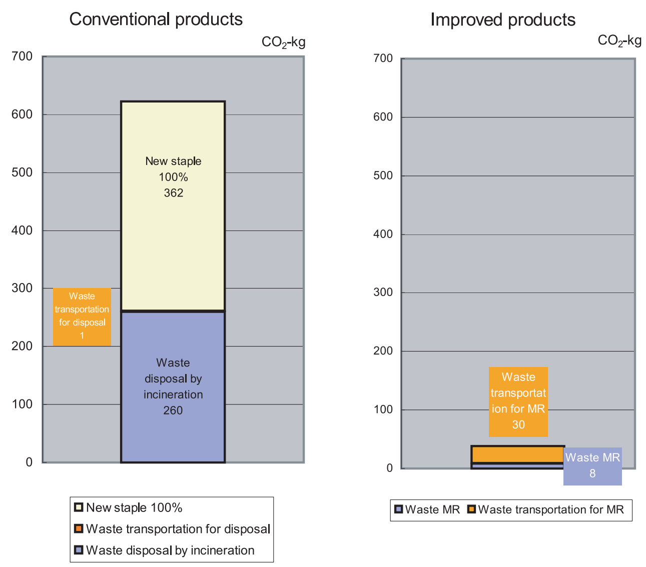

Figure 7 Processing of waste generated when cutting material

Figure 6 shows the integrated environmental loads for manufacturing raw materials for the outer material (virgin or recycled) and those for used uniform processing (incineration or recycling). The comparison of the environmental load for the raw material phase between the conventional and improved products indicated that the environmental load for the conventional product was 1,518 CO_2-kg while it was 831 CO_2-kg for the improved product, suggesting that there would be more than a 40% reduction. What needs to be focused on the most is, however, that the environmental load caused by incineration of used uniforms was 1,790 CO_2-kg, which was approximately the same as manufacturing virgin raw materials and approximately twice as much as manufacturing recycled raw materials.

Figure 7 shows the comparison of waste processing methods between the conventional and improved products. For the conventional product, the environmental loads generated when incinerating the waste and when manufacturing a product having the same quality as the improved product starting from production of the virgin raw materials were added. Meanwhile, the environmental load for the improved product was the burden generated in material recycling of the waste. The comparison between the two products indicated that the burden could be reduced by 90% or more, but as seen in the maximum vertical-axis value, the burden reduction in terms of volume would not be too high.

2-10. Sensitivity Analysis

In this assessment, the conventional product was assumed to be incinerated. When examining how uniforms were disposed of at companies where employees wore uniforms, there were not many cases where uniforms were subject to simple incineration. Instead, even though they did not recycle the uniforms, they often carried out heat recovery. In this section, assuming that heat recovery was adopted as the conventional product disposal method, we compared the assessment results between the improved product disposal method (recycling) and heat recovery.

		Weight of polyester and cotton required for manufacturing 1 ton of product			Calorific value for combustion
		Waste	Used product	Total	
Unit	kcal/kg	kg	kg	kg	kg
Calorific value of cotton	4.90E+03	3.38E+01	2.05E+02	2.39E+02	1.17E+06
Calorific value of polyeste	5.70E+03	1.13E+02	7.10E+02	8.23E+02	4.69E+06
				Total	5.86E+06

(Zipper, metal snap-on button, bag, and flat elastic tape were not included in the assessment)

Table 3: Calorific values of cotton and polyester combustion

Power generation	Unit kWh	Environmental impact
When 10%	6.81E+02	2.88E+02
When 20%	1.36E+03	5.75E+03
When 30%	2.04E+03	8.63E+03
When 50%	3.41E+03	1.44E+03

Table 4: Conversion of calorific value for combustion into electric power

Table 3 shows the calorific values resulting from incinerating the assessed product, and cotton and polyester contained in the waste generated in the manufacturing phase. Then, CO2 emission resulting from recovering heat when the power generation efficiency was 10%, 20%, 30%, or 50% was calculated based on the national emission factor average for 2003 and the obtained values were listed in Table 4. Table 5 shows the differences between the conventional and improved products, and also the reduction ratio. Regardless of the power generation efficiency, the study showed that the impact on global warming is lower when the product was recycled than when the product was subject to heat recovery. Based on these findings, Figure 8 shows as bar graphs CO2 emission of the conventional product (simple incineration), power recovery (heat recovery), and improved product (recycling).

	Conventional products	Power generation efficiency	Reduction	After heat recovery	Improved products	Improved products - after heat recovery	Improved products - after heat recovery
Global warming (GWP)	**2.09E+04**	**0%**	0.00E+00	**2.09E+04**	1.79E+04	**-2.97E+03**	**86%**
	2.09E+04	**10%**	-2.88E+02	**2.06E+04**	1.79E+04	**-2.68E+03**	**87%**
	2.09E+04	**20%**	-5.75E+02	**2.03E+04**	1.79E+04	**-2.39E+03**	**88%**
	2.09E+04	**30%**	-8.63E+02	**2.00E+04**	1.79E+04	**-2.11E+03**	**90%**
	2.09E+04	**50%**	-1.44E+03	**1.95E+04**	1.79E+04	**-1.53E+03**	**92%**

