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Life-Cycle Assessment Society of Japan

Contents

From LCA to Eco-Efficiency

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In recent years, a growing number of companies and organizations have been using eco-efficiency as an indicator of environmental performance. While the definition, aims, and calculation methods used for eco-efficiency tend to differ from company to company and case-by-case, essentially this measure is defined as the ratio of the "value" represented by a product or organization (numerator) to the corresponding environmental impact (denominator). Here, we consider the question, "Why is it necessary to calculate the environmental efficiency of products and services as the ratio of value to environmental impact?"

Normally, the term "environmental impact" in the denominator is quantified by LCA (life cycle assessment). However, LCA has been recognized as having various limits. LCA is a technique for evaluating the environmental impact of a product or service based on a functional unit. In specifying the functional unit, subjectivity enters and gives rise to differences in evaluation results. When comparing an emerging teleconference and an existing face-to-face meeting which requires business trip, one would come up with a question about how to set a functional unit. The teleconference is found advantageous as its attendees do not need to move around but its effectiveness should be limited, compared with that of the face-to-face conference. The differences in these values, however, are not subject to assessment when "holding a conference for a certain time" is used as a functional unit. Therefore, a new framework is required for evaluating the value of products and services that cannot be properly evaluated in terms of the functional units used in existing LCAs.

With this background, in 2005 the Ministry of Economy, Trade and Industry enlisted the Japan Environmental Management Association for Industry to form a working group consisting of eight major IT corporations participating in the Japan Environmental Efficiency Forum (Canon, Toshiba, NEC, NTT, Hitachi, Fuji-Xerox, Fujitsu, and Matsushita) and the University of Tokyo, and to formulate the Guidelines of Eco-Efficiency Evaluation for Information and Communication Technology (ICT). The guidelines provide a general framework, a set of principles, and the requirements for evaluating the environmental impact and eco-efficiency of ICT activities as well as for making comparative evaluations. The aim of the guidelines is to provide an objective method for evaluating the effect of ICT on the environmental impact made by individuals and companies, and the society they make up—in particular, the environmental impact of the CO2 emissions that contribute so significantly to global warming.

All of the IT companies involved in this effort develop and sell solutions/services that make use of various kinds of ICT. Their customers need to be shown that such solutions/services are effective in reducing costs and environmental impact. To ensure the objectivity and reliability of any environment-related claims, it has become increasingly important to establish some common rules for environmental impact evaluations. Recognizing this need, these companies voluntarily came together and set out to draft guidelines for the evaluation of eco-efficiency. The working group was made up exclusively of specialists who have done pioneering work in the field of LCA.

In the drafting of these guidelines, the most contentious point of debate was the question of how to quantify the value of a product or service. If companies set the values for their products and services to suit themselves, such that they utilize eco-efficiency indexes to "pardon" themselves, then the credibility of eco-efficiency indicators would inevitability erode. Personally, as a chairman of the Working Group, I believe these guidelines must give the highest priority to transparency and objectivity.

The indicators to express value vary according to the level of the object of the eco-efficiency evaluation (e.g., product, enterprise, country) and the purpose of the evaluation. In addition, value can be expressed by a variety of indexes. The principles used to decide the indexes for expressing value were determined.

The Guidelines are currently published on the website. I hope that the creation of these guidelines for the evaluation of eco-efficiency help to improve and more widely promote the understanding and credibility of eco-efficiency indicators in the field of ICT as well as in other industrial sectors.

Case Study

Impact of global warming associated with detached housing

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1. Introduction

Since the oil crisis, energy-saving measures for housing have focused on energy conservation in the phase of habitation, and our main activity has been to reduce air-conditioning load by improving heat insulation and air-tight sealing as a housing manufacturer. In particular, it was about 10 years ago when we started to see an increase in housing that promised super-insulation, but just before that, we started to read about LCA of buildings in research papers. I remember the idea of life-cycle including the phases of building and disposal as well as energy consumption in the phase of habitation seemed very fresh.
The outcome of the calculation showed that the load is great in the phase of habitation, but there was no doubt that the building phase that housing suppliers are directly associated with must also be considered for change. It was also when the utilization of recycled building materials and the improvement of waste disposal were starting to get attention, and there was a need to know the inventory data on our products (housing). As such, we decided to make an estimate by process analysis without using the Input-Output table based database calculated by the Architectural Institute of Japan. Here, I will present the outline of the estimation work and the overall picture of the impact of housing on global warming.

2.Study on 5,000 types of components

Although detached housing is prefabricated, it is a single-building production and it is rare to build houses that are exactly the same. A detached house is an assembled product with a lot of constructional elements manufactured by several components manufacturers, which are assembled on site by builders or housing manufacturers. However, since it is near impossible to estimate all buildings by each building, we wanted to get the “responses on average buildings” and the “gap due to different conditions” first. With that, we studied several buildings with different construction methods, scales, shapes and specifications.
Our houses consist of approximately 1,000 components per house. Since we were to study three construction methods and 10 houses, we needed to study about 5,000 types of components. About 80% of them were composite materials that consist of several parts. “The type of parts that constitute the component”, “The weight of each part”, “The energy used in the manufacturing process”, and “The energy used in transport” were studied, and it was easy to imagine that it was going to be quite an arduous study. And since we had no choice but to ask the components manufacturers (132 companies at the time), which supply components to our company, to cooperate with the most difficult work, it was a rather uncomfortable job. We have of course tried to simplify the work as much as possible by enabling them to obtain the information required by processing the data that is calculated daily in order to reduce the work of the person in charge as much as possible. We also created a special data input tool that operates on the PC to eliminate careless errors such as missing data as much as possible. We created the original database on 5,000 components by adding the processing energy at our factory to the information gathered through the study. Although this is only part of the components that our company handles, it became possible to see in some small measure the condition of the load associated with the manufacturing of components.

3. Estimate including life in general in the home

With regards to the habiting phase that is considered to produce the most CO_2 emissions in the housing life-cycle, we have carried out estimates on the various activities of life in the home in addition to energy consumption such as electricity, gas and heating oil that have been estimated before. The annual consumer spending on approximately 550 items in the general household is summarized in the Family Income and Expenditure Survey annually published by the Ministry of Internal Affairs and Communications. From this survey, we extracted 344 items related to life in the home, and estimated the amount of emission by multiplying the CO_2 emission rate by value. The items included water supply, sewage, food/drink, newspaper/books, durable goods such as furniture and clothes, home appliances, consumable goods, maintenance and repair of housing, and various repair services. We also added CFC substitutes such as HCFC for air conditioners and refrigerators and household garbage, which have been feared to have impact on global warming, although they were not included in the said survey since they are not directly considered as household spending.