Table 5: Difference between heat recovery and recycling of the improved products

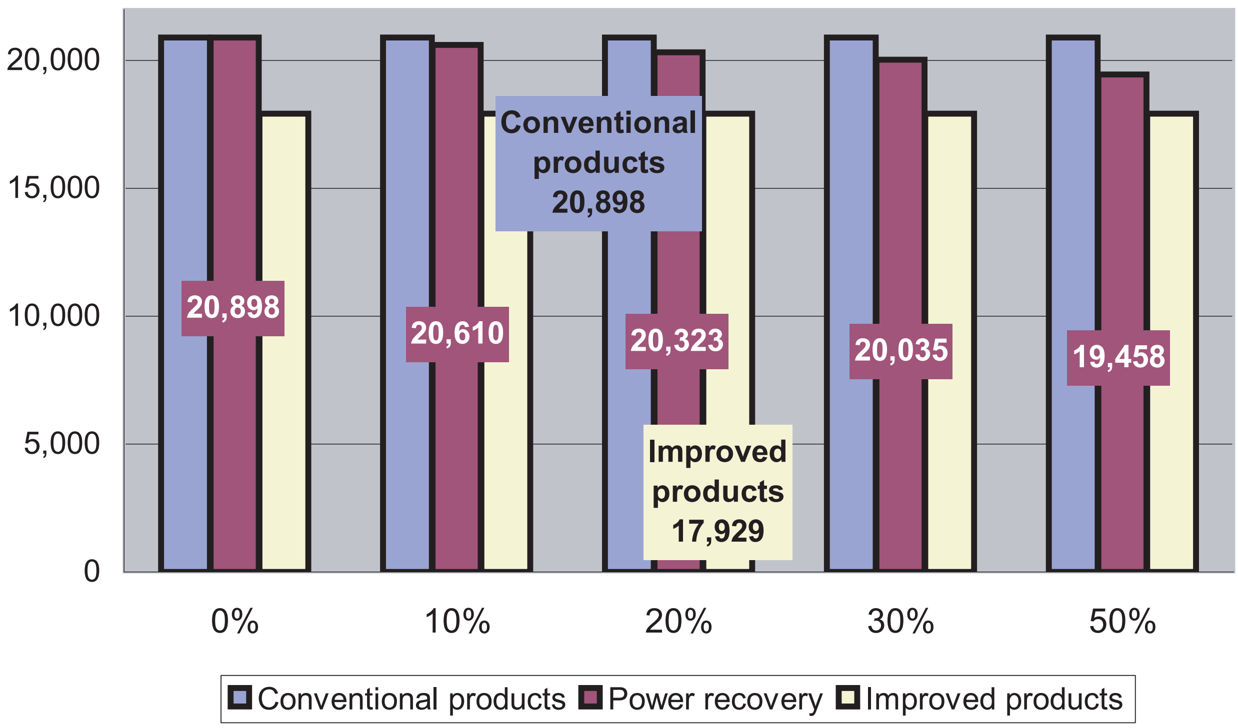

Figure 8: Comparison of CO_2 emissions among the conventional products (incineration), heat recovery, and improved products (recycling); in kg-CO_2

3. Conclusion

Although the assessment must still be refined, the study showed that, when the impact on global warming was quantitatively compared between the conventional product and the improved product, the improved product could reduce the environmental impact. In particular, the result revealed that the uniform disposal method (incineration or recycling) had a great impact on the environmental load.

In the future, we would like to extend the scope of the assessment to other products (wool blend products, for example) and to quantify the environmental load in the uniform use phase in which, for example, irons may be used or uniforms may be repaired.

Incentive Award

Quantification of CO2 Reduction Effect through Carbon Fiber Usage - Importance of Life Cycle Assessment (LCA) -

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1. Introduction

We, as a corporation in the material industry, have been developing technologies to reduce greenhouse gasses emitted during material manufacturing, to save energy, to realize recycling, and new materials for reducing the environmental load not only in the material sector but also in all sectors.

Figure 1 shows environmental loads such as greenhouse gasses to each of the major sectors. There are the material sector, processing and assembly sector that produces products, commercial sector that uses the products, and power sector that supplies energy to the sectors listed above. As for lightweight materials, for example, use of special steel and carbon fiber has been contributing to a reduction of the environmental load of cars and airplanes. Also, silicon materials used in solar batteries are one of the major examples of clean energy generation. The environmental improvement effect achieved by new materials therefore emerges in sectors outside the material sector.

For this reason, it is important to include the assembly and product use phases in quantitative assessment in order to accurately assess the impact of materials on the environment.

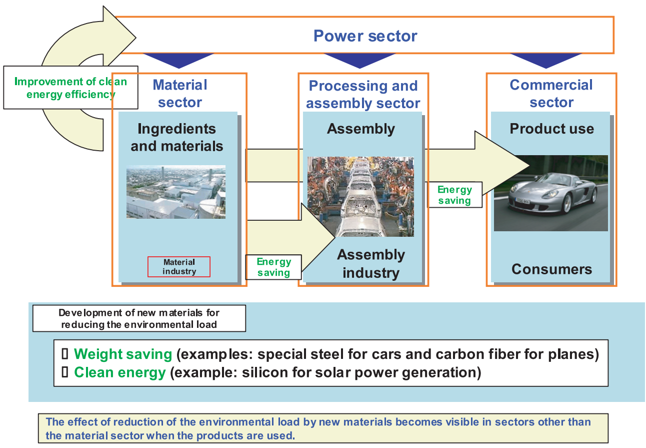

Figure 1: Contribution of the material industry to reduction of the environmental load

LCA is the method to assess the environmental impact of materials including the environmental improvement effect realized by assembling and using the products in other sectors. As shown in Figure 2, LCA allows comprehensive assessment of the environmental load reduction effect for the entire life cycle from the material, assembly, product use, and disposal phases.

Compared to conventional materials, new materials for environmental improvement may cause an increase of the environmental load when being manufactured; however, they are able to contribute to environmental improvement by dramatically reducing the environmental load in the assembly, product use, and disposal phases of the life cycle.

The schematic diagrams shown in the bottom half of Figure 2 suggest that new high tensile steel in cars emits more carbon dioxide than the conventional material when being manufactured, but it can contribute to a reduction of carbon dioxide emission as a result of product weight saving which in turn results in mileage improvement. Also, when using new heat insulating glass in a house, manufacturing of the new glass generates more carbon dioxide than conventional glass, but prevention of heat loss during product use can lead to reduction of carbon dioxide emission from the house.

Therefore, in order to assess the environmental load of a particular material, it is important to quantitatively assess the environmental load of the entire life cycle of the product in which the subject material is used.

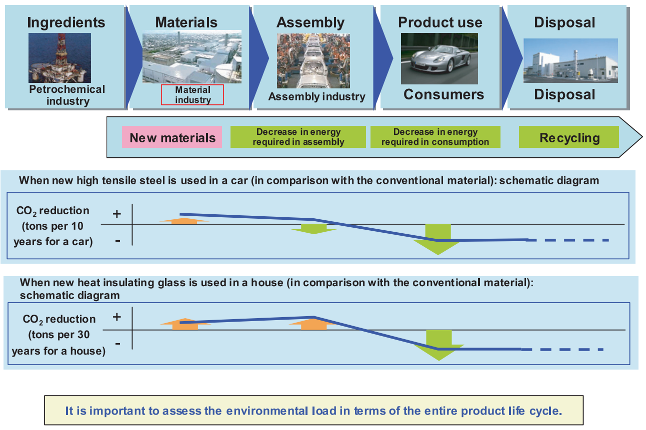

Figure 2: LCA of a product in which new materials are used

Figure 3 shows the material industry's recommendations for a low environmental load society. The first recommendation is promotion of quantification of the environmental load throughout a product life cycle. Since the environmental improvement effect of a particular material is demonstrated when the product is used, product LCA for quantified examination of the environmental improvement effect of material is considerably important.

The second recommendation is generation and expansion of new materials that can contribute to environmental improvement. The materialization of a low environmental load society requires generation and expansion of new materials that can contribute to environmental improvement, and such generation and expansion of new materials will support the technologies of Japan, a nation based on creativity in science and technology, and also a nation founded on the principles of environmental protection.

The third recommendation is the establishment of a social infrastructure that covers recycling, collection, and logistics of waste management. This will further improve the environmental improvement effect of new materials.

Finally, the fourth recommendation is innovative process development in the field of material manufacturing to reduce energy consumption and to make low environmental load materials available.