4. Overall structure of the impact on global warming

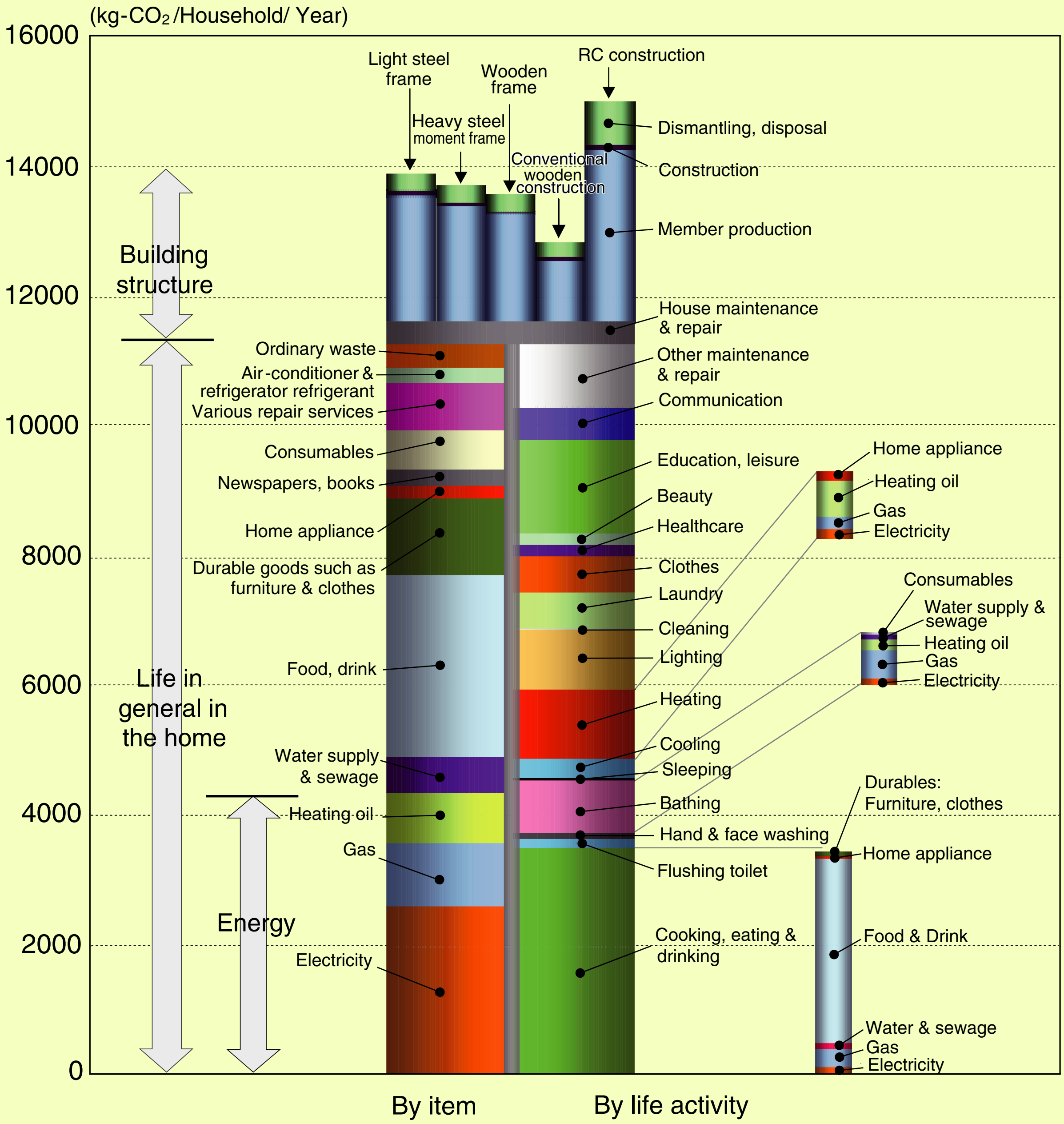
Fig.1 shows the result of the overall structure of life-cycle CO_2 after adding to the result obtained from above the CO_2 emission based on the field survey on energy consumption in the construction phase, the dismantlement site and the intermediate treatment site. The method of estimate differs slightly, but it shows the outcome of timber construction and RC (Reinforced Concrete) construction by conventional construction methods together. According to the outcome, the order of emission rate associated with a building's structural elements from great to small was “component manufacturing”, “dismantlement, disposal”, “maintenance, repair” and “construction”. However, the emission rate of such structural elements against all stages including the habitation phase was about 25% even with the largest RC structure and under 20% with other construction methods, indicating that energy consumption such as electricity, gas and heating oil in the habitation phase, and even more so the amount of emission associated with other life activities had a huge percentage.
The CO_2 associated with life activities other than energy consumption is hard for inhabitants or housing suppliers to reduce directly. However, presenting such an outcome to inhabitants would enable them to be aware of the impact their individual life activities have on the environment, and such awareness could lead to an effective review of life. Housing suppliers should not leave it up to the inhabitants but should actively support their efforts.
Finally, parts of this estimate were made roughly and it is not based on stringent methods. But it is enough to give an idea of the whole picture, and we believe that it could be very useful in studying various efforts once it has been carried out at this level.

References

(1)Toshiya Chikada & Takashi Inoue: Whole picture of the impact of housing on global warming, Architectural Institute of Japan Journal Volume 1, pp.55 -61, 2.2003.

(2)Architectural Institute of Japan: Action plan for the promotion of an anti-global-warming lifestyle, July 2005

Fig.1 Overall structure of life-cycle CO_2 for detached housing



Case Study

LCA Activities of Toyota Industries Corporation

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1. Introduction

Toyota Industries Corporation is involved in a wide range of businesses such as textile machinery, variety of industrial vehicles including forklift trucks, material handling systems, car air conditioning compressors, engines, automobiles, semiconductors and electronics. Considering that environmental preservation is one of our top priorities for corporate management, we are placing emphasis on the three themes in particular the prevention of global warming, improvement of resource productivity, and reduction of environmental risks. With regards to LCA, we initiated a trend survey from the latter half of fiscal 1999, and have implemented LCA on some products to date.

2. Examples of LCA

Here are examples of LCA we have carried out in the past. The following have been reported in the environmental reports of each fiscal year.

(1) Comparison of mufflers attached to diesel engines for forklift trucks (2001 report)

The forklift trucks installed with a diesel engine (1DZ-II) has a setting for options for two types of mufflers, and we made a comparison with the Standard Muffler (STD). We found that the Catalytic Muffler (CAT) emits less CO and NMHC than the Standard Muffler, and the Soot-Reducing Muffler with Diesel Particulate Filter (DPF II) emits less particle matter than the Standard Muffler (Fig.1.) The reason why DPF II emits a lot of CO2 is due to electricity usage for recovering the filter.

(2) Comparison of internal combustion forklift trucks and electric forklift trucks (2002 report)

We assessed a diesel engine-powered forklift trucks (rated loading 2.5 tons), currently our core model, (hereinafter, "internal combustion forklift trucks") as well as an electric-powered model (hereinafter, "electric forklift trucks") of the same class.
We consequently found that both the internal combustion forklift trucks and electric forklift trucks were emitting most of the CO_2 and air pollutants in their usage stage, and that the electric forklift trucks was emitting 50% less CO_2 than the internal combustion forklift trucks. We also found that the electric forklift trucks was emitting more SOX than the internal combustion forklift trucks (Fig.2.). Air pollutants in using the electric forklift trucks are emitted when electricity is generated while charging the battery at a generating station and between the time when fuel for generating electricity is mined and refined.

Fig.1 Comparisons of mufflers

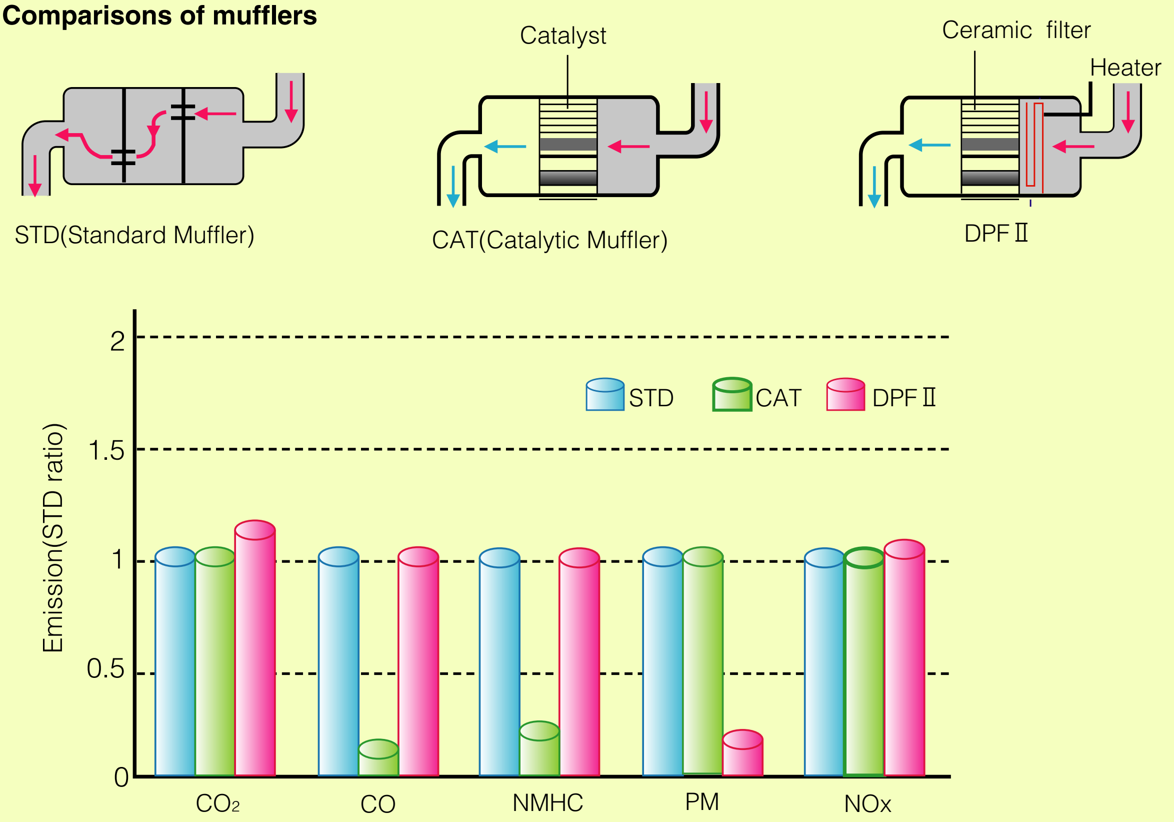
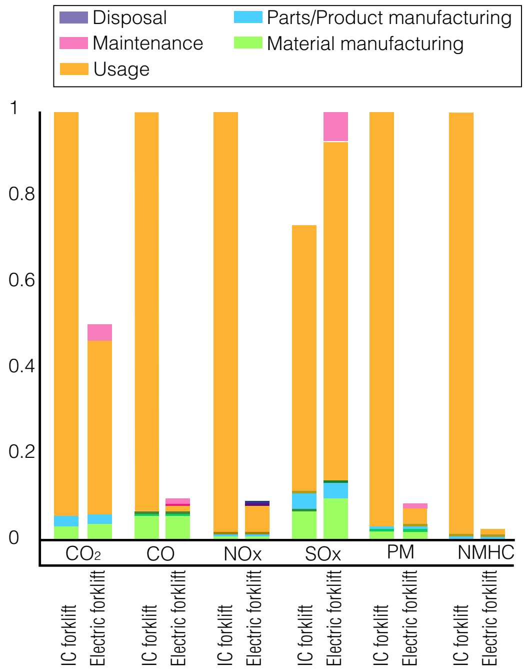