1. Quantification of the environmental load throughout a product life cycle (LCA)
2. Generation and expansion of new materials that can contribute to environmental improvement
3. Development of a low energy operated social infrastructure including waste recycling
4. Reduction of energy consumption in material manufacturing through innovative process development

Figure 3: Recommendations for a low environmental load society

2. Carbon Fiber

As shown in the upper left corner of Figure 4, the specific gravity of carbon fiber is one-fourth that of iron, and also, the specific strength of carbon fiber, which is obtained by dividing tensile strength by the density, is 10 times that of iron; therefore, it is contributing to weight reduction of products.

The upper right corner of Figure 4 shows the changes in the world carbon fiber demand by application. When the production of carbon fiber started in the 1970's, it was used only for limited purposes such as sporting goods and space satellites. Its use then started to rapidly spread in the aerospace and industrial fields. As shown in the figure below, the manufacture of carbon fiber first requires production of acrylonitrile and acrylic fiber from petroleum and then carbonization of them at a high temperature between 1,000 and 3,000 °C]. Manufacturing of carbon fiber therefore requires a large amount of energy.

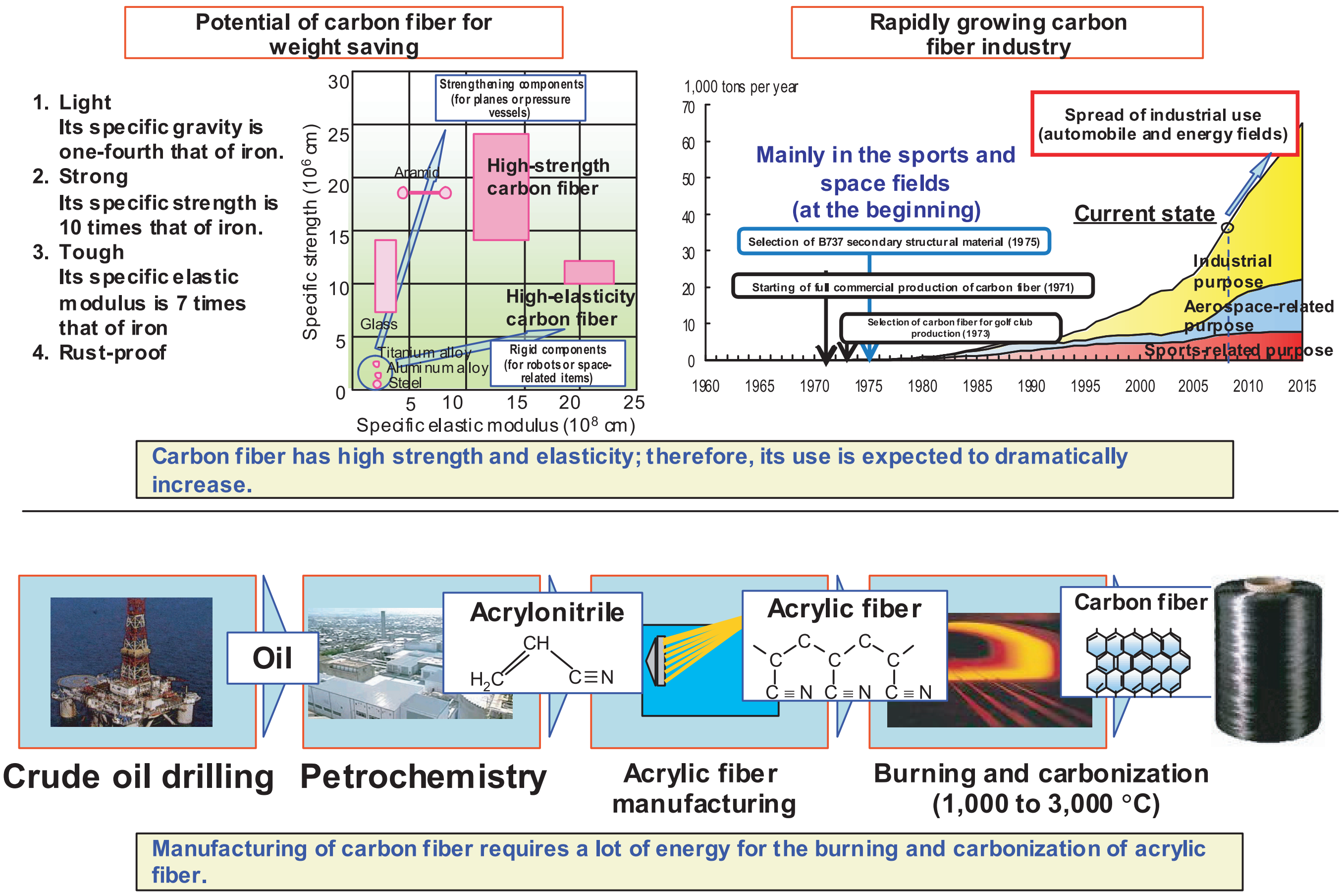

Figure 4: The carbon fiber industry of which Japan is the world leader and the future of said industry

Next, how carbon fiber is used and how it is contributing to the prevention of global warming are described. As seen in Figure 5, carbon fiber contributes to the reduction of CO_2 emission by achieving weight saving in airplanes and cars, and also through use as a material for light compressed natural gas (CNG) tanks used in buses and trucks. Furthermore, carbon fiber contributes to clean energy generation by improving the efficiency for wind turbines as well as nuclear power generation and also through use as a material for high pressure hydrogen tanks or electrode materials that are required for fuel cell vehicles.