Fig.2 Comparison of internal combustion forklift trucks and electric forklift trucks



(3) Comparison of new and old forms of hydraulic fittings used in forklift trucks (2003 report)

We evaluated the amount of air pollutants emitted from new and old hydraulic fittings used in forklift trucks that differ due to their manufacturing methods, which link the oil cylinder for forklift trucks tilt with a hose. This LCA was carried out only from the process of manufacturing the materials to the process of manufacturing the products. In the result, we found that the new products emitted 20% less CO_2 and air pollutants, since their manufacturing method has been simplified (bending of thick-walled tube + machining) compared to the conventional products which follow the process of forging and machining a round bar (Fig.3.).

3. LCA promoting activities within the company

Based on the LCA technique used until now, we have created our LCA guidelines so that we could implement LCA on all our products. The guidelines are available on our in-house intranet and can be perused by the designers of each division. We have also established our in-house rules in an aim to promote the development of improved environmentally friendly products by studying and grasping the environmental load and impact of each product. These in-house rules establish the implementation of LCA as a mechanism of the stages of development, and stipulate that the target value of the reduction of environmental load is checked and followed as an item of assessment similarly as quality, performance and costs in the design review (DR) of new product development.

4. Conclusion

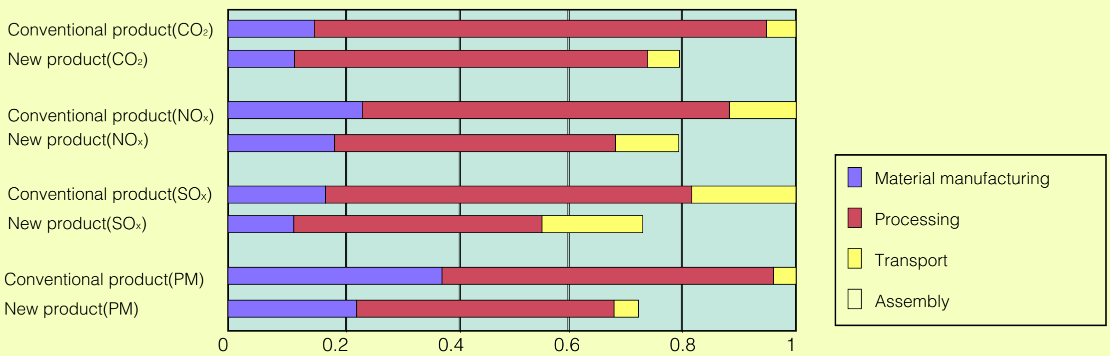
It is extremely difficult for the designer to hand calculate the LCA with complicated data gathering, organizing and calculation in the development period shortened (short-term development) by SE activities that utilize CAE and 3D-CAD. It is particularly more difficult for a product that has many parts. And it is difficult to use the LCA results of a product as a product appeal compared to the costs and performance. Due to these reasons, LCA tends to be shunned by designers. Given this factor, we are currently developing an in-house system that could calculate the LCA, recycling rate and factors with the view to eliminate as many man-hours of inputting and operating for designers to calculate LCA. By utilizing this system, and by establishing the QCD+E as an item of DR assessment as mentioned above, we will carry out the activities that enable the designs for the environment to be promoted further by getting the designers to be thorough with PDCA cycles to achieve the target value, while being aware of the reduction of environmental load from the initial stage of development.

*The case studies were evaluated based on Japanese data.

Fig.3 Comparison of new and old forms of hydraulic fittings

(Forklift trucks and hydraulic fittings)

(Conventional and new products for comparison)



Case Study

Improvement of spark plugs using the LCA

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Introduction

At NGK Spark Plug, we have been evaluating environmental impact at the design stage to assess our products, but in order to implement a more specific evaluation we have introduced the LCA from FY2002.

Overview of spark plugs

Our anchor product, spark plugs for automobiles, plays an active role for the normal functioning of the engine, and it influences fuel combustion and fuel consumption. Over 2 billion spark plugs are currently produced throughout the world, and there are various environmental impacts in their production process. Since about four to six spark plugs are fitted on one gasoline engine vehicle, we could say that the spark plug is a critical component in the environmental aspect of automobiles.

Details of LCA activities

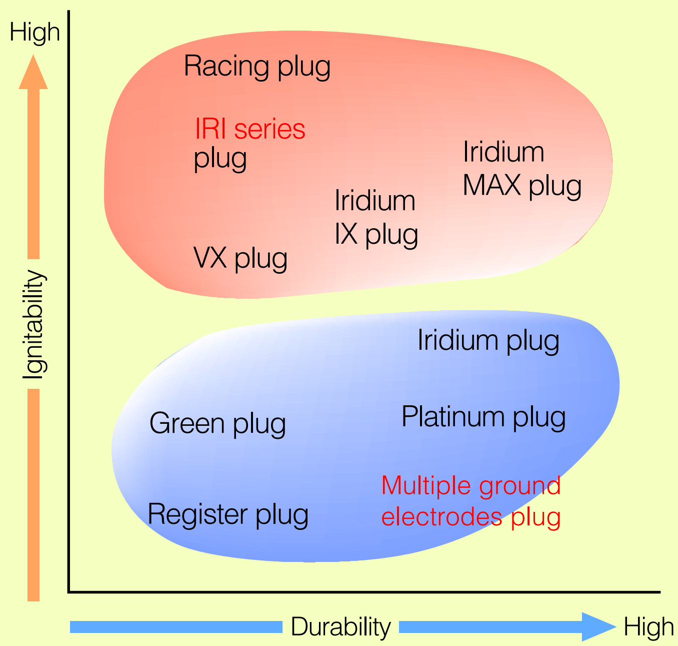
The types of spark plugs include those for four-wheel vehicles, two-wheel vehicles, and those for agricultural, marine vessel and industrial use. They are also categorized by their performance such as the standard plug, plugs for racing, iridium plug and platinum plug. Among them, compact and lightweight spark plugs and those made of precious metal for improved performance and longevity have become popular in recent years. We have carried out the LCA on three types of spark plugs for four-wheel vehicles: the standard type, the lightweight type, and the lightweight, long-life platinum type.

Implementation of LCA

We carried out the LCA to measure the environmental impacts of one spark plug and to specify the causes that increase those environmental impacts. We established the system boundary to be from the collection of raw material to the manufacturing of the product, and the landfill disposal of the used plug. We also measured five environmental impacts: consumption of resources, global warming, destruction of the ozone layer, acidification and solid waste.

Outcome

As a result of implementing the JEMAI-LCA, we were able to specify the extent of the environmental load and the causes of each of the five environmental impacts. The following concerns the impact on global warming.



Standard | Lightweight | Lightweight, long-life (platinum plug)

(1) Impact per plug

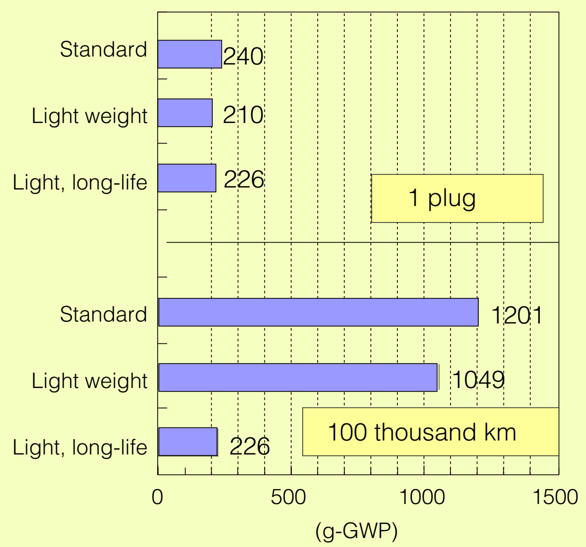
The global warming impact in CO_2 equivalent was 13% less for the lightweight type than for the standard type with 240g for the standard type, 210g for the lightweight type and 226g for the lightweight/long-life type.