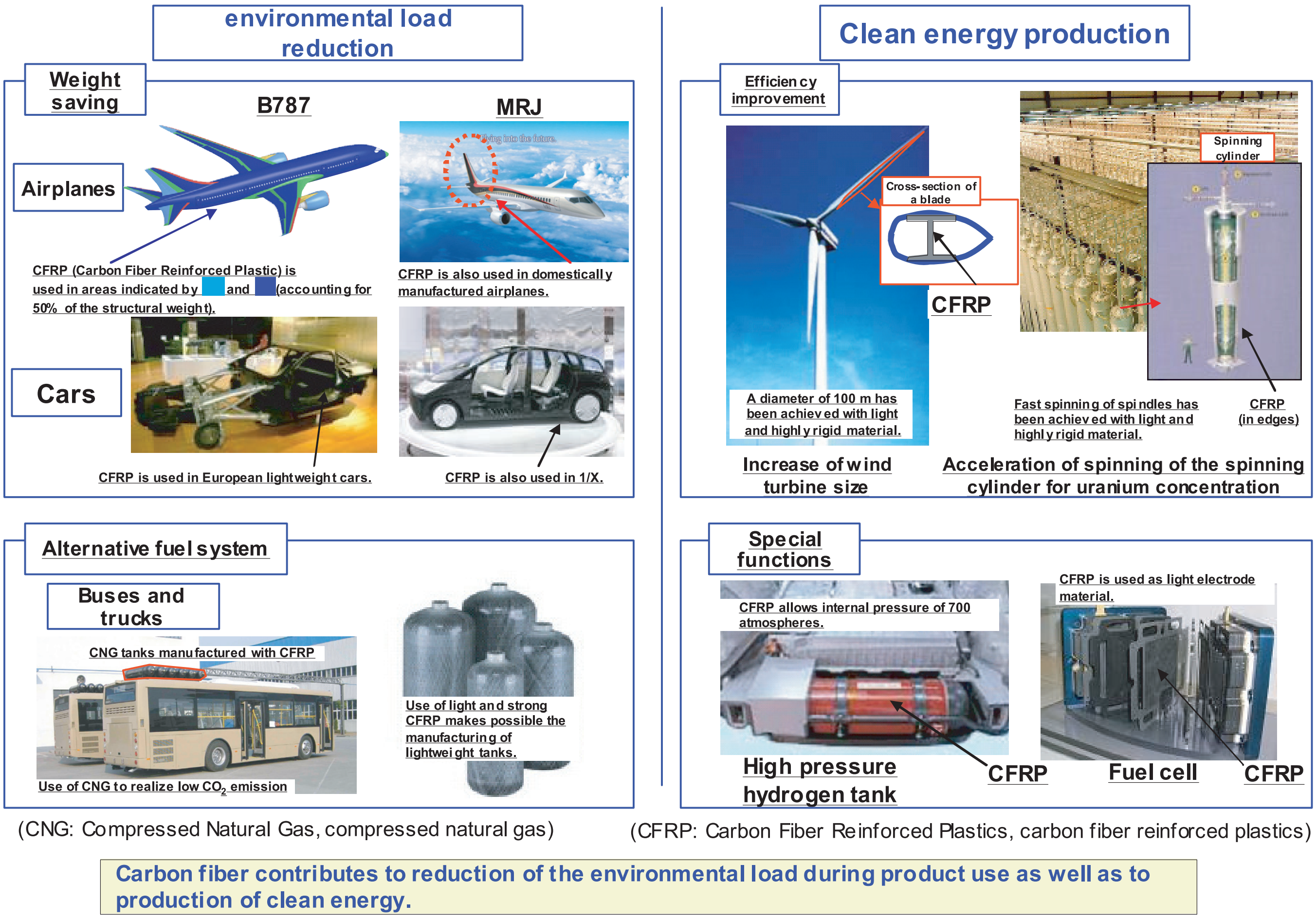

Figure 5: Carbon fiber contributing to measures against global warming (1)

Figure 6: Carbon fiber contributing to measures against global warming (2)

Furthermore, as shown in Figure 6, carbon fiber is used as a material of ferry bodies, airplane engine parts, truck racks, car hoods, tires, and propeller shafts. It is also used as a reinforcing material for railway bridges and bridge decks. These applications do not require use of heavy machinery and the resulting environmental load is therefore low.

As for use of carbon fiber as an airplane-related material, as shown in Figure 7, the next-generation eco-friendly passenger plane Boeing 787 is called an "all-composite plane" since approximately 50% of the plane structure weight including the fuselage and the main wings made of a carbon fiber reinforced composite, and for one airplane, approximately 35 tons of carbon fiber reinforced composite is used. Among these planes, 35% of them are manufactured by three Japanese heavy industries companies.

Also, Mitsubishi Heavy Industries has been developing the small-size eco-friendly high-performance passenger plane MRJ, contributing to reduction of CO_2 emission by combining Japan's most advanced material, carbon fiber, and sophisticated production technologies.

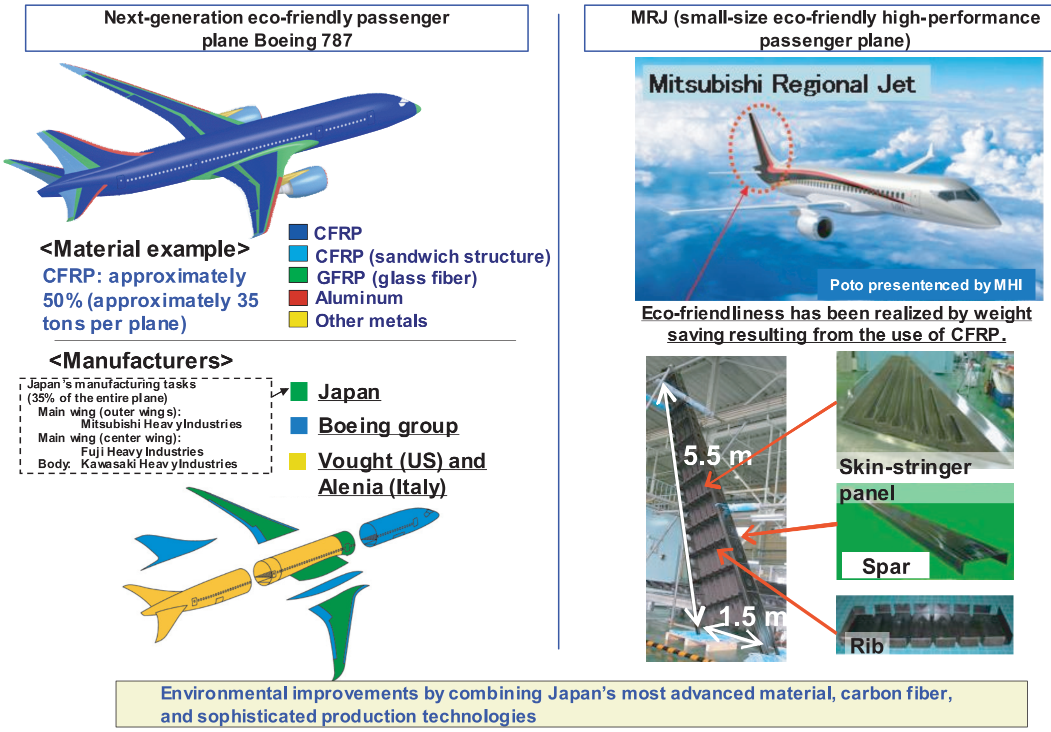

Figure 7: Carbon fiber contributing to measures against global warming (3)