(2) Impact during a 100 thousand km drive

We carried out the LCA to examine the plug's longevity. During a 100 thousand km drive, the lightweight, long-life type requires no replacement, but the standard and lightweight types need to be replaced every 20 thousand km and require five plugs, therefore creating five times the environmental load. Accordingly, although the load for the light, long- life type remains at 226g, the load for the lightweight type becomes 1,049g, and that for the standard type 1,201g, creating great differences.

Conclusion

By evaluating the spark plug as well as the scale of environmental load created in each manufacturing process, we were able to confirm the points of improvement in the products and processes. We will continue to further promote environmentally friendly designs for our products and facilities by utilizing the LCA technique.



Spark plug's longevity
Standard & lightweight: 20 thousand km
Light & long- life: 100 thousand km

Comparing LC-CO_2 by the cooking method of pasta pomodoro

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Introduction

Easy-cook pasta for one person that can be prepared in 5 minutes from boiling the pasta to tossing it in sauce was launched in 2003. Easy-cook pasta comes in a packet containing pasta and powdered sauce mix, which is placed in a frying pan and cooked adding a specified amount of water. We made a comparison of the life-cycle CO_2 (LC-CO_2) between easy-cook pasta and home-cooked pasta to see the difference in the environmental load.
We chose pasta pomodoro with cheese for comparison. We compared three cooking methods: (1) Home cooking using imported cans of whole tomatoes, (2) Home cooking using fresh tomatoes bought from the market, and (3) Easy-cook pasta using dry tomato powder. To recreate the actual setting of cooking to measure the amount of gas used in cooking, we measured the amount of city gas while cooking with a pot and frying pan found in the kitchen of ordinary households.

2. Estimation Technique

2-1. Cooking method and measurement technique of the amount of city gas

The noodles of easy-cook pasta have a diameter of 1.7mm. To have the same texture, we used noodles with a 1.7 diameter or the quick-cook pasta with a diameter of 1.5mm (Cooking time: 4-5min) for the home cooking. They were each cooked more than twice to compare the average of the collected data. The amount of pasta cooked each time was two portions, and the amount of two portions of ingredients used for each cooking method is shown in Table-1.
Since the easy-cook pasta cooks quickly, we used quick-cook pasta that can be cooked in 5 minutes for the home-cooked pastas.
As for the cooking procedure of home-cooked pasta, we followed the one that can be found in common cookbooks. To make the pomodoro sauce, we fried garlic slowly in olive oil on simmer, and added chopped onions once the garlic started to turn light brown and produce aroma, and fried the onions on medium heat until they turned light brown. Next, we added pureed tomato prepared beforehand, simmered it for 3 to 4 minutes until the sauce thickened, seasoned the sauce by adding salt, pepper and basil and simmered for another minute. We put the pasta in a boiling pot of water with added salt, boiled the pasta on high heat for five mimutes, and drained. We then tossed the drained pasta and sauce in a frying pan.
Easy-cook pasta was cooked following the instructions on the packet. We placed 500ml of water, two portions of pasta and the powdered sauce in a frying pan and heated it up on high heat until it boiled. After it boiled, we turned the heat down to medium, stirred it occasionally, and took it off the heat once the sauce started to thicken and the pasta was cooked to the desired firmness. It took about six minutes to cook.
The amount of city gas was measured using a gas meter installed in homes, and the amount of city gas was measured for the respective unit processes of each cooking method.

Table-1. Amount of ingredients used and CO_2 emission factor

	unit	CO_2 emission factor		Home-cook pasta (1) Consumption	Home-cook pasta (2) Consumption	Easy-cook pasta: Consumption
		Source	g-CO_2/unit	unit	unit	unit
Pasta	g	a)	0.55	160	160	160
Cooking salt	g	a)	0.78	16	16	
Can of whole tomato	g	b)	0.97	280		
Fresh tomato	g	a)	0.54		280	
Powdered tomato	g	b)	4.79			17
Natural cheese	g	a)	2.98	22	22	
Powdered cheese	g	b)	7.45			11
Fresh onion	g	a)	0.18	57	57	
Dried onion	g	a)	1.57			4
Olive oil	g	a)	0.82	30	30	
Other	g	a)				41
Packaging	Packet		46			2

Notes a) Calculated from 3EID and prices in the Input-Output Tables
b) Calculated using the process analysis method

2-2. Estimation technique of CO_2 emission factor of each ingredient

The ingredients for which the CO_2 emission factor was estimated by process analysis in Table-1 are those predicted to be with large usage and have a great ratio in the outcome of CO_2 load calculation of cooked pasta. The packaged materials were calculated using our LC-CO_2 calculation system. The estimation technique of the CO_2 emission factor of tomatoes and processed tomatoes is explained in the following section. Other ingredients were calculated from the Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables (3EID) 1995 published by the National Institute for Environmental Studies and the producers' prices listed in the domestic production table by sector and by commodity in the 1995 Input-Output Tables for Japan. For those without a listed producers' price in the Input-Output Tables, we checked the wholesale price or factory purchase price, and used it as the producers' price. The CO_2 emission factor of the ingredients is also shown in Table-1.

3. Outcome

3-1. CO_2 emission factor of cultivated tomatoes

The LC-CO_2 of cultivation of tomato for eating fresh based on the process analysis is available to the public, which is 104g-CO_2/kg-tomato (outdoor culture) and 676g-CO_2/kg-tomato for basic greenhouse cultivation[1]. Tomatoes for processing are grown in the summer, and their price is stable at ¥47 per kg[2]. When we calculate from the 3EID and price, the emission factor is 105g-CO_2/kg. The LC-CO_2 of outdoor cultivated tomatoes indicated fair consistency between the method based on the Input-Output Tables and the process analysis method.
The emission factor of tomatoes for eating fresh was 541g-CO_2/kg-tomato when we used its yearly average price from the 1995 Input-Output Tables and calculated it in the same way. From the above results, the emission factor of tomatoes for processing was 105 g-CO_2/kg, and tomatoes for eating fresh was 541 g-CO_2/kg.

3-2. LC-$CO_2$of cans of whole tomato

Since the cans of whole tomatoes sold in the Japanese market are mostly from Italy, we determined that the place of origin was Naples, Italy, and that they were transported by ship to Japan on container vessels. The LC-CO_2 of processed tomato has already been stated in 3-1. We used the 400g can, which is most frequently found in the market for domestic use, measured its weight and estimated the emission factor of a 400g can based on the CO_2 emission factor of small cans produced in Japan. We estimated the sea transport distance to be 1.1 times that of the nautical distance, since the container vessels will have to stop by a hub port. We used the documented value listed in Table-2 as the CO_2 emission factor of the container vessel.
Cans of whole tomato are produced in the following manner: Cleansing ⇒ Soaking in hot water ⇒ Pealing ⇒ Can filling ⇒ Sterilization ⇒ Cooling ⇒ Boxing ⇒ Shipping. We referred to technical books[3), 4)] for the unit energy consumption and unclear areas were figured out from process analysis. The outcome is shown in Table-2.

Table-2. LC-CO_2 of a can of whole tomatoes imported in Japan

	unit	CO_2 emission factor		Basic unit	LC-CO_2
		Source	g-CO_2 /unit	unit/ kg-whole tomato	g-CO_2/ kg-whole tomato
Tomato for processing	kg	a)	105	1.05	110
Vapor	kg	b)	256	0.20	51
Electricity	kg	c)	505	0.025	13
Can (Size4)	kg	b)	113	2.5	283
Cardboard box	kg	b)	210	0.104	4
Transport	kg	d)	21	23.5	972

c) Italys electricity emission factor: APME,Brussels July 2003
d) http://nippon.zaidan.info/seikabutsu/2000/00964/mokuji.htm

3-3. LC-CO_2 of powdered tomato

According to the importer, the production area is the northern part of Central Europe. Since we could not find tomato cultivation areas in the production area of powdered tomato on the statistics, we hypothesized that tomato paste produced in Italy has been processed into powder after being transported by land to the northern part of Central Europe. The product is imported into Japan on a container vessel. Its packaging consists of 15kg plastic inner bags and 15kg outer cardboard boxes for powder.
As for the manufacturing process of the powdered tomato, its flow of process and basic mass balance are published on websites concerning "tomato powder"[5), 6)]. We used those numerical values. However, since the vapor content used in the process is not listed, we calculated it supposing a single-effect evaporator was used in the concentration process, and hypothesizing the dehydration thermal efficiency according to the description that dehydration is carried out using a belt dryer or a tray dryer. The product's water content is 5%. We identified the drying agent used in the dehydration process as potato starch according to the ingredients label and built up the mass balance. The manufacturing process of powdered tomato and its estimated mass balance are shown in Fig.1. The results of the estimate of the LC-CO_2 of dried tomato based on Fig.1 are shown on Table-3. Calculations were made by presuming the CO_2 emission factor of the packaging materials in the table to be the same as that of the packaging materials in Japan.