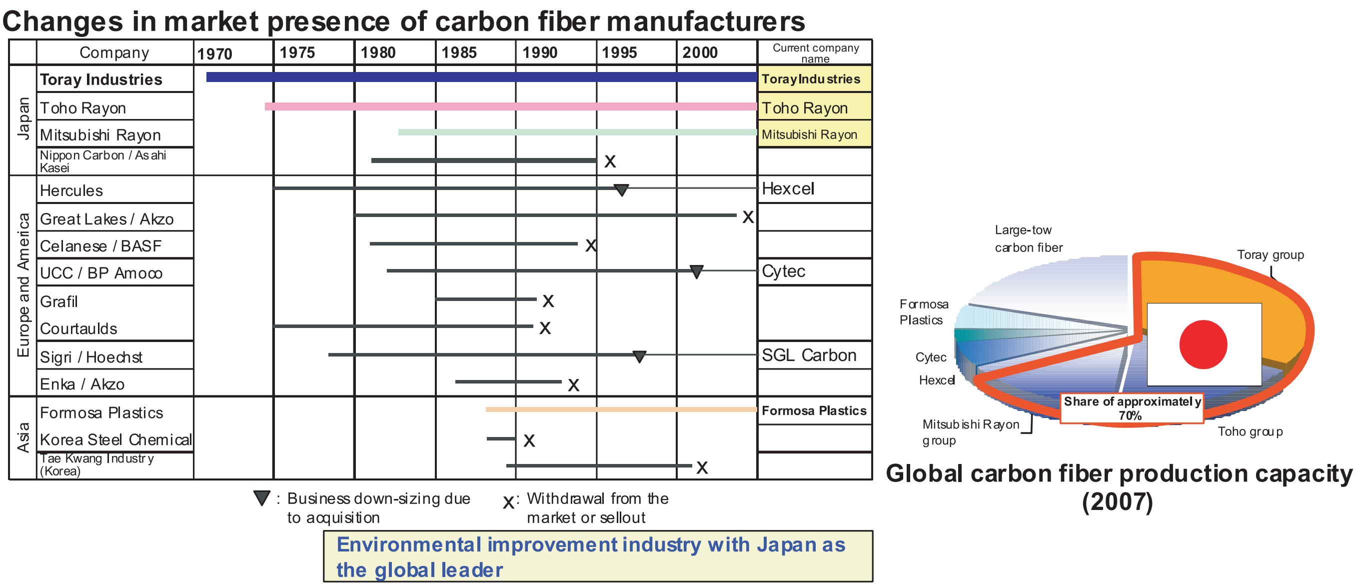

Figure 8: Carbon fiber industry with Japan as the global leader

Figure 8 shows changes in market presence of various carbon fiber manufacturers. During the 40 year history of the carbon fiber industry, major European and American chemical companies entered the carbon fiber market, but all of them withdrew after being unable to endure the pressure of research and development. Finally, only three Japanese companies survived, and currently, these three companies manufacture approximately 70% of the carbon fiber produced worldwide. Therefore, the carbon fiber industry can be considered the environmental improvement industry with Japan as the global leader.

3. Quantification of the Environmental load Reduction Realized through the Effective Use of Carbon Fiber

We quantified carbon dioxide reduction throughout the product life cycle as a result of using carbon fiber as an airplane material. This quantification was carried out with the cooperation of the University of Tokyo, Kobe Yamate University, All Nippon Airways, and Boeing, and it, together with its results, has been publicized by the Japan Carbon Fiber Manufacturers Association.

As Figure 9 shows, when carbon fiber is used in an average passenger jet Boeing 767 in the same way that it is used in a Boeing 787 which has been under development as an all-composite passenger jet, approximately 20% of the airplane structural weight can be reduced.

As seen in the bar graph below, within the life cycle of an airplane, 99% of the carbon dioxide is emitted when the airplane is in operation. Therefore, mileage improvement as a result of weight saving can allow reduction of 27,000 tons (7%) of carbon dioxide per airplane during a 10-year life cycle, meaning that carbon dioxide emission can be reduced by 2,700 tons per year. When this calculation is applied to 430 passenger jets in Japan, approximately 1.2 million tons of carbon dioxide emission can be reduced per year.

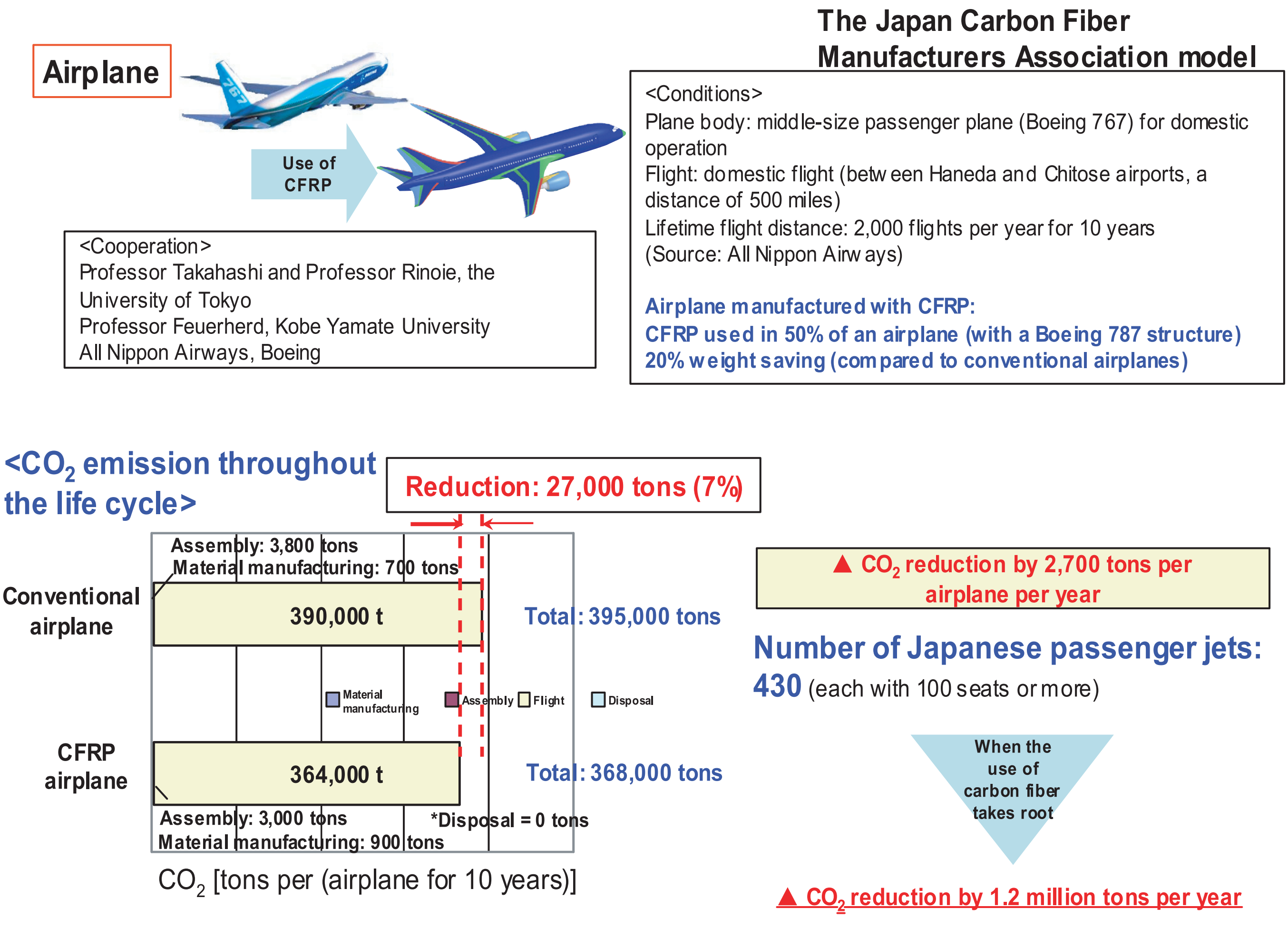

Figure 9: Quantification of the CO_2 reduction effect realized through the carbon fiber usage

Figure 10 shows the effect of the use of carbon fiber as a car material. When an average-sized Japanese car is manufactured with carbon fiber, the weight can be reduced by approximately 30%.

As seen in the bar graph below, although carbon dioxide emission increases during material manufacturing, mileage will improve due to the resulting weight saving and this in turn allows reduction of carbon dioxide emission while in motion. As a result, for a 10-year life cycle, it is possible to reduce 5 tons (16%) of carbon dioxide per car. This means 0.5 tons of carbon dioxide emission reduction per year; therefore, when the use of carbon dioxide is expanded to the 42 million cars currently owned in Japan, it will be possible to reduce 21 million tons of carbon dioxide per year.

If, therefore, carbon fiber is used in the manufacturing of airplanes and cars owned in Japan, 1.2 million tons of carbon dioxide can be expected in terms of airplanes and 21 million tons in terms of cars, resulting in a total carbon dioxide emission of 22.2 million tons. This means that it is possible to reduce approximately 1.5% of carbon dioxide that was emitted in 2006 (1.3 billion tons).

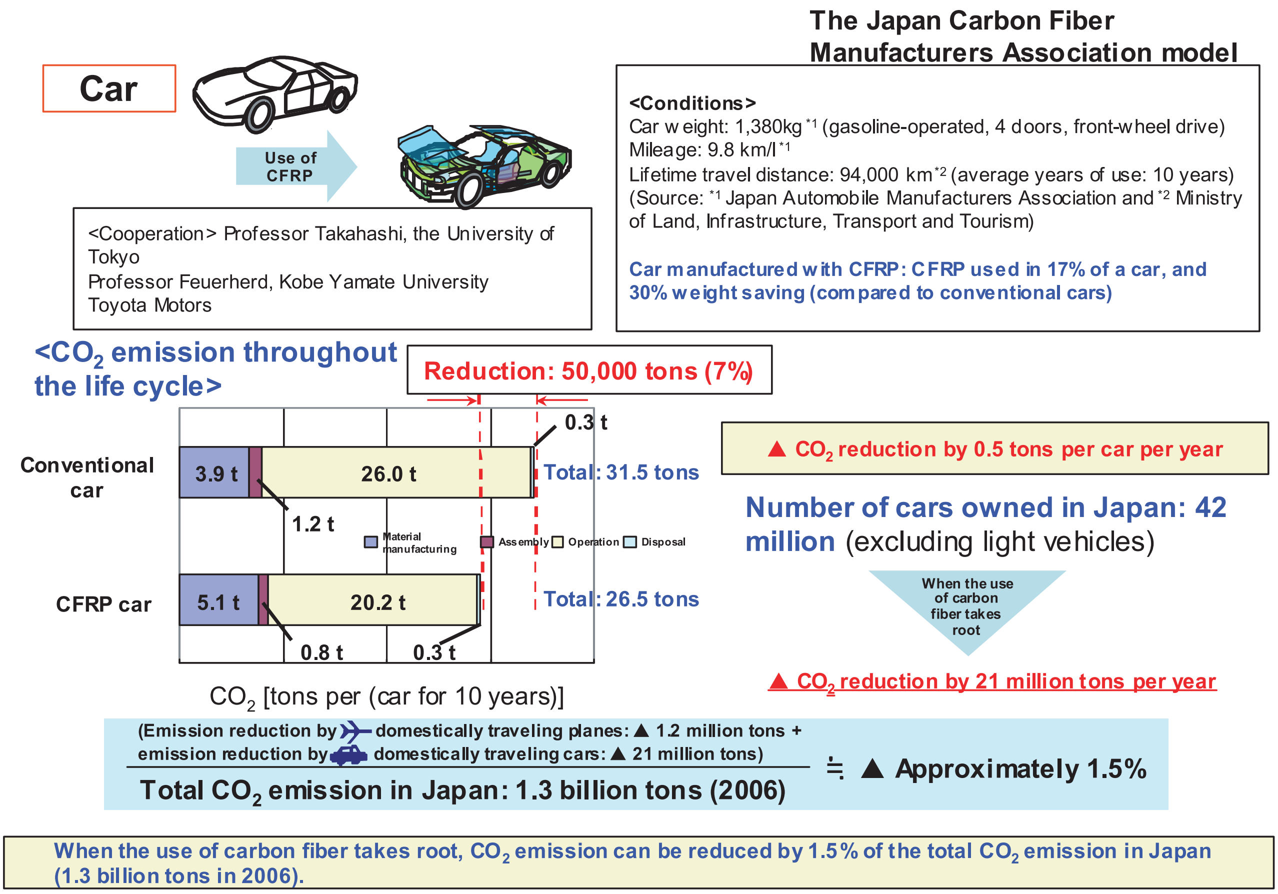

Figure 10: Quantification of the CO2 reduction effect realized through the effective use of carbon fiber

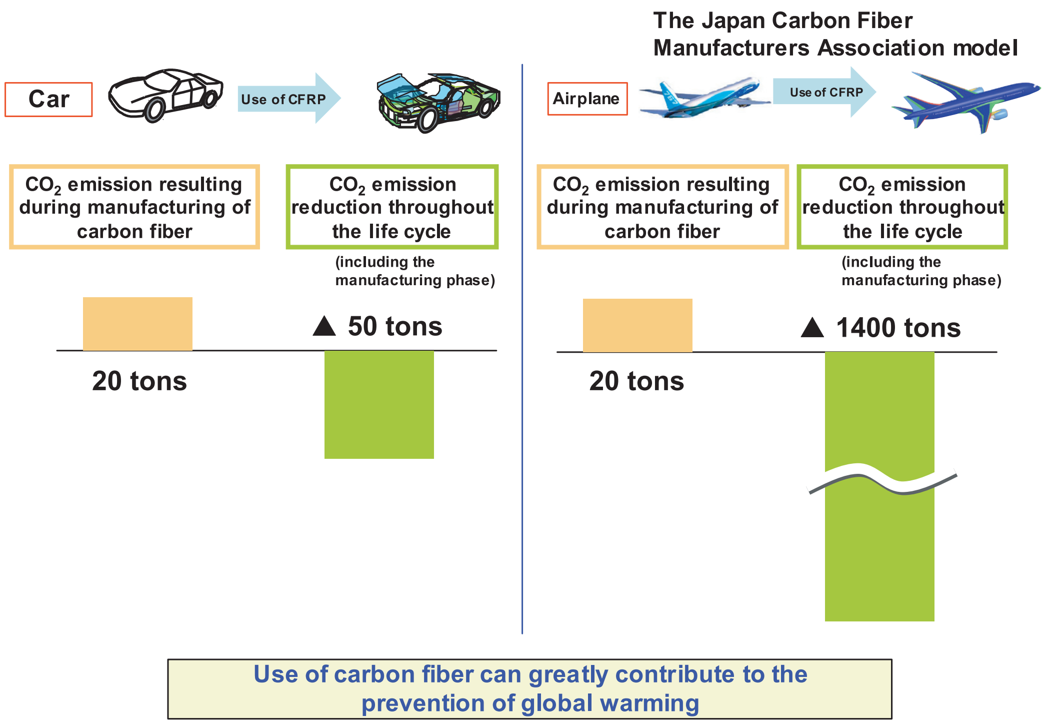

Figure 11: CO2 emission reduction realized by one ton of carbon fiber

Figure 11 shows reduction of carbon dioxide emission that can be achieved per one ton of carbon fiber when it is used to manufacture cars and airplanes.