Fig.1. Estimated mass balance of powdered tomato's manufacturing process

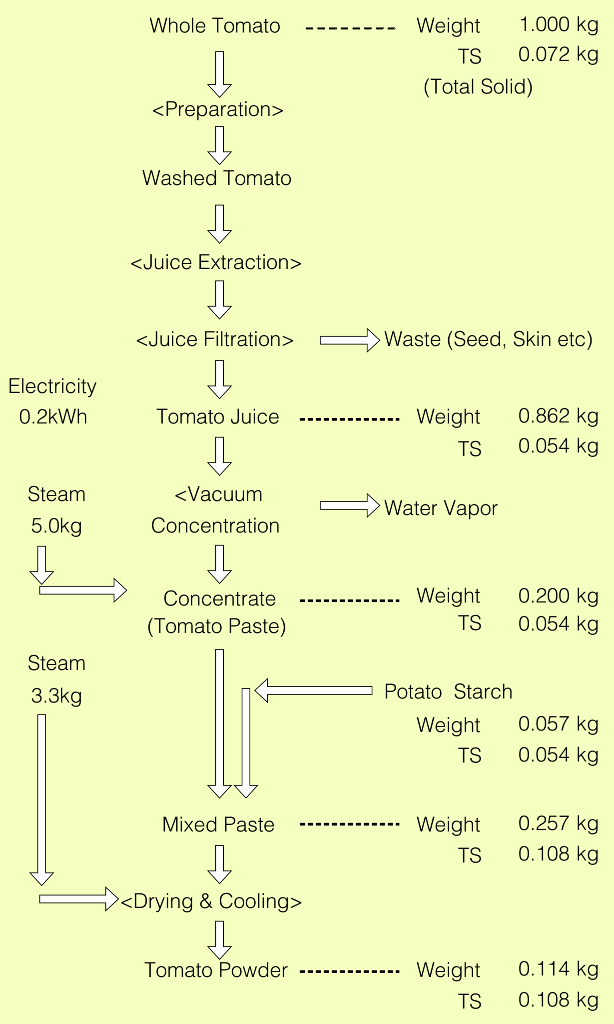
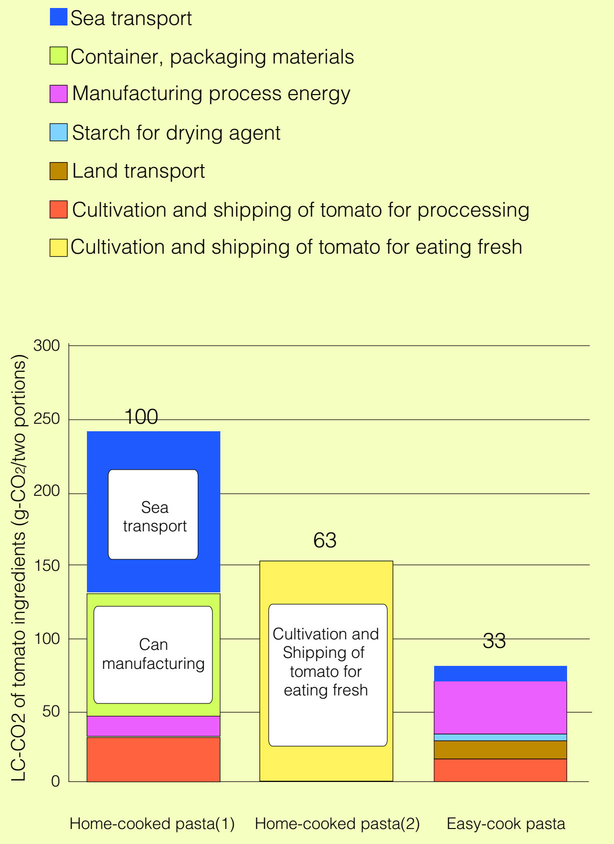


Table-3. LC-CO_2 of powdered tomato

	unit	CO_2 emission factor		Basic unit	LC-CO_2
		Source	g-CO_2 /unit	unit/ kg-whol tomato	g-CO_2/ kg-whol tomato
Tomato for processing	kg	a)	105	8.8	924
Tomato paste production processing energy					1,370
Powderd tomato processing energy					900
Potato starch	kg	a)	587	0.5	294
Inner plastics bag	pc	b)	502	0.067	34
Cardboard box	pc	b)	430	0.067	29
Land transport	tkm	d)	176	3.9	686
Sea transport	tkm	d)	21	26.5	557
Total					4,793

The LC-CO_2 of a can of imported whole tomato (home-cooked pasta (1)), tomato for eating fresh (home-cooked pasta (2)), and powdered tomato (easy-cook pasta) are shown in Fig.2, respectively. The share of the LC-CO_2 for a can of whole tomato was 51% for sea transport and 29% for can manufacturing, and 20% for tomato cultivation and the canning process.

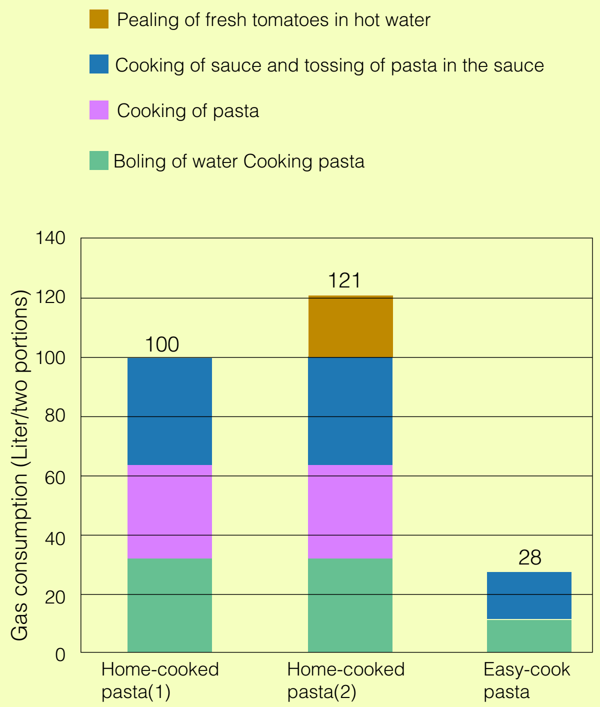
Fig.2. LC-CO_2 comparison of two portions of tomato ingredients



3-4. Amount of city gas used in domestic kitchens

We made an actual measurement of gas volume for each unit process following the respective cooking procedures. We have set up four unit processes: Boiling of the water, cooking of the pasta, peeling of the fresh tomatoes in hot water, and cooking of the sauce as well as the tossing of the pasta in the sauce.
The results are shown in Fig.3.

Fig.3. City gas consumption volume of each cooking method



When the cooking experiment is repeated, one wonders about the thermal efficiency caused by the cooking equipment. Given this factor, we tried to measure the thermal efficiency using a scale, an alcohol thermometer and a city gas meter. The results are shown in Table-4. The gas cooker we used was a domestic one that produces 4,100kcal/hr on high heat value(gross calorific value). The thermal efficiency changed by the shape and material of the cooking equipment and the gas flow volume, and varied greatly from 27 to 41% (base on the high heat value).

Even simple cooking consumes 100 liters of city gas per cooking as shown in Fig.2. If this could be improved by 10%, and if we multiply the improvement by the number of households throughout Japan, it will lead to significant energy saving. The improvement of thermal efficiency of cooking equipment is expected to become a theme that should be considered in domestic energy-saving.