Manufacturing of one ton of carbon fiber results in emission of approximately 20 tons of carbon dioxide, but when it is viewed in terms of a 10-year span, 50 tons and 1,400 tons of carbon dioxide emission can be reduced for cars and airplanes respectively. These values are net reduction amount including manufacturing emission.

Therefore, when used as a material for cars and airplanes, carbon fiber can reduce carbon dioxide emission by a degree far greater than the amount generated during its production. The use of carbon fiber thus greatly contributes to improvement of the global environment.

As described above, it is important to quantify not only the environmental load during material production but also the total environmental load throughout the life cycle in order to accurately examine the environmental load of a particular material. In future discussions regarding environmental impact of new materials, we hope that the readers of this article will thoroughly study the approach taken in LCA and understand the concept of generation as well as expansion of use of new materials that can contribute to protection of the environment.

I would like to express my gratitude to Toyota Motors, All Nippon Airways, Boeing, Professor Takahashi of the University of Tokyo, Professor Feuerherd of Kobe Yamate University, and the Japan Carbon Fiber Manufacturers Association for advice and cooperation in the assessment carried out for this article.

Case Example

A Case Study of Carbon Footprint for Beer Product

Ryo Atsumi
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Sapporo Breweries Limited

1. Introduction

We at Sapporo Breweries have been implementing measures against global warming for a long time, and we have produced positive outcomes in terms of reduction of CO_2 emission during the production process. In 2003, our breweries achieved the environmental goal set in 1994 (reduction of the CO_2 emission rate by 12% by 2010 with respect to the emission of 1990). In 2004, in order to expand our eco-activities to all processes included in a product life cycle, we carried out the first beer product life cycle assessment (LCA) in the beer manufacturing industry in accordance with ISO14040. The LCA result was critically reviewed by Japan Environmental Management Association for Industry in 2005. In 2008, the Ministry of Economy, Trade and Industry (METI) established the Carbon Footprint System Implementation and Promotion Study Group. Sapporo Breweries participated in the study group and experimentally carried out a carbon footprint calculation with our leading product, canned Sapporo Black Label Draft , 350 ml.

2. Calculation Method

The calculation was performed based on the temporary rule established at the study group (December, 2008).

3. Subject and Scope of Analysis

3.1 Subject

Among the leading and the most popular products of Sapporo Breweries, the Sapporo Black Label Draft series, we selected a 350 ml can for this study. Figure 1 shows the product specifications such as ingredients and container. Note that indirect materials (materials that are used at a breweries but are not shipped with products such as packing materials of ingredients and cleaning chemicals) used during the beer manufacturing process were not included in the analysis.

Sapporo Black Label Draft, 350 ml, can

Ingredients: malt, hops, corn, starch, rice, and water
Container: drawn and ironed aluminum can (aluminum DI can)
Exterior packaging material: cardboard

Figure 1: Subject of the study

3.2 Study Method and Data Collected

3.2.1 Method

We calculated CO_2 emission for the entire life cycle of the 350 ml study subject. Figure 2 shows the scope of calculation. Following the study group rule, we calculated based on 2007 data. In this study, we included the sales phase of the life cycle in the scope of calculation which we had not included in previous LCA study.

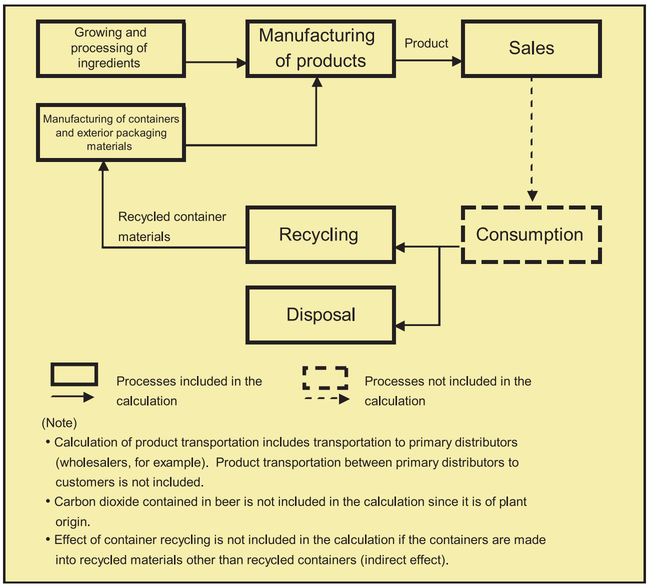

Figure 2: Process flow and system boundary

3.2.2 Environmental Load of Each Process and Data Collection

(1) Procurement of ingredients (growing, processing, and transportation of ingredients)

This section describes the environmental load generated as a result of growing and processing of ingredients as well as transportation of ingredients to a brewery. The environmental load of the main ingredients of beer, malt and hops, was calculated using the primary data, and the secondary data was used to calculate the environmental load of auxiliary materials that were corn, starch, and rice. Table 1 shows the description of the environmental load resulting from the growing and processing of barley and hops. The amount of agricultural materials (such as agrichemicals and chemical fertilizers) used for a unit quantity of barley and hops was obtained by extracting and averaging the data, collected from multiple producers from various countries, provided in a database managed as a part of the"Collaborative Contract Farming System"(*).

Table 1: Environmental load of growing and processing of the main beer ingredients

	Growing	Processing
Barley	• Agricultural materials (such as agrichemicals and chemical fertilizers) • Fuel for Agricultural machines	Fuel, power, and water used in the malt production process
Hops	• Agricultural materials (such as agrichemicals, chemical fertilizers, wires) • Fuel, power, and water for using agricultural machines (including sorting machines and dryers)	Fuel, power, and water in the hop pellets and extract production processes

For the amount of fuel, power, and water used in growing and processing malt and hops, we collected sample data from producers and processors. As for the amount of agricultural materials used for malt and hops, we collected data from contracted producers in 10 countries through the network of the cooperative agreement-based activity.

* Collaborative Contract Farming System: it is a malt and hops procurement system unique to Sapporo Breweries in order to offer customers a "good taste" and a sense of "safety and security".

(2) Procurement of containers and exterior packaging materials (manufacture and transportation)

This section describes the environmental load generated as a result of manufacturing the containers and exterior packaging materials as well as transportation thereof. The environmental load of the container is calculated for a 350 ml aluminum DI can by Toyo Seikan Kaisha who was also a member of the study group. The secondary data was used to calculate the environmental load of a cardboard box (for 24 cans) and then the obtained value was divided such that the environmental load of the cardboard box per can of beer was obtained.