Table-4: Results of the thermal efficiency measurement of cooking equipment

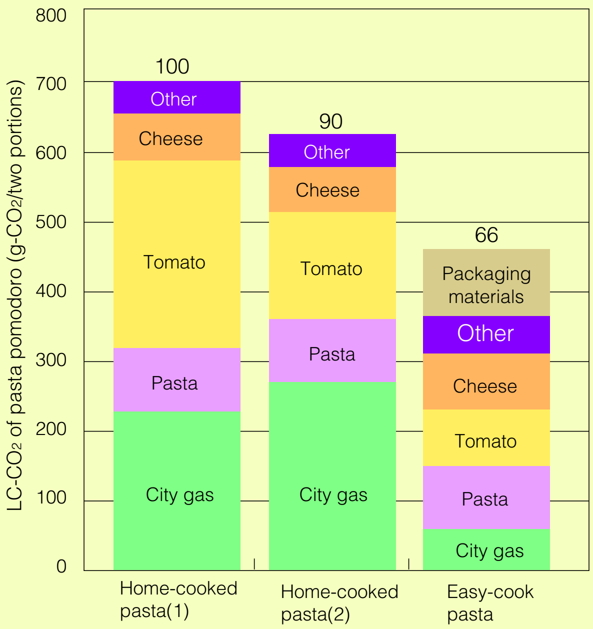
Thermal power	Gas flow rate (Liter/min)	Thermal efficiency		
		Moulded aluminium pot	SUS inverse truncated cone pot	Aluminium frying pan
High heat	5.8～6.7	31～35%	27～28%	29～32%
Medium high heat	5.0～5.8	31～35%		
Medium low heat	3.0～4.0	34～40%		37～41%

3-5. LC-CO_2 comparisons of two portions of cooking pasta

The LC-CO_2 comparisons of cooking pasta by the three cooking methods are shown in Fig.4.

We also estimated the LC-CO_2 produced in disposing the water left over from boiling the pasta for the home-cooked pasta by combining the publicly released data. The results were small at 1 to 2% of the whole, and since we did not believe that they would influence the main point of discussion, they have not been included in these comparisons.

Fig.4. LC-CO_2 comparisons of three cooking methods of pasta pomodoro (two portions)



4. Summary

1) The results of the LC-CO_2 comparisons of cooking pasta were: Home-cooked pasta (1) > Home-cooked pasta (2) > Easy-cook pasta, as seen in Fig.4. The main factors of the differences in the cooking methods were the differences in the cultivation and processing of tomato ingredients and the volume of city gas for cooking.

2) The city gas consumption volume used in cooking was home-cooked pasta (2) > home-cooked pasta (1) > easy-cook pasta. The results have shown that the easy-cook pasta only required 23% of the city gas volume used for home-cooked pasta (2), and 28% of the city gas volume used for home-cooked pasta (1).

3) Since easy-cook products require damp-proofing for the powdered sauce, the LC-CO_2 of the packaging materials becomes relatively high. It made up for 20% of the entire LC-CO_2 for the easy-cook pasta.

4) As a result of measuring the thermal efficiency of domestic cooking equipment, it was a third to a half of the 75 to 85% thermal efficiency of boilers used in factories (both thermal efficiencies are base on the high heat value), and it changed according to the shape and material of the cooking equipment and the gas flow volume.

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Postscript

This report was created based on the contents presented in the same title at the 1st presentation meeting of the Institute of Life Cycle Assessment, Japan.
Although the production of easy-cook pasta we studied for this paper has unfortunately been discontinued, we hope to continue with the study on the attributes seen from the environmental load of processed food.

Case Study

Discoveries through the LCA of wood products

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NPO Donguri-no-kai

1. Introduction

The non-profit organization Donguri-no-kai is involved in the planting of approximately 10,000 broad-leaved trees each year. The participants of our activities range widely. They are not only those interested in environmental issues, but also those from the fisheries industry and residents in the downstream areas who advocate that "rich forests make a rich sea," and from this year, sports equipment manufacturers and people involved in baseball also joined the activity with an aim to create "baseball bat forests" to pay respect to trees that are used for bats.

By implementing the LCA of wood products, we would like to take a specific look at what it means to plant trees, the role trees play in preventing global warming, and the flow of people, materials and money surrounding trees from a slightly different perspective.

2. LCA of wood products

A tree grows itself by absorbing CO_2 in the air and changing it to polymer carbon compounds such as cellulose and lignin. The fact that timber locks in the CO_2 from the atmosphere is the greatest characteristic of timber. Therefore, we defined the extent of the LCA of wood products to be from the absorption of CO_2 in the process of the tree's growth to its disposal (Fig.1.).

Wood products for which we have implemented LCA this time were lacquered tables that are solely made of untreated materials produced in Japan, and do not use any secondary materials such as metals or urethane paint. Therefore, we only studied CO_2 as an environmental load substance.

When we examine the LCA of wood products based on these premises, we can first point out that

a) Absorption of CO_2 equals c) Emission of CO_2.

In other words, there is no burden on the environment, since the CO_2 emitted into the atmosphere when a wood product is disposed (incinerated) is the CO_2 that was absorbed in the process of the tree's development.

Table 1 below shows the calculation of the amount of CO_2 emitted from the time a tree is felled to when it is manufactured and used (Conversion per table.)

Fig.1 Tree's Life Cycle

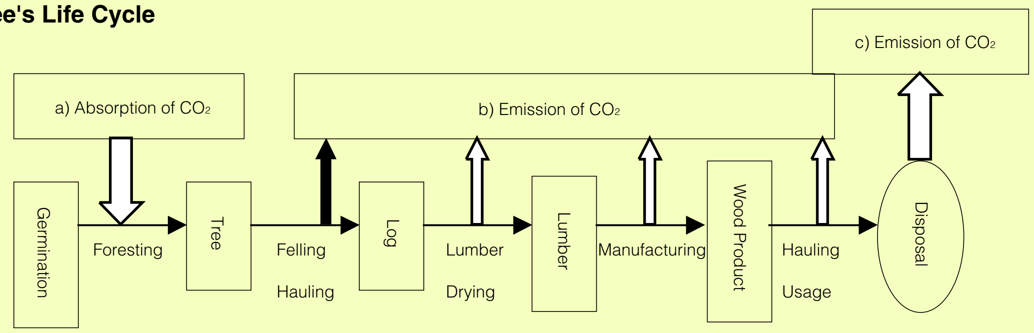


Table 1

Element	CO_2 source	Basic unit of CO_2 emission	CO_2 (kg)per table
Felling-hauling	Truck(diesel oil)	88.8 kg/t	5
Lumber sawing	Saw mill(electric)	18.8 kg/m^3	2
Drying	Dryer(heavy oil)	8.7 kg/m^3	11
Processing and assembly	Wood working machine(electric)	10.9 kg/table	11
Painting(lacquering)	Human power	–	0
Delivery	Truck(diesel)	25.6 kg/t	3
Use	–	–	0
		Total	32

The result was: CO_2 consumption (i.e. b) Emission of CO_2) from felling to use = 32kg/table
Meanwhile, since nearly 50% of the weight of timber is carbon[1] according to the molecular structure of timber, the amount of CO_2 locked in a 45kg table can be calculated as follows.
(45kg table x 50%) x (CO_2 molecular mass 44 / Carbon atomic mass 12) = 82.5kg

From the above, we have found that the Amount of CO_2 (32kg) emitted in the manufacturing and using processes is less than the Amount of CO_2 locked in the product (82.5kg). In other words, a table made using an untreated material produced in Japan has a greater amount of CO_2 locked inside the table than the amount of CO_2 emitted by making the table. Because timber has CO_2 locked in and less energy is consumed in the manufacturing process (it does not require a high temperature like metal or glass), such a relational expression can be formed. What this relational expression represents is that we should use more wood in our lives if we are concerned about preventing global warming. It shows the importance of using a lot of timber in interior decorating, furniture, accessories and wooden dwellings and to continue to use and care for them for many years.

When we looked further into this finding, we have found that this relational expression only works with untreated timber produced in Japan. For instance, we can see from applying LCA that it becomes hard to form the above relational expression if we use plywood instead of untreated timber, as plywood would emit four times the amount of CO_2 of untreated timber in the production stage, and that the relational expression cannot be formed if we use imported timber, as the amount of CO_2 would increase in several orders of magnitude during shipping. Even though they are both timber, domestic is better than imported, and untreated timber is better than plywood.

3. Establishing an ideal inverse manufacturing system

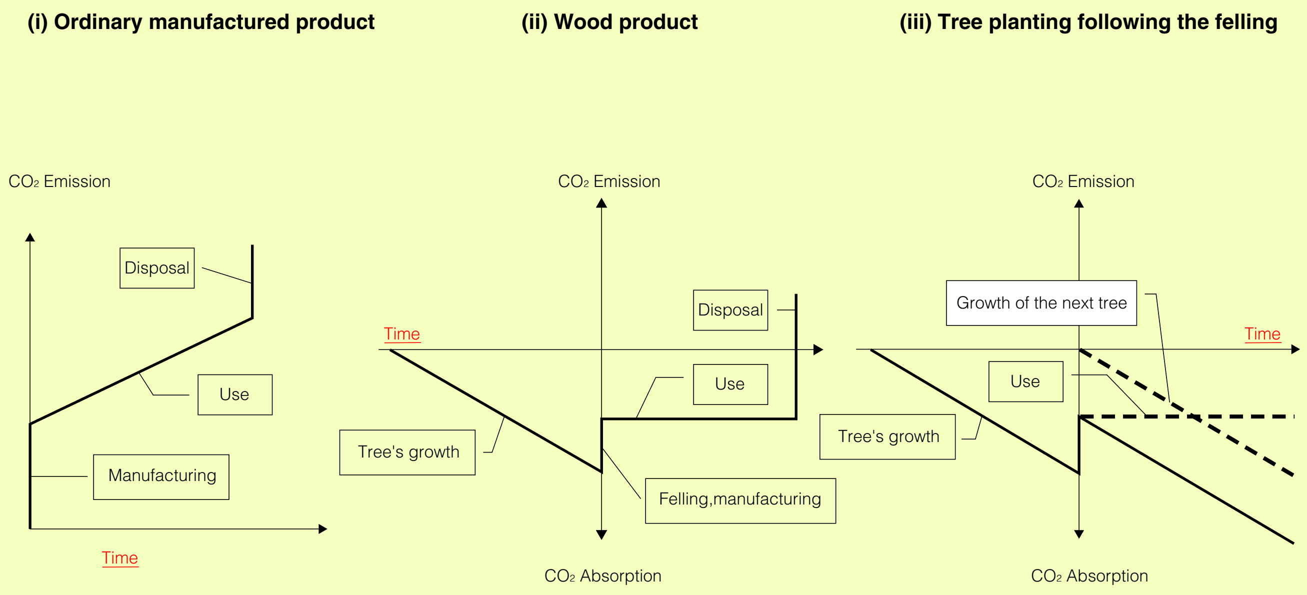
The following Fig.2 (i)-(iii) are the models created by comparing the amount of CO_2 emitted over time for this wood product to that for an ordinary manufactured product. The ordinary manufactured product constantly emits CO_2 from its manufacturing to disposal (Fig. 2 (i)). Meanwhile, the timber product absorbs CO_2 through photosynthesis until it is felled, and its negative CO_2 emission is maintained even when it is processed into a product. This negative CO_2 emission status is kept the longer it is used (Fig.2. (ii)). Although CO_2 from the processed portion is emitted when the product is incinerated, if we postulate that a tree was planted at the same time another tree was felled (See Fig.2 (iii)), the CO_2 balance would perpetually be on the minus. In other words, recycling (ideal inverse manufacturing system) in which good products are manufactured and used without burdening the global environment is established.

The point here is that it is just as important to plant trees as it is to use wood. As described above, timber can be made into a product without putting too much burden on the global environment. However, if we were to maximize the attributes of wood further, it would be important to have the awareness that wood is a rare material (recyclable resource) that allows us to do the natural act of replacing what is used.

4. Caring for Trees Campaign and Tree Recycling Project

Japan has promised in the Kyoto Protocol to reduce 6% of greenhouse gas by 2020, and about two-thirds of that reduction (3.9%) relies on CO_2 absorption by woodlands. The Forestry Agency has reinforced its efforts of promoting CO_2 reduction by obtaining funds for woodland conservation by getting people to use more domestic timber in their lives through its Caring for Trees Campaign since fiscal 2005. The LCA of wood products we carried out revealed that this Caring for Trees Campaign not only promotes the circulation funds, but is a very effective method of promoting

Fig.2. Comparative Model of CO_2 emission between wood product and other manufactured product



"Recycling society and timber" by Takanori Arima
"Wood Information" Aug. 2002, Forestry and Forest Products Research Institute

the absorption of CO_2 by controlling its emission.
Finally, I would like to introduce a unique activity that is being carried out at the private sector level. It is called the Tree Recycling Project by the sports goods manufacturer Mizuno, the woodwork manufacturer Oak Village, and the non-profit organization Donguri-no-kai.
Mizuno has about 15,000 timber materials a year that cannot be processed into baseball bats due to the bur or split in the timber found in the process of manufacturing wooden baseball bats. These timbers that used to be disposed (incinerated) have been purchased by Oak Village to manufacture wooden accessories that form parts of key-rings and cell phone straps, which are sold in sports goods shops and various retailers. Part of their sale is donated to the non-profit organization Donguri-no-kai, which is used as funds for its foresting activities. The officials of Mizuno, former professional baseball players, boys' baseball teams and officials of Oak Village participated in the Baseball Bat Foresting Ceremony hosted by Donguri-no-kai at the beginning of November 2005, and planted the seedlings of Japanese ash and magnolia.

The project has the following three significances.

a) Economic effect:
Mizuno improved its yield, Oak Village expanded its new product development and market, and Donguri-no-kai obtained funds for its activities.

b) Environmental effect:
It extends and lengthens the life of faulty timber, and creates new woodlands through planting trees. It improves the consuming public's awareness that by buying Recycled Tree Goods they can contribute to preventing global warming albeit in a small way.

c) Social effect:
The producer of baseball bats (Mizuno) and their users (people involved in baseball) planted trees in the forest, and the staff of Oak Village and Donguri-no-kai sold the recycled tree goods at Koshien Stadium and Seibu Dome.

What we have found through the LCA of wood products was that a) Using a lot of domestically produced wood products in life and b) Directly and indirectly supporting the efforts of woodland conservation such as tree planting and thinning are effective in contributing to the prevention of global warming on a personal level, and I have described here the Tree Recycling Project as the specific system for achieving those efforts.

LCA and Environmental proposition of industrial adhesives development

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1. Introduction

Adhesives are used in various most kinds of manufacturing industries such as paper/packaging, printing/publishing, constructions/public works architecture/civil engineering, housing/building materials, electrical/electronics and vehicles. Approximately 1 million tons are manufactured annually in Japan, and they are classified into formaldehydes series, aqueous adhesives, solvent-based ones, reactive ones, hot melts and pressure sensitive ones. Formaldehyde, toluene, ethylbenzene and xylene from adhesives have been noted to cause the sick-house syndrome, but measures have been taken against formaldehyde by the Amended Building Standards Law in 2002, and measures for toluene and other chemicals mentioned above are due to be provided for by the standard revision of School Environmental Health Standards. Meanwhile, solvent-based type adhesives that contain non-methane volatile organic compounds (NMVOC) are still widely used. However, the Air Pollution Control Law was revised in 2004 to control the emission of VOCs, as they have been identified to cause an increase of environmentally hazardous photochemical oxidants and suspended particle matter (SPM) when emitted into the atmosphere. LCA for industrial solvents are not sufficiently implemented even though they are widely used in the manufacturing industries and required inventory data. We have carried out an LCA for five kinds of typical industrial adhesives manufactured in our factory in Aichi prefecture, and studied the possibility of developing environmentally friendly industrial adhesives by also carrying out one of the integrated assessments, the Life-cycle Impact assessment Method, based on Endpoint modeling[1,2] (LIME) developed by the National Institute of Advanced Industrial Science and Technology (AIST.)

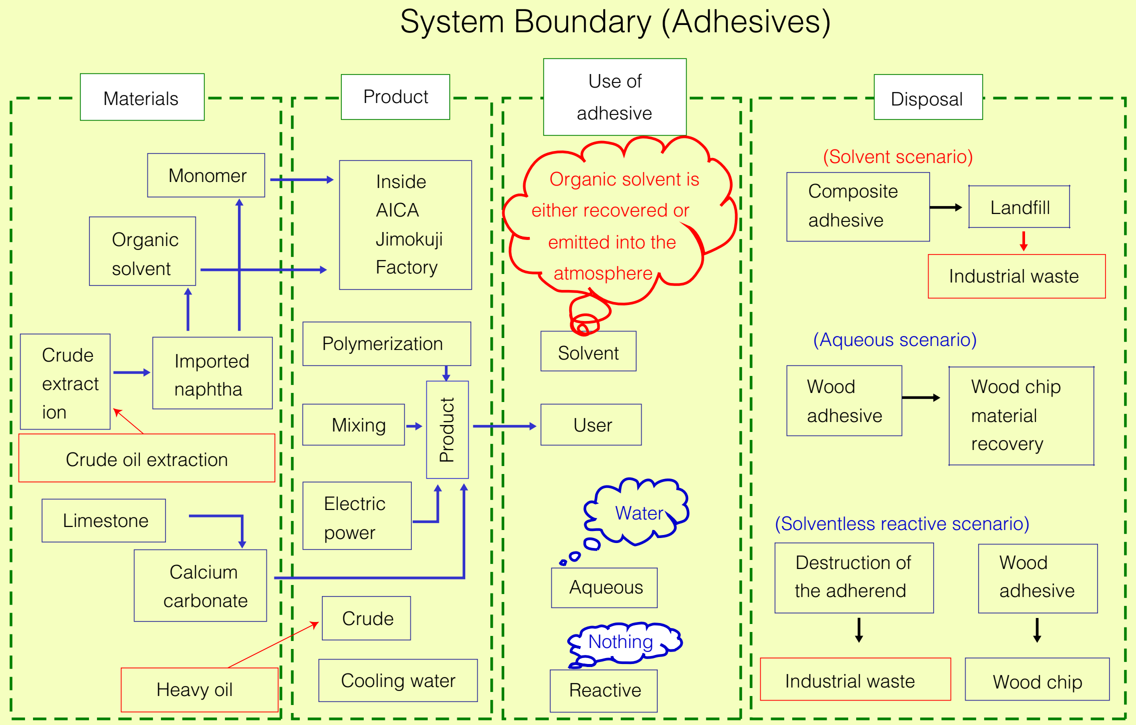
2. Inventory analysis and Impact assessment of five kinds of industrial adhesives

Object products: Five kinds of industrial adhesives manufactured by AICA Kogyo Co., Ltd.