(3)Product manufacturing

This section describes the environmental load of the beer manufacturing process at breweries. Figure 3 shows the beer manufacturing process. The environmental load of this process was calculated using data of the amount of energy used in each process.

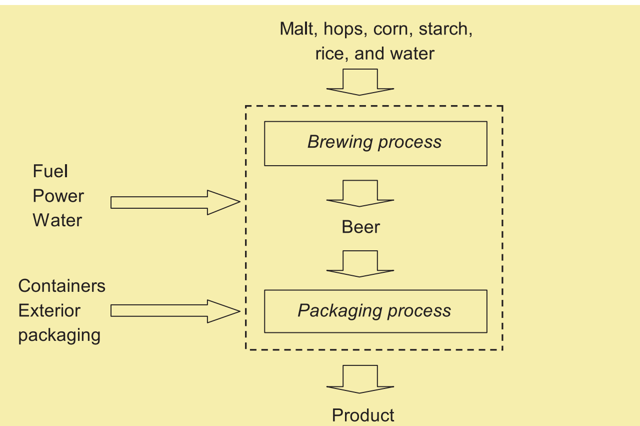

Figure 3: Beer manufacturing process

(4) Product transportation.

This section describes the environmental load generated as a result of transporting products from each brewery to primary distributors (wholesalers for example). We collected information necessary for calculation such as means and distance of transportation. As the product transportation distance, we used a weighted average direct shipment distance obtained using the transportation volume for the distance between individual breweries to primary distributors.

(5) Sales

The environmental load of sales was obtained using the method and data provided by the study group. The environmental load of each shop was obtained using refrigerated sales as a model case.

(6) Disposal and recycling

This section describes the environmental load generated as a result of disposal and recycling of containers. The effect of recycling of waste containers into new containers was included in the container production process while such effect was not included in the process if waste containers were recycled into other recycled materials (indirect effect). We used the calculated values obtained by Toyo Seikan Kaisha.

4. Assessment Result

Table 2 shows CO_2 emission of each process.

Table 2: CO_2 emission in each life cycle process

Process	CO_2 emission (g-CO_2 per product)
Procurement of the ingredients	35
Procurement of containers and exterior packaging materials	125
Product production	56
Product transportation	5
Sales	74
Disposal and recycling	0.1
Total	295

Among the processes listed above, CO_2 emission resulting from container procurement accounted for approximately 40%. Sales of products also generated a larger amount of CO_2. Measures for reduction of CO_2 emission would be effective if the measures targeted the process with the highest environmental load. Although the environmental load for this study was calculated following the temporary rule established by the study group, we hope to examine how CO_2 emission can be reduced in each process when the calculation rule is standardized in the future as is currently planned.

Figure 4 shows the tentative carbon footprint information display designed by the study group. A prototype product was exhibited in the METI booth of Eco-Products 2008 held

Figure 4: Carbon footprint information display

in December, 2008, as an achievement of the study group. In February, 2009, we started experimental sales of this product in order to examine how consumers in the market would accept it.Among the processes listed above, CO2 emission resulting from container procurement accounted for approximately 40%. Sales of products also generated a larger amount of CO2. Measures for reduction of CO2 emission would be effective if the measures targeted the process with the highest environmental load. Although the environmental load for this study was calculated following the temporary rule established by the study group, we hope to examine how CO2 emission can be reduced in each process when the calculation rule is standardized in the future as is currently planned.

5. Conclusion

METI has been designing rules for the carbon footprint system prior to its full implementation. So far, technical issues were identified in the experimental assessment by companies participating in the study group, and in March, 2009, the standardized calculation rules called the Carbon Footprint System Policy and the Product Category Rule (PCR) Establishment Criteria were established. The result of our experimental assessment is considered to have been used as basic data for these rules.

In order to implement the carbon footprint system, provide information to consumers, and to finally realize a low-carbon emission society, we believe it is important for companies to cooperate with each other to improve data accuracy and to establish detailed carbon footprint calculation rules. Based on our experience with past LCA and the carbon footprint calculation described in this article, we at Sapporo Breweries will continue studying product CO_2 emission and will contribute to the implementation and dissemination of the system.

Information

LCM 2009	
September 6- 9, 2009 Cape Town, SOUTH AFRICA	Univ. of Cape Town / Pre Consultants http://www.lcm2009.org/
Life Cycle Assessment IX	
September 29 to October 2, 2009 Boston, USA	American Center for Life Cycle Assessment http://www.lcacenter.org/
SETAC Latin America Annual Meeting	
October 5-9, 2009 Lima, Perú	SETAC Latin America http://www.setacperu.org/
Sustainable Innovation 09	
October 26- 27, 2009 Farnham,UK	The Centre for Sustainable Design http://www.cfsd.org.uk/events/tspd14/index.html
4th SETAC Africa meeting	
November 2-5, 2009 Kampala, Uganda	SETAC Africa http://kampala.setac.eu/?contentid=160
3rd International Conference on Eco-Efficiency Modelling and Evaluation for Sustainability: Guiding Eco-Innovation	
November 18- 20, 2009 Egmond aan Zee, the NETHERLANDS	CML, Leiden University http://www.eco-efficiency-conf.org/
SETAC North America 30th Annual Meeting	
November 19-23, 2009 New Orleans, USA	SETAC http://neworleans.setac.org/
1st LCM China Conference	
November, 2009 Beigin, CHINA	
EcoDesign2009	
December 7- 9, 2009 Sapporo,JAPAN	the Union of EcoDesigners and AIST, Japan, http://www.mstc.or.jp/imf/ed/
SETAC Europe 16th LCA Case Studies Symposium	
February 1-2, 2010 Poznań, Poland	Poznan University of Technology http://lcapoznan.setac.eu/?contentid=144
International Conference on Environmental Pollution, Restoration, and Management (SETAC Asia/Pacific Joint Conference)	
May 1- 5, 2010 Ho Chi Minh City, VIETNAM	SETAC Asia/PACIFIC http://vniceporm.com/
SETAC Europe 20th Annual Meeting	
May 23 - 27, 2010 Seville, Spain	SETAC Europe http://events.setac.eu/?contentid=179
SETAC Asia/Pacific Annual Meeting	
June 4-7, 2010 Guangzhou, China	SETAC Asia/PACIFIC http://www.conferencenet.org/conference/setacap.htm
7th International Conference on Life Cycle Assessment in the Agri-Food Sector 2008	
September 22-24, 2010 Bari, Maraisia	
Brazilian LCM Conference 2010	
October 13-15, 2010	
SETAC North America 31st Annual Meeting	
November 7-11, 2010 Portland, Oregon, USA	SETAC North America

Information

9th International Conference EcoBalance	
November, 9-12, 2010 Tokyo, JAPAN	JLCAJ http://www.sntt.or.jp/EcoBalance2010/
SETAC North America 32nd Annual Meeting	
November 13-17, 2011 Boston, MA, USA	SETAC North America

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