(i) Aqueous adhesive: Polyvinyl acetate emulsion adhesive (PVAc)
(ii)Aqueous adhesive: Acrylic Resin emulsion adhesive including inorganic filler (RA)
(iii) Solvent-free reactive: Silyl-terminated PolyEther adhesive including inorganic filler (SE)
(iv) Solvent-free reactive: Polyurethane adhesive including inorganic filler (PU)
(v) Solvent adhesive: Solvent based Polychloroprene rubber contact adhesive (PCR)

Since any of the adhesives above can adhere an area of approximately 3.3 m2 with 1kg of adhesive, we established their functional unit as 1kg, and conducted inventory analysis for raw material extraction, materials, manufacturing, distribution, use and disposal using the JEMAI LCA ver.1 software as shown in Fig.1.
We calculated the environmental impact as the social cost by LIME on Excel sheet, and indicated the results by type of adhesive and type of causative parameters in Fig.2.

Fig.1 System Boundary of the Inventory Analysis of Industrial Adhesives



3. LIME assessment results for five types of industrial adhesives

The following results were obtained after carrying out the LCI and LCIA based on LIME on five kinds types of adhesives.

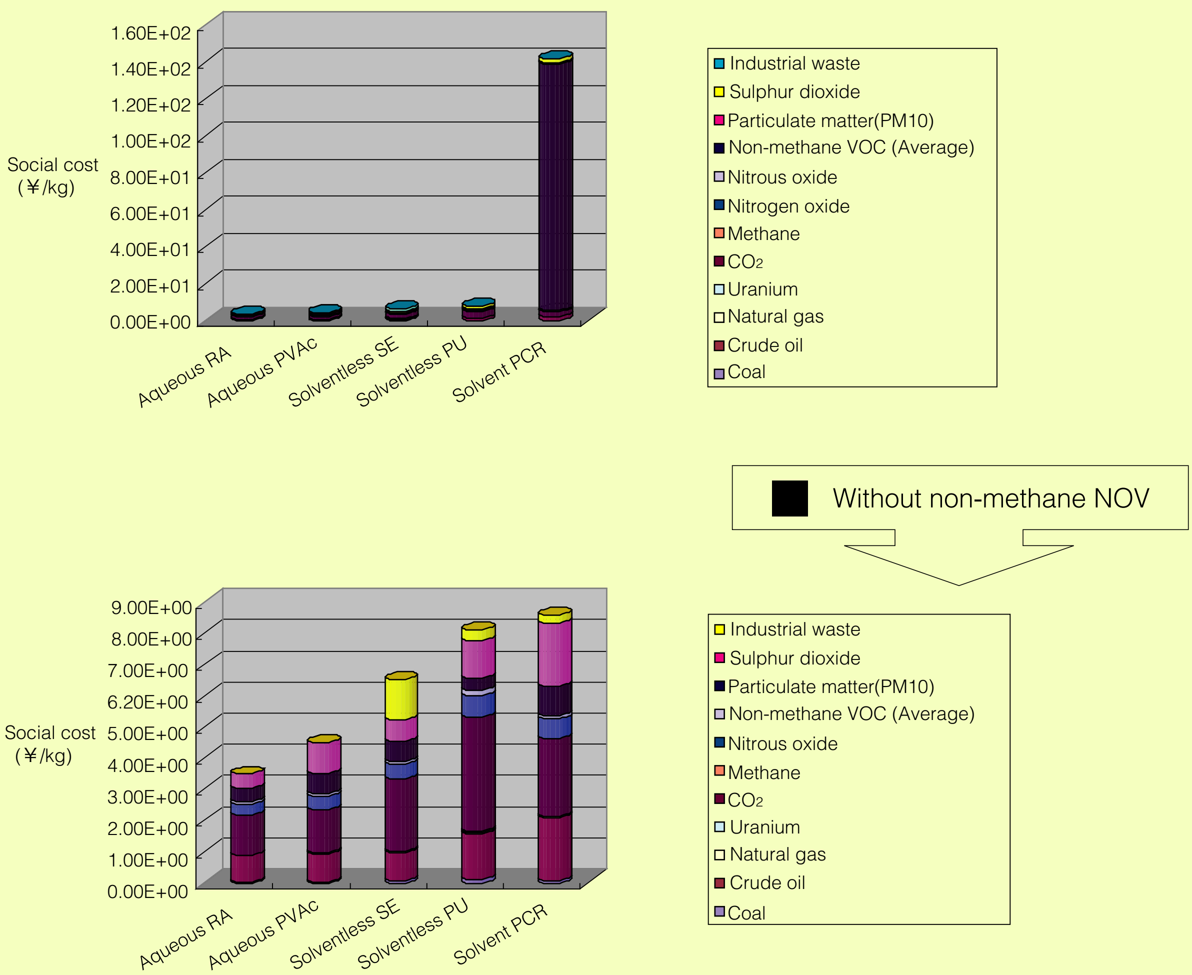
1) When the NMVOC of solvent adhesives are emitted into the atmosphere, the photochemical oxidant and SPM that are generated cause great damage to human health, primary production and social assets. A typical synthetic rubber solvent type is estimated to incur about ¥140 social cost per 1kg, so a shift towards the installation of a solvent recovery equipment or use of non-solvents could reduce the environmental impact significantly. Although the results for the NMVOC's ability to generate photochemical oxidants differs between Maximum Increment Reactivity (MIR) and Photochemical Ozone Creation Potential (POCP), we can see that it is possible to reduce environmental impact by selecting VOC with a less potential for creating photochemical oxidants in the designing process.

2) The four kinds other than the solvent types, most of the social cost derived from material production, and there is a two-digit difference in the social cost compared to solvent types with about ¥4/kg for aqueous types to ¥8/kg for solvent-free reactive types. We have found that these gaps in the social cost are proportional to the usage rate of crude oil derived naphtha, which is the raw material of adhesives.

3) There are two types of adhesive in the disposal scenario: one that becomes industrial waste and one that does not. Since they do not contain hazardous substances such as heavy metals, the social cost created by the industrial waste of adhesives is small.

There is great hope for utilizing such results of the LCI and LCIA based on LIME in the design and development of industrial adhesives.

Fig. 2 Types of adhesives and the social costs involved by causative agent



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Nov. 14 - 16, 2006 Tsukuba, Japan	The Institute of Life Cycle Assessment, Japan, The Society of Non-Traditional Technology/ECOMATERIALS Forum National Institute for Agro-Environmental Sciences Japan Environmental Management Association for Industry/ Life Cycle Assessment Society of Japan Institute for Building Environment and Energy Conservation Center for Environmental Information Science	http://www.sntt.or.jp/ecobalance7/
SETAC Europe LCA Case Study Symposium		
December. 7-8, 2006, Stuttgart, Germany	Society of Environmental Toxicology and Chemistry (SETAC)	http://www.setaceumeeting.org/lca2006/
ISIE 2007		
June. 17-20. 2007, Toronto, Canada	International Society of Industrial Ecology	http://www.isie.ca/
14th CIRP International Conference on Life Cycle Engineering		
Jun. 11 - 13, 2007, Tokyo, Japan	International Academy for Production Engineering	http://cirp-lce2007.jspe.or.jp/
3rd International Conference on Life Cycle Management		
August. 27- 29, 2007, University of Zurich, Switzerland	Swiss Federal Institute of Technology (ETH)	http://www.lcm2007.org/
IV Global Conference on Sustainable Product Development and Life Cycle Engineering		
October 3-6, 2006, São Paulo, Brazil,	University of São Paulo	http://www.gcsm.org.br/

